Monetary Policy and Global Spillovers: Mechanisms, Effects, and Policy Measures

Enrique G. Mendoza, Ernesto Pastén,
and Diego Saravia
editors

Banco Central de Chile / Central Bank of Chile

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Central Banks in emerging markets have been forced in the last decade to deal with spillovers from the crises in the United States and Europe and from the extraordinary measures respectively taken by the Federal Reserve and the European Central Bank.

This volume provides a comprehensive study of the channels, mechanisms, and quantitative effects of spillovers from developed economies on emerging economies, as well as policy responses from policy makers in the latter. It collects seven papers by world-leading experts discussing the role of information, connectivity, the international financial network, sovereign bonds prices, capital flows and financial frictions.

Puesta de Sol
Alberto Valenzuela Llanos (1869–1925)
Oil on canvas, 60 x 84 cm
Collection of the Central Bank of Chile

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Series on Central Banking, Analysis, and Economic Policies

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Monetary Policy and Global Spillovers: Mechanisms, Effects and Policy Measures – An Overview

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The global economy of today "is a small world after all." The high degree of international trade integration and financial interconnectedness has created tight linkages across most countries, even between countries that may be very distant geographically, or that may not have significant trade or financial relations with each other. This phenomenon is particularly evident when observing the international implications of monetary policy decisions made by the authorities of key advanced economies, mainly the U.S. Federal Reserve (Fed) and the European Central Bank (ECB), and the global spillovers of fluctuations in commodity prices or changes in capital markets conditions in individual countries or regions. These implications run in a two-way street, in which changes in interest rates by key central banks have global effects on financial conditions and real activity, and at the same time there are also important effects of, for example, world commodity markets or financial vulnerabilities in emerging economies or Eurozone members on monetary policy decisions made by the Fed or the ECB as well as by other central banks.

The complex linkages created by the globalization of financial markets and economic activity make the study of monetary policy

Monetary Policy and Global Spillovers: Mechanisms, Effects and Policy Measures, edited by Enrique G. Mendoza, Ernesto Pastén, and Diego Saravia, Santiago, Chile.

and global spillovers a complex subject. Traditionally, international macroeconomics (e.g. the Mundell-Fleming model or the Metzler diagram) viewed the analysis of the international implications of monetary policy and global spillovers mainly as exogenous changes in foreign monetary policy, or the terms of trade affecting the savings-investment imbalance of a small open economy, or the world allocation of savings, investment and the equilibrium interest rate in two-country models. But what we observe in the global economy today are spillovers operating through a variety of transmission mechanisms, particularly financial, that are absent from traditional models. These mechanisms end up affecting both advanced and emerging economies through various channels, and have posed new policy challenges that have been met with different policy responses. These have included reconsidering the pros and cons of traditional policies (e.g., capital controls, exchange rate management, monetary policy), as well as the use of new instruments or new approaches to use existing ones (e.g., macroprudential financial regulation, "leaning against the wind" of financial instability with monetary policy). To a large extent, however, the practice of these policies has moved at a much faster pace than the research work and the development of quantifiable models needed to understand them better and enhance their effectiveness.

The Twentieth Annual Conference of the Central Bank of Chile brought together some of the world's leading experts on this new frontier, and the papers published in this volume reflect some of the transformative new perspectives and policy insights derived from their latest research. The works included here shed light on some of the central questions in the analysis of monetary policy and global spillovers.

The seven papers included in this conference volume are organized in two sections. The first section consists of four empirical studies. The first three provide strong evidence on the relevance of global spillovers via linkages between U.S. monetary policy and sovereign and corporate bond markets worldwide (Burger, Warnock, and Warnock), fluctuations in the intensity of financial information acquisition and the occurrence of financial crises (Chousakos, Gordon, and Ordóñez), and interconnectedness across world markets of different commodities (Diebold, Liu and Yilmaz). The fourth empirical study, authored by Eichengreen and Gupta, demonstrates that sudden stops in emerging markets (i.e., sudden reversals in capital flows) remain a relevant problem even twenty years after the sudden stops of the 1990s.

The second section of this volume includes three papers that focus on the transmission mechanisms of global spillovers and policy responses stemming from them. These papers propose innovative models in the intersection of macro and finance, in which traditional policies, such as monetary and exchange-rate policies, have new implications because of their impact on the financial transmission mechanism (Devereux and Yu, and Gourinchas), or in which the promise and challenges of new policies, particularly macroprudential policy, can be analyzed in theory and evaluated quantitatively (Mendoza).

In the following paragraphs we provide a brief summary of the papers included in this volume.

Section 1: Spillovers – Empirical Relevance

This section includes four papers that conduct empirical studies of the relevance of selective channels of spillovers of monetary policy from developed to emerging economies.

In "*Global Information Spillovers*," Kyriakos Chousakos, Gary Gorton and Guillermo Ordoñez use a panel dataset of advanced and emerging countries to study the link between financial fragility, economic activity, and a measure of information production specified below. They reach three key findings: (1) Recessions that involve financial crises are characterized by a boom in the production of information previous to the crisis; (2) there is evidence of global spillovers: a boom in production of information in some advanced economies predict crises in other advanced as well as emerging economies; and (3) booms in the production of information predict global imbalances, suggesting that the production of information is one determinant for the international reallocation of resources.

The measure of information production the authors use is based on the cross-sectional average returns of firms' stock prices. If financial markets are (approximately) efficient, differences in firms' stock returns are related to the intensity in the use of information specific to firms in portfolio decisions. Then, they identify recessions in their dataset and sort them according to whether these recessions involve episodes of financial crises or not. In line with their previous work, they find that only a subset of recessions is associated with financial crises. To reach the first of their key findings, they show that recessions with crises are preceded by an increase in the cross-sectional average of firms' stock prices, while recessions with no crises do not.

To reach their second key result, regarding global spillovers, they use a principal component analysis to estimate common information factors across a number of advanced countries with a long history of stock prices data. These factors turn significant not only in the countries used in the estimation, but also in other advanced and emerging countries in their dataset. They interpret this result as evidence of global spillovers. If this interpretation is correct, a boom in the production of information should trigger strong reallocation of resources across economies. This is exactly what they find in their third key result: an increase in information production is associated with a higher level of domestic imbalances and a lower level of foreign imbalances. This implies that more information is related to a higher level of domestic assets funded with foreign liabilities.

In the second paper, "*The Effects of U.S. Monetary Policy on Emerging Market Economies' Sovereign and Corporate Bond Markets,*" John Burger, Francis Warnock, and Veronica Cacdac Warnock use data on the denomination of emerging economies' sovereign and corporate bond markets in an attempt to understand what drives U.S. investors' portfolios in those markets. For this purpose, they use a panel dataset covering a large number of countries from 2007 to 2015.

They find that the structure of emerging bond markets has changed in the sample period: The share of bonds denominated in local currency has increased and, after controlling for local variables, there has been a trend toward a larger local currency sovereign bond market and a larger foreign currency corporate bond market. In turn, countries that are more stable, with stronger regulatory quality/creditor rights, and more positive current account balances have more developed local currency bond markets, both sovereign and corporate.

In "*Commodity Connectedness,*" Francis Diebold and Laura Liu focus on spillovers through commodity markets. This is a very important channel of international spillovers for Chile, as well as other mineral commodity exporters.

For their analysis, they use variance decompositions of high-dimensional vector autoregressions to characterize 'connectedness' among the return volatility of 19 commodities underlying the Bloomberg Commodity Price Index, using daily data between 2011 and 2016. Connectedness is defined as a statistic that incorporates dynamic cross-variable interactions across commodity markets as well innovations correlations, which is estimated by using machine-learning techniques.

The main results that emerge from their work are the clustering behavior of commodity returns into groups that match traditional industry classifications, and the relevance of particular sectors in the transmission of shocks to other sectors. Notably, the energy sector is most important in terms of sending shocks to others; and energy, industrial metals, and precious metals are highly connected among themselves.

A different aspect of the broad focus of this section is covered in "*Managing Sudden Stops,*" by Barry Eichengreen and Poonam Gupta. These authors empirically analyze the incidence of sudden stops in capital flows to emerging economies in a sample including data for many developed and developing countries from 1991 to 2014. They show that the frequency of sudden stops has remained surprisingly unchanged despite all the advancements in the design and implementation of policies to prevent them and to deal with them once they occur. Stronger macroeconomic and financial frameworks have allowed policy makers to respond more flexibly, but these more flexible responses have neither guaranteed insulation from nor mitigated the impact of sudden stops. However, the authors also found that the factors behind sudden stops have changed. Sudden stops now tend to affect different parts of the world simultaneously rather than bunching regionally, especially since 2002. Global factors, particularly global risk aversion as captured by the VIX, appear to have become more important.

In terms of the effects of sudden stops, the financial effects show up first: the exchange rate depreciates, reserves decline, and equity prices fall. GDP growth then decelerates, investment slows, and the current account strengthens. The growth of GDP falls by roughly 4 percent year on year in the first four quarters of a sudden stop. The decline in GDP is somewhat larger in the second sub-period, reflecting a larger global shock (larger increase in the VIX, in particular), something whose effects were offset only partially by stronger macroeconomic positions.

Section 2: Spillovers – Mechanisms and Policy Implications

This section includes three papers that study the transmission mechanisms of global spillovers and the policy responses by using quantitative dynamic stochastic general equilibrium models of small open economies.

In "*Monetary Policy Responses to External Spillovers in Emerging Market Economies,*" Michael B. Devereux and Changhua Yu explore the degree to which emerging market economies can utilize monetary and exchange rate policies to respond to external and internal macroeconomic shocks when the country is prone to endogenous financial crises. The model exhibits nominal price rigidity and collateral constraints depending on asset prices, and considers shocks either to the world interest rates or to leverage limits, both of which may lead the economy to a crisis.

The authors compare three alternative monetary policy regimes: inflation targeting with flexible exchange rates, optimal discretionary policy with flexible exchange rates, and an exchange rate peg. The three variations of the model match quite well emerging markets' stylized facts abstracting from financial crises. But during crises, the exchange rate peg puts severe constraints on the capacity of the country to take debt abroad. By contrast, there is little difference between the two policy regimes with flexible exchange rates: the economy performs much better to smooth the effects of an external shock. Consequently, these results indicate that there should be no macro-prudential role for monetary policy, in the sense that it should not respond to expectations of future crises but react only upon the occurrence of a crisis. When the authors extend their model to include nominal wage rigidity, results are similar, with the only exception that inflation targeting performs worse than the discretionary optimal policy, but still performs much better than a fixed exchange rate policy.

"*Macro-prudential Policy: Promise and Challenges,*" by Enrique G. Mendoza, takes a different perspective by focusing on macro-prudential policy analysis rather than on the use of monetary policy as a macroprudential tool. The quantitative approach also differs markedly, because it emphasizes the use of global, nonlinear solution methods that capture financial crisis dynamics accurately, as well as the self-insurance incentives on which macro-prudential policies operate. Importantly, the framework studied in this paper exhibits Fisherian collateral constraints such that agents are subject to borrowing limits that depend on the market value of assets or goods posted as collateral. This introduces a pecuniary externality, because private agents do not internalize the effect of their borrowing decisions made in "good times" on the collapse of collateral values in "bad times." In this way, financial amplification of domestic shocks or global spillovers provide a sound theoretical foundation for a macro-prudential policy.

The quantitative results show that macro-prudential policy is a powerful tool for preventing financial crises, in the sense that a constraint-efficient financial regulator can reduce significantly the severity and frequency of such crises. However, macro-prudential policy is not free of implementation challenges. First, its sophistication makes it difficult to implement, as an optimally-designed macro-prudential policy rule involves non-linear responses to a wide variety of domestic factors as well as regime shifts in global liquidity, news about global fundamentals, financial innovation and regulatory changes in world capital markets. Second, the optimal policy design suffers of time-inconsistency: policies promised before crises to be implemented during crises that are optimal before crisis may not be optimal at the time of a crisis. In turn, expectations about policies to be implemented during crises are crucial for the design and success of macro-prudential policies. In particular, when a crisis hits, regulators pledge to lower consumption in the future so as to prop up the value of collateral, but when that future arrives, delivering on this pledge is not optimal for the regulator. Third, a successful macro-prudential policy relies on the delicate interaction of authorities with different scope, such as monetary policy, fiscal policy, and the financial regulator. This last point is illustrated with a quantitative analysis of a calibrated New Keynesian model augmented with the Bernanke-Gertler financial accelerator. This analysis shows that monetary and financial policies are much more effective when implemented *via* separate policy rules, but that coordination of the monetary and financial authorities is also necessary in order to prevent costly strategic interaction in the conduct of both policies.

The last, but by no means the least, of the papers covered in this section is "*Monetary Policy Transmission in Emerging Markets: An Application to Chile,*" by Pierre-Olivier Gourinchas. This paper discusses the role of financial spillovers in the transmission of U.S. and domestic monetary policy to emerging market economies, with special emphasis on the Chilean economy. The model is an extension of the Mundell-Fleming model of a small open economy with financial spillovers, which is estimated with Chilean data between 1999 and 2015 by using Bayesian methods.

There are three distinct channels by which the tightening of monetary policy in the U.S. generates international spillovers: The response of aggregate demand in the U.S. generates a contraction of exports in an small open economy, the local currency depreciates if allowed to float, which invigorates local aggregate demand, and affects the value of collateral in the small open economy, thus tightening de balance sheets of local financial intermediaries and a contraction of credit which impact negatively in local economic activity. The overall effect of these spillovers is, in principle, not clear; quantitatively, however, it turns out to be that a tightening in U.S. monetary policy is contractionary for the Chilean economy. But this finding does not overturn the basic conclusion of the Mundell-Fleming analysis: the transmission of domestic monetary policy is not perverse, and therefore flexible exchange rates remain the primary line of defense against foreign monetary policy and global financial cycles alike.

Managing Sudden Stops

Barry Eichengreen
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Sudden stops are when capital inflows dry up abruptly. The banker's aphorism—"It's not speed that kills, but the sudden stop"—has been popularly invoked since at least the Mexican crisis in 1994. Awareness then rose with impetus from the Argentine crisis (1995), the Asian crisis (1997), the Russian crisis (1998), and the Brazilian crisis (1999). Google's Ngram Viewer shows a sharp increase after 2000 in references to the phrase.[1]

The question is whether this increase reflects the growing incidence of the problem or simply the growing currency of the term. The gradual diffusion of scholarly terminology suggests that the observed trend may simply reflect the latter. At the same time, however, there is heightened awareness in the policy community of capital-flow volatility and reversals as reflected in the decision of the International Monetary Fund to adopt a new, more sympathetic view of capital controls and international capital market interventions generally (IMF 2012), indicative perhaps of a growing problem. Episodes like the "taper tantrum" in 2013, when talk that the Federal Reserve might taper its purchases of securities, leading emerging-market currencies to crash, and the "normalization" episode in 2015, when expectations that the Fed would soon start raising U.S. interest rates leading to an outflow of funds from emerging markets, suggest that sudden stops may in fact be growing more frequent or, perhaps, more disruptive.

We thank Anderson Ospino, Serhat Solmaz, and Rama Yanamandra for their excellent research assistance. For comments we thank Andrés Velasco and conference audiences at the Central Bank of Spain and Central Bank of Chile.

1. See https://books.google.com/ngrams/graph?content=sudden+stop&year_start=1970&year_end=2008&corpus=15&smoothing=0&share=&direct_url=t1%3B%2Csudden%20stop%3B%2Cc0.

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In this paper we extend previous analyses of sudden stops, contrasting their incidence and severity before and after 2002, the end of the period covered by most of the classic contributions to the literature.[2] Our central contributions are two. First, we update those earlier classic contributions, highlighting what if anything has changed in the decade or so since their initial publication. Second, we analyze the policy response, asking whether that response has evolved over time and, specifically, whether there is evidence of central banks and governments in emerging markets responding in ways that promise to better stabilize output, employment and, not least, domestic financial markets.

We show that the frequency and duration of sudden stops in emerging markets have remained largely unchanged since 2002. Casual impression gleaned from the tapering episode in 2013 might suggest otherwise. But excitable press coverage notwithstanding, we find that interruptions to capital flows during the Fed's discussion and implementation of its policy of "tapering" security purchases were milder than the sudden stops of prior years. These episodes were shorter, entailed smaller reversals, and had a milder impact on financial and real variables.[3] One might call them "sudden pauses" rather than "sudden stops".

At the same time, global factors appear to have become more important for the incidence of sudden stops. Similarly, when we consider a measure of contagion or concurrence such as the number of sudden stops occurring simultaneously in other countries, we find that it is sudden stops globally that matter after 2002, whereas in the preceding period it had been sudden stops in the same region. Again, we are inclined to interpret this in terms of the growing importance of global factors.

Sudden stops, as is well known, have both financial and real effects. We confirm that the financial effects materialize first: the exchange rate depreciates, reserves decline, and equity prices fall. GDP growth then decelerates, investment slows, and the current account strengthens. The growth of GDP falls by roughly 4 percent year on

2. The five most widely cited empirical papers on sudden stops, according to Google Scholar, are Calvo, Izquierdo, and Mejia (2004), Calvo, Izquierdo, and Talvi (2003), Cavallo and Frankel (2008), Edwards (2004a), and Edwards (2004b). None uses data for the period after 2002.

3. The picture may look different once we have enough data to analyze the 2015 normalization episode. But the partial data available at the time of writing suggest that for only a few countries did capital flow shifts in 2015 qualify as sudden stops.

year in the first four quarters of a sudden stop. The decline in GDP is somewhat larger in the second sub-period, reflecting a larger global shock (larger increase in the VIX, in particular), something whose effects were offset only partially by stronger macroeconomic positions.

Countries responded in the 1990s by stepping down the exchange rate, sometimes floating the currency, and then supporting that new exchange rate or float with a tighter monetary policy. In the worst-hit cases there was resort to an IMF program, extension of which was typically conditional on trade reforms, fiscal tightening, and privatization of public enterprises. In the second sub-period, there was less of a tendency to tighten both monetary and fiscal policies. Indeed some countries were able to reduce policy interest rates as a way of supporting economic activity and financial markets. Less monetary stringency and some currency depreciation were feasible because countries had reduced foreign currency mismatches in the interim, limiting balance-sheet damage from depreciation. Budgets already being closer to balance (fiscal positions being stronger), governments were able to respond with less fiscal consolidation. Recourse to IMF programs was less frequent in the 2000s, partly because countries had accumulated larger international reserves and moved to more flexible exchange rates in the interim.

This is progress, after a fashion. At the same time, it is clear that the recipe of stronger fiscal positions, more flexible exchange rates, deeper financial markets and less foreign currency mismatch has not insulated emerging markets from sudden stops; the frequency of the event has not declined. Any benefit from stronger country fundamentals has been offset by larger external shocks. Nor has progress on the policy front limited the negative output effects. As we show below, the drop in output in the first four quarters is no smaller in the second sub-period than the first; if anything it is slightly larger.[4] It would appear, with the continued growth of international financial markets and transactions, countries are now exposed to larger capital flow reversals, and those larger reversals have more disruptive output effects. It is troubling that neither national officials, with their increased policy space, nor the international financial institutions, with their proliferation of financing facilities, have succeeded in cushioning emerging markets from these effects.

4. Although the difference is not statistically significant at standard confidence levels.

1. Basics

Our country sample is all emerging markets with their own currencies for which capital flow data are available for at least 24 consecutive quarters between 1991 and 2014. Our primary source of quarterly gross capital flow data is the International Monetary Fund's International Financial Statistics (accessed through Haver Analytics). We have data for 20 emerging markets in 1991, 28 in 1995, and 34 from 2000 onwards, resulting in an unbalanced panel. In robustness checks, we work with a smaller, balanced sample for which data are available for the entire period.[5]

Sudden stops are when inflows are a certain number of standard deviations below their average in a specified number of prior years. Most studies only classify episodes as such when they last more than one quarter. While some papers focus on net capital inflows by nonresidents, others add net capital outflows by residents.[6] Some papers use data for all capital flows, while others use data for only items other than FDI, on the grounds that FDI flows are relatively stable.[7]

We focus on portfolio flows and other flows (consisting in practice primarily of loans and trade credits) by nonresidents on the grounds

5. The full list of countries and the periods for which their data are available is in appendix A.

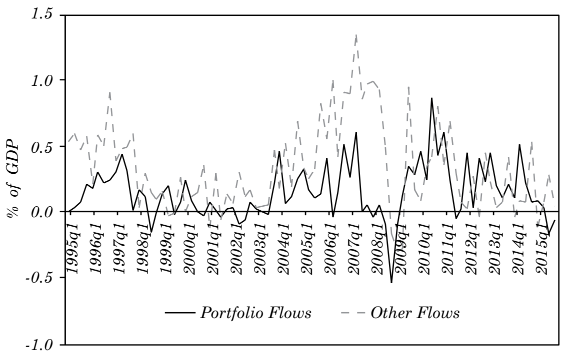
6. See for example Forbes and Warnock (2014). Cavallo and others (2013) show that the sudden stops in flows from nonresidents tend to be larger and have stronger impacts on economies than those which are driven by outflows by residents.

7. This, of course, is not the only country sample, periodicity and algorithm for identifying sudden stops. Calvo and others (2004), in an early influential study, use monthly data for 20 advanced and emerging markets over the period 1990-2001. Since capital flow data are unavailable monthly, they instead use the change in reserves and the trade balance. According to their definition, a sudden stop begins when capital flows so measured fall one standard deviation below the mean for the past 24 months; the episode continues until flows recover to above the earlier mean. In addition they require that in at least one month during the duration of the episode capital flows fall two standard deviations below their earlier mean. They also construct an alternative indicator that adds to the above an additional criterion of costly disruption to economic activity, defined as a fall in output of at least two standard deviations below the mean change in the log of output (more on this below). Forbes and Warnock (2012) define sudden stops similarly but use data on actual capital flows available at a quarterly frequency. A sudden stop is said to occur when the year-on-year change in capital flows over four quarters is at least one standard deviation below the average in the previous five years and when, in at least one quarter, flows are two standard deviations below that prior average. They discard episodes lasting only one quarter.

that these are the most volatile component (figure 1).[8] We classify an episode as a sudden stop when portfolio and other inflows by nonresidents decline below the average in the previous 20 quarters by at least one standard deviation, when the decline lasts for more than one quarter, and when flows are two standard deviations below their prior average in at least one quarter. Episodes end when capital flows recover to the prior mean minus one standard deviation. When two sudden stops occur in close proximity (which is the case in only a few instances), we treat them as a single episode.[9]

The resulting dates are listed in appendix A. We double-checked the list for consistency against country details provided in IMF Article IV reports.[10] Episodes identified by an alternative criterion where the sudden stop ends when capital flows recover to the average of the past 20 quarters are listed in appendix A as well.

Figure 1. Portfolio and Other Capital Flows
(median flows for all emerging markets in percent of GDP)



8. One might cut the data other ways. For example, Forbes and Warnock (2014) suggest focusing on debt and other flows while excluding equity flows on the grounds that these are fundamentally different. Blanchard and Acalin (2016) suggest that it may be desirable to include also foreign direct investment on the grounds that this behaves in broadly similar fashion to portfolio capital flows. In what follows, we provide some limited comparisons with other categories of capital movements (FDI flows and portfolio flows by residents).

9. In some cases where the criterion of capital flows declining by two standard deviations below mean was missed by a whisker, we still identified that episode as a sudden stop. One could, of course, measure capital flows and their volatility in a number of different ways. In focusing on gross inflows by nonresidents, we follow Efremidze and others (2015), who show that sharp reductions in gross flows from abroad tend to be most strongly associated with sudden stops as defined here (and are more informative for understanding the latter than, inter alia, net flows).

10. In a very few cases where we noted discrepancies, we took the qualitative discussion in the Article IV reports as definitive.

As measures of the stance of monetary and fiscal policies, we consider changes in policy interest rates and announcements of tax increases and expenditure changes. Information on these monetary and fiscal policies, participation in IMF programs, and the implementation of structural reforms is gathered from a detailed reading of the relevant IMF Article IV reports, program reports and other documents, both from Haver Research and from other market-oriented websites. We rely on IMF's AREAER to code changes in exchange rate arrangements, changes in capital-account liberalization and restriction measures, and macroprudential policy measures.[11] We scan these documents for policy changes over the same window (the same quarters) for which we code a country as experiencing a sudden stop.

The sources of these data as their correlation matrix are in appendix B.

2. Updating the Stylized Facts

We identify 46 sudden stops since 1991. These are listed in appendix A. These episodes last on average for four quarters. Capital outflows during sudden stops average about 1.5 percent of GDP per quarter (cumulatively 6 percent of GDP for the duration of the stop), as compared to inflows of about 1.7 percent of GDP a quarter over the preceding year. This implies a swing in capital flows of some 3 percent of GDP in a quarter—(a large amount).

The frequency of sudden stops in any one quarter is about 2 percent, or 8 percent in a year. The frequency and duration of these episodes and the magnitude of the associated capital outflows are all similar across sub-periods. While the duration of sudden stops is slightly less in the second sub-period, the difference is not statistically significant. In other words, none of the statistics in the first five rows of table 1 differs significantly across columns at standard confidence levels. The significant difference between the two sub-periods is the magnitude of the capital flow turnaround, defined as average capital flows during the sudden stop (either the first four quarters of the event or all quarters of the event) minus average capital flows in the four preceding quarters, all scaled by GDP. The turnaround is significantly larger in the second sub-period than in the first.

11. For macroprudential policy initiatives, we utilized AREAER information under Heading XII: Provisions Specific to the Financial Sector, supplemented with information from IMF Article IV reports.

Table 1. Sudden Stops, 1991-2002 vs. 2003-2015

	1991-2002	*2003-2015*
No. of sudden stops	16	30
As percent of available observations	1.8 % (16/903)	2.1% (30/1446)
No. of quarters for which the sudden stops last	4.5	3.6
Capital flows during sudden stops (% of GDP), first quarter	–1.61	–1.25
Capital flows during sudden stops (% of GDP), average for first four quarters	–1.79	–1.36
Capital flows in the four quarters preceding sudden stops (% of GDP)	1.28	2.00^
Portfolio flows in the four quarters preceding sudden stops (% of GDP)	0.68	0.42*
Other flows in the four quarters preceding sudden stops (% of GDP)	0.60	1.57^^
Capital flow turnaround: Avg. capital flows during four quarters of sudden stops- Avg. capital flows in the four preceding quarters	–3.06	–3.54*
Capital flow turnaround: Avg. capital flows during all quarters of sudden stops- Avg. capital flows in the four preceding quarters	–2.28	–3.16***

*, **, *** indicate that the value is significantly lower in the second column, compared to its value in the first column at 10, 5 or 1% level of significance (in a one tailed test). ^, ^^, ^^^ indicate that the value is significantly higher in the second column, compared to its value in the first column, at 10, 5 or 1% level of significance (in a one tailed test).

Figure 2. Magnitude of FDI and Non-FDI Flows
(median flows for all emerging markets in percent of GDP)

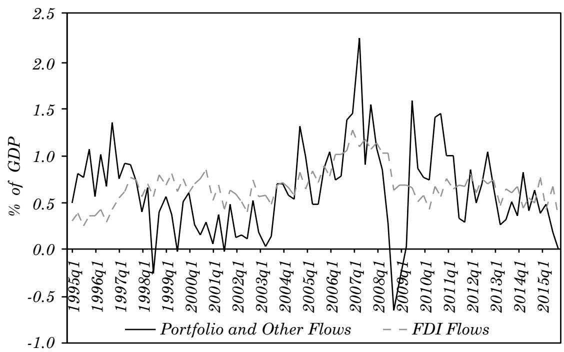


Table 1 also shows that capital inflows in the four quarters preceding sudden stops were larger as a share of recipient-country GDP in the second period. (What is true of four quarters is similarly true of the preceding eight and 12 quarters, here and in the remainder of this paragraph.) That increase in the volume of inflows in the preceding period does not reflect an increase in portfolio capital (equity and bond-market related) flows. Rather, it is more than fully accounted for by an increase in other inflows (interbank borrowing, suppliers' credits, trade credit and other more difficult to classify items). Figure 1 confirms that these other flows have grown larger and more volatile. One suspect that as the authorities have tightened oversight and regulation of short-term portfolio debt and equity flows in response to earlier problems, other flows have become a more important conduit for short-term capital movements.[12] Figure 2 shows that it is still the case, as before 2003, that FDI flows are less volatile than portfolio and other flows.

As before, sudden stops continue to bunch in certain years. While in the 1990s they were concentrated around the Asian and Russian crises, in the last decade the most prominent cluster was in 2008-2009 at the time of the turmoil triggered by the collapse of the Lehman Brothers. This suggests that, in accounting for incidence, it will be important to consider global factors.

No sudden stops so defined occurred during the "taper tantrum" of mid-2013, when Federal Reserve officials mooted the possibility of curtailing the institution's security purchases, provoking volatility in emerging financial markets (see the first column of appendix A). A decline in capital inflows into emerging markets and, in some cases, capital-flow reversals occurred in this period, but these lasted only one quarter, as opposed to more than four quarters on average in our sudden stops cases. The decline, thus, was not of the duration required to qualify as a sudden stop according to our algorithm.

In addition, the magnitude of the capital flow reversal was not comparable. Capital inflows in the prior four quarters averaged less than one percent of GDP in the tapering episode, as opposed to more than 1.5 percent in sudden stops. The swing from inflow to outflow was one and a half percent of GDP a quarter as opposed to more than three

12. This pattern is especially striking in light of official efforts in the second half of the period, in Asia and elsewhere, to develop bond markets as a "spare tire" for intermediation. The data show that, such initiatives notwithstanding, it is bank lending and related flows that have grown most rapidly on average between the two sub-periods.

percent of GDP in our sudden stop episodes. Currency depreciation was more than three times as large in sudden stop episodes. The decline in equity prices was five times as large.[13] We do pick up two sudden stops in early 2014, in the Russian Federation and Ukraine, but these are plausibly attributable to factors other than the Fed's tapering talk, given the time lag and concurrent geopolitical developments.[14]

It is similarly interesting to observe that only two countries, Chile and South Korea, register on our criteria as experiencing sudden stops in 2015. The decline in net capital flows to emerging markets in 2015 has been much commented upon. But this decline was "an intensification of trends that have been underway since 2012, making the current episode feel more like a lengthening drought rather than a crisis event," according to the Institute of International Finance (quoted in Strohecker 2016). It can be argued that this is a different kind of episode: a gradual stop rather than a sudden stop, although as data for 2016 become available, more countries may still register as experiencing sudden stops starting in the final quarters of 2015.

In table 2 we regress different types of capital flows on a dummy variable for the first four quarters of a sudden stop.[15] The results indicate that while both portfolio and other inflows by nonresidents decline significantly during sudden stops, the shift is larger for other flows than for portfolio flows. Consistent with previous studies, we see that residents respond in stabilizing ways, reducing capital outflows during sudden stops (more so in the 2000s than previously), although the decline in outflows by residents is not sufficient to offset the impact of flight by nonresidents.[16]

13. It might be objected that our criteria for defining sudden stops include that the capital flow interruption lasts at least two quarters, whereas these tapering events typically lasted only one, meaning that we are comparing apples and oranges. If we relax the requirement that sudden stops last at least two quarters and include also one quarter interruptions, the reversal in capital flows is still 50 percent larger in this expanded sample of sudden stops. Depreciation of the exchange rate in the quarter in question is still more than twice as large. The decline in equity prices is still three times as large.

14. Specifically, there was a role for low oil prices, Russian intervention in Ukraine, and the threat of Western sanctions.

15. We drop subsequent quarters of sudden stop episodes, if any, from the regressions. Regressions are estimated using country fixed effects, with robust standard errors.

16. This contrast between outflows by nonresidents and inflows by residents during the same sudden stop episodes is consistent with the focus on gross as opposed to net capital inflows in recent analyses of capital-flow volatility (e.g. Forbes and Warnock, 2014).

Table 2. FDI, Portfolio and other Capital Flows by Nonresidents and Residents during Sudden Stops

Variable	*(1)* *Portfolio flows (% of GDP)*	*(2)* *Other flows (% of GDP)*	*(3)* *Total flows (portfolio + other, % of GDP)*	*(4)* *Net capital flows by residents and nonresidents (% of GDP)*
Sudden stop	−0.587***	−1.823***	−2.410***	−2.289***
	[3.40]	[4.18]	[6.73]	[6.85]
Dummy for 2003-2015	0.118**	0.095	0.211*	−0.082
	[2.24]	[0.90]	[1.82]	[0.72]
Sudden stop* dummy for 2003-2015	−0.376	0.117	−0.243	0.338
	[1.63]	[0.28]	[0.61]	[0.82]
Constant	0.273***	0.533***	0.798***	0.419***
	[8.51]	[8.19]	[11.81]	[6.46]
No. observations	2,626	2,610	2,610	2,610
R-squared	0.052	0.079	0.130	0.085
No. of countries	34	34	34	34
Adj. R-squared	0.0513	0.0775	0.129	0.0835

Data are quarterly over the period 1991-2015. Dependent variable is portfolio, other flows, or their sum by nonresidents; or net flows by residents and nonresidents, in percent of GDP. Regressions include country fixed effects. First four quarters of the sudden stop are included in the regressions. Robust t statistics are in parentheses. *, **, or *** indicate the coefficients are significant at 10, 5 or 1% level of significance. Regressions with year fixed effects instead of a different intercept for post 2003 period yield similar coefficients.

Overall, then, the frequency and duration of sudden stops has remained largely unchanged since the period covered by earlier studies. Although the countries concerned have changed over time, the reversal in portfolio flows is larger, and "other flows" have become more important.

Turning to effects, tables 3 and 4 show that when a sudden stops occurs, the exchange rate depreciates and reserves decline (not unexpectedly). The fall in investment being proportionally larger than the fall in GDP and, by implication, than the fall in saving, the current account strengthens. While the impact on financial variables peaks in the first two quarters, the impact on real variables, like the current account, GDP growth and investment, peaks later.[17] The fall in GDP growth is significant: growth is roughly 4 percentage points slower year over year in the first four quarters of the sudden stop.[18] There is no significant difference between the first and second sub-periods in magnitude of that growth slowdown—the drop in output is larger in the second sub-period, but the difference is not significant at conventional confidence levels. Interestingly, the one variable for which the impact is significantly greater in the second sub-period is equity prices, presumably reflecting the greater attention paid to emerging equity markets in the second period by international investors. Another variable for which the impact differs across sub-periods is the real effective exchange rate (and to a lesser extent the nominal effective exchange rate), which shows a smaller depreciation in the second sub-period, perhaps reflecting greater bunching of sudden stops in the second period.

We analyze the probability of a country experiencing a sudden stop by estimating:

$$Prob\left(SS_{it}=1\right)=F(X_t^{Global}\alpha+Z_{i\,avg\,(t-1..t-8)}^{Domestic}\gamma\ ) \qquad (1)$$

where SS_{it} is a dummy variable that takes the value of 1 if country i is experiencing an episode of sudden stop in quarter t.[19]

As global or external factors, we consider the log of the VIX as a proxy for global risk aversion; G4 money supplies (calculated as the percent change in the sum of M2 in the US, Eurozone, Japan, and UK, or in percent of their combined GDP) as a proxy for global liquidity; world GDP growth (to account for the strength of the global economy, perhaps another reflection of the investment appetite of the investors), and the Federal Reserve's policy interest rate (to account for the special role of the dollar as a source of liquidity to the global

17. In the spirit of Eichengreen, Rose and Wyplosz (1995), we also construct a composite index of the impact of sudden stops on the foreign exchange market, consisting of the rate of exchange rate depreciation and decline in reserves, as well as in some cases the decline in equity prices. We normalize the series by subtracting the average values of the respective variables in the previous 20 quarters and dividing by the standard deviation over that period. These indices, without and with equity prices, show similar patterns (results not reported for brevity).

18. Here it is important to note that our indicator of sudden stops is not based on the falls in output around the indicated dates, in contrast to the alternative measure in Calvo and others (2004) (see footnote 8 above).

19. We estimate the equation by a probit, as well as other limited dependent variable models such as logit and complementary logarithmic framework, cloglog (following Forbes and Warnock, 2012), since the distribution of F is likely to be asymmetric, owing to the fact that episodes occur irregularly).

financial system).[20] In addition, we count the number of sudden stops starting elsewhere in the region or world in the same quarter.

Table 3. Comparing the Impact over Time

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Dependent variable ▸	*Exchange rate depreciation*	*REER change (%)*	*Change in reserves (%)*	*Real change in equity prices (%)*	*GDP growth (quarterly yoy)*	*Investment growth (quarterly yoy)*	*Current account balance % GDP*
Sudden stop	11.11**	8.80***	–12.51**	–3.16	–3.74***	–11.62***	1.68
	[2.58]	[3.54]	[2.70]	[0.95]	[3.35]	[2.88]	[1.55]
Dummy 2003-2015	–4.38***	–0.15	–1.05	2.63***	0.68	0.24	–0.10
	[2.86]	[0.53]	[1.48]	[4.10]	[1.58]	[0.14]	[0.12]
Sudden stop* dummy for 2003-2015	–3.37	–5.66**	5.43	–7.30*	–1.17	1.60	–0.78
	[0.76]	[2.20]	[1.06]	[1.88]	[0.83]	[0.26]	[0.57]
Constant	4.47***	–0.31	2.82***	0.89**	3.76***	7.74***	–1.55***
	[4.71]	[1.54]	[5.99]	[2.05]	[12.56]	[7.05]	[2.77]
No. observations	2,616	2,234	2,669	2,355	2,236	2,031	2,076
R-squared	0.053	0.072	0.007	0.024	0.071	0.029	0.004
No. of countries	34	28	34	31	33	29	31
Adj. *R*-squared	0.0516	0.0705	0.00628	0.0229	0.0700	0.0275	0.00288

Data are quarterly over the period 1991-2015. Dependent variables are as indicated in the first row. All variables are in percentage. GDP growth and investment growth are year-over-year. Regressions include country fixed effects. Robust t statistics are in parentheses. *, **, or *** indicate the coefficients are significant at 10, 5 or 1% level of significance. Regressions with year fixed effects instead of a different intercept for post 2003 period yield similar coefficients.

20. Variables within each category are correlated with one another; hence we include them parsimoniously in the regressions. When using quarterly data for World GDP, we aggregate data for the largest countries for which it is available. These account for approximately two-thirds of global GDP.

Table 4. Impact on Economic and Financial Variables

Dependent variable ▸	*Exchange rate depreciation*	*Change in reserves (%)*	*Real change in equity prices (%)*	*GDP growth (yoy)*	*Investment growth (yoy)*	*Current account balance / GDP*
Quarter 1	10.126***	–14.538***	–15.826***	–2.270***	–6.019**	–0.662
	[4.37]	[4.75]	[5.45]	[3.09]	[2.75]	[1.12]
Quarter 2	12.853***	–6.494***	–10.442***	–5.521***	–9.038**	1.045
	[3.40]	[2.85]	[3.20]	[4.97]	[2.17]	[1.14]
Quarter 3	3.514**	–7.844	2.883	–5.845***	–16.643***	2.506**
	[2.39]	[1.50]	[0.79]	[4.51]	[3.83]	[2.32]
Quarter 4	5.621	–4.861	–0.304	–5.193***	–14.447**	3.272***
	[1.67]	[0.64]	[0.07]	[2.95]	[2.46]	[2.84]
Constant	1.823***	2.173***	2.549***	4.204***	7.904***	–1.622***
	[17.68]	[15.93]	[22.86]	[70.94]	[41.00]	[38.16]
No. observations	2,658	2,669	2,355	2,236	2,031	2,076
R-squared	0.029	0.008	0.032	0.074	0.034	0.010
No. of countries	34	34	31	33	29	31
Adj. R-squared	0.027	0.01	0.03	0.07	0.03	0.01

Data are quarterly over the period 1991-2015. Dependent variables are as indicated in the first row. All variables are in percentage. GDP growth and investment growth are year-over-year. Regressions include country fixed effects. Robust t statistics are in parentheses. *, **, or *** indicate the coefficients are significant at 10, 5 or 1% level of significance. Regressions with year fixed effects instead of a different intercept for post 2003 period yield similar coefficients.

As country-specific factors, we consider GDP growth, public debt, the budget deficit, and the increase in capital flows in previous period (portfolio and other inflows by nonresidents in percent of GDP to account for the possibility that sudden stops are preceded by large capital inflows). We include variables intended to capture overheating and increased leverage during episodes of large capital inflows, such as the current account balance, bank credit, and real exchange rate appreciation. We also consider reserves (as percent of GDP) as a measure of the ability to withstand the impact of sudden stop and thus lowering the probability of sudden stop itself. To account for the possibility that more financially open economies are more susceptible to a sudden stop in response to external shocks or domestic vulnerabilities, we include the *de facto* financial openness of the economy, calculated as the international investment position for portfolio and other flows in percent of GDP. For these domestic variables, endogeneity is a concern, so we enter their average over eight prior quarters.[21] Variables are normalized around a zero mean and standard deviation equal to one.

In table 5 we report marginal effects from probit regressions. The results indicate that an increase in the VIX significantly raises the probability of a sudden stop. The effect is not just statistically significant, but numerically large. A one standard deviation increase in the VIX raises the probability of a sudden stop in the same quarter by 1.2%. This is a 60 percent increase over the unconditional probability of two percent. In terms of magnitudes, the impact of the VIX dominates that of other variables, as is evident from the size of the marginal effects.

The significance and magnitude of the two "sudden stops in other countries" variables similarly point to the importance of the external environment and global factors.

Domestic factors associated with the increase in the probability of a sudden stop are capital flows in prior years and domestic credit as a share of GDP; both are positively associated with the probability of a country experiencing a sudden stop. International reserves and the real exchange rate do not show up as significant, perhaps because of their correlation with the capital-flow and credit variables.

The two sub-periods are compared in tables 6 and 7 and further in appendix C. There appears to have been some change in the relative importance of different external factors over time. U.S. monetary policy was evidently more important in the 1990s, while global risk aversion as captured by the VIX mattered more subsequently. This may seem surprising in light of the attention paid to Federal Reserve policy in the second sub-period, first when quantitative easing by the U.S. central bank propelled capital flows to emerging markets (the currency war problem), and then when its tapering talk precipitated a reversal, but the pattern in question comes through in the data.

21. This should also help to attenuate problems of noise in the quarterly data. Results do not change when we average the domestic variables over somewhat shorter or longer periods. In addition, we drop crisis observations after the first quarter. If capital flows reverse, the real exchange rate depreciates, or credit growth slows when the sudden stop hits an economy, including all subsequent quarters might lead one to erroneously conclude that lower capital flows real exchange rate depreciation, or slower credit growth increase the probability of a sudden stop (see e.g. Demirgüç-Kunt and Detragiache, 2000; Gourinchas and Obstfeld, 2012).

Table 5. Correlates of Sudden Stops
(Probit model, marginal effects in percent, 1991-2014)

	(1)	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*	*(7)*	*(8)*
VIX, log	1.00***	1.21***	1.20***	1.20***	1.21***	0.69***	0.94***	0.66***
	[7.02]	[6.92]	[6.66]	[6.87]	[6.90]	[3.62]	[4.36]	[3.28]
US policy rates (%)	0.30*	0.30**	0.30*	0.34**	0.31**	0.42***	0.42***	0.45***
	[1.81]	[2.04]	[1.81]	[2.34]	[2.15]	[2.61]	[2.75]	[2.77]
Capital flows/ GDP	0.50***	0.52***	0.50***	0.50***	0.51***	0.40***	0.43***	0.38**
	[4.03]	[3.62]	[3.50]	[3.65]	[3.60]	[2.58]	[2.59]	[2.32]
Domestic credit/GDP		0.29**	0.33***	0.22*	0.28**	0.28**	0.34***	0.30***
		[2.49]	[2.96]	[1.71]	[2.48]	[2.48]	[2.98]	[2.68]
RER (% change)			–0.13					
			[1.04]					
Reserves/GDP				0.19				
				[1.21]				
External liabilities/GDP					0.10			
					[0.35]			
No. of sudden stops elsewhere in the world						0.53***		0.45***
						[4.41]		[2.86]
No. of sudden stops elsewhere in the Region							0.36***	0.14
							[3.16]	[1.01]
No. observations	2,208	2,178	2,150	2,178	2,177	2,178	2,178	2,178
Pseudo R-squared	0.180	0.185	0.185	0.188	0.186	0.229	0.213	0.232

Dependent variable is a binary variable which is equal to 1 if a sudden stop occurs and 0 otherwise. The first quarter of sudden stop is included in the regressions, and all subsequent quarters dropped. Domestic variables are averages of previous eight quarters. All variables have been standardized around zero mean and standard deviation equal to 1. Capital flows, domestic credit and reserves, and international investment are in percent of GDP. Real exchange rate is in percent change; an increase denotes a depreciation. VIX is in log; sudden stop episodes elsewhere in the world or region are the number of sudden stops elsewhere in the same quarter. Regressions are estimated with robust standard errors, and observations clustered by countries. Z statistics reported in parentheses. ***,** and * indicate significance at 1, 5, and 10% levels, respectively.

Table 6. Correlates of Sudden Stops
(Probit model, marginal effects in percent, 1991-2002)

	(1)	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*	*(7)*	*(8)*
VIX, log	0.91*	0.86*	0.79*	0.87**	0.83**	0.79*	0.67	0.74
	[1.93]	[1.92]	[1.92]	[2.18]	[2.10]	[1.65]	[1.61]	[1.61]
US policy rates (%)	1.00***	0.97***	0.92***	0.83***	0.84***	0.92***	0.85***	0.90***
	[4.27]	[4.79]	[4.32]	[4.25]	[4.15]	[3.46]	[4.22]	[3.61]
Capital flows/ GDP	1.00***	1.28***	1.17***	1.30***	1.39***	1.28***	1.21***	1.21***
	[6.46]	[6.02]	[6.09]	[6.27]	[5.12]	[5.99]	[6.13]	[6.17]
Domestic credit/GDP		−0.23	−0.12	−0.12	−0.21	−0.22	−0.17	−0.17
		[1.07]	[0.72]	[0.48]	[1.08]	[1.05]	[0.76]	[0.80]
RER change (%)			−0.45*					
			[1.93]					
Reserves/GDP				−0.68*				
				[1.93]				
External liabilities/ GDP					−0.44*			
					[1.70]			
No. of sudden stops elsewhere in the world						0.21		−0.32
						[0.47]		[0.50]
No. of sudden stops elsewhere in the region							0.65*	0.79*
							[1.96]	[1.66]
No. observations	882	862	840	862	861	862	862	862
Pseudo R-squared	0.120	0.121	0.130	0.137	0.129	0.122	0.135	0.137

Dependent variable is a binary variable which is equal to 1 if a sudden stop occurs and 0 otherwise. The first quarter of sudden stops are included in the regressions, all subsequent quarters dropped. Domestic variables are averages of previous eight quarters. All variables have been standardized around zero mean and standard deviation equal to 1. Capital flows, domestic credit and reserves, and international investment are in percent of GDP. Real exchange rate is in percent change; an increase denotes a depreciation. VIX is in log; sudden stop episodes elsewhere in the world or region are the number of sudden stops elsewhere in the same quarter. Regressions are estimated with robust standard errors, and observations clustered by countries. Z statistics reported in parentheses. ***,** and * indicate significance at 1, 5, and 10% levels, respectively.

Table 7. Correlates of Sudden Stops
(Probit model, marginal effects in percent, 2003-2014)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
VIX, log	1.0***	1.14***	1.14***	1.06***	1.13***	0.64**	0.99***	0.62**
	[6.63]	[6.56]	[6.74]	[6.29]	[6.42]	[2.25]	[3.75]	[2.04]
US policy rates (%)	0.51	0.51*	0.54*	0.48*	0.53*	0.35	0.57*	0.39
	[1.60]	[1.76]	[1.88]	[1.75]	[1.79]	[1.05]	[1.87]	[1.21]
Capital flows/ GDP	0.14*	0.14	0.17	0.13	0.09	0.11	0.05	0.07
	[1.72]	[1.22]	[1.58]	[1.17]	[0.75]	[0.80]	[0.37]	[0.52]
Domestic credit/ GDP		0.34***	0.32***	0.17	0.30***	0.36***	0.40***	0.37***
		[3.06]	[2.91]	[1.43]	[2.95]	[2.92]	[3.36]	[3.05]
RER change (%)			0.20*					
			[1.76]					
Reserves/GDP				0.31**				
				[2.42]				
External liabilities/GDP					0.12			
					[1.13]			
No. of sudden stops elsewhere in the world						0.41***		0.37**
						[3.06]		[2.39]
No. of sudden stops elsewhere in the region							0.24**	0.09
							[2.22]	[0.80]
No. observations	1,326	1,316	1,310	1,316	1,316	1,316	1,316	1,316
Pseudo R-squared	0.263	0.278	0.281	0.291	0.281	0.327	0.305	0.330

Dependent variable is a binary variable which is equal to 1 if a sudden stop occurs and 0 otherwise. The first quarter of sudden stops are included in the regressions, all subsequent quarters dropped. Domestic variables are averages of previous eight quarters. All variables have been standardized around zero mean and standard deviation equal to 1. Capital flows, domestic credit and reserves, and international investment are in percent of GDP. Real exchange rate is in percent change; an increase denotes a depreciation. VIX is in log; sudden stop episodes elsewhere in the world or region are the number of sudden stops elsewhere in the same quarter. Regressions are estimated with robust standard errors, and observations clustered by countries. Z statistics reported in parentheses. ***,** and * indicate significance at 1, 5, and 10% levels, respectively.

The level of the VIX, the percentage change in the VIX, the standard deviation of the VIX and the coefficient of variation of the VIX, all in the quarter of sudden stops, are significantly larger in the second sub-period than the first; this is not true, in contrast of the change in the U.S. policy rate. The influence of country characteristics like the reserve-to-GDP ratio, real exchange rate appreciation, and a negative international investment position (as defined and calculated by Lane and Milesi-Feretti, 2007) seem to matter less consistently in the more recent period. This suggests that global (push) factors have been playing a larger role in sudden stops in the more recent decade. The changing nature of contagion effects (regional in the 1990s, global in the 2000s) similarly points to the growing influence of global factors.[22]

Finally, we can return to the determinants of the output drop following the sudden stop and ask how this is shaped by the magnitude and composition of the capital inflow in the immediately preceding period. Table 8 is consistent with the idea that the decline in GDP in the first four quarters of the sudden-stop episode is an increasing function of the total capital inflow (portfolio plus other, as a share of GDP) in the preceding eight quarters (the coefficient on capital flows in the preceding period is significant at the 5 percent confidence level). Subsequent columns show that the explanatory power in this relationship is concentrated in the second sub-period. There is no evidence that the breakdown of those prior inflows into portfolio and other (bank-related) flows makes a difference for the magnitude of the output drop.

22. A battery of sensitivity tests supports the robustness of these results. We used the alternative sudden stop dates presented in the last column in appendix A. We eliminated outliers by winsorizing observations at 1 percent on each end. We worked with a balanced panel. We re-estimated eq. (1) using fixed-effects probit to control for time invariant characteristics of countries. We re-estimated eq. (1) using logit. We added back in the fifth and subsequent quarters of sudden stops, where the baseline regressions included only the first four quarters. We shifted the partition between periods two years in each direction. We included additional measures of external conditions (G4 money supply growth, global economic growth) and country characteristics (presence of capital controls, per capita income, political stability, the exchange rate regime, trade openness, and incidence of sudden stops elsewhere in the preceding as opposed to the current quarter). Results are available on request.

Table 8. Average (Year on Year) GDP Growth in the First Four Quarters of Sudden Stops

	(1)	*(2)*	*(3)*
Capital flows (% of GDP, average of past 8 quarters)	−1.800** [2.14]	1.080 [0.68]	1.727 [1.11]
Capital flows (% of GDP, average of past 8 quarters)* dummy 2003-2014		−3.305* [1.80]	−3.861** [2.12]
Other flows/Total flows	−0.677 [1.09]		−3.819 [1.40]
(Other flows/Total flows)* dummy 2003-2014			3.235 [1.16]
Dummy for 2003-2014		5.145* [1.99]	4.790* [1.85]
Constant	2.018* [1.71]	−2.494 [1.12]	−2.045 [0.92]
No. observations	41	41	41
R-squared	0.241	0.281	0.309
Adj. R-squared	0.201	0.223	0.211

Robust t statistics in parentheses. **,** and * indicate significance at 1, 5, and 10% levels, respectively.

3. The Policy Response

We next consider how countries adjust policy in response to sudden stops. If there is a conventional wisdom, it is that they tighten monetary and fiscal policies to counter the drop in the exchange rate and in an effort to restore confidence. In extreme cases, they tighten controls on capital outflows and appeal to the International Monetary Fund for emergency assistance.

In fact, this conventional response is evident in only a minority of cases. In only eight of the 43 cases considered here did countries in fact tighten both monetary and fiscal policies in response to sudden stops. Over the entire period, monetary policy was eased in response to sudden stops more often than it was tightened. Instead (or in addition), governments respond to sudden stops with a variety of other measures targeted at buttressing the stability of their domestic financial system and signaling to investors their commitment to sound and stable policies.

Moreover, there are differences in the nature of the typical response between the first and second sub-periods. There was less of a tendency to tighten both monetary and fiscal policies in the second sub-period. In both sub-periods countries experiencing sudden stops moved in the direction of a more flexible exchange rate, but that tendency was more pronounced in the first sub-period than the second. And, there is more recourse to the IMF and program finance in the first sub-period.

As noted in section 2, we rely on a detailed reading of IMF reports and relevant market commentary to code changes in monetary and fiscal policies, as well as participation in IMF programs and implementation of structural reforms. In relying on reports of fiscal initiatives for coding the timing and direction of fiscal policy changes, we are following the narrative approach—see e.g. Romer and Romer (1989) and Alesina and others (2016)—which attempts to pinpoint exogenous changes in policy, rather than relying on heavily changes in fiscal and financial accounts.

A first pattern in table 9 is that a majority of countries experiencing sudden stops between 1991 and 2014 in fact eased monetary policy in response, whereas a majority tightened fiscal policy. Countries experiencing sudden stops need to simultaneously do something to reduce the level of spending relative to income when foreign finance becomes more difficult to tap, while at the same time taking other steps to support economic activity and aid the financial system.[23] Fiscal tightening evidently is the preferred policy for pursuing the former, while monetary easing is the preferred instrument for achieving the latter. Governments could conceivably adopt the opposite policy mix, but in only 1 of 44 episodes do we observe this response. Budget deficits become more difficult to finance in the wake of sudden stops, especially if monetary policy is tightened, making some degree of fiscal consolidation inevitable for countries with preexisting fiscal deficits. Monetary tightening could reinforce the expenditure-reducing effects of fiscal consolidation, but monetary easing has the advantage of potentially relieving the strain on commercial-bank balance sheets.

23. One is reminded, for example, of Brazil's response to its sudden stop in 2015, which entailed fiscal consolidation and a reluctance to tighten monetary policy (keeping central bank interest rates on hold in a period when inflation was rising).

Table 9. Policies during Sudden Stops 1991-2014

	1991-2014	
	Number of cases	*Fraction of cases (%)*
Monetary policy		
Eased	27	63
Tightened	9	21
No change, or no clear stance	7	16
Fiscal policy		
Eased	14	33
Tightened	23	53
No change, or no clear stance	6	14
Capital account transactions		
Eased	9	23
Tightened	7	17
No change, or no clear stance	24	60
Macroprudential measures		
Strengthened	13	33
Eased	4	10
No change, or no clear stance	22	56
Exchange rate regime		
Changed	14	33
No change	29	67
IMF program		
New or ongoing	22	49
No program	21	51
New program	12	29
No new program	29	71

Table 10 shows that this tendency to ease monetary policy in response to sudden stops was more prevalent in the second sub-period. The constraint on easing monetary policy and allowing the currency to depreciate is the existence of currency mismatches on the national balance sheet, insofar as depreciation raises the burden of foreign-currency-denominated liabilities. A number of emerging markets took steps to limit such mismatches following the Asian financial crisis and more generally; this may help to account for their greater willingness to ease monetary policy in the second sub-period. We provide more evidence of this in table 12 below.

Table 10. Policies during Sudden Stops – Sub-periods

	1991-2002		*2003-2014*	
	Number of cases	*Fraction of cases*	*Number of cases*	*Fraction of cases (%)*
Monetary policy				
Eased	7	44	20	74
Tightened	6	38	3	11
No change, or no clear stance	3	19	4	15
Fiscal policy				
Eased	1	6	13	48
Tightened	13	81	10	37
No change, or no clear stance	2	13	4	15
Capital account transactions				
Eased	5	39	4	15
Tightened	3	23	4	15
No change, or no clear stance	5	39	19	70
Macroprudential measures				
Strengthened	3	25	10	37
Eased	0		4	15
No change, or no clear stance	9	75	13	48
Exchange rate regime				
Changed	10	63	4	15
No change	6	37	23	85
IMF program				
New or ongoing	15	94	7	26
No program	1	6	20	74
New program	7	50	5	19
No new program	7	50	22	81
Structural reforms				
Reforms	14	7	14	52
No reforms	1	93	13	48

The tendency to tighten fiscal policy is similarly more evident in the first sub-period. On average, budget deficits as a share of GDP in the years preceding sudden stops were larger in the first sub-period. This plausibly explains why fiscal tightening was more widely resorted to in the first sub-period, reflecting both the greater difficulty of financing those deficits following sudden stops and the importance of fiscal consolidation in sending a confidence-enhancing signal to financial markets.[24]

In terms of financial policies, only a small handful of countries altered capital controls in response to sudden stops. Strikingly, that minority of cases was divided roughly equally between instances where controls were tightened (to limit capital outflows) and eased (presumably to enhance confidence in the effort to attract inflows). It is fair to say that there is no consensus on or general answer to the question of how capital-control measures are best utilized in the event of a sudden stop.

Macroprudential policies were strengthened in roughly a third of cases. Almost all of these were concentrated in the second sub-period, when greater attention was paid to macroprudential regulation. We also observe a few cases where macroprudential policies were loosened for reasons of forbearance, not unlike how capital controls were loosened in a minority of cases. But these are exceptions to the rule. The exchange rate regime was changed in almost half of all cases in the 1991-2002 decade, uniformly in the direction of greater flexibility. In contrast, it was rarely changed in the second sub-period, a larger number of countries already having moved to more flexible rates.

We see more recourse to IMF support in the first sub-period than in the second. Implementation or at least mention of structural reforms goes along with IMF programs, as shown in table 11. Nearly three-fourths of structural reforms were implemented in conjunction with IMF programs, while almost all IMF programs entailed structural reforms. Mention of structural reforms is much more common in the first sub-period than in the second. In the second sub-period, in almost half of all instances where countries experiencing sudden stops responded with self-advertised structural reform measures, they did so without resorting to an IMF program. There is also a greater tendency for countries in IMF programs to tighten monetary policy and loosen

24. Vegh and Vuletin (2014) note that the response of fiscal and monetary policies to growth crises has, on average, become more countercyclical in Latin American countries since 1998.

the exchange rate regime. Whether this difference is a function of IMF conditionality or of the fact that most program cases are in the first sub-period when the monetary and fiscal condition of the countries considered was weaker on average is difficult to say; the observed effect most likely reflects both influences.

Table 11. IMF Programs and Structural Reform

Full period, 1991-2014

Structural reform ▼	*IMF program* ▶	*No*	*Yes*	*Total*
No		13	8	21
Yes		1	20	21
Total		14	28	42

First Sub-period, 1991-2002

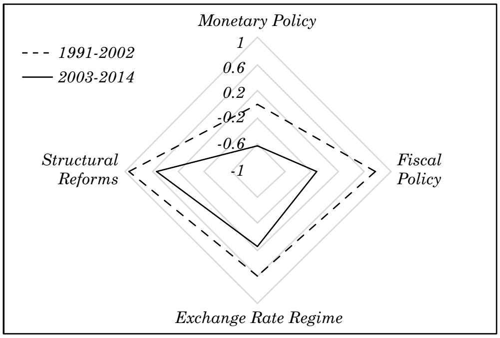
Structural reform ▼	*IMF program* ▶	*No*	*Yes*	*Total*
No		1	0	1
Yes		0	14	14
Total		1	14	15

Second Sub-period, 2003-2014

Structural reform ▼	*IMF program* ▶	*No*	*Yes*	*Total*
No		12	8	20
Yes		1	6	7
Total		13	14	27

Source: See text.

Figure 3. Policy Tradeoffs in Sudden Stop Episodes



We assign either a zero, one, or negative one to a country in each episode, with a one when a country tightened monetary policy, tightened fiscal policy, made its exchange rate regime more flexible, or committed to structural reforms common followed by lowe case "z". Zero when there is no change, and minus one when a country eased monetary policy or fiscal policy. Countries with all minus one are at the center of the figure, whereas countries with all ones are at the four vertexes (they trace out the diamond).

Figure 3 summarizes the pattern of responses in the two sub-periods. We assign either a zero, one, or negative one to a country in each episode: a one when a country tightened monetary policy, tightened fiscal policy, made its exchange rate regime more flexible, or committed to structural reforms; a zero when there is no change; and minus one when a country eased monetary policy or fiscal policy, or reversed the structural reforms, or made its exchange rate regime less flexible. Countries with all minus one are at the center of the figure, whereas countries with all ones are at the four vertexes (they trace out the diamond). We see a less sharp response along all four dimensions in the second sub-period, most noticeably in the cases of fiscal and monetary policies.

These choices seem consistent with the changing nature of the sudden stops and of the position of countries experiencing them. Table 12 shows the average values of a variety of policy variables in the eight quarters prior to sudden stops, again distinguishing the two sub-periods. In the 1990s, sudden stops were heavily associated with weak macroeconomic fundamentals, whereas episodes in the subsequent decade were associated more with external factors and occurred despite stronger domestic economic and financial fundamentals.

Table 12. Macroeconomic Frameworks and Structural Factors in the Eight Quarters Before Sudden Stops

Dependent Variable ▸	*(1)* *Fiscal balance / GDP*	*(2)* *Public debt / GDP*	*(3)* *Inflation*	*(4)* *Exchange rate regime*	*(5)* *Reserves / GDP*	*(6)* *Foreign currency position*	*(7)* *Capital controls*	*(8)* *Inflation targeting*	*(9)* *Domestic credit*
Dummy for 2003 -2014	1.4*	–11.03*	–3.27**	0.44**	11.39***	0.32***	–0.14*	0.46***	14.78**
	[1.14]	[1.09]	[1.31]	[1.70]	[4.01]	[5.25]	[0.97]	[3.34]	[1.34]
Constant	–2.45**	51.20***	10.69***	1.75***	8.95***	–0.31***	0.55***	0.06	43.33***
	[2.31]	[6.33]	[5.19]	[8.61]	[3.98]	[6.52]	[4.55]	[0.58]	[4.95]
No. Observations	36	42	38	43	43	32	30	43	43
R-squared	0.037	0.029	0.046	0.066	0.282	0.479	0.033	0.214	0.042

For inflation, we dropped two episodes where inflation was more than 40%. Exchange rate regime is an index; a higher value implies a more flexible exchange rate regime. Foreign currency position is an index; a higher value means a less negative foreign currency position. For capital controls, a higher value means more controls. Inflation targeting is a dummy for inflation targeting countries. Domestic credit is the ratio of private sector bank credit to GDP. Results are for linear regressions of dependent variables in first row. Coefficients indicate averages for the sudden stops across two sub-periods. *, **, *** indicate if the coefficients across sub-periods are significant at 20, 10 or 1% level of significance in a one-tailed test. Data are from the sources noted in appendix A, and from the IMF reports.

In the first sub-period, sudden stops required countries with large budget deficits and rapid inflation to tighten monetary and fiscal policies and request IMF assistance, both in order to adjust to tighter financing conditions and to send the necessary signal to the markets. In the second sub-period, compared to the first, countries experiencing sudden stops had smaller budget deficits and public debts (as shares of GDP) and significantly lower rates of inflation. Their international reserves as a share of GDP were more than twice as high as in the first sub-period. These stronger fundamentals made IMF support less imperative and gave them some additional leeway to adjust in ways that provided more support to domestic economic activity and the financial system, in some cases loosening monetary policy and limiting the extent of fiscal consolidation.

In the more recent decade, countries experiencing sudden stops were significantly more likely to have flexible exchange rates; they were more likely to be operating inflation targeting regimes. They had significantly deeper financial sectors (as measured by bank credit to the private sector as a share of GDP). They had significantly smaller foreign currency mismatches, as measured by net foreign currency position, enabling them to rely more on exchange rate changes to facilitate adjustment.

All this points to the possibility that countries have more leeway to apply policies designed to buffer the real economic impact of sudden stops. It is worth emphasizing, therefore, that the year-on-year drop in growth rates in the first four quarters of sudden stops is no different in the second period than in the first. The drop in the second period is actually larger, as noted above, although the difference is not statistically significant. This suggests that something else was also changing in a direction with less favorable consequences, where that something else could be the magnitude of capital inflows and the size of the capital-flow reversal, which were larger in the second sub-period.[25]

25. Some readers will wonder how our results relate to those of Rey (2013), who concludes that exchange rate flexibility is largely ineffective in insulating economies from capital flow volatility. Technically, we are not able to distinguish between the views that (a) exchange rate flexibility is ineffective, and (b) that exchange rate flexibility is partially effective in offsetting the impact of international financial shocks, but only partially, while those shocks have grown larger the second period.

4. Conclusion

We have updated earlier analyses of sudden stops in order to shed light on what is known, what is not known, and what is changing. We compare the 1991-2002 period that was the focus of early analyses and on whose basis generalizations and conclusions were drawn with the subsequent period 2003-2015.

We confirm, perhaps obviously, that sudden stops remain a problem. We count more of them in the second sub-period, but there are also more emerging economies actively involved in global financial markets. On balance, the frequency, duration, and severity of sudden stops remains roughly unchanged across sub-periods. However, the associated decline in GDP is larger in the second sub-period, plausibly reflecting larger capital inflows in the preceding quarters and a larger turnaround in capital flows.

In addition, there are indications of changes over time in the relative importance of global economic conditions versus country characteristics and policies in the incidence of sudden stops. We present some evidence that global factors, though always important, have grown more important recently. Our evidence suggests also that the global factors that matter most have been changing. Increases in U.S. policy interest rates, which matter for the supply of global liquidity, were relatively important in the 1990s. In contrast, the VIX, which contains information about global risk aversion and the demand for liquidity, was more important in the subsequent decade. In a number of respects, the policies of countries experiencing sudden stops were stronger in the second sub-period, but this was still no guarantee of insulation from sudden stops.

What stronger policies did permit, however, was a different response at the national level. In the first sub-period, countries with large budget deficits and high inflation had no choice but to tighten monetary and fiscal policies. In the second sub-period, the deficits and inflation rates of the affected countries were lower. Sudden stops still made financing deficits more difficult and required policy makers to take painful steps in order to send reassuring signals to financial markets. But, in a number of cases, they were able to do so by tightening fiscal policy, while at the same time loosening monetary policy so as to support domestic economic activity and the financial system. That foreign currency mismatches were less and a significant number of central banks had installed inflation targeting permitted them to adopt a more permissive attitude toward currency depreciation than in the first sub-period. Larger foreign reserves similarly provided reassurance that the authorities had the wherewithal to intervene were those currency movements to get out of hand.

That governments seemingly have more leeway in the more recent second sub-period for using monetary, fiscal and exchange rate policies in response to sudden stops would suggest that the negative output effects should have been less. Paradoxically, the year-on-year output drop is at least as large in the second sub-period. This suggests that something else is also changing to magnify the output effects, where that something else could be the volume and make-up of international capital flows and/or the prevalence and impact of external shocks.

That stronger fiscal positions, more flexible exchange rates, deeper financial markets, and less foreign currency mismatch have not better insulated emerging markets from sudden stops and their output effects is troubling. Evidently, neither national officials, with their increased policy space, nor the international financial institutions, with their proliferation of new financing facilities, have succeeded in cushioning emerging markets from these effects. It would appear that any benefit from stronger country fundamentals has been offset by larger external shocks.

The question is what to do. One option would be to limit exposure to capital flows and external shocks at the border through the application of capital inflow taxes and regulations, reducing the volume and volatility of capital movements; doing so would be consistent with the IMF's so-called "new institutional view" of capital flow regulation.

A second option would be to invest further in reforms designed to enhance the flexibility of the policy response to capital flow surges and stops (strengthen fiscal positions still further, make exchange rates still more flexible, deepen financial markets further, reduce foreign currency mismatches even more from current levels), on the grounds that existing policy reforms, while an appropriate response to the circumstances of the earlier period, are no longer sufficient in a world of larger and more volatile capital flows.

A third option would be to arrange financial insurance against sudden stops: credit lines with the IMF, with regional arrangements like the Chiang Mai Initiative Multilateralization, and with individual national partners. This will require additional reforms to make the terms and conditions of these facilities more attractive, so that countries experiencing sudden stops are actually willing to take recourse to them. There is reason to think that these options are complements, not incompatible alternatives.

Appendix A

A1. Countries, Data Availability, and Sudden Stops

Country	*Data from*	*SS1 start date, duration in quarters*		*SS 2 start date, duration in quarters*		*SS1 modified start date, duration in quarters*		*SS2 modified start date, duration in quarters*	
Argentina	1985					1998Q4	3	1998Q4	4
Armenia	1996	No SS							
Belarus	1996					2012Q1	3	2012Q1	5
Brazil	1984	1998Q3	3	1998Q3	9	1998Q3	3	1998Q3	9
						2008Q4	2	2008Q4	2
Bulgaria	1996								
Chile	1991	2015 Q1	3	2015Q1	3	2008Q4 2015 Q1	3 3	2008Q4 2015 Q1	3 3
Colombia	1996	No SS							
Croatia	1996	2011Q3	2	2011Q3	7	2011Q3	2	2011Q3	7
Czech Republic	1994	2008Q4	2	2008Q4	2	2008Q4	2	2008Q4	2
Guatemala	1995	2008Q4	2	2008Q4	4	2008Q4	4	2008Q4	4
Hungary	1993	1996Q1	2	1996Q1	3	1996Q1	2	1996Q1	3
						2011Q4	5	2011Q4	5
India	1992	2008Q3	4	2008Q3	4	2008Q3	4	2008Q3	4
Indonesia	1993	1997Q4	2	1997Q4	9	1997Q4	2	1997Q4	9
Israel	1994	2011Q3	4	2011Q3	5	2011Q3	4	2011Q3	5
Jordan	1985	2003Q1	2	2003Q1	6	1993Q1	5	1993Q1	5
		2003Q4	2			2003Q1	5	2003Q1	5
						2007Q3	3	2007Q3	3
Kazakhstan	1995					2007Q3	13	2007Q3	13
Korea, South	1990	1997Q4	2	1997Q4	9	1997Q4	5	1997Q4	5
		2008Q3	2	2008Q3	3	2008Q3	2	2008Q3	2
		2015 Q3	2	2015 Q3	2	2015 Q3	2	2015 Q3	2
Latvia	2001	2008Q4	3	2008Q4	3	2008Q4	3	2008Q4	3
Lithuania	1995					2008Q4	2	2008Q4	2
Malaysia	2000-2009	2008Q3	2	2008Q3	4	2008Q3	3	2008Q3	4
Mexico	1985	1994Q4	3	1994Q4	4	1994Q2	5	1994Q2	6
Pakistan	1995	1998Q1	4	1998Q1	13	1998Q1	9	1998Q1	13
		1999Q2	5						
Peru	1991	1998Q4	4	1998Q4	10	1998Q4	4	1998Q4	4
						2008Q3	4	2008Q3	4

A1. (continued)

Country	*Data from*	*SS1 start date, duration in quarters*		*SS 2 start date, duration in quarters*		*SS1 modified start date, duration in quarters*		*SS2 modified start date, duration in quarters*	
Philippines	1990	1997Q3	3	1997Q3	6	1997Q3	3	2008Q1	6
						2008Q1	4	2008Q1	6
Poland	2000	2008Q4	2	2008Q4	2	2008Q3	3	2008Q3	3
Romania	1991	2008Q4	3	2008Q4	3	2008Q4	3	2008Q4	3
Russia Federation	1994					1998Q4	8	1998Q4	8
		2008Q4	2	2008Q4	10	2008Q4	2	2008Q4	2
		2014Q1	5	2014Q1	5	2014Q1	5	2014Q1	5
South Africa	1985	2000Q4	3	2000Q4	10	2000Q4	3	2000Q4	10
		2008Q3	2	2008Q3	4	2008Q3	2	2008Q3	4
Sri Lanka	1985					2001Q1	7	2001Q1	7
Thailand	1985	1997Q2	6	1997Q2	15	1997Q2	6	1997Q2	15
		2008Q3	3	2008Q3	4	2008Q3	3	2008Q3	4
Turkey	1985	1994Q1	3	1994Q1	5	1994Q1	3	1994Q1	5
		2000Q4	3	2000Q4	8	2000Q4	3	2000Q4	8
		2008Q4	3	2008Q4	6	2008Q4	3	2008Q4	6
Ukraine	1994					2008Q4	5	2008Q4	5
		2014Q1	4	2014Q1	4	2014Q1	4	2014Q1	4
Venezuela, RB	1994	2006Q1	2	2006Q1	3	2006Q1	2	2006Q1	3
Vietnam	2005								

SS1 denote sudden stop dates identified using the filters laid out in the text: a sudden stop episode starts when portfolio and other flows by nonresidents decline below the average of the previous 20 quarters by more than one standard deviation, and for more than one quarter; and in at least in one quarter of this period, flows are two standard deviations or more below the average. Sudden stops end when capital flows recover to a level above mean minus one standard. In SS2 a sudden stop ends when the flows have recovered to the average of the past 20 quarters. In SS1 modified and SS2 modified we make some judgment calls by looking at the trends in the data and include sudden stops even if the respective criteria are missed by a whisker. By design SS2 lasts longer than SS1.

Appendix B

B1. Correlations between Domestic Variables

In the main body of the text we include only subsets of our country characteristics and policy variables in the regressions on the grounds that a number of these variables are highly correlated with one another. It is also interesting that some of these correlations seem to have changed significantly over time. In the first half of the period correlation is stronger between capital flows and current account deficit and weaker between capital flows and reserves—suggestive of that the capital flows were instrumental in financing current account deficit than in the accumulation of reserves. The domestic banking sector seems to have played a less prominent role in mediating the capital flows in the first half of the period. In comparison, in the last decade capital flows correlate more strongly with reserves than in the past; and larger capital inflows go hand in hand with larger banking sector and rapid credit growth. These patterns suggest that the concerns related to financial sector stability matter more in recent sudden stops.

Table B1. Correlation Coefficients between Selective
Domestic factors, 1991-2002

	Capital flows / GDP	*Current account deficit / GDP*	*Reserves / GDP*	*Credit / GDP*	*Credit growth*	*Change in real exchange rate (%)*
Capital flows/ GDP	1					
Current account deficit/GDP	0.62 (0.0)	1				
Reserves/GDP	0.017 (0.62)	−0.05 (0.26)	1			
Credit/GDP	0.066 (0.05)	−0.12 (0.01)	0.36 (0.0)	1		
Credit growth	0.28 (0.0)	0.25 (0.0)	0.004 (0.92)	−0.03 (0.50)	1	
Change in real exchange rate (%)	−0.19 (0.0)	0.003 (0.95)	−0.03 (0.32)	0.009 (0.79)	−0.071 (0.08)	1

Table B1. (continued)
Domestic factors, 2003-2015

	Capital flows/ GDP	*Current account deficit/ GDP*	*Reserves/ GDP*	*Credit/ GDP*	*Credit Growth*	*Change in real exchange rate (%)*
Capital flows/ GDP	1					
Current account deficit/GDP	0.56 (0.0)	1				
Reserves/GDP	0.08 (0.00)	-0.15 (0.00)	1			
Credit/GDP	0.13 (0.05)	-0.10 (0.00)	0.51 (0.00)	1		
Credit growth	0.54 (0.0)	0.27 (0.00)	-0.12 (0.00)	-0.22 (0.00)	1	
Change in real exchange rate (%)	-0.29 (0.0)	-0.06 (0.04)	-0.03 (0.24)	0.04 (0.16)	-0.35 (0.00)	1

In parentheses are the *p* values to accept the null hypothesis that the correlation coefficients are equal to zero.

Table B2. Variables and Sources of Data

Variable	*Definition*	*Sources*
Portfolio liabilities	Transactions with nonresidents in financial securities (such as corporate securities, bonds, notes, and money market instruments)	IFS (line 78bgd)
Other liabilities	Other transactions with nonresidents, major categories are: transactions in currency and deposit loans and trade credits	IFS (line 78bid)
Direct foreign liabilities	Equity capital, reinvested earnings	IFS (line 78bgd)
Capital flows	Sum of portfolio and other liabilities	IFS
Public debt	Gross general government debt (in some cases central government debt), % of GDP	IFS/National sources
Fiscal balance	Revenue (including grants) minus expense, net acquisition of nonfinancial assets. % of GDP.	WEO
Capital controls	Overall restrictions index of all asset categories	Klein and others, (2015)
Fed funds rate	Fed fund rate (%) (US policy rate)	IFS
World GDP	World GDP (% per annum)	WDI, World Bank
VIX	CBOE Volatility Index	Bloomberg
Net foreign currency position	An index which takes values between (-1; 1):value of -1 corresponds to zero foreign-currency foreign assets and only foreign-currency liabilities, +1 corresponds to only foreign-currency foreign assets and no domestic-currency foreign liabilities	Lane and Shambaugh (2014), updated version of Lane and Milesi-Ferretti (2007) dataset
Political risk	Risk ratings range from a high of 100 (least risk) to a low of 0 (highest risk)	Political risk services (PRS)
Exchange regime	de facto exchange rate regime classification	Ilzetzki, Reinhart, and Rogoff (2008)
Investment growth	Quarterly investment growth	IFS
Nominal GDP	Quarterly Nominal GDP	GEM, World Bank
Real GDP	Quarterly Real GDP	IFS
Foreign reserves	Foreign Exchange Reserves in Million USD (End of period data)	IFS
Exchange rate	Official exchange rate local currency per USD (Monthly average)	IFS
Stock price index	National Stock Price Indices, monthly average in current prices	IFS and Haver
Current account balance	Sum of net exports of goods and services, net primary income, and net secondary income, % of GDP	National sources
Domestic credit to private sector	Financial resources provided to the private sector by financial corporations	WDI
Real effective exchange rate	Nominal effective exchange rate index adjusted for relative movements in national price or cost indicators of the home country, selected countries, and the Eurozone	JPMorgan Real Broad Effective Exchange Rate Index
Nominal effective exchange rate	Ratio (base 2010 = 100) of an index of a currency's period-average exchange rate to a weighted geometric average of exchange rates for currencies of selected countries and the Eurozone.	JPMorgan Nominal Broad Effective Exchange Rate Index
Real exchange rate	Computed as nominal exchange rate*US consumer price index/ consumer price index	Exchange rate from IFS; CPI from WDI
Inflation	CPI inflation calculated as % change over previous year. (% yoy)	IFS
Inflation targeting	dummy variable takes a value of 1 after a country moves to an inflation targeting regime and 0 before that	
External liabilities	External liabilities include portfolio equity, FDI and debt liabilities.	Lane and Milesi-Ferretti (2007)
G4-money supply	Sum of US, UK, Japan and Eurozone money supply (M2)	Haver

APPENDIX C

C1. Sensitivity Analysis

We can further compare the impact of global and domestic variables during the sudden stops and tranquil periods in the two halves of the sample period as per the equation below.

External or Domestic Factor $k_{,it} = \alpha_i + \beta_k$ Sudden $\text{Stop}_{it} + \gamma_k$ *Dummy* for 2003-2014 + τ Sudden Stop_{it} * *Dummy* for 2003-2014 + ε_{it}.

Regressions are estimated with country fixed effects and robust standard errors. The average value of each variable in non-crisis years prior to 2003 are given in row (i); variable averages during sudden stops until 2002 is given by (i) + (ii). Average value in tranquil years post 2002 is given by (i) +(iii). Variable averages during sudden stop after 2003 is given by (i) +(ii)+(iii) +(iv). A significant coefficient in (iv) indicates that the (Average value of variable in SS-lagged value in tranquil $\text{years})_{2003\text{-}2014}$ - (Average value of variable in SS-lagged value in nonstop $\text{years})_{1991\text{-}2002}$ is significant] This is the difference in difference estimate of the change in variables across sudden stops in two sub-periods compared to their relative tranquil averages.

Differences are evident across sub-periods. A high U.S. fed funds rate is more strongly associated with sudden stops in the first sub-period than the second. The disproportionate importance of U.S. interest rates in triggering sudden stops—given the importance of dollar funding in global financial markets—is well known. Less obvious, especially given all the talk surrounding "tapering," is that this role appears to have diminished in the 2000s. The VIX is significantly higher during sudden stop episodes only in the second sub-period, pointing to the growing importance of global as opposed to U.S. and financial as opposed to monetary factors. Whereas the external factors associated with the likelihood of sudden stops have changed over time, there is less evidence of such changes in the associated domestic factors. Two exceptions are the ratio of reserves to GDP (which was lower prior to sudden stop episodes in the 1990s compared to tranquil periods, but not in the 2000s) and foreign currency positions (which similarly were lower in sudden stop episodes in the 1990s but not subsequently).

Table C1. External and (lagged) Domestic Variables in Sudden Stop and Normal Years

	(1)	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*	*(7)*
Dependent variables ▸	*Fed fund rate (%)*	*VIX, Log*	*Capital flows/ GDP*	*Change in real exchange rate (%)*	*Domestic credit/ GDP*	*Reserves/ GDP*	*Foreign currency position*
Sudden stop (ii)	0.63***	0.12	0.86***	–0.41	2.64	–1.19	–0.04*
	[3.32]	[1.56]	[3.62]	[1.53]	[0.91]	[1.29]	[1.75]
Sudden stop in 2003-2014 (iv)	–1.25***	0.51***	–0.23	0.071	0.34	2.62*	0.057***
	[3.03]	[4.50]	[0.71]	[0.21]	[0.10]	[1.99]	[2.83]
Dummy 2003 (iii)	–2.63***	–0.16***	0.13	–1.23***	11.8***	6.36***	0.19***
	[35.43]	[6.00]	[1.00]	[5.92]	[3.34]	[6.18]	[5.80]
Constant (i)	4.38***	3.01***	0.73***	0.39***	37.94***	10.15***	–0.22***
	[100.55]	[186.3]	[9.63]	[3.10]	[17.63]	[16.42]	[11.02]
No. observations	2,257	2,257	2,209	2,229	2,194	2,224	1,539
R-squared	0.336	0.098	0.015	0.084	0.14	0.323	0.419
No. of countries	34	34	34	34	34	34	27

Dependent variables are averages of eight previous quarters, except VIX and federal fund rate which are current quarter values. Capital flows are portfolio and other flows by nonresidents as percent of GDP; real exchange rate is in percent change; an increase denotes a depreciation. Robust t-statistics in parentheses. ***,** and * indicate significance at 1, 5, and 10% levels.

Table C2. Probability of a Sudden Stop: Alternative Regression Models

	Logit regressions		*Probit with random effects*		*Probit with country fixed effects*	
	1991-2002	*2003-2014*	*1991-2002*	*2003-2014*	*1991-2002*	*2003-2014*
VIX, log	0.841*	1.362***	0.332	0.605***	0.596***	0.779***
	[1.88]	[7.47]	[1.46]	[5.86]	[2.73]	[7.29]
US policy rate	0.905***	0.695**	0.375***	0.274	0.317	0.308**
	[4.43]	[2.08]	[4.04]	[1.47]	[1.56]	[2.12]
Capital flows/ GDP	1.049***	0.146	0.493***	0.075	1.021***	0.032
	[6.06]	[1.17]	[4.54]	[1.04]	[4.26]	[0.29]
Domestic credit/ GDP	-0.128	0.448***	-0.09	0.179***	0.196	0.410
	[0.68]	[3.63]	[0.75]	[2.66]	[0.79]	[1.47]
No. observations	862	1316	862	1316	515	914
Pseudo R-squared	0.116	0.285	.	.	0.237	0.348

Dependent variable is a binary variable which is equal to 1 if a sudden stop occurs and 0 otherwise. The first quarter of sudden stop is included in the regressions, and all subsequent quarters dropped. Domestic variables are averages of previous eight quarters. All variables have been standardized around zero mean and standard deviation equal to 1. ***,** and * indicate significance at 1, 5, and 10% levels, respectively.

Table C3. Probability of a Sudden Stop: Additional Domestic Variables

(probit model, marginal effects in %)

	(1)	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*	*(7)*	*(8)*	*(9)*	*(10)*	*(11)*	*(12)*
	1991-2002	*2003-2014*	*1991-2002*	*2003-2014*	*1991-2002*	*2003-2014*	*1991-2002*	*2003-2014*	*1991-2002*	*2003-2014*	*1991-2002*	*2003-2014*
VIX, log	0.89*	1.09***	0.51	1.11***	0.91*	1.15***	1.25**	1.22***	0.87*	1.13***	0.88*	0.91***
	[1.93]	[6.34]	[1.49]	[6.22]	[1.86]	[6.53]	[2.46]	[5.82]	[1.89]	[6.60]	[1.70]	[6.43]
US policy rate	1.01***	0.38	0.56***	0.40	0.92***	0.52*	0.80***	0.49	0.99***	0.50*	0.89***	0.52***
	[4.39]	[1.54]	[2.96]	[1.31]	[4.22]	[1.78]	[3.25]	[1.37]	[4.88]	[1.72]	[5.45]	[2.68]
Capital flows/GDP	1.23***	0.09	0.88***	0.12	1.33***	0.16	0.54***	0.20	1.31***	0.12	1.24***	0.06
	[5.96]	[0.72]	[5.43]	[1.04]	[5.14]	[1.37]	[3.50]	[1.36]	[6.52]	[1.00]	[6.00]	[0.67]
Domestic credit/GDP	−0.27	0.38***	−0.20	0.30**	−0.23	0.34***	−0.22	0.28**	−0.30	0.31***	−0.06	0.37**
	[1.28]	[3.83]	[1.21]	[2.56]	[0.98]	[3.05]	[1.55]	[2.49]	[1.31]	[3.08]	[0.26]	[2.13]
GDP growth	0.20	0.26										
	[0.65]	[1.06]										
Fiscal deficit/GDP			−0.29	−0.28*								
			[1.05]	[1.65]								
Debt/GDP					−0.07	0.07						
					[0.43]	[0.32]						
Capital controls							0.11	−0.01				
							[0.76]	[0.08]				
Political risk									0.05	0.10		
									[0.30]	[0.58]		
Foreign currency position											−0.91***	−0.04
											[3.42]	[0.22]
No. Observations	861	1307	660	1286	777	1306	454	1073	846	1316	603	875
Pseudo R-squared	0.124	0.269	0.156	0.283	0.132	0.277	0.205	0.265	0.130	0.278	0.162	0.363

Dependent variable is a binary variable which is equal to 1 if a sudden stop occurs and 0 otherwise. The first quarter of sudden stop is included in the regressions, and all subsequent quarters dropped. Domestic variables are averages of previous eight quarters. All variables have been standardized around zero mean and standard deviation equal to 1. Regressions are estimated with robust standard errors, and observations clustered by countries. Z statistics reported in parentheses. ***,** and * indicate significance at 1, 5, and 10% levels, respectively.

References

Alesina, A., G. Azzalini, C. Favero, F. Giavazzi and A. Miano. 2016. "Is It the 'How' or 'When' that Matters in Fiscal Adjustments?" Paper presented to the 17th annual Jack Polak IMF Research Conference (November).

Blanchard, O. and J. Acalin. 2016. "What Does FDI Actually Measure?" Peterson Institute of International Economics Policy Brief 16–17 (October).

Calvo, G.A., A. Izquierdo, and L.F. Mejia. 2004. "On the Empirics of Sudden Stops: The Relevance of Balance-Sheet Effects." NBER Working Paper No. 10520 (May).

Calvo, G.A., A. Izquierdo, and E. Talvi. 2003. "Sudden Stops, the Real Exchange Rate and Fiscal Sustainability: Argentina's Lessons." NBER Working Paper No. 9828 (July).

Cavallo, E. and J. Frankel. 2008. "Does Openness to Trade Make Countries More Vulnerable to Sudden Stops, or Less? Using Gravity to Establish Causality." *Journal of International Money and Finance* 27: 1430–52.

Cavallo E., A. Powell, M. Pedemonte, and P. Tavella. 2013. "A New Taxonomy of Sudden Stops: Which Sudden Stops Should Countries Be Most Concerned About?" Inter-American Development Bank Working Paper No. 430.

Demirgüç-Kunt, A. and E. Detragiache. 2000. "Financial Liberalization and Financial Fragility." *In Financial Liberalization: How Far? How Fast?*, edited by G. Caprio, P. Honohan, and J. Stiglitz. Cambridge University Press.

Edwards, S. 2004a. "Financial Openness, Sudden Stops, and Current Account Reversals." *American Economic Review* 94(2): 59–64.

————. 2004b. "Thirty Years of Current Account Imbalances, Current Account Reversals and Sudden Stops." NBER Working Paper No. 10276 (February).

Efremidze, L., S. Kim, O. Sula, and T. Willett. 2015. "The Relationships Among Capital Flow Surges, Reversals and Sudden Stops." Unpublished manuscript, Claremont Institute for Economic Policy Studies (December).

Eichengreen, B., A. Rose, and C. Wyplosz. 1995. "Exchange Market Mayhem: The Antecedents and Aftermath of Speculative Attacks." *Economic Policy* 21: 249–315.

Forbes, K.J. and F.E. Warnock. 2012. "Capital Flow Waves: Surges, Stops, Flight, and Retrenchment." *Journal of International*

Economics 88: 235–51.

————. 2014. "Debt- and Equity-Led Capital Flow Episodes." In *Capital Mobility and Monetary Policy*, edited by M. Fuentes, C. Raddatz, and C.M. Reinhart. Central Bank of Chile.

Gourinchas, P.O. and M. Obstfeld. 2012. "Stories of the Twentieth Century for the Twenty-First." *American Economic Journal: Macroeconomics* 4: 226–65.

International Monetary Fund. 2012. *The Liberalization and Management of Capital Flows-An Institutional View*, Washington, D.C.: IMF.

————. (various years). *Annual Report on Exchange Arrangements and Exchange Restrictions*, Washington, D.C.: IMF.

————. (various years). "Article IV Reports." Washington, D.C.: IMF.

Jorda, O., M. Schularick, and A.M. Taylor. 2013. "When Credit Bites Back." *Journal of Money, Credit and Banking* 45: 3–28.

Lane, P.R. and G.M. Milesi-Ferretti. 2007. "The External Wealth of Nations Mark II: Revised and Extended Estimates of Foreign Assets and Liabilities, 1970–2004." *Journal of International Economics* 73: 223–50.

Lane, P.R. and J.C. Shambaugh. 2010. "Financial Exchange Rates and International Currency Exposures." *American Economic Review* 100: 518–40.

Rey, H. 2013. "Dilemma Not Trilemma: The Global Financial Cycle and Monetary Policy Independence." Federal Reserve Bank of Kansas City Monetary Policy Symposium. (August).

Romer, C. and D. Romer. 1989. "Does Monetary Policy Matter? A New Test in the Spirit of Friedman and Schwartz." *NBER Macroeconomic Annual*: 121–84.

Strohecker, K. 2015. "Emerging Market Net Capital Flow Negative in 2015 – IIF." Reuters (1 October), Available at: http://www.reuters.com/article/emerging-flows-iif-idUSL5N1212XO20151001.

Vegh, C.A. and G. Vuletin. 2014. "The Road to Redemption: Policy Response to Crises in Latin America." *IMF Economic Review* 62(4): 526–68.

The Effects of U.S. Monetary Policy on Emerging Market Economies' Sovereign and Corporate Bond Markets

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The global environment for emerging market economy (EME) bond markets has changed dramatically over the past few decades. Local currency bond markets (LCBMs) have developed, especially in EMEs with low inflation, stronger institutions, and well defined creditor rights (see Burger and Warnock 2003, 2006; Eichengreen and Luengnaruemitchai 2006; Claessens, Klingebiel, and Schmukler, 2007). Some EMEs have been able to borrow globally in their local currency, which enhances financial stability by ameliorating the

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currency mismatches that were at the core of past crises (Goldstein and Turner, 2004). However, large inflows of foreign investment can be problematic, as most extreme capital flow episodes are driven by debt flows (Forbes and Warnock, 2013), credit booms lead to crises (Mendoza and Terrones, 2008; Gourinchas and Obstfeld, 2012; Schularick and Taylor, 2012), and large foreign investment flows into LCBMs can complicate the tasks of EME policymakers by appreciating real exchange rates, fanning asset price bubbles, and intensifying lending booms. Indeed, the threat of the virtuous cycle turning vicious when unconventional monetary policy (UMP) by many advanced economies (AEs) may have propelled a global search-for-yield strategy has many EME policymakers worrying about exactly those problems: The erstwhile excessive upward pressure on EMEs' local currencies and indiscriminate flows into EMEs creating bond market bubbles that might have enabled increasingly risky borrowing being transformed by an external shock (such as U.S. monetary policy tightening) that prompts a stampede for the exits.

This paper is the latest in a series of ours on EME bond markets. Early work was primarily concerned with whether EME bond markets could ever develop and whether foreign investors would hold EME local currency bonds as opposed to only holding EMEs' foreign currency denominated bonds. Burger and Warnock (2006, 2007) found that, counter to the "original sin" literature, policies and laws indeed matter, as EMEs with stable inflation rates and strong creditor rights have more developed local bond markets, rely less on foreign currency-denominated bonds, and can attract U.S. investors. Subsequent work focused in part on whether the global financial crisis put an end to EMEs' bond market development and foreigners' interest in EME local currency bonds. Burger, Warnock and Warnock (2012), focusing on the period from 2001 to the end of 2008—when the crisis had already begun—find that policies and laws that helped improve macroeconomic stability and creditor rights enabled EME local currency bond markets to grow substantially and also provided U.S. investors with attractive returns. U.S. investors responded by sharply increasing their holdings of EME local currency bonds, especially in EMEs with investor-friendly institutions and policies. Burger and others (2015) extend that analysis in a panel dataset from 2006 through 2011, focusing on U.S. investors' reallocations within their international bond portfolios. They note that the steady increase in U.S. investors' allocations towards EME local currency bonds, which was unabated by the global financial crisis and even accelerated after the crisis, was due in part to global 'push' factors, such as low U.S. long-term interest rates and subdued risk aversion or expected volatility. But also evident was investor differentiation among EMEs, with the largest reallocations going to those EMEs with strong macroeconomic fundamentals, such as less volatile inflation and more positive current account balances. Finally, Burger, Warnock, and Warnock (2017), using a panel dataset from 2006 to 2015, find a home currency bias: Not only do factors associated with greater (or less) cross-border investment in bonds differ by currency denomination, but also the ever-present home bias actually disappears in some cases when bonds are denominated in the investor's currency.

In this paper, we analyze bond markets using a panel dataset similar to that in Burger, Warnock, and Warnock (2017), spanning the period 2007 to 2015. Currency denomination, as in all of our bond market papers, is an important aspect of our analysis, but unlike in our earlier work, the focus here is squarely on sectoral aspects of EME bond markets. In particular, we assess the development of EME sovereign and corporate bond markets, both local currency and foreign currency, and attempt to understand what drives U.S. investors' portfolios in those markets.

We find that the structure of EME bond markets has generally continued to improve over the 2007 to 2015 period, as many EMEs have lessened their reliance on foreign currency bonds. That trend has reversed slightly in recent years, in particular because of increased private sector issuance of foreign currency denominated bonds. Nevertheless, the share of EME bonds denominated in the local currency is markedly higher than a decade ago, and time-fixed effects in our regressions indicate that, after controlling for local variables, over the 2007-2015 period there has been a trend toward larger sovereign local currency bond markets and larger private foreign currency bond markets. It is this latter trend that creates the recent decline in the share of private bonds denominated in local currency.[1] Regarding the determinants of bond market development, we find that local factors matter: countries with better macroeconomic stability (i.e., lower inflation volatility) have larger sovereign local currency bond markets and a greater share of private local currency denominated

1. For this study, a local currency bond is denominated in the currency of the country of residence of the issuer, in keeping with residence-based international accounts. A recent focus on the ultimate nationality of the issuer —for example, when a Chinese firm issues a yuan-denominated bond through an off-shore subsidiary (see, for example, McCauley and others, 2013)— is relevant, but beyond the scope of our study.

bonds; stronger regulatory quality/creditor rights are associated with larger sovereign local currency bond markets and a greater share of local currency denominated bonds (both sovereign and private issued); and countries with more positive current account balances have larger bond markets (both local currency and foreign currency denominated, and especially private sector issued bonds) and a greater share of bonds denominated in local currency. Interestingly, larger economies in our sample have *smaller* foreign currency bond markets and a larger share of local currency bonds. U.S. conditions and policies also influence EME bond markets: (a) local currency (both sovereign and private) and private foreign currency bond markets increased in size when U.S. yields, especially the non-large scale asset purchase portion (non-LSAP), were lower, and (b) EME bond markets grew most during periods of lower CBOE Volatility Index (VIX). Controlling for the level of U.S. long-term interest rates, we fail to find robust evidence for an additional impact of UMP on EME bond market development, as across three UMP proxies there is limited and mixed evidence linking U.S. unconventional monetary policy and bond market development.

We also examine the evolution of U.S. investors' EME bond portfolios, employing data on countrylevel holdings (by currency and sector of issuer) built from high-quality security-level data. While holdings of private sector local currency bonds remain quite small—the data appear to indicate that EME corporates must issue in U.S. dollars to attract a meaningful amount of U.S. investment—, holdings of sovereign issued local currency bonds and private-issued USD-denominated bonds have increased significantly over the past decade. For sovereign local currency bonds, we find that U.S. investment is greater in EMEs with more positive fiscal balances, higher yields, greater regulatory quality and creditor rights, and stronger trade ties with the U.S. Some global factors matter. For example, lower U.S. long-term interest rates and a lower VIX are associated with increased investment in EME sovereign local currency bonds. However, results for UMP proxies were mixed, including some (but not much) evidence that the LSAP-induced fall in U.S. rates was associated with increased investment in EME sovereign local currency bonds. Overall results for these bonds are consistent with the classic result of low U.S. rates being associated with a surge in investment in EMEs. From our analyses of U.S. cross-border investment in USD-denominated bonds, we find investment was greater in EMEs with stronger regulatory quality and creditor rights, lower inflation volatility, and lower yields. We also find evidence that lower U.S. interest rates are associated with increased investment in USD-denominated sovereign bonds, but global push factors do not appear important in determining investment in EME private sector bonds.

In addition to being related to our series of papers on EME bond markets, as discussed above, this paper is related to academic literature in four respects. First, on bond market development, it adds to Burger and Warnock (2006), Claessens and others (2007), and many others (to be discussed in section 3). Second, it contributes to the literature on relationships between international portfolios, and global and local factors. For example, Calvo and others (1993) noted the importance of global factors such as U.S. interest rates in explaining capital inflows, and Chuhan and others (1998) made the important contribution of separating different types of flows and found that global factors were important in explaining capital inflows, but country-specific developments were at least as important. Many subsequent papers confirmed points made by those two papers. A recent example, Fratzscher (2012), using weekly fund flows data, found that global factors were the main drivers of capital flows in the midst of the recent crisis, but that country-specific determinants were dominant in the years immediately following the crisis. Third, our paper is also directly related to work on international investment in bonds—including Lane (2006), and Fidora and others (2007)—and on U.S. investors' local currency bond portfolios—Burger and Warnock (2007); Burger, Warnock, and Warnock (2012). Fourth, a closely related but separate literature looks at cross-border banking flows—see, for example, Blank and Buch (2007), and Hale and Obstfeld (2016).

Our assessment of EME bond markets—their size, structure and international investment—starts in the next section with a discussion of considerations about existing data on bonds outstanding and bond holdings. Section 2 describes the three ways UMP proxies enter our regression analysis. In section 3, we describe and assess the evolution of EME markets. In section 4, we assess U.S. investors' EME bond portfolios. Section 5 concludes.

1. Bonds Outstanding and Bond Holdings Data

1.1 Working Dataset

Our assessment of the development of EME bond markets demands a careful appraisal of available datasets. We consider the following four points: First, the currency denomination of bonds should be identified for both bonds outstanding and cross-border bond holdings—the location of the issuer is not an accurate proxy for the currency denomination of bonds—so that we can examine the development of local currency denominated bonds against foreign currency denominated ones, as well as investors' allocations within the two (local and foreign currency). Second, we are interested in revealing any differences in trends between sovereign issued bonds and private sector issued bonds, and so we require data disaggregated by sector (public v. private). Third, we choose a class of investors, namely, those residing in the U.S., for which consistent and complete data are available. Fourth, we obviously need data through time.

Given the above requirements, our working dataset for this paper consists of annual data from 2007 to 2015 on 15 EMEs, assembled from two main sources: portfolio data from U.S. Treasury comprehensive benchmark surveys and bond market data from the recently redesigned debt securities datasets of the Bank for International Settlements (BIS). Local currency denominated debt is clearly identified in the Treasury data and, in the BIS data, it is the sum of the long-term debt component of "domestic debt" and the local currency/local issuer portion of "international bonds". Overall, our dataset allows us to separately analyze bonds by sector of the issuer (sovereign or private) and by currency denomination (local currency and foreign currency, including a separate entry for USD-denominated bonds). We consider this dataset appropriate for our study; but, it also posed significant challenges, which we outline below.

1.2 The Amount of Bonds Outstanding

Before 2012, data that identified the currency denomination and issuer of bonds were available from BIS for more than 40 countries, including over 20 EMEs. The relevant data on debt securities and international bonds statistics formed the BIS Quarterly Review "Table 16A: Domestic debt securities, by sector and residence of issuer" and "Table 14B: International bonds and notes all issuers, by residence of issuer". Domestic debt was defined by the BIS as local currency bonds issued by locals in the local market (i.e., not placed directly abroad), while international bonds were bonds issued either in a different currency or in a different market. It was possible to back out data on bonds (debt securities with original maturity over one year)[2] placed either domestically or internationally, as well as to identify the issuer's residence, the currency denomination of the bonds, and the type of issuer (sovereign or private). Burger and others (2015), using this BIS dataset, were able to include 21 EMEs and 23 AEs. However, this dataset was discontinued and is thus available only through 2011, and is possibly inconsistent with the new dataset based on new methodology that the BIS established in 2012 (Gruić and Wooldridge, 2012).

In the new BIS dataset (with 2012 definitions) that we use in this paper, "international bonds" are largely the same as in the discontinued pre-2012 dataset described above. The challenge with this new dataset is that central banks of some countries have opted to report data that sum together domestic and international debt. We argue that, even for an aggregated analysis, combining domestic and international debt hampers analysis. For analyses that explicitly require splits on currency and maturity—a split that used to be readily available because the international portion was built up from security-level data and the domestic portion was assumed (by definition) to be denominated in the local currency—aggregated debt data presents a severe limitation.

1.3 Bond Holdings

International bond portfolio data must identify the currency denomination of the underlying bonds, because the location of the issuer does not indicate the currency denomination of the bonds. One dataset that identifies currency denomination is available for a particular set of investors: U.S. resident investors. Data on U.S. holdings of foreign bonds have been obtained from periodic, comprehensive security-level benchmark surveys conducted by the

2. The split between bonds/notes and short-term paper can be important. Consider, for example, Brazil. A large proportion of Brazilian debt securities are short-term; see Leal and Carvalhal da Silva (2008) for a detailed analysis. In the old BIS database, Brazilian debt securities were broken out by maturity (and currency denomination), and it showed that, as of end-2011, about $1 trillion of its $1.5 trillion in domestic debt securities were short-term instruments (e.g., money market). Using the old dataset, one can omit Brazilian short-term instruments and focus on Brazilian domestic long-term debt securities (which totaled $0.5 trillion at end-2011).

U.S. Treasury Department, the Federal Reserve Bank of New York and the Board of Governors of the Federal Reserve System. The *security-level* holdings data are not available to researchers outside the Federal Reserve Board, but the country-level aggregates (with currency and sector breakdown) that are built from the security-level data are available for over 100 countries and provide a clean annual dataset beginning in 2007.[3] These holdings data also constitute the official U.S. data on international positions; for example, the figure for international bonds in the International Investment Position report issued by the Bureau of Economic Analysis is formed by aggregating the survey's security-level information.

The data based on the granular security-by-security data are aggregated according to the currency denomination of a bond, the country residence of its issuer, and the sector (sovereign or private) of the issuer. Starting with year-end 2007 data, the data are posted on the Treasury website, in a report with a table labeled as "U.S. holdings of foreign long-term debt securities, by country and sector of issuer, denominated in U.S. dollars and in local currency."[4]

Although in our analysis we are forced, by limited data availability, to focus on U.S. investors' cross-border bond holdings (and not investors across a number of countries), it is sufficiently rich because U.S. investors are a large group for which we have high-quality, publicly available data. And to reiterate, U.S. investors' bond holdings are captured at the security level, so the exact nature of the bond is known to the data clearinghouse (i.e., Treasury, NY Fed, and Federal Reserve Board) and, therefore, this enables the production of publicly available reports on bonds by various classifications (currency, sector, etc.)

3. Note that, while for foreign currency bonds we limit our portfolio analysis to USD-denominated bonds, U.S. investors' holdings of third-currency bonds (i.e., neither in USD, nor in the issuer's currency) are extremely small, amounting to only 2.3% of their foreign bond portfolio in 2011.

4. For more detail, see, for example, U.S. Department of the Treasury and others (2008), or the Griever, Lee, and Warnock (2001) primer. For the exact table we use, see, for example, table 29 from U.S. Department of the Treasury and others (2008) or table A11 from U.S. Department of the Treasury and others (2016). Note that we alter the underlying Treasury data in two ways. One, we leave true zeros as zeros, but we replace asterisks, which indicate that U.S. holdings are greater than zero but less than $500,000, with $250,000. Two, there are instances when, for a particular split of the data, reported U.S. holdings are greater than the amount outstanding; in these cases, we set holdings equal to the amount outstanding.

2. Unconventional Monetary Policy in the Empirical Model

Several proxies for unconventional monetary policy (UMP) are available, although for our purposes no one method seems to be superior over the rest.[5] We therefore use three approaches for UMP.

First, following Ahmed and Zlate (2014), we decompose the ten-year Treasury yield into two components: one that may be due to LSAPs (*usi10_LSAP*) and the yield estimated in the absence of LSAPs (*usi10_nonLSAP*). Specifically, in a first-stage regression, we regress Treasury yields on one-quarter ahead Fed net asset purchases (since the QE programs were announced ahead of implementation) over the period from 2002:Q4 to 2016:Q2, and then we compute the LSAP component of yields as *beta*LSAP*.[6] The remaining yield is the *non-LSAP* component. For the period prior to the first QE program, we set the LSAP component to zero. The results suggest that, on average, $100 billion in LSAPs in a quarter would decrease yields by 37.5 basis points (bp), in line with the Ahmed and Zlate (2014) estimate of 31 bp, and roughly consistent with other estimates in the literature. For example, the D'Amico and King (2013) event study estimated a persistent downward shift in yields averaging 30 bp, and the VAR estimates of Bhattarai, Chatterjee, and Park (2015) suggest $100 billion in LSAPs would have a 25 basis point effect on impact. Figure 1 shows the actual ten-year Treasury yield (solid line), our estimate of what the ten-year yield would have been without LSAPs

5. In the literature, a number of UMP proxies have been employed; see Ahmed and Zlate (2014) for a discussion focused on LSAPs. For example, an indicator variable has been used to mark initial announcements and implementation periods of the first three rounds of LSAPs; see Gagnon and others (2010), Krishnamurthy and Vissing-Jorgensen (2011), and Bauer (2012). See also D'Amico and King (2013), Wright (2012), Hamilton and Wu (2012), Bauer and Rudebusch (2014), Rogers and others (2014), and the Fawley and Neely (2013) narrative account of the LSAPs of four major central banks. Another technique is to use a VAR-based approach to assess the effects of quantitative easing (QE); see Wright (2012), Baumeister and Benati (2013), Gambacorta and others (2014), and Bhattarai, Chatterjee, and Park (2015). Swanson (2016) uses techniques from Gurkaynak, Sack, and Swanson (2005) to estimate separate forward guidance and LSAP effects. Other work on the international effects of U.S. QE policy include Glick and Leduc (2012, 2013), Chen and others (2012), and Bauer and Neely (2014); Eichengreen and Gupta (2015), Aizenman and others (2016), and Bowman and others (2015); Tillmann (2014) estimates of the QE effects on the aggregate data of EMEs; and the Ahmed and Zlate (2014), Ahmed and others (2016), Dahlhaus and Vasishtha (2014), and Lim and others (2014) analyses of the QE effects on capital flows to EMEs.

6. LSAP is the change in the size of Federal Reserve securities holdings (from the Federal Reserve Statistical Release H.4.1) scaled by GDP.

(dashed line), and LSAP scaled by GDP (bars, right-hand scale). Table 1 shows the two series from the decomposition that enter our annual regressions: an estimate of what the U.S. ten-year yield would have been without LSAPs (*usi10_nonLSAP*), and the effect of LSAPs on the U.S. ten-year yield (*usi10_LSAP*). The LSAP effect averages 31 bp per year from 2009 through 2014 with peaks in 2010 and 2013.

Figure 1. 10-year Treasury Yields and LSAPs

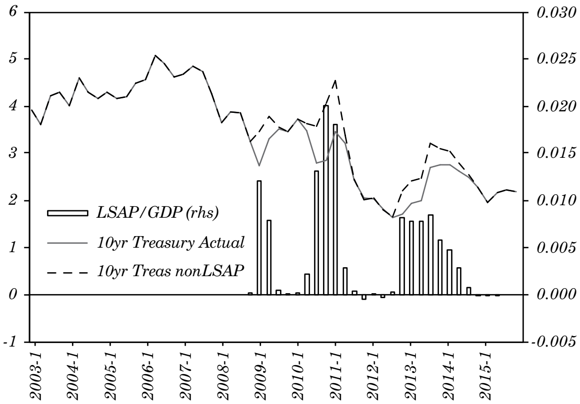


Table 1. U.S. 10-year Treasury Yields, Decomposition and Unconventional Monetary Policy

	10-year Treasury Yield				
	Actual	*Non-LSAP*	*LSAP*	*UMP*	*LSAP/GDP*
	usi10	*usi10_ nonlsap*	*usi10_lsap*	*us_ump10*	*lsap_ flow_gdp*
2007	4.63	4.63	0.00	0.000	0.000
2008	3.67	3.67	0.00	–0.351	0.000
2009	3.26	3.57	–0.31	–0.322	0.094
2010	3.21	3.75	–0.54	–0.026	0.021
2011	2.79	3.10	–0.32	–0.062	0.029
2012	1.80	1.93	–0.13	0.108	0.003
2013	2.35	2.80	–0.45	–0.019	0.066
2014	2.54	2.67	–0.13	0.207	0.027
2015	2.14	2.14	0.00	–0.411	0.000

The second approach augments the first by adding a direct measure of the amount of LSAPs scaled by GDP (*lsap_flow_gdp*) in regressions that also include the ten-year interest rate.

The third approach uses well-identified UMP shocks to the ten-year interest rate, as calculated by Rogers, Scotti, and Wright (2016), henceforth RSW, which updates Rogers and others (2014). Specifically, RSW use high-frequency financial market data around Federal Reserve announcements (FOMC statements as well as governors' speeches) to help identify monetary policy shocks in a VAR setting. We use the RSW shock to the ten-year rate—the change in ten-year Treasury rates within a 2hour window of announcements—and, at the same time, also include the level of the ten-year Treasury interest rate (which itself captures some of the impact of unconventional monetary policy).

We are agnostic on the many ways to proxy UMP; we therefore utilize the three approaches described above and attempt to discern effects that are robust to the choice of a proxy.

3. Bond Markets in Emerging Market Economies

3.1 Structure of EME Sovereign and Corporate Bond Markets

We start by presenting salient features of EME sovereign and corporate bond markets, specifically, their size and structure. For consistency, in descriptive tables or figures that present aggregates, we include only the 13 EMEs for which we have complete data for 2009 and 2015: Chile, Colombia, Mexico, and Peru; South Korea, Malaysia, Pakistan, Philippines, and Thailand; and Israel, Russia, South Africa, and Turkey.

Table 2, which presents information on 13 EME bond markets in 2009 and 2015, shows that, over that period, local currency bond markets grew from \$2289 billion to \$3281 billion, just over half of which were issued by sovereign entities. The size of local currency bonds, measured as a percent of the country's GDP, increased modestly from 42% to 46%, and their weight in the global bond market increased from 2.7% to 3.5%. Foreign currency denominated bonds—most of which are issued by the private sector—also increased, from \$436 billion in 2009 to \$851 billion in 2015, increasing from 8.0% to 11.8% of national GDP and nearly doubling their weight in the global bond market (from 0.5% to 0.9%). Of the foreign currency denominated bonds, most are USD-denominated

($714 billion out of $851 billion in 2015). Overall, most EME bonds are denominated in the local currency; in 2015, 87% of sovereign bonds and 72% of private sector bonds were denominated in the local currency.

The evolution of EME sovereign and corporate bonds markets is plotted in figures 2a-2e. We see the stark predominance of local currency bonds over USD-denominated bonds, and a milder predominance of sovereign over private bonds (figure 2a). Though smaller in size, USD-denominated private sector bonds have rapidly grown, more than doubling between 2009 and 2015. Bonds outstanding by country, plotted in figures 2b-2e, help uncover any regional trends, while showing differences across countries within a region. As a share of GDP (figure 2b), local currency sovereign bond markets increased smartly since 2007 in many Asian and Latin American EMEs, but less so in other countries. In contrast, trends in the development of many private-sector local currency bond markets are less discernible (figure 2c). Further, local currency share—the share of local currency bonds in all bonds—is generally high for sovereign bonds (figure 2d), but lower and even declining for private sector bonds (figure 2e). This last point—the decline in local currency share of private bonds—is due to the doubling of private sector foreign currency bonds evident in figure 2a.

Table 2. EME Bond Markets

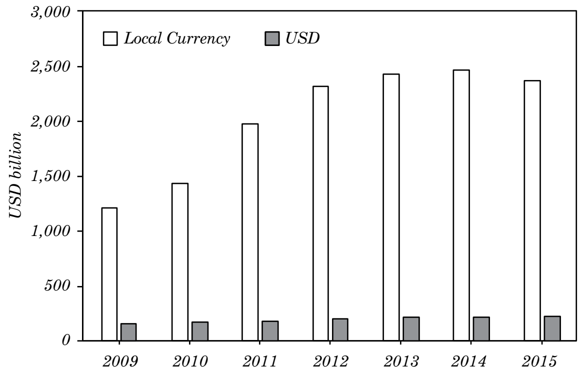
	2009	*2015*
Size of EME Local Currency Bond Markets		
USD billion	2289	3281
Percent sovereign	52.7	54.1
Percent of GDP	41.9	45.7
Percent of global bond market	2.7	3.5
Size of EME USD-denominated Bond Markets		
USD billion	357	714
Percent sovereign	44.1	31.0
Percent of GDP	6.5	9.9
Percent of global bond market	0.4	0.8
Ratio of Local Currency to Total Bonds (%)	84.0	79.4
Local currency share of sovereign bonds (%)	86.4	87.1
Local currency share of private bonds (%)	81.5	71.9

Note: This table includes data for Chile, Colombia, Mexico, Peru; South Korea, Malaysia, Pakistan, Philippines, Thailand; and Israel, Russia, South Africa, and Turkey.

Figure 2. Currency Composition of Bond Markets

Figure 2a. Amounts in Billions of Dollars

Total Bonds Outstanding: Government Bonds



Total Bonds Outstanding: Private-Sector Bonds

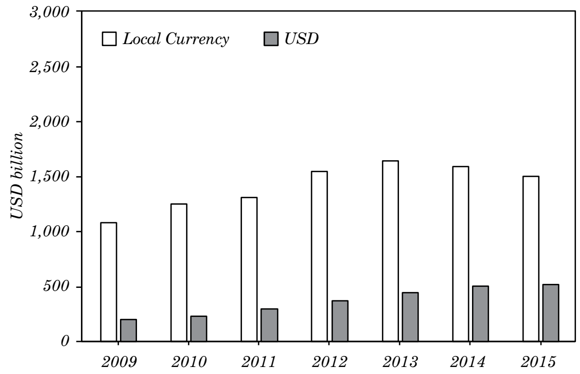
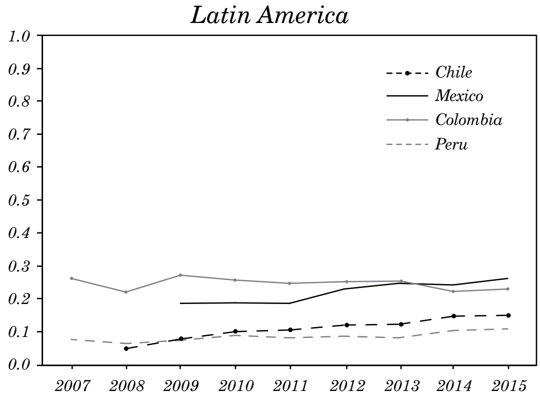
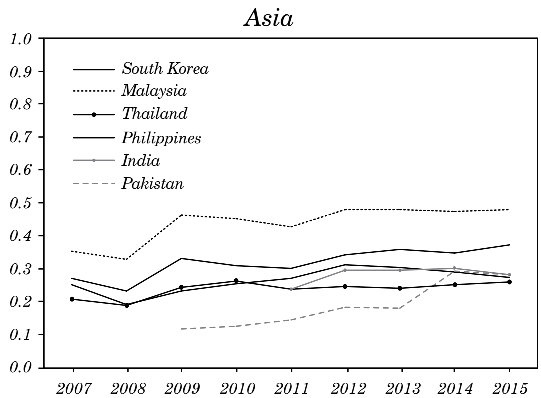


Figure 2. (continued)

Figure 2b. As a Share of GDP: Sovereign Local Currency Bonds





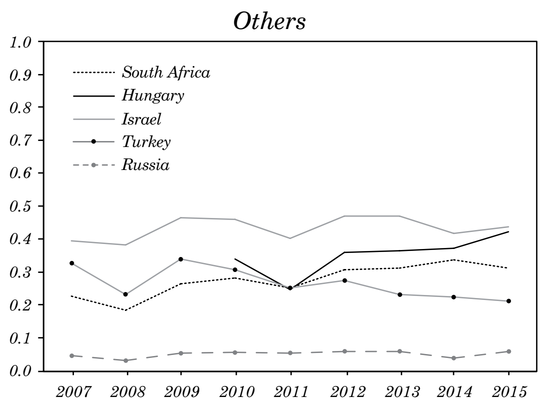


Figure 2. (continued)

Figure 2c. As a Share of GDP: Private Sector Local Currency Bonds

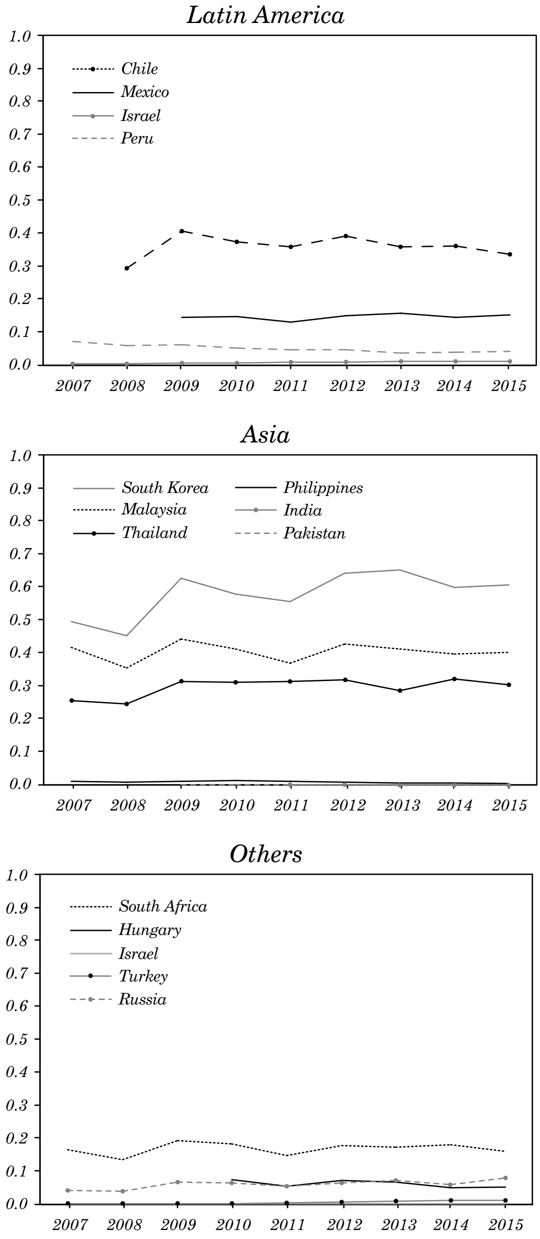


Figure 2. (continued)

Figure 2d. As a Share of All Sovereign Bonds: Local Currency Bonds

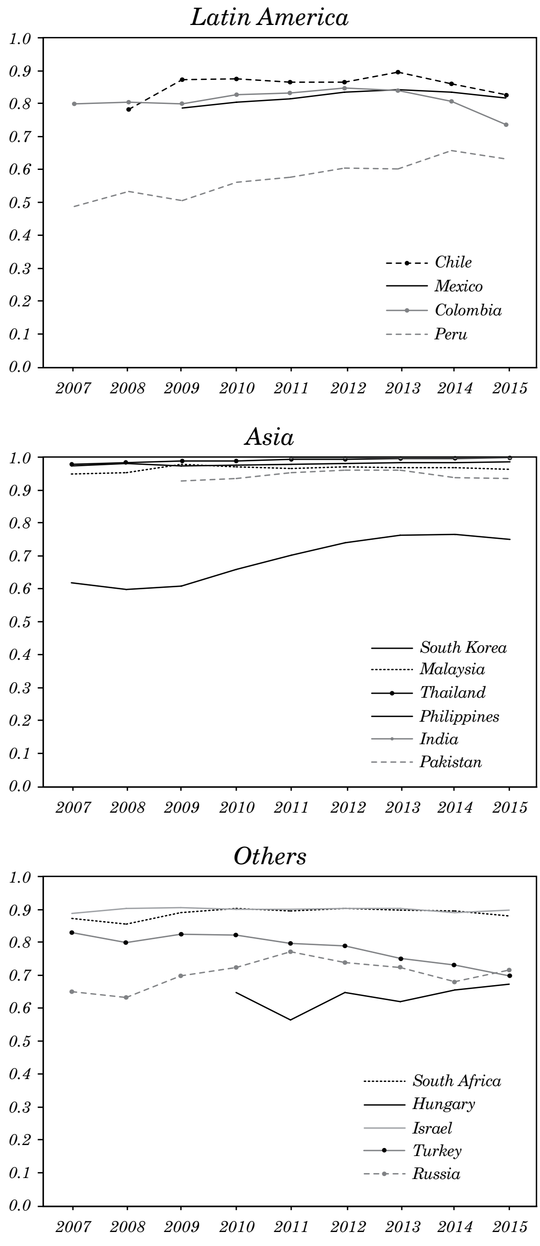
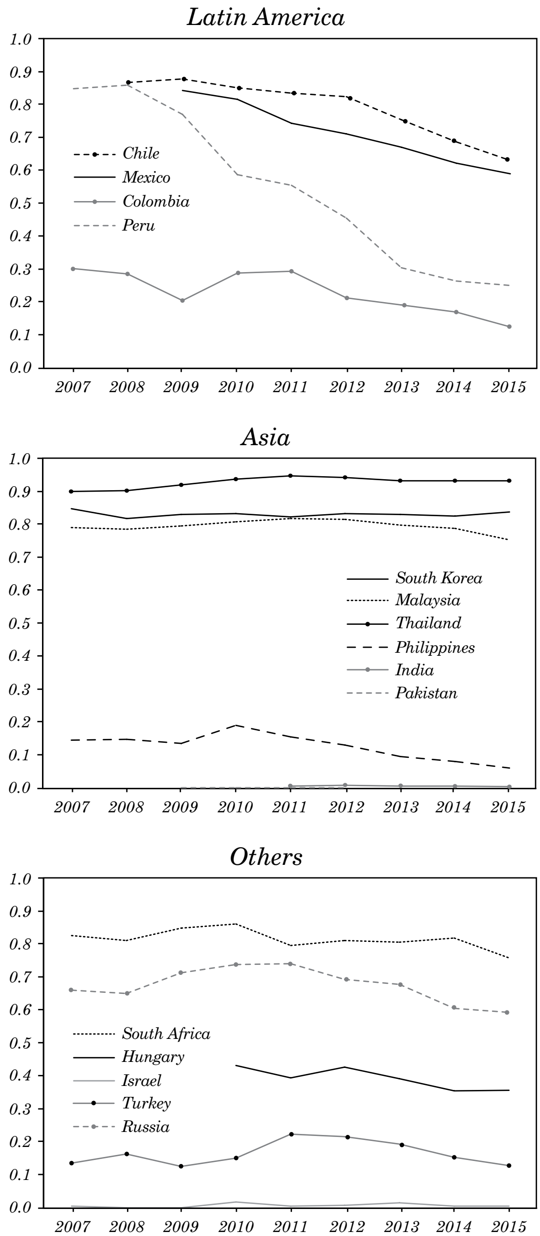


Figure 2. (continued)

Figure 2e. As a Share of All Private Bonds: Local Currency Bonds



3.2 The Determinants of the Size and Structure of EME Bond Markets

Why do some EMEs have larger local currency bond markets than others? In Burger, Warnock, and Warnock (2012), we assessed the size of local currency bond markets in 2008 and found that EMEs with lower inflation volatility and stronger legal rights have more developed local bond markets. In Burger and Warnock (2006), the findings were similar; economies can (and have) put in place institutions and policies that foster the development of debt markets. Economies with better inflation performance (an outcome of creditor-friendly policies) have more developed local bond markets, both private and sovereign, and rely less on foreign currency denominated bonds. Creditor-friendly laws matter. Stronger rule of law is associated with deeper local bond markets, and countries with stronger creditor rights are able to issue a larger share of bonds in their local currencies.

With an annual panel dataset spanning 2007 to 2015, we refresh our analysis on the size and currency composition of bond markets. Similar to Burger and Warnock (2006), and Claessens and others (2007), we employ three measures of bond market development, each defined by sector (sovereign and private) as follows: the ratio of the size of the local currency bond markets to GDP, the ratio of the size of the *foreign currency* bond markets to GDP, and the share of the country's outstanding bonds denominated in the local currency (local currency share).

Explanatory variables include regulatory quality, creditor rights, fiscal and current account balances, country size, GDP growth rate, the extent of trade with the U.S., a bond-specific measure of capital account openness, and inflation volatility. Specifically:

- *regcr* is a measure of regulatory quality and creditor rights, calculated as a weighted average of the Regulatory Quality Index from the World Bank's World Governance Indicators and the Legal Rights Index from the 'Getting Credit' section of the World Bank's Doing Business report. We construct a composite measure with twice the weight on regulatory quality, according to the GEMLOC Investability Indicator Methodology (Markit 2013).[7] We recast the

7. The regulatory quality index measures a government's ability to formulate and implement sound policies and regulations that promote private sector development, while the creditor rights index measures the degree to which collateral and bankruptcy laws protect the rights of borrowers and lenders.

indicators to have values from 0 to 1—instead of from 0 to 100—to easily interpret the regression coefficients.

- *caopen* is a Markit (2013) *de jure* measure of the openness of a country's local currency bond market to foreign investment, with higher scores indicating that a bond market is more open to cross-border investment. From the update of Markit (2013), we use the November observation of "Capital Control, Convertibility, and Access" for each country and year, and merge with the Burger and others (2015) estimates for 2006 and 2007. We assume top scores (i.e., completely open) for South Korea (which enters the Markit dataset in 2011 with score of 100), and Israel and Singapore (which are not in the Markit sample). We recast *caopen* to range from 0 to 1.
- *ca_gdp* and *fbal* (current account balance and fiscal balance, both scaled by GDP) are from IMF's IFS as reported in Haver Analytics.
- *infvol*, inflation volatility, is computed on a rolling basis using three years of quarterly data (from the IMF's International Financial Statistics (IFS) data as reported in Haver Analytics).
- *growth* is calculated as the three-year average growth rate in real GDP per capita (from IMF's IFS data as reported in Haver Analytics).
- *nomgdp* is the log of nominal GDP in USD.
- *trade_gdp* is bilateral imports and exports between the U.S. and the foreign country, scaled by the respective countries' nominal GDP (source: IMF).
- For global variables, we include the VIX, as well as several proxies for unconventional monetary policy and U.S. ten-year Treasury yields (as described in section 2 and presented in table 1).

In our regressions, we use an annual panel dataset that spans the period 2007 to 2015 and includes 15 EMEs. In all, we have 123 observations, as due to data limitations some EMEs enter the panel later than 2007.[8] We report our results in table 3 for sovereign bonds and for private sector bonds using three measures: local currency scaled by GDP, foreign currency scaled by GDP, and share of local currency in total. Constants are included but not reported. Estimates are calculated using panel feasible generalized least squares (FGLS), which allows for heteroscedastic error structures and different

8. Ten countries have data for all 9 years. In addition, Chile enters in 2008; Mexico and Pakistan, in 2009; Hungary, in 2010; and India, in 2011. We lose 3 observations in the final column of table 3, because Pakistan had no reported private sector bonds.

autocorrelation coefficients for each country. Wald tests (not reported) show that the explanatory variables are always jointly significant.

First, in table 3a we include time-fixed effects (but not global factors) to capture the impact of global forces on EME bond markets during each year in the sample; coefficients for 2008 to 2015 are reported and should be interpreted relative to 2007. The strongest results (in a statistical sense and also robust across specifications) are as follows:

- Countries with stronger regulatory/creditor rights have larger local currency sovereign bond markets and a greater share of bonds denominated in local currency (both sovereign and private).
- Countries with stronger current account balances have larger local currency bond markets (and higher local currency share).
- Trade with the U.S. matters for private sector bonds, but negatively impacts sovereign bonds. While we cannot see the underlying firm-level data, it could be that corporates that trade a lot with the U.S. also issue more bonds (some of which are USD-denominated).
- Capital account openness matters only for foreign currency private bonds. Macroeconomic stability (infvol) impacts only local currency sovereign bonds.
- The impact of country size varies across the specifications: Larger countries in our sample have smaller foreign currency bond markets and a larger share of local currency bonds.
- The time effects are often positive and significant for sovereign local currency bonds and foreign currency private bonds, and often negative for the local currency share of private bonds. In other words, after controlling for other variables, over the 2007 to 2015 period there has been a trend toward larger sovereign local currency bond markets and larger private foreign currency bond markets (the latter trend leading to a decline in the share of all private bonds denominated in local currency).

In tables 3b-3d, we include global push variables and omit the time-fixed effects. The impact of country-specific macroeconomic conditions and policies is broadly similar to the analysis in table 3a. In addition, we see that U.S. yields and global risk conditions matter. EME local currency (both sovereign and private) and foreign currency private bond markets increased in size when the non-LSAP component of the ten-year Treasury was lower (table 3b). We also find evidence that EME bond markets grew most during periods of lower VIX. Further, there is no robust evidence showing an independent impact of UMP—that is, above and beyond what is embedded in long-term Treasury yields—on the size and currency composition of EME bond markets. Across the three UMP proxies, there is limited and inconsistent evidence linking Fed policy and bond market development (beyond the ever-present U.S. long-term interest rate effect). That said, we do find some evidence suggesting that UMPs that lower U.S. long rates are associated with increased EMEs' private sector issuance in U.S. dollars.

Table 3. Bond Market Structure Regressions

Table 3a. Bond Market Structure Regressions (with time-fixed effects)

	Sovereign			*Private*		
	Local currency	*USD*	*Share of local currency*	*Local currency*	*USD*	*Share of local currency*
	LC Govt	*FC Govt*	*LCShr Govt*	*LC Pvt*	*FC Pvt*	*LCShr Pvt*
fbal	–0.004*	0.001	–0.007***	0.002	0.000	0.024***
	(0.002)	(0.000)	(0.002)	(0.001)	(0.001)	(0.005)
cab	0.234**	–0.000	0.192*	0.285**	0.160***	0.518**
	(0.108)	(0.024)	(0.115)	(0.123)	(0.035)	(0.251)
infvol	–0.011**	–0.001	0.004	–0.003	–0.001	–0.022**
	(0.005)	(0.001)	(0.004)	(0.003)	(0.001)	(0.010)
growth	0.671**	–0.057	0.328	–0.122	0.078	–1.006
	(0.299)	(0.048)	(0.348)	(0.195)	(0.070)	(0.675)
nomgdp	–0.000	–0.000***	0.000**	–0.000	–0.000***	0.000***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
trade_gdp	–2.532***	–0.834**	8.130*	2.680**	1.276***	4.213**
	(0.618)	(0.360)	(4.726)	(1.290)	(0.340)	(1.770)
regcr	0.138***	–0.029***	0.123**	0.077*	0.058***	0.377***
	(0.038)	(0.010)	(0.056)	(0.046)	(0.014)	(0.092)
caopen	0.042	0.004	–0.022	0.023	0.034***	0.183*
	(0.038)	(0.006)	(0.046)	(0.032)	(0.009)	(0.099)
2008.year	–0.019*	–0.004**	–0.003	–0.004	0.004	0.040**
	(0.010)	(0.002)	(0.010)	(0.009)	(0.003)	(0.020)
2009.year	0.039**	–0.001	–0.002	0.027*	0.011**	0.089***
	(0.016)	(0.003)	(0.016)	(0.015)	(0.005)	(0.033)
2010.year	0.049***	0.000	0.003	0.016	0.013**	0.046
	(0.015)	(0.003)	(0.016)	(0.015)	(0.006)	(0.034)

Table 3. (continued)

Table 3a. Bond Market Structure Regressions

	Sovereign			*Private*		
	Local currency	*USD*	*Share of local currency*	*Local currency*	*USD*	*Share of local currency*
	LC Govt	*FC Govt*	*LCShr Govt*	*LC Pvt*	*FC Pvt*	*LCShr Pvt*
2011.year	0.043***	–0.000	0.010	0.001	0.016***	–0.023
	(0.014)	(0.003)	(0.016)	(0.016)	(0.005)	(0.033)
2012.year	0.060***	0.003	0.006	0.013	0.022***	–0.037
	(0.013)	(0.003)	(0.016)	(0.015)	(0.005)	(0.031)
2013.year	0.073***	0.003	0.005	0.013	0.031***	–0.070**
	(0.014)	(0.003)	(0.017)	(0.016)	(0.005)	(0.033)
2014.year	0.081***	0.003	0.005	0.007	0.037***	–0.089***
	(0.015)	(0.004)	(0.018)	(0.017)	(0.006)	(0.034)
2015.year	0.086***	0.006	–0.011	0.007	0.043***	–0.106***
	(0.015)	(0.004)	(0.018)	(0.017)	(0.006)	(0.036)
N	123	123	123	123	123	120

Notes: The annual panel data spans 2007 to 2015, and includes 15 Emerging Market Economies (EMEs). Because of data limitations, some EMEs enter the panel later than 2007. In table 3a, time-fixed effects are included and independent variables are, in the order that they are listed, local currency bonds (all, sovereign or private) scaled by GDP; foreign currency bonds (all, sovereign or private) scaled by GDP; and the share of local currency to total bonds (all, sovereign or private). Independent variables are, in order, fiscal balance (scaled by GDP), current account balance (scaled by GDP), inflation volatility, real GDP growth, size of the local economy (calculated as the log nominal GDP in USD), our Regulatory quality/Creditor Rights variable, and openness. In Panels b-d, the time-fixed effects are replaced by global variables (the non-LSAP portion of U.S. 10-year Treasury yields and the LSAP effect on U.S. 10-year Treasury yields). Constants are included but not reported. Estimates are calculated using panel-feasible generalized least squares (FGLS), allowing for heteroscedastic error structures and different autocorrelation coefficients within countries. p-values are reported in parentheses. ***, ** and * denote significance levels at 1%, 5% and 10%, respectively. Wald tests (not reported) show that the explanatory variables are always jointly significant.

Table 3. (continued)

Table 3b. Bond Market Structure Regressions (with 10-year Treasury yield decomposition)

	Sovereign			*Private*		
	Local currency	*USD*	*Share of local currency*	*Local currency*	*USD*	*Share of local currency*
Fbal	−0.007***	0.000	−0.006***	0.001	−0.000	0.014***
	(0.002)	(0.000)	(0.002)	(0.001)	(0.001)	(0.004)
cab	0.328***	0.012	0.107	0.345***	0.125***	0.505**
	(0.102)	(0.022)	(0.116)	(0.119)	(0.041)	(0.220)
infvol	−0.012***	−0.001	−0.001	−0.001	−0.001	−0.011
	(0.004)	(0.001)	(0.003)	(0.003)	(0.002)	(0.008)
growth	0.119	−0.070*	0.226	−0.083	−0.149*	−0.372
	(0.245)	(0.042)	(0.295)	(0.188)	(0.081)	(0.500)
nomgdp	−0.000	−0.000***	0.000**	−0.000***	−0.000	0.000***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
trade_gdp	−2.783***	−0.375*	6.144*	1.868*	1.140**	1.431
	(0.620)	(0.214)	(3.581)	(1.082)	(0.538)	(1.969)
regcr	0.087**	−0.030***	0.117**	0.049	0.097***	0.423***
	(0.039)	(0.009)	(0.049)	(0.045)	(0.013)	(0.080)
caopen	0.038	0.005	−0.024	0.041	0.041***	0.090
	(0.039)	(0.006)	(0.046)	(0.033)	(0.011)	(0.093)
usi10_nonlsap	−0.017***	−0.001	−0.000	−0.011***	−0.005**	0.004
	(0.004)	(0.001)	(0.005)	(0.004)	(0.002)	(0.008)
usi10_lsap	−0.021	−0.001	−0.006	−0.021*	0.009	−0.030
	(0.014)	(0.003)	(0.017)	(0.012)	(0.007)	(0.029)
vix	−0.244***	−0.026***	−0.013	−0.033	−0.052***	0.241***
	(0.051)	(0.009)	(0.050)	(0.040)	(0.019)	(0.089)
_cons	0.297***	0.091***	0.765***	0.103**	−0.016	0.202
	(0.038)	(0.011)	(0.057)	(0.050)	(0.017)	(0.124)
N	123	123	123	123	123	120

Table 3. (continued)

Table 3c. Bond Market Structure Regressions (with LSAP)

	Sovereign			*Private*		
	Local currency	*USD*	*Share of local currency*	*Local currency*	*USD*	*Share of local currency*
	LC Govt	*FC Govt*	*LCShr Govt*	*LC Pvt*	*FC Pvt*	*LCShr Pvt*
fbal	−0.006***	0.000	−0.005***	0.001	0.000	0.013***
	(0.002)	(0.000)	(0.002)	(0.001)	(0.001)	(0.004)
cab	0.290***	0.008	0.081	0.420***	0.129***	0.480**
	(0.104)	(0.021)	(0.105)	(0.128)	(0.041)	(0.227)
infvol	−0.010**	−0.001	−0.002	0.001	−0.002	−0.008
	(0.004)	(0.001)	(0.003)	(0.003)	(0.002)	(0.008)
growth	0.115	−0.067*	0.074	0.025	−0.095	−0.296
	(0.217)	(0.039)	(0.263)	(0.185)	(0.080)	(0.475)
nomgdp	−0.000	−0.000***	0.000	−0.000***	−0.000*	0.000***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
trade_gdp	−2.761***	−0.394*	16.687***	−1.299	1.615*	2.169
	(0.617)	(0.204)	(4.875)	(1.779)	(0.969)	(2.183)
regcr	0.106***	−0.032***	0.092**	0.069	0.081***	0.475***
	(0.040)	(0.009)	(0.046)	(0.043)	(0.013)	(0.079)
caopen	0.040	0.004	−0.009	0.008	0.036***	0.106
	(0.039)	(0.006)	(0.043)	(0.033)	(0.011)	(0.094)
usi10	−0.019***	−0.001	−0.000	−0.009**	−0.006***	0.009
	(0.004)	(0.001)	(0.005)	(0.004)	(0.002)	(0.008)
lsap_flow_gdp	0.097	0.005	0.056	0.089*	0.011	0.080
	(0.063)	(0.011)	(0.059)	(0.053)	(0.029)	(0.133)
vix	−0.267***	−0.027***	−0.012	−0.089**	−0.033*	0.241***
	(0.048)	(0.008)	(0.044)	(0.042)	(0.019)	(0.085)
N	123	123	123	123	123	120

Table 3. (continued)

Table 3d. Bond Market Structure Regressions
(with unconventional monetary policy)

	Sovereign			*Private Sector*		
	Local currency	*USD*	*Share of local currency*	*Local currency*	*USD*	*Share of local currency*
fbal	–0.007***	0.000	–0.006***	0.001	0.000	0.011***
	(0.002)	(0.000)	(0.002)	(0.001)	(0.001)	(0.004)
cab	0.325***	0.015	0.174	0.372***	0.140***	0.497**
	(0.102)	(0.020)	(0.108)	(0.121)	(0.041)	(0.218)
infvol	–0.012***	–0.001	0.000	0.001	–0.002	–0.007
	(0.004)	(0.001)	(0.003)	(0.003)	(0.001)	(0.008)
growth	0.096	–0.061*	0.266	–0.067	–0.056	–0.350
	(0.219)	(0.034)	(0.267)	(0.183)	(0.078)	(0.458)
nomgdp	–0.000	–0.000***	0.000	–0.000***	–0.000	0.000***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
trade_gdp	–2.815***	–0.932***	3.545	–1.162	1.121***	1.788
	(0.604)	(0.209)	(2.943)	(2.105)	(0.396)	(2.094)
regcr	0.085**	–0.032***	0.142***	0.055	0.098***	0.477***
	(0.039)	(0.009)	(0.050)	(0.045)	(0.012)	(0.078)
caopen	0.034	0.005	–0.027	0.032	0.040***	0.082
	(0.039)	(0.006)	(0.045)	(0.034)	(0.012)	(0.091)
usi10	–0.016***	–0.001	0.001	–0.010***	–0.005***	0.007
	(0.004)	(0.001)	(0.005)	(0.004)	(0.002)	(0.008)
ump_i10	–0.011	–0.003	0.024**	0.003	–0.021***	0.035
	(0.011)	(0.002)	(0.011)	(0.008)	(0.005)	(0.022)
vix	–0.280***	–0.033***	0.046	–0.045	–0.084***	0.313***
	(0.052)	(0.009)	(0.055)	(0.043)	(0.021)	(0.102)
N	123	123	123	123	123	120

4. U.S. Investors' International Bond Portfolios

4.1 Analyzing U.S. Investors' Portfolios: Measure

The dependent variable in this analysis is the Ahmed and others (2016) measure of portfolio weights—the *normalized relative weight*.[9] Relative weight is simply a country's weight in U.S. investors' portfolio relative to its weight in a benchmark portfolio. Specifically, country *i*'s relative portfolio weight in U.S. portfolios is the ratio of its weight in U.S. investors' portfolio to its weight in the global market. Relative weight can be defined as:

$$Rel\,Wgt_i^{US} = \frac{\omega_{i,US}}{\omega_{i.m}} = \frac{H_i^{US} \Big/ \sum_i H_i^{US}}{MCap_i \Big/ \sum_i MCap_i} \quad (1)$$

where H_i^{US} is defined as U.S. investors' holdings of country *i*'s bonds and $\sum H_i^{US}$ represents the global portfolio of bonds held by U.S. investors, while $MCap_i$ is the market capitalization of country *i*'s bond market and $\sum MCap_i$ is the market capitalization of the global bond market. If the portfolio weight assigned to a particular bond market equals its weight in the global bond market, the relative weight for that market is one. In reality, U.S. investors' relative portfolio weights are often far less than one—this is one dimension of the well-known home bias in asset holdings—because over 90 percent of U.S. investors' bond holdings are issued by U.S. entities. That said, for some asset classes—such as bonds denominated in the investor's currency—relative weights can and sometimes do exceed one (Burger, Warnock, and Warnock 2017).

9. Relative weight is consistent with an international Capital Asset Pricing Model (CAPM)-based model of international portfolio allocation as presented in Cooper and Kaplanis (1986). That model, described in some detail in Holland and others (2016), includes country-specific proportional investment costs representing both explicit and implicit costs of investing abroad, and is designed to optimize an investor's allocation of wealth among risky securities in n countries in order to maximize expected returns net of costs. If there are no costs to investing, the allocation collapses to the global market capitalization allocation; that is, the investor allocates his wealth across countries according to market capitalizations. If costs are non-zero and non-uniform, allocations deviate from market weights. The higher the costs in a particular foreign market, the more severely underweighted that country will be in the investor's portfolios. The international CAPM, therefore, provides a theoretical underpinning for our focus on relative weight.

Relative price changes will cause movements in Relative Weight even if investors do not alter their positions. This relative price effect can be removed through the simple normalization of dividing the relative weight from equation (1) by the relative weight for the home market:

$$norm\,Rel\,Wgt = \frac{\omega_{i,US}}{\omega_{i,m}} \Bigg/ \frac{\omega_{US,US}}{\omega_{US,m}} \qquad (2)$$

This *normalized relative weight* is shown in Ahmed and others (2016) to isolate portfolio reallocations that are independent of relative price changes and are consistent with the Bekaert and Wang (2009) adjustment of scaling by the source country's home bias. In our panel regressions, we use *normalized relative weight*, a measure of portfolio allocations that omits passive portfolio changes due to relative price changes.

4.2 Evolution of EME Bond Holdings

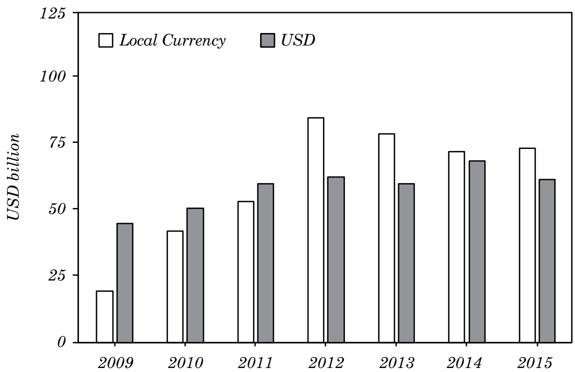
The EME local currency bond portfolio of U.S. investors grew dramatically from $20 billion in 2009 to $72 billion in 2015 (lower panel of table 4). EME local currency bonds were 2.7% of the global bond market in 2009, and grew to 3.5% in 2015. U.S. holdings increased even faster: U.S. investors held 0.87% of outstanding EME local currency bonds in 2009, and this increased to 2.2% by 2015. Because the weight of EME local currency bonds in U.S. portfolios has increased relative to their weight in the global bond market, the relative weight measure for EME local currency bonds in U.S. investors' portfolios more than doubled over this period, from 0.029 in 2009 to 0.070 in 2015.

Holdings of USD-denominated bonds issued by EMEs are substantially larger at $73 billion in 2009, which increased to $152 billion by 2015, and U.S. investors hold a slightly higher percentage of outstanding EME USD-denominated bonds (20.5% in 2009, 21.3% in 2015). Indeed, the weights of EME USDdenominated bonds in U.S. bond portfolios (0.29% in 2009, 0.51% in 2015) are not too dissimilar from their weight in the global bond market (0.4% in 2009, 0.8% in 2015), so U.S. investors' relative weight on EME USD-denominated bonds are much closer to one (0.68 in 2009, 0.67 in 2015).

U.S. holdings of EME bonds, levels by currency and sector, are presented in figure 3, which can be compared with the amount of bonds outstanding from figure 2a. Quite apparent is the fact that the ratio of local-to-USD bonds is much smaller in U.S. portfolios than in bonds outstanding. Most EME bonds are denominated in the local currency, but most U.S. holdings (especially of private sector bonds) are in USD. In fact, whereas U.S. investors hold roughly equal amounts of local currency and USD-denominated sovereign bonds, U.S. holdings of private-sector EME local currency bonds are so low, that it appears that EME corporates must issue in USD to reach U.S. investors.

Figure 3. U.S. Investors' Portfolio in EME Bonds

U.S. Holding: Government Bonds



U.S. Holding: Private Sector Bonds

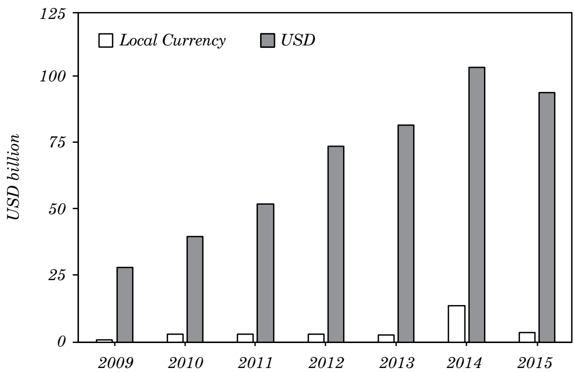
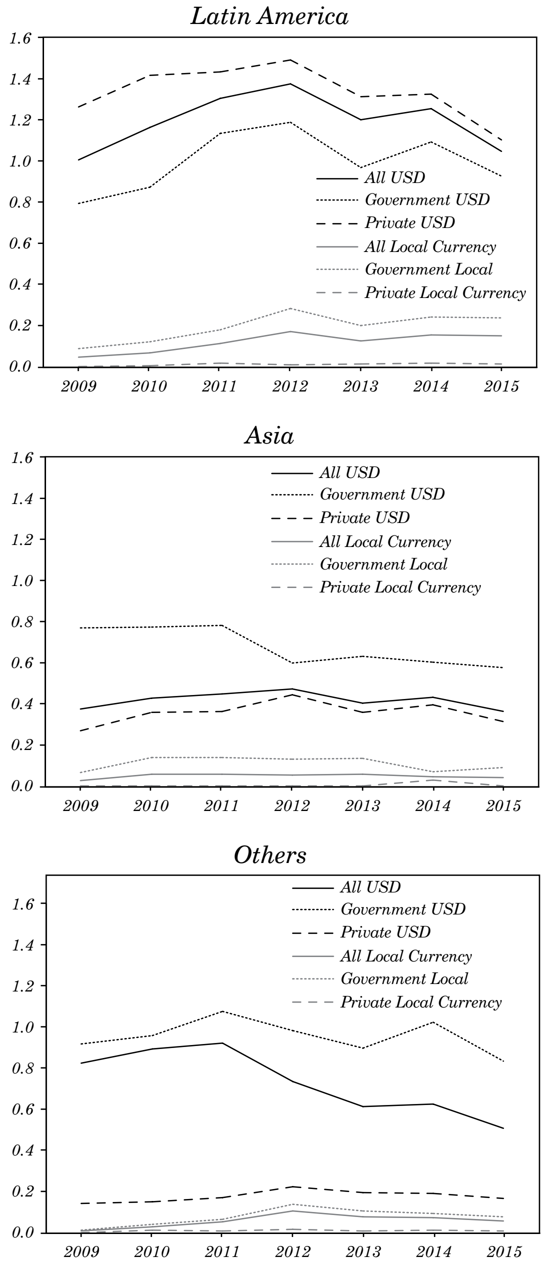


Table 4. U.S. Portfolios of EME Bonds

	2009	*2015*
Size of EME Local Currency Bond Markets		
USD billion	2289	3281
Percent sovereign	52.7	54.1
Percent of GDP	41.9	45.7
Percent of global bond market	2.7	3.5
Size of EME USD-denominated Bond Markets		
USD billion	357	714
Percent sovereign	44.1	31.0
Percent of GDP	6.5	9.9
Percent of global bond market	0.4	0.8
Ratio of Local Currency to Total Bonds (%)	84.0	79.4
Local Currency Share of Sovereign Bonds (%)	86.4	87.1
Local Currency Share of Private Bonds (%)	81.5	71.9
U.S. Holdings of EME Local Currency Bonds		
USD billion	20	72
Percent of outstanding EME Local Currency bonds	0.87	2.20
Percent of U.S. bond portfolio	0.08	0.24
RelWgt	0.029	0.07
U.S. Holdings of EME USD-denominated Bonds		
USD billion	73	152
Percent of outstanding EME USD bonds	20.5	21.3
Percent of U.S. bond portfolio	0.29	0.51
RelWgt	0.684	0.674

Notes. For ease of comparison, the top half of this table is identical to table 2. This table, and the below figure 3, includes data for Chile, Colombia, Mexico, Peru; South Korea, Malaysia, Pakistan, Philippines, Thailand; and Israel, Russia, South Africa, and Turkey.

Figure 4. U.S. Investors' Relative Weights



Regional aggregates (figure 4) add insight into the stylized fact presented in Burger and others (2017) that home bias is, to some extent, a home currency bias. In each graph in figure 4, there are two thick lines; the higher of the two is the relative weight for USD-denominated bonds, whereas the lower thick line is for local currency bonds. As in Burger and others (2017), relative weights for USD-denominated bonds are always much greater than for local currency bonds. Also shown are the sectoral splits. That EME corporates must issue in USD to reach U.S. investors is evident from the private-sector USD relative weights being near zero. Relative weights for sovereign local currency bonds are also quite low, but nowhere near zero. And relative weight for USD bonds, whether sovereign or corporate, is quite high.

4.3. Empirical Analysis of U.S. Investors' Foreign Bond Portfolios

Over the past decade, U.S. investors have significantly increased their cross-border holdings of EME bonds. We use a common framework to analyze the evolution in U.S. investors' country-specific relative portfolio weights—that is, their portfolio weights relative to a global benchmark—for bonds split by currency and sector. Our annual panel dataset of U.S. investor relative portfolio weights includes 15 destination countries over the 2007 to 2015 period.[10] For explanatory variables, in addition to the country-specific factors from table 3, we include another "pull" factor, yield, to proxy for expected return.[11] The other *macroeconomic indicators* are shown in table 3 and here represent factors that likely impact the attractiveness of an economy as a destination for cross-border bond investment. Inflation volatility (calculated as a rolling, trailing 12-quarter standard deviation) is included as a proxy for the uncertainty of *ex-ante* real returns—increased inflation volatility will also lead to more volatile nominal bond yields, thus increasing reinvestment risk. We include the current account to GDP ratio as a proxy for financial imbalances. A country running a current account deficit must attract capital flows; if those

10. The number of destination countries is limited not by the holdings data, but by data on the size and composition of bond markets and by explanatory variables.

11. Yield, expressed in basis points, is the annual average of monthly bond yields (yield-to-maturity from the J.P Morgan GBI indexes). JPMorgan provided yield data through 2013; we gathered 2014 and 2015 data from the Bloomberg.

inflows do not materialize, adverse financial market outcomes (such as currency depreciation and/or a spike in bond rates) are likely to occur. We also include the three-year average growth rate in real GDP per capita as an indicator of the vigor of the destination economy. Our primary *institutional* variable (our measure of regulatory quality and creditor rights) and our *de jure* measure of the openness of a country's local currency bond market to foreign investment are described in section 3. For global "push" factors, we include the VIX volatility index (which measures variation in expected volatility and risk appetite, and which we divide by 100 for readability of regression coefficients) and the three measures of U.S. long rates and U.S. unconventional monetary policy discussed in section 2.

We present results for U.S. cross-border investment in local currency bonds in table 5, and in USD-denominated bonds in table 6. In each case, we split by sector with—sovereign bonds in panel a and private sector bonds in panel b. In both of them, we include either time-fixed effects (column 4) to show the impact of global forces on bond allocations over time without having to specify the precise nature of the global variables, or specific global "push" factors (columns 1-3). For the time effects, coefficients for 2008 to 2015 are reported and should be interpreted relative to 2007.

4.3.1 Panel Results for Local Currency Portfolio Allocations

The results for investment in local currency bonds (table 5) show a stark contrast between sovereign and private sector bonds. Much fewer explanatory variables are significant for private sector bonds (panel b), but this is not surprising given the minimal investment by U.S. investors in local currency bonds issued by the private sector in EMEs. For sovereign bonds (panel a), U.S. investment is greater in countries with more positive fiscal balances, higher yields, greater regulatory quality and creditor rights, and stronger trade linkages with the U.S. The time-fixed effects indicate that, after controlling for country-specific factors, U.S. investors increased their allocations to EME local currency sovereign bonds during the 2010 to 2015 period. When including specific global factors (columns 1-3), results suggest that lower U.S. interest rates and lower VIX are associated with increased investment in local currency sovereign bonds. We get mixed results when we bring in unconventional monetary policy, but we do find that the LSAP-induced fall in U.S. rates was associated with increased investment in EME local currency sovereign bonds.

In summary, the results for EME sovereign local currency bonds in table 5 are consistent with the classic result of low U.S. rates being associated with a surge in EME investment, therefore providing a plausible channel through which U.S. conditions could have contributed to the appreciation of EME currencies (and also providing support to currency war claims).

4.3.2 Panel Results on USD-denominated Portfolio Allocations

We analyze U.S. cross-border investment in USD-denominated bonds, and report our results in table 6 for sovereign bonds (panel a) and private sector bonds (panel b), including country-level "pull" factors, and either time-fixed effects (column 4) or global "push" factors (columns 1-3). The time-fixed effects for USD-denominated sovereign bonds are positive and significant for many years between 2009 and 2014. For private-sector USD-denominated bonds the time-fixed effects are all negative and usually statistically insignificant. Investment in USD-denominated sovereign EME bonds was greater in countries with stronger regulatory quality/creditor rights, lower inflation volatility, and lower yields. For USD-denominated bonds issued by the private sector in EMEs, investment is greater in smaller economies and in those with greater trade linkages with the U.S. For global factors, there is a sharp contrast in the impact on U.S. investment in USD-denominated sovereign v. private sector bonds. Low U.S. interest rates and lower VIX are associated with increased relative weights on USD-denominated sovereign bonds, but we fail to find a significant impact of these global push factors on relative weights for the growing stock of USD-denominated private sector bonds.

Table 5. Determinants of U.S. Investment in Local Currency Bonds

Table 5a. Determinants of U.S. Investment: Sovereign Local Currency Bonds

	(1)	*(2)*	*(3)*	*(4)*
fbal	0.002***	0.003***	0.003***	0.001
	(0.001)	(0.001)	(0.001)	(0.001)
cab	0.065	0.022	0.004	0.111*
	(0.050)	(0.055)	(0.056)	(0.057)
infvol	0.004*	0.005***	0.004**	0.005**
	(0.002)	(0.002)	(0.002)	(0.002)
yield	0.174*	0.185**	0.194**	0.204**
	(0.091)	(0.093)	(0.095)	(0.102)
growth	−0.042	−0.052	−0.033	0.241*
	(0.107)	(0.115)	(0.121)	(0.144)
nomgdp	−0.000***	−0.000***	−0.000***	−0.000***
	(0.000)	(0.000)	(0.000)	(0.000)
trade_gdp	2.828***	2.973***	2.957***	2.944***
	(0.576)	(0.457)	(0.478)	(0.495)
regcr	0.042**	0.047**	0.044**	0.060***
	(0.021)	(0.021)	(0.021)	(0.023)
caopen	0.015	0.012	0.007	0.019
	(0.014)	(0.015)	(0.015)	(0.016)
usi10	−0.013***	−0.011***		
	(0.003)	(0.003)		
ump_i10	0.012*			
	(0.006)			
vix	−0.077***	−0.106***	−0.088***	
	(0.028)	(0.025)	(0.024)	
lsap_flow_gdp		0.026		
		(0.033)		
usi10_nonlsap			−0.012***	
			(0.003)	
usi10_lsap			−0.026***	
			(0.008)	
2008.year				0.001
				(0.005)

Table 5. (continued)

Table 5a. (continued)

	(1)	*(2)*	*(3)*	*(4)*
2009.year				0.010
				(0.009)
2010.year				0.029***
				(0.009)
2011.year				0.038***
				(0.009)
2012.year				0.047***
				(0.009)
2013.year				0.048***
				(0.009)
2014.year				0.049***
				(0.009)
2015.year				0.044***
				(0.010)
N	123	123	123	123

Notes: Sovereign bonds are in panel a and private sector bonds are in panel b. Annual panels span the period 2007 to 2015 and includes 15 EMEs. Because of data limitations, some EMEs enter the panel later than 2007. Dependent variables are normalized relative weights for local currency bonds in table 5 and USD-denominated bonds in table 6. Constants are included but not reported. Estimates are calculated using panel-feasible generalized least squares (FGLS), allowing for heteroscedastic error structures and different autocorrelation coefficients within countries. Standard errors are reported in parentheses. ***, ** and * denote significance at the 1%, 5% and 10% levels, respectively.

Table 5. (continued)

Table 5b. Determinants of U.S. Investment: Private Local Currency Bonds

	(1)	*(2)*	*(3)*	*(4)*
fbal	–0.016*	–0.024**	–0.018*	–0.030**
	(0.009)	(0.011)	(0.010)	(0.012)
cab	–0.062	–0.188	–0.271	–0.139
	(0.524)	(0.590)	(0.569)	(0.599)
infvol	–0.002	–0.014	0.004	–0.012
	(0.020)	(0.022)	(0.023)	(0.024)
yield	0.113	–0.600	–0.346	–0.852
	(1.034)	(1.120)	(1.100)	(1.050)
growth	1.551	1.476	1.356	1.833
	(0.971)	(1.027)	(1.129)	(1.309)
nomgdp	0.000	0.000	0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.000)
trade_gdp	–2.987	–4.065	–3.473	–4.473
	(3.022)	(2.608)	(3.163)	(2.884)
regcr	0.225	0.161	0.264	0.185
	(0.204)	(0.200)	(0.212)	(0.195)
caopen	–0.248*	–0.219	–0.287*	–0.210
	(0.141)	(0.146)	(0.156)	(0.147)
usi10	0.035	0.043*		
	(0.022)	(0.024)		
ump_i10	–0.019			
	(0.053)			
vix	–0.184	0.013	–0.194	
	(0.263)	(0.256)	(0.256)	
lsap_flow_gdp		–0.644		
		(0.407)		
usi10_nonlsap			0.039	
			(0.024)	
usi10_lsap			0.096	
			(0.084)	
2008.year				–0.032
				(0.053)

Table 5. (continued)

Table 5b. (continued)

	(1)	*(2)*	*(3)*	*(4)*
2009.year				–0.139*
				(0.076)
2010.year				–0.079
				(0.076)
2011.year				–0.063
				(0.068)
2012.year				–0.130*
				(0.069)
2013.year				–0.135*
				(0.072)
2014.year				–0.103
				(0.070)
2015.year				–0.099
				(0.072)
N	116	116	116	116

Notes: Sovereign bonds are in panel a and private sector bonds are in panel b. Annual panels span the period 2007 to 2015 and includes 15 EMEs. Because of data limitations, some EMEs enter the panel later than 2007. Dependent variables are normalized relative weights for local currency bonds in table 5 and USD-denominated bonds in table 6. Constants are included but not reported. Estimates are calculated using panel-feasible generalized least squares (FGLS), allowing for heteroscedastic error structures and different autocorrelation coefficients within countries. Standard errors are reported in parentheses. ***, ** and * denote significance at the 1%, 5% and 10% levels, respectively.

Table 6. Determinants of U.S. Investment in USD-denominated Bonds

Table 6a. Determinants of U.S. Investment: Sovereign USD-denominated Bonds

	(1)	(2)	(3)	(4)
fbal	0.006*	0.010**	0.006	0.012**
	(0.004)	(0.004)	(0.004)	(0.005)
cab	0.444**	0.512**	0.425*	0.567**
	(0.224)	(0.259)	(0.258)	(0.287)
infvol	–0.015*	–0.018**	–0.018**	–0.009
	(0.008)	(0.008)	(0.009)	(0.009)
yield	–0.744**	–0.663*	–0.906**	–0.249
	(0.315)	(0.398)	(0.393)	(0.455)
growth	–0.672*	–0.843*	–0.869*	–0.142
	(0.383)	(0.451)	(0.458)	(0.560)
nomgdp	–0.000**	–0.000**	–0.000*	–0.000***
	(0.000)	(0.000)	(0.000)	(0.000)
trade_gdp	0.130	0.330	–0.074	0.881
	(1.275)	(1.392)	(1.429)	(1.353)
regcr	0.243***	0.226**	0.215**	0.317***
	(0.087)	(0.091)	(0.093)	(0.092)
caopen	0.124*	0.038	0.056	0.001
	(0.074)	(0.083)	(0.084)	(0.069)
usi10	–0.026***	–0.029***		
	(0.009)	(0.011)		
ump_i10	0.088***			
	(0.022)			
vix	0.054	–0.217**	–0.180*	
	(0.101)	(0.106)	(0.100)	
lsap_flow_gdp		0.157		
		(0.159)		
usi10_nonlsap			–0.019*	
			(0.011)	
usi10_lsap			0.001	
			(0.035)	
2008.year				–0.038*
				(0.023)

Table 6. (continued)

Table 6a. (continued)

	(1)	*(2)*	*(3)*	*(4)*
2009.year				0.072**
				(0.036)
2010.year				0.084**
				(0.036)
2011.year				0.121***
				(0.034)
2012.year				0.136***
				(0.033)
2013.year				0.100***
				(0.036)
2014.year				0.126***
				(0.036)
2015.year				0.086**
				(0.038)
N	111	111	111	111

Notes: Sovereign bonds are in panel a and private sector bonds are in panel b. Annual panels span the period 2007 to 2015 and includes 15 EMEs. Because of data limitations, some EMEs enter the panel later than 2007. Dependent variables are normalized relative weights for local currency bonds in table 5 and USD-denominated bonds in table 6. Constants are included but not reported. Estimates are calculated using panel-feasible generalized least squares (FGLS), allowing for heteroscedastic error structures and different autocorrelation coefficients within countries. Standard errors are reported in parentheses. ***, ** and * denote significance at the 1%, 5% and 10% levels, respectively.

Table 6. (continued)

Table 6b. Determinants of U.S. Investment: Private USD-denominated Bonds

	(1)	(2)	(3)	(4)
fbal	–0.001	–0.000	–0.001	–0.003
	(0.005)	(0.006)	(0.006)	(0.006)
cab	–0.407	–0.464	–0.496	–0.692**
	(0.333)	(0.321)	(0.344)	(0.320)
infvol	0.007	0.007	0.009	0.009
	(0.012)	(0.013)	(0.013)	(0.015)
yield	1.092	1.085	0.983	0.752
	(0.724)	(0.764)	(0.746)	(0.796)
growth	–0.601	–0.952	–0.899	–1.211
	(0.679)	(0.728)	(0.769)	(0.768)
nomgdp	–0.000***	–0.000**	–0.000**	–0.000**
	(0.000)	(0.000)	(0.000)	(0.000)
trade_gdp	17.136***	17.521***	17.469***	16.530***
	(1.870)	(2.221)	(1.978)	(1.848)
regcr	0.178	0.172	0.131	0.195
	(0.128)	(0.121)	(0.127)	(0.129)
caopen	0.009	0.031	0.017	–0.000
	(0.093)	(0.095)	(0.099)	(0.093)
usi10	–0.001	0.003		
	(0.013)	(0.013)		
ump_i10	0.062*			
	(0.035)			
vix	–0.054	–0.166	–0.228	
	(0.162)	(0.145)	(0.147)	
lsap_flow_gdp		–0.166		
		(0.218)		
usi10_nonlsap			0.007	
			(0.014)	
usi10_lsap			0.043	
			(0.048)	
2008.year				–0.032
				(0.034)

Table 6. (continued)

Table 6b. (continued)

	(1)	*(2)*	*(3)*	*(4)*
2009.year				–0.058
				(0.048)
2010.year				–0.047
				(0.047)
2011.year				–0.040
				(0.043)
2012.year				–0.009
				(0.043)
2013.year				–0.033
				(0.044)
2014.year				–0.012
				(0.045)
2015.year				–0.050
				(0.046)
N	120	120	120	120

Notes: Sovereign bonds are in panel a and private sector bonds are in panel b. Annual panels span the period 2007 to 2015 and includes 15 EMEs. Because of data limitations, some EMEs enter the panel later than 2007. Dependent variables are normalized relative weights for local currency bonds in table 5 and USD-denominated bonds in table 6. Constants are included but not reported. Estimates are calculated using panel-feasible generalized least squares (FGLS), allowing for heteroscedastic error structures and different autocorrelation coefficients within countries. Standard errors are reported in parentheses. ***, ** and * denote significance at the 1%, 5% and 10% levels, respectively.

4. Conclusion

Our assessment of EME sovereign and corporate bond markets suggests that local factors matter. For example, countries with stronger regulatory quality/creditor rights have larger sovereign issued local currency bond markets and also attracted relatively more U.S. investment into their sovereign bonds. But a long standing global factor—the level of U.S. long-term interest rates—is also important in much of our analysis: We find strong evidence that, when U.S. long rates were low, (1) EMEs issued more sovereign and private-sector local-currency bonds and more private-sector foreign-currency bonds, and (2) U.S. investment in EME sovereign bonds (both local-currency and USD-denominated) increased.

We use three methods to isolate the effects of unconventional monetary policy of the U.S., but we find UMP was rarely important. The low-frequency (annual) data we use is potentially hiding important effects; for example, shocks in June could be undone by December. Still, the contrast between the importance of U.S. long-term rates and UMP is striking.

The interesting stylized fact from Burger and others (2017) that the home bias is, at least in part, a home currency bias—U.S. investors exhibit no home bias against some countries' USD bonds—is also evident here. Our sectoral analysis provides additional insight. Relative investment weights, whether for sovereign or corporate bonds, are always substantially higher for USD-denominated bonds than local currency bonds. And while the home bias against sovereign local currency bonds is substantial, it pales in comparison to that against corporate local currency bonds. Indeed, to a first approximation, EME corporates can only reach U.S. investors if they issue USD-denominated bonds.

References

Ahmed, S. and A. Zlate. 2014. "Capital Flows to Emerging Market Economies: A Brave New World?" *Journal of International Money and Finance* 48: 221–48.

Ahmed, S., S. Curcuru, F. Warnock, and A. Zlate. 2016. "Decomposing International Portfolio Flows." Mimeographed.

Aizenman, J., M. Binici, and M.M. Hutchison. 2016. "The Transmission of Federal Reserve Tapering News to Emerging Financial Markets." *International Journal of Central Banking* 317–56.

Bauer, M.D. 2012. "Fed Asset Buying and Private Borrowing Rates." FRBSF Economic Letter 2012–16, May 21.

Bauer, M.D. and G.D. Rudebusch. 2014. "The Signaling Channel for Federal Reserve Bond Purchases." *International Journal of Central Banking* 10(3): 233–89.

Bauer, M.D. and C.J. Neely. 2014. "International Channels of the Fed's Unconventional Monetary Policy." *Journal of International Money and Finance* 44: 24–46.

Baumeister, C. and L. Benati. 2013. "Unconventional Monetary Policy and the Great Recession: Estimating the Macroeconomic Effects of a Spread Compression at the Zero Lower Bound." *International Journal of Central Banking* 9: 165–212.

Bekaert, G. and X. Wang. 2009, "Home Bias Revisited." Unpublished working paper.

Bhattarai, S., A. Chatterjee, and W.Y. Park. 2015. "Effects of U.S. Quantitative Easing on Emerging Market Economies." Federal Reserve Bank of Dallas Globalization and Monetary Policy Institute Working Paper No. 255.

Blank, S. and C. Buch. 2007. "The Euro and Cross-Border Banking: Evidence from Bilateral Data." *Comparative Economic Studies* 49: 389–410.

Bowman, D., J.M. Londono, and H. Sapriza. 2015. "U.S. Unconventional Monetary Policy and Transmission to Emerging Market Economies." *Journal of International Money and Finance* 55: 27–59.

Burger, J. and F. Warnock. 2003. "Diversification, Original Sin, and International Bond Portfolios." International Finance Discussion Paper No.755, Board of Governors of the Federal Reserve System.

————. 2006. "Local Currency Bond Markets." *IMF Staff Papers* 53: 133–46.

———. 2007. "Foreign Participation in Local-Currency Bond Markets." *Review of Financial Economics* 16(3): 291-304.

Burger, J., F. Warnock, and V.C. Warnock. 2012. "Emerging Local Currency Bond Markets." *Financial Analysts Journal* 68(4): 73–93.

———. 2017. "Currency Matters: Analyzing International Bond Portfolios." NBER Working Paper 23175.

Burger, J., R. Sengupta, F. Warnock, and V. C. Warnock. 2015. "U.S. Investment in Global Bonds: As the Fed Pushes, Some EMEs Pull." *Economic Policy* 30 (84): 729–66.

Calvo, G.A., L. Leiderman, and C.M. Reinhart. (1993). "Capital Inflows and Real Exchange Rate Appreciation in Latin America: The Role of External Factors." *IMF Staff Papers* 40(1): 108–51.

Chen, H., V. Curdia, and A. Ferrero. 2012. "The Macroeconomic Effects of Large-Scale Asset Purchase Programmes." *Economic Journal* 122: 289–315.

Chuhan, P., S. Claessens, and N. Mamingi. 1998. "Equity and Bond Flows to Latin America and Asia: The Role of Global and Country Factors." *Journal of Development Economics* 55(2): 439–63.

Claessens, S., D. Klingebiel, and S. Schmukler. 2007. "Government Bonds in Domestic and Foreign Currency: The Role of Institutional and Macroeconomic Factors." *Review of International Economics* 15(2): 370–413.

Cooper, I. and E. Kaplanis. 1986. Costs to Crossborder Investment and International Equity Market Equilibrium." In *Recent Developments in Corporate Finance*, edited by J. Edwards, J. Franks, C. Mayer and S. Schaefer. Cambridge University Press.

Dahlhaus, T. and G. Vasishtha. 2014. "The Impact of U.S. Monetary Policy Normalization on Capital Flows to Emerging-Market Economies." Bank of Canada Working Paper No. 2014–53.

D'Amico, S. and T.B. King. 2013. "Flow and Stock Effects of Large-Scale Treasury Purchases: Evidence on the Importance of Local Supply." *Journal of Financial Economics* 108: 425–48.

Eichengreen, B. and P. Luengnaruemitchai. 2006. "Why Doesn't Asia Have Bigger Bond Markets?" In *BIS Papers No. 30: Asian Bond Markets: Issues and Prospects*. Basel, Switzerland: Bank for International Settlements.

Eichengreeen, B. and P. Gupta. 2015. "Tapering Talk: The Impact of Expectations of Reduced Federal Reserve Purchases on Emerging Markets." *Emerging Markets Review* 25: 1–15.

Fawley, Brett W. and Christopher J. Neely. 2013. "Four Stories of Quantitative Easing." *Federal Reserve Bank of St. Louis Review*, Jan/Feb, 51–88.

Fidora, M., M. Fratzscher, and C. Thimann. 2007. "Home Bias in Global Bond and Equity Markets: The Role of Real Exchange Rate Volatility." *Journal of International Money and Finance* 26: 631–55.

Fratzscher, M. 2012. "Capital Flows, Push Versus Pull Factors and the Global Financial Crisis." *Journal of International Economics* 88(2): 341–56.

Forbes, K. and F. Warnock. 2013. "Debt- and Equity-Led Capital Flow Episodes." in *Capital Mobility and Monetary Policy*, edited by M. Fuentes and C.M. Reinhart. Santiago: Central Bank of Chile. Also available as NBER Working Paper No. 18329.

Gagnon, J., M. Raskin, J. Remache, and B. Sack. 2010. "Large-scale Asset Purchases by the Federal Reserve: Did They Work?" *Staff Reports* No. 441, Federal Reserve Bank of New York.

Gambacorta, L., B. Hoffman, and G. Peersman. 2014. "The Effectiveness of Unconventional Monetary Policy at the Zero Lower Bound: A Cross-Country Analysis." *Journal of Money, Credit and Banking* 46: 615–42.

Glick, R. and S. Leduc. 2012. "Central Bank Announcements of Asset Purchases and the Impact on Global Financial and Commodity Markets." *Journal of International Money and Finance* 31: 2078–101.

————. 2013. "The Effects of Unconventional and Conventional U.S. Monetary Policy on the Dollar." San Francisco Fed Working Paper No. 2013–11.

Goldstein, M. and P. Turner. 2004. *Controlling Currency Mismatches in Emerging Economies*. Washington, DC: Institute for International Economics.

Gourinchas, P.-O. and M. Obstfeld. 2012. "Stories of the Twentieth Century for the Twenty-First." *American Economic Journal: Macroeconomics* 4(1): 226–65.

Griever, W., G. Lee, and F. Warnock. 2001. "The U.S. System for Measuring Cross-Border Investment in Securities: A Primer with a Discussion of Recent Developments." *Federal Reserve Bulletin* 87(10): 633–50.

Gruić, B. and P. Wooldridge. 2012. "Enhancements to the BIS Debt Securities Statistics." *BIS Quarterly Review* (December): 63–76.

Gurkaynak, R., B. Sack, and E. Swanson. 2005. "Do Actions Speak Louder than Words? The Response of Asset Prices to Monetary Policy Actions and Statements." *International Journal of Central Banking* 1: 55–93.

Hale, G. and M. Obstfeld. 2016. "The Euro and the Geography of International Debt Flows." *Journal of European Economic Association* 14(1): 115–44.

Hamilton, J.D. and C. Wu. 2012. "The Effectiveness of Alternative Monetary Policy Tools in a Zero Lower Bound Environment." *Journal of Money, Credit, and Banking* 44: 3–46.

Holland, S., S. Sarkissian, M. Schill, and F. Warnock. 2016. "Global Equity Investment." Mimeographed.

Krishnamurthy, A. and A. Vissing-Jorgensen. 2011. "The Effects of Quantitative Easing on Interest Rates: Channels and Implications for Policy." *Brookings Papers on Economic Activity*, Fall.

Lane, P. 2006. "Global Bond Portfolios and EMU." *International Journal of Central Banking* 2(2): 1–23.

Leal, R.P.C. and A.L. Carvalhal da Silva. 2008. "Development of the Brazilian Bond Market." In *Bond Markets in Latin America: On the Verge of a Big Bang?* , edited by E. Borensztein, K. Cowan, B. Eichengreen, and U. Panizza. MIT Press.

Lim, J.J., S. Mohapatra, and M. Stoker. 2014. "Tinker, Taper, QE, Bye? The Effect of Quantitative Easing on Financial Flows to Developing Countries." Background paper for Global Economic Prospects 2014, Washington, DC: World Bank.

Markit Indices Limited. 2013. "GEMLOC Investability Indicator Methodology." February 2013, https://www.markit.com/assets/en/docs/products/data/indices/bond-indices/GEMLOC%20Investability%20Indicator%20Methodology.pdf

McCauley, R., C. Upper, and A. Villar. 2013. "Emerging Market Debt Securities Issuance in Offshore Centers." *BIS Quarterly Review* (September, box 2).

Mendoza, E.G. and M. Terrones. 2008. "An Anatomy of Credit Booms: Evidence from Macro Aggregates and Micro Data." NBER Working Paper No. 14049.

Rogers, J.H., C. Scotti, and J. Wright. 2014. "Evaluating Asset-Market Effects of Unconventional Monetary Policy: A Multi-Country Review." *Economic Policy* 749–99.

———. 2016. "Unconventional Monetary Policy and International Risk Premia." International Finance Discussion Papers No. 1172.

Schularick, M. and A. M. Taylor. 2012. "Credit Booms Gone Bust: Monetary Policy, Leverage Cycles, and Financial Crises, 1870-2008." *American Economic Review* 102: 1029–61.

Swanson, E. 2016. "Measuring the Effects of Federal Reserve Forward Guidance and Asset Purchases on Financial Markets." Mimeographed, University of California, Irvine.

Tillmann, P. 2014. "Unconventional Monetary Policy Shocks and the Spillovers to Emerging Markets." Working Paper.

U.S. Department of the Treasury, Federal Reserve Bank of New York, and Board of Governors of the Federal Reserve System. 2008. Report on Foreign Portfolio Investment in the United States as of December 31, 2007.

———. 2016. U.S. Portfolio Holdings of Foreign Securities as of December 31, 2015.

Wright, J. 2012. "What Does Monetary Policy Do to Long-Term Interest Rates at the Zero Lower Bound?" *Economic Journal* 122: F447–F466.

Commodity Connectedness

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Commodities and commodity markets play a central role in the global economy[1]. Hence, commodity market developments are widely chronicled and followed[2]. Commodities are a key input to all countries' production and a key output of many emerging economies, so fluctuations in commodity prices may contribute strongly to common business cycle fluctuations in emerging economies and beyond, as emphasized by Fernández and others (2015). Commodities have also emerged as important financial asset classes (e.g., energy, agriculture, metals), with properties different from those of "traditional" asset classes (e.g., stocks, bonds, foreign exchange), as emphasized by Kat and Oomen (2007a) and Kat and Oomen (2007b).

Understanding connectedness, which is central to risk measurement and management, seems particularly important in the commodities context, particularly for emerging economies relying heavily on commodities production. Relevant aspects include connectedness across firms, markets, and countries, both nominal or financial, and real. In particular, we have in mind elements like connectedness of commodity company stocks (both within and across countries), connectedness of commodity prices, and links between commodity price connectedness and country real output connectedness.

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1. For a broad overview from an empirical perspective, see Chevallier (2013).

2. See, for example, the World Bank Commodity Market Outlook, http://www.worldbank.org/en/research/commodity-markets.

Monetary Policy and Global Spillovers: Mechanisms, Effects and Policy Measures, edited by Enrique G. Mendoza, Ernesto Pastén, and Diego Saravia, Santiago, Chile.

Moreover, measuring connectedness in real time is of special relevance for policy making. Successful real-time policy (and all policy is real-time) demands real-time monitoring, often exploiting high-frequency data[3]. As we shall later describe in detail, the daily commodity volatilities that we study in this paper are in precisely that tradition, built from key parts of trade-by-trade intra-day price paths.

Several approaches to connectedness measurement have been considered recently[4]. Billio and others (2012) use pairwise Granger causality. Bonaldi and others (2013) work with vector autoregressions (VARs), which allow for full multivariate dynamic cross-variable interaction and hence richer connectedness assessment, focusing on connectedness due to cross-lag interactions, as opposed to innovation correlations. Diebold and Yilmaz (2009), Diebold and Yilmaz (2012), and Diebold and Yilmaz (2014) also use VARs, but they use variance decompositions, which account for innovation correlations in addition to dynamic cross-variable interactions[5]. Demirer and others (2016) extend the Diebold-Yilmaz framework to high-dimensional environments, which are increasingly relevant, by incorporating LASSO estimation.

In this paper, we characterize global commodity market connectedness by using the Demirer and others (2016) framework. This is of interest in a variety of contexts. One such key context is private-sector investment management strategies, whose portfolio concentration risk is directly related to connectedness. Another is public-sector monitoring and policy formulation, because connectedness tends to increase during commodity-market crises, which may then spill over into the broader macroeconomy.

We proceed as follows. In section 1, we discuss our commodity price indices, our construction and verification of realized return volatility, and our framework for measuring commodity volatility connectedness.

3. See, for example, John Taylor's inaugural Feldstein Lecture at the National Bureau of Economic Research. http://www.nber.org/feldstein_lecture/feldsteinlecture_2009.html

4. For an interpretive survey see Kara and others (2015).

5. The Diebold and Yilmaz (2014) framework extends earlier variance-decomposition work by Diebold and Yilmaz, including Diebold and Yilmaz (2009) and Diebold and Yilmaz (2012), by using network visualization methods to understand the variance decompositions. Importantly, moreover, as emphasized in Diebold and Yilmaz (2014), the Diebold-Yilmaz framework allows measurement of connectedness at levels ranging from highly granular to highly aggregative, with close connections to marginal expected shortfall or S-risk (Acharya and others, 2010) and CoVaR (Adrian and Brunnermeier, 2016).

In section 2, we provide benchmark results for static connectedness and, in section 3, we provide results for dynamic connectedness. We conclude in section 4, and we explore variations and extensions several appendices.

1. Commodities Data and Volatility

In this section, we describe our commodities data—prices, returns, and range-based return volatilities—and their properties.

1.1 Price Indices

We study nineteen sub-indices of the Bloomberg Commodity Price Index: four energy commodities (crude oil, heating oil, natural gas, unleaded gasoline), two precious metals (gold, silver), four industrial metals (aluminum, copper, nickel, zinc), two livestock commodities (live cattle, lean hogs), four grains (corn, soybeans, soybean oil, wheat), and three so-called "softs" (coffee, cotton, sugar). It is important to note that this category labeling is not ours; rather, it is standard among industry participants, which will subsequently be of interest when interpreting our empirical results[6]. Details on the underlying futures contracts, and the exchanges on which they are traded appear in table 1[7].

The nineteen sub-indices that we study are those underlying the Bloomberg Commodity Price Index when we obtained our data sample[8]. Our data are daily, 2006/5/11 - 2016/1/25, with holidays and weekends dropped. This results in 2,443 observations per series, for a total of 2443x19 = 46,417 observations. We show time-series plots of log sub-indices in figure 1.

6. See Bloomberg (2016).

7. Based on Bloomberg (2016), table 2.

8. Subsequently, Bloomberg (2016) slightly enlarged the set of underlying sub-indices.

Figure 1. Time Series Plots of Log Commodity Sub-Indices

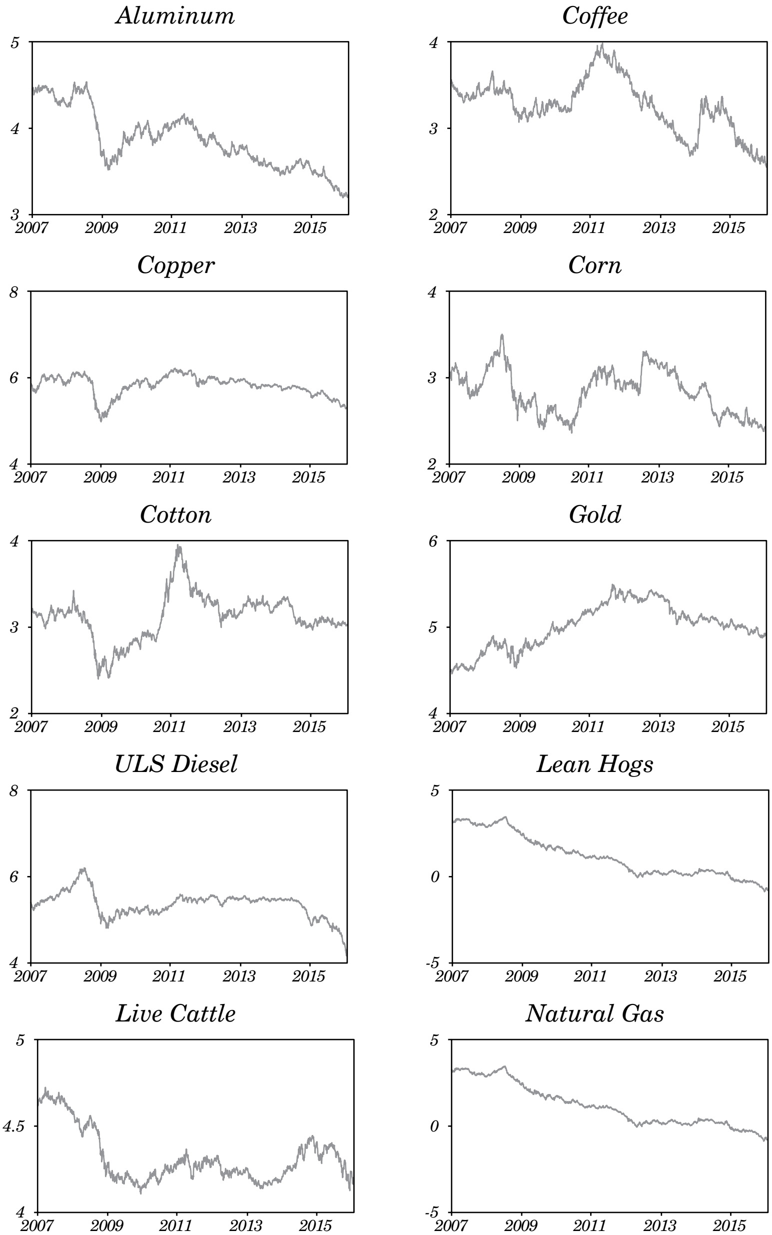


Figure 1. (continued)

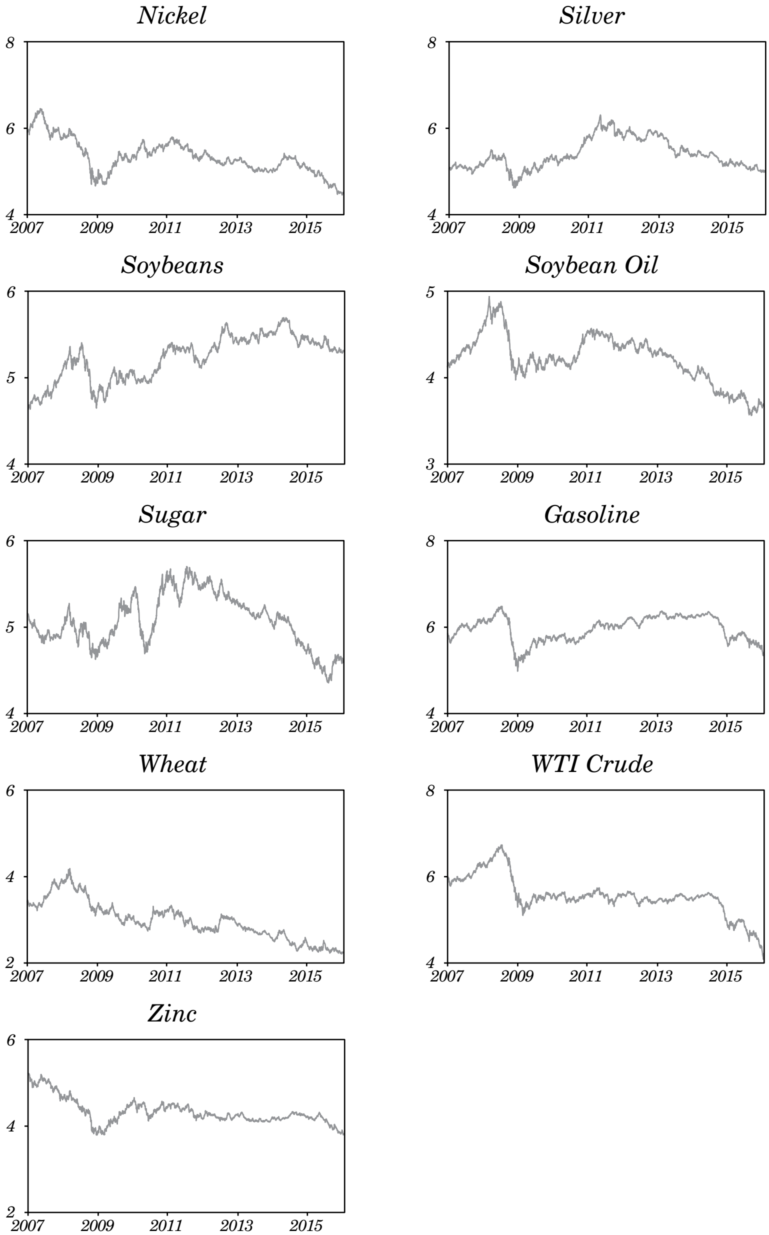


Table 1. Commodity Contracts

Commodity	*Designated contract*	*Exchange*	*Units*	*Price quote*
Natural Gas	Henry Hub Natural Gas	NYMEX	10,000 mmbtu	USD/mmbtu
WTI Crude Oil	Light, Sweet Crude Oil	NYMEX	1,000 barrels	USD/barrel
Unleaded Gasoline	RBOB	NYMEX	42,000 gal	U.S. cents/gallon
ULS Diesel (Heating Oil)	ULS Diesel	NYMEX	42,000 gal	U.S. cents/gallon
Live Cattle	Live Cattle	CME	40,000 lb	U.S. cents/pound
Lean Hogs	Lean Hogs	CME	40,000 lb	U.S. cents/pound
Wheat	Soft Wheat	CBOT	5,000 bushels	U.S. cents/bushel
Corn	Corn	CBOT	5,000 bushels	U.S. cents/bushel
Soybeans	Soybeans	CBOT	5,000 bushels	U.S. cents/bushel
Soybean Oil	Soybean Oil	CBOT	60,000 lb	U.S. cents/pound
Aluminum	High Grade Primary Aluminum	LME	25 metric tons	USD/metric ton
Copper	Copper	COMEX	25,000 lb	U.S. cents/pound
Zinc	Special High Grade Zinc	LME	25 metric tons	USD/metric ton
Nickel	Primary Nickel	LME	6 metric tons	USD/metric ton
Gold	Gold	COMEX	100 troy oz.	USD/troy oz.
Silver	Silver	COMEX	5,000 troy oz.	U.S. cents/troy oz.
Sugar	World Sugar N°11	NYBOT	112,000 lb	U.S. cents/pound
Cotton	Cotton	NYBOT	50,000 lb	U.S. cents/pound
Coffee	Coffee "C"	NYBOT	37,500 lb	U.S. cents/pound

1.2 Realized Volatility

We define commodity returns as change in log price, and we study daily range-based realized commodity-return volatility. That is, following Garman and Klass (1980), we construct range-based realized volatility (variance) as:

$$\hat{\sigma}_{it}^2 = 0.511(H_{it} - L_{it})^2 - 0.019[(C_{it} - O_{it})(H_{it} + L_{it} - 2O_{it}) \quad (1)$$
$$-2(H_{it} - O_{it})(L_{it} - O_{it})] - 0.383(C_{it} - O_{it})^2,$$

where H_{it}, L_{it}, O_{it} and C_{it} are, respectively, the logs of daily high, low, opening, and closing prices for commodity i on day t.

Range-based realized volatility is almost as efficient as realized volatility based on ultra high frequency sampling (since it is based on the key pieces of the intra-day price path—open, close, high, low), much less tedious to construct, robust to microstructure noise, and widely available, often for many decades[9].

In appendix 1, we verify the key properties of realized volatility. Results for other markets like equities (Andersen, Ebens, and others, 2001) and foreign exchange (Andersen, Labys, and others, 2001), indicate that daily realized volatilities are (1) generally distributed asymmetrically, with a right skew, (2) approximately Gaussian after taking natural logarithms, and (3) very strongly serially correlated. Despite the fact that the economics of commodity markets are quite different from those of foreign exchange or equities, the results in appendix 1 make clear that all three properties hold for commodity returns. Given property (2), from this point onward we work in logarithms. That is, even if we simply say “realized volatility” or “volatility”, we mean the natural logarithm of range-based realized volatility, as defined in equation (1). We show time-series plots of the log realized volatilities in figure 2.

9. See Alizadeh and others (2002).

Figure 2. Time Series Plots of Log Realized Volatilities

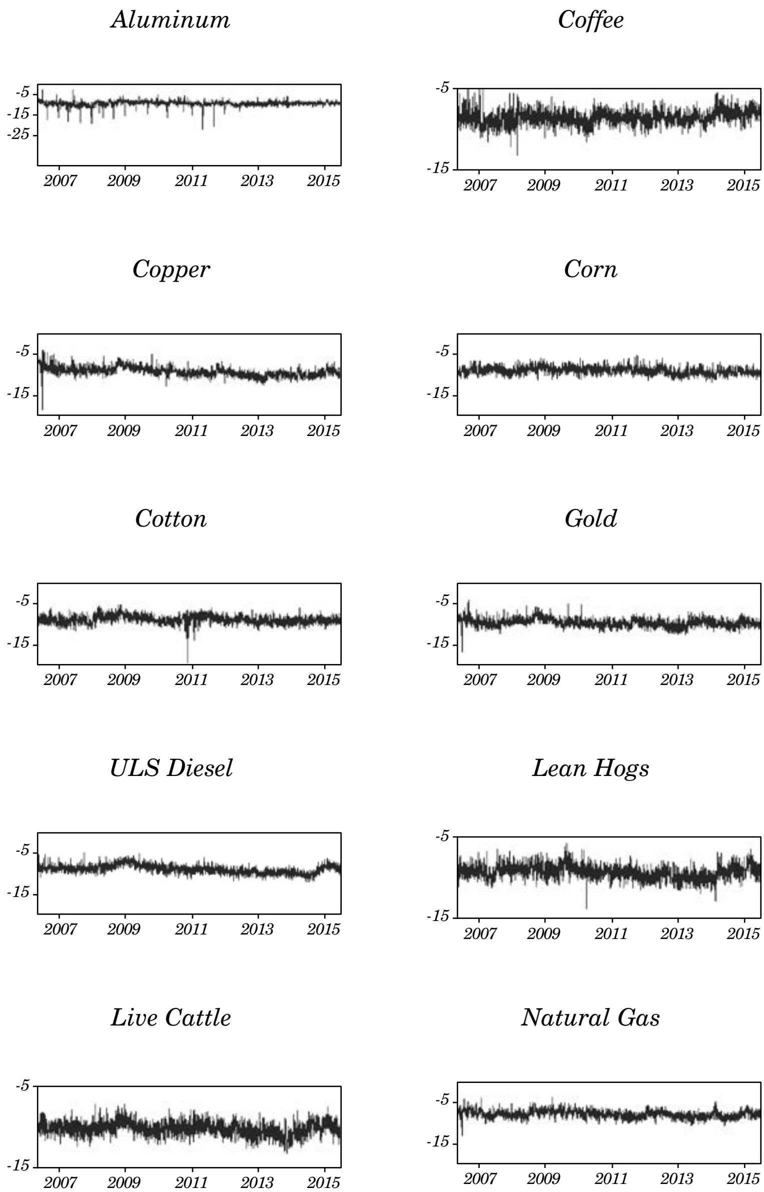
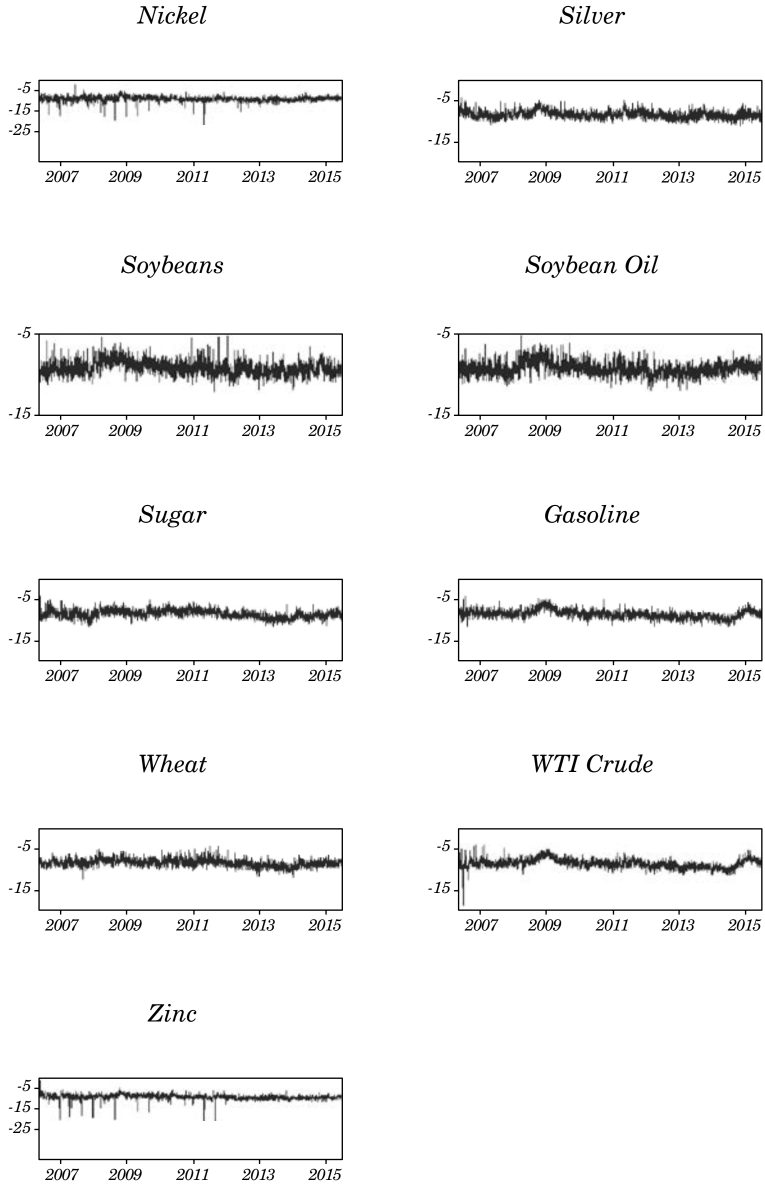


Figure 2. (continued)



2. Benchmark Results I: Static (Full-Sample) Connectedness

2.1 Measuring Connectedness

We examine commodity return volatility connectedness by using the framework of Demirer and others (2016), which builds on Diebold and Yilmaz (2014). In particular, for the benchmark results that we report in sections 2 and 3:

1. We use a *VAR*(3) approximating model, estimated by using an adaptive elastic net with penalty parameter chosen by ten-fold cross validation.
2. We identify the estimated *VAR* by using the generalized approach of Koop and others (1996) and Pesaran and Shin (1998), and then we examine variance decompositions at horizon H =10 days.
3. We summarize the variance decomposition matrix by using connectedness statistics (pairwise directional, total directional "to" and "from", and system-wide).
4. We visualize the variance decomposition matrix by using network "spring graphs".
5. In appendix 2, we explore different horizons (various h, fixed p = 3), and in appendix 3 we explore different approximating models (fixed h = 10, various p).

We perform static (full-sample) analyses in this section, and dynamic (rolling-sample) analyses in section 3.

Let us elaborate upon our approach to network visualization. Node shading indicates total directional connectedness "to others"; the darker, the stronger. The spring graph node location layout represents a steady state in which repelling and attracting forces exactly balance, where (1) nodes repel each other, but (2) edges attract the nodes they connect according to average pairwise directional connectedness[10]. Edge thickness also indicates average pairwise directional connectedness. Finally, edge arrow size indicates pairwise directional connectedness "to" and "from".

10. The steady-state node locations depend on initial node locations and hence are not unique. They are, however, topologically unique up to rotation and flipping.

2.2 System-Wide Connectedness

System-wide connectedness is 40%. That is, on average, almost half of a commodity's future volatility uncertainty is due to "non-own" shocks. It is interesting that the 40% system-wide commodity return volatility connectedness is significantly lower than the system-wide equity return volatility connectedness found by Demirer and others (2016) for the world's largest banks. It makes sense, however, as large parts of commodity price movements come from idiosyncratic fluctuations in national and regional macroeconomic fundamentals that drive commodity supply and demand.

2.3 To-Degrees and From-Degrees

It is of interest to know the individual commodity degrees, particularly to-degrees, as we are especially interested in which sectors are sending the most uncertainty to others. From largest to smallest, the to-degree ranking is: ULS Diesel, WTI Crude Oil, Unleaded Gasoline, Soybeans, Gold, Zinc, Copper, Silver, Corn, Soybean Oil, Wheat, Aluminum, Nickel, Sugar, Cotton, Live Cattle, Lean Hogs, Natural Gas, and Coffee. From largest to smallest, the from-degree ranking is: ULS Diesel, WTI Crude Oil, Unleaded Gasoline, Zinc, Gold, Soybeans, Copper, Silver, Corn, Soybean Oil, Aluminum, Wheat, Nickel, Live Cattle, Cotton, Lean Hogs, Sugar, Natural Gas, and Coffee. The rank correlation is 0.9794. Bar charts appear in figure 3, ordered by to-degrees, from largest to smallest. It is interesting to note that the to-degree ordering is almost identical to the from-degree ordering.

In figure 4, we show estimates of the the static (full-sample) "from" and "to" degree distributions, based on three-bin histograms. Their means are of course equal, and equal to system-wide connectedness (again, 40%). Their shapes are similar but slightly different. The to-degree distribution has a slightly thicker right tail, consistent with a few commodities sending a rather large amount of future uncertainty to others.

Figure 3. Full-Sample Individual Commodity From/To Degrees

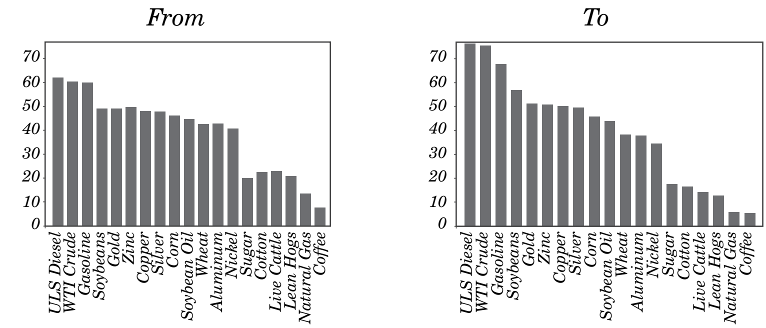
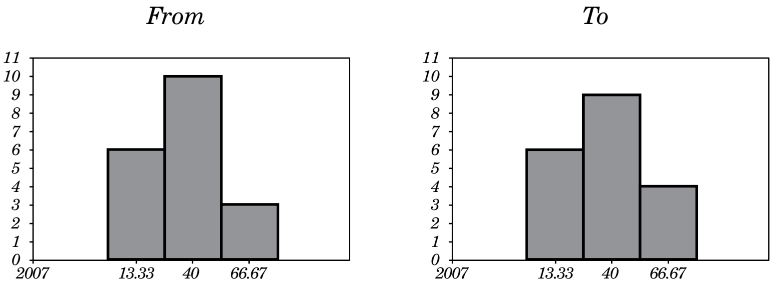


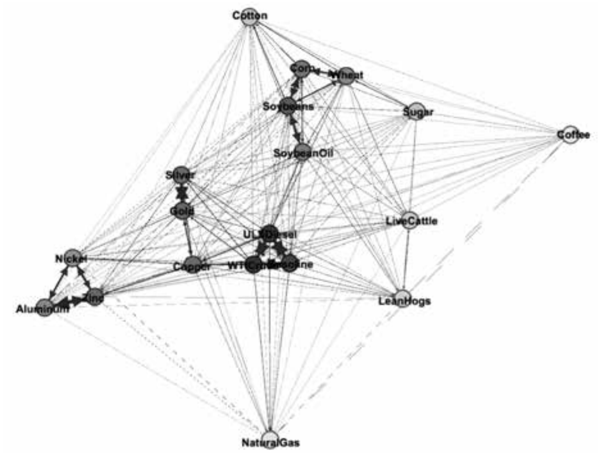
Figure 4. Full-Sample From and To Degree Distributions



2.4 The Network Graph

In figure 5, we show the static (full-sample) network graph. Several aspects are notable. First, there is clear clustering, associated primarily with the traditional industry groupings (energy, industrial metals, precious metals, grains, livestock, and softs), perhaps due to the nature of production processes; e.g., upstream/downstream, substitutes/complements, etc. This implies that a commodity volatility shock is likely to be transmitted to the commodity's sub-group, but not necessarily to all commodities. So we have an interesting situation: rather low system-wide connectedness, but clear group clustering and high within-group connectedness.

Figure 5. Full-Sample Network Graph



a. There is clear clustering in precious metals, grains, and livestock.
b. There is clear clustering in energy and industrial metals, but in each case with a noteworthy exception. In the energy group, heating oil, crude oil, and gasoline cluster tightly, but natural gas is quite far away. In the industrial metals group, aluminum, nickel, and zinc cluster tightly, but copper is noticeably elsewhere, closer to precious metals and energy. Perhaps this "copper anomaly" is due to its role in production. Alternatively, perhaps it is not a copper anomaly, but rather an "aluminum-nickel-zinc anomaly" associated with the London Metal Exchange rules mentioned in appendix 1.
c. There is no clustering in softs (coffee, cotton, sugar). Presumably, this is because softs is largely a residual category.

Taken together, (a), (b), and (c) suggest that the traditional commodity groupings are largely, but not entirely, accurate. Natural gas, in particular, is far from the other energy commodities.

2.5 Six-Group Aggregation

We present full numerical results in a six-group (6x6) "connectedness table", or "variance decomposition table" (table 2), obtained by aggregating the original (19x19) connectedness table within the six traditional commodity categories (energy, industrial metals, precious metals, grains, livestock, softs)[11]. The individual entries are pairwise directional connectedness, the row sums are total directional connectedness "from", the column sums are total directional connectedness "to", and the grand sum in the lower right corner is system-wide connectedness[12].

We show the associated network graph for the six-group aggregation in figure 6. There are several results. First, the energy, industrial metals, and precious metals groups themselves form a tight cluster. Second, there is a very large amount of total directional connectedness to others from energy. Third, livestock and softs are largely peripheral and net receivers, rather than transmitters, of shocks.

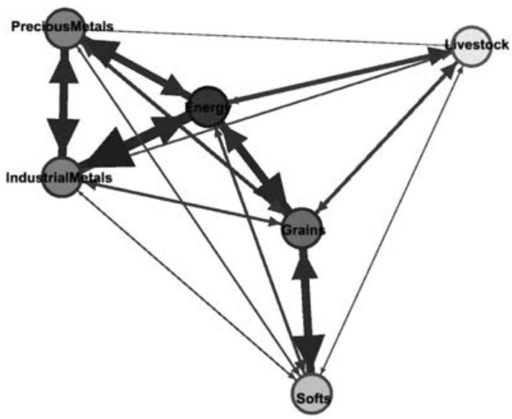
Table 2. Full-Sample Connectedness Table, Six-Group Aggregation

	Energy	*Grains*	*Ind. Metals*	*Prec. Metals*	*Softs*	*Livestock*	*From*
Energy	N/A	17.11	21.59	16.49	6.01	5.43	66.63
Grains	23.05	N/A	7.23	10.57	18.06	7.02	65.93
Ind. Metals	30.67	8.35	N/A	22.88	2.94	3.05	67.88
Prec. Metals	20.78	9.38	20.28	N/A	3.26	1.11	54.80
Softs	8.33	22.88	4.75	5.67	N/A	3.63	45.25
Livestock	13.48	10.39	6.09	3.09	4.22	N/A	37.26
To	96.30	68.10	59.94	58.70	34.48	20.23	56.29

11. In principle, we could of course have shown a (19x19) connectedness table earlier, but its size proved unwieldy.

12. All sums exclude the main diagonal, because we are interested in non-own transmissions.

Figure 6. Full-Sample Network Graph, Six-Group Aggregation



3. Benchmark Results II: Dynamic (Rolling-Sample) Connectedness

Here we study time series of connectedness, estimated by using a rolling window with a width of 150 days. We study both total system-wide and total directional (to and from) connectedness.

3.1 On the Economics of Commodity Connectedness Dynamics

Thus far we have introduced our commodity price index data, constructed the corresponding returns and return volatilities, and provided a basic statistical characterization. Here we delve into more economic aspects.

Commodity prices differ in important ways from those of bonds and stocks. Unlike bonds and stocks, commodity prices are determined more by traditional supply and demand considerations. Perhaps with the exception of precious metals, which in significant part serve as alternative investment vehicles to hedge against global uncertainty, demand for commodities is closely linked to global income. In that regard, at times, commodity prices can be subject to highly-correlated demand-side shocks. This was indeed the case during the global financial crisis, when prices of all major commodities dropped sharply as the near-collapse of global financial markets led to the Great Global Recession of 2009.

The emergence of China as a global economic powerhouse since the early 2000s provides another example of how commodity prices are affected by global consumption demand. From 2001 to 2011, China's industrial production quadrupled, its consumption of industrial metals increased by 330%, and its oil consumption increased by 98% (World Bank, July 2015). China's phenomenal growth in commodity demand is reflected in a broad upward trend in commodities prices that lasted until 2011, but then subsided, as demand from China and other emerging-market economies lessened (World Bank, October 2014).

Unlike commodity demand, which is driven at least in part by a common "global demand" factor, commodity supply is more idiosyncratic. Supplies of energy, industrial metals, precious metals, and agricultural commodities can be affected by very different factors. For example, while the Organization of Petroleum Exporting Countries (OPEC) controls part of the global oil supply, a larger share of it, as well as supplies of metals, can be affected by the decisions of exporting country governments. In the case of agricultural commodities, moreover, weather conditions can play an important role in the short run, while government policies (e.g., export and/or import taxes) can have significant impact in the longer run. Therefore, due to the existence of rather different processes in effect on the supply side, it is quite normal to observe different price movements in different commodity markets.

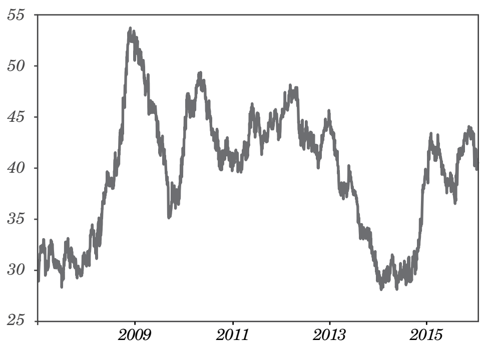
3.2 System-Wide Connectedness

We show total system-wide connectedness in figure 7. It fluctuated between 28.3% and 53.8% over the sample period, from the end of 2006 to the end of January 2016. Commodity return volatilities tend to generate lower connectedness than the global bank return volatilities, global stock market return volatilities, and bond yield volatilities. There are several reasons for this difference. Global bank return volatility shocks, in general, generate higher connectedness, because even though they are located in different countries, big global banks are subject to shocks to global banking as well as to international financial markets. Global stock market return volatility connectedness (and, for that matter, global bond market yield volatility connectedness) indices tend to be higher because return volatility shocks are likely to be transmitted within the same asset class across countries. When there is an idiosyncratic shock to one of the major stock markets, or a shock common to a subset of stock markets, it is likely to be transmitted to others.

Returning to dynamic system-wide volatility connectedness in commodity markets, we observe a spike in total connectedness around late 2008 and early 2009. The U.S. recession that started in the first half of 2008 triggered a global growth slowdown, which in turn prompted commodity prices to start falling in mid-2008, several months before the climax of the crisis was reached in the last quarter of 2008. The transformation of the U.S. financial crisis into a global one and the resulting downward spiral in the world economy accelerated the downward process of commodity prices that lasted until mid-2009.

As a result of these developments, system-wide connectedness increased from 32% at the end of February 2008 to close to 40% by the end of May 2008. After a brief respite, system-wide connectedness started to increase again and, following Lehman's bankruptcy, it increased at a much faster pace, from around 47% to 53.8% by mid-November.

Figure 7. Rolling-Sample System-Wide Connectedness



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Once it became apparent that the global financial crisis would not lead to a complete meltdown of the financial system, commodity prices gradually turned upwards in early 2009, which in turn led the system-wide commodity connectedness turn downwards. The decline in connectedness was at first gradual, but it gained momentum in a couple of months' time, dropping as low as 35% by the end of August 2009. The system-wide connectedness did not stay around 35% for a long time. After a significant correction due to the global financial crisis, commodity prices started to recover from September 2009 onwards; as markets continued their upward journey, the volatility connectedness started to go up reaching as high as 48% by April 2010. During this upswing, there was not a widespread trend in the commodity return volatilities, but increased volatility in precious metals, especially in silver, caused the system-wide connectedness to increase slightly.

Commodity prices continued to increase until mid-2011; then energy prices stayed more or less steady in the following three years or so, until a sharp drop in oil prices occurred in the second half of 2014. In the meantime, agricultural commodities, as well as industrial and precious metals, followed a downward trend that lasted until the end of our sample. While the agricultural commodities' prices declined by an average of 35%, that of precious and industrial metals dropped by 45% and 52%, respectively, over this period. Oil prices did not decline as fast as other major commodities because the impact of China on oil demand was more limited than on the demand for other commodities, especially industrial metals. Secondly, the geopolitical risks in some countries in the Middle East and North Africa, as well as in Ukraine, when combined with Saudi Arabia's policy of adjusting its supplies to keep oil price high, played a role in oil prices fluctuating in a band of $80-$105 per barrel for more than three years.

System-wide commodity volatility connectedness reflects the developments over the period. From mid-2010 to early 2013, the system-wide connectedness fluctuated in the narrow band of 40%-45%. System-wide connectedness followed a short-lived upward trend from early 2011 to early 2012, during which period it reached as high as 48%. This increase was mostly due to the worries about the political upheavals in the Middle East and North Africa. In particular, the worries about the Suez Canal due to the civil conflict in Egypt and the sharp cut in Libya's oil production due to the civil war in the country fed into the oil price volatility, which in turn contributed to the system-wide connectedness in commodity markets. After the overthrow of the Qaddafi regime in Libya 2011, the political crisis in Egypt was resolved with a coup d'etat in mid-July 2013. Following the turn of events in Egypt, volatility in oil prices subsided and the system-wide connectedness started to decline from around 37% in mid-July 2013 to 28.5% within six months.

After fluctuating around 30% for several months, system-wide connectedness started to increase from its 30% lows in July 2014, to reach 43% by the early 2015. The latest upward move in system-wide connectedness was due to worries about the civil war in Ukraine and whether it would lead to the temporary suspension of oil supplies from the Russian Federation to the world market.

At the same time, military actions of Russian-backed separatists increased confrontation between Russia, on the one side, and the U.S. and the EU, on the other side. It is speculated that, as the tensions between the two sides increased, Saudi Arabia decided to change its policy of playing the marginal supplier, which aims to keep oil prices high. With this policy change, Saudi Arabia wanted to push high-cost shale frackers out of business. Thanks to high global oil prices, shale frackers were able to profitably increase global supply of oil, which threatened the dominant position of the OPEC and, in particular, Saudi Arabia, in the long-run. Secondly, Saudi Arabia helped the U.S. to increase pressure on the Russian government, which had become increasingly belligerent not only in Ukraine, but in other civil unrests in parts of the world. As a result, the oil price was almost halved, from around $100 at the end of July 2014, to around $50 by the end of the year.

After staying above 40% for several months, system-wide connectedness dropped to 37% in the summer of 2015, as the oil price ended its downward spiral and settled around $50 per barrel. However, news about China's financial market troubles in August 2015 increased tensions and system-wide connectedness not only in commodity markets, but in all financial markets. As a result, system-wide connectedness increased by more than five percentage points within a month, and later reached 44% by the end of October 2015.

3.3 Total Directional Connectedness

In this section we analyze the dynamics of directional connectedness of individual commodities as well as commodity groups, based on net total directional connectedness graphs ("to" – "from") in figure 8.

Figure 8. Rolling-Sample Net Total Directional Connectedness

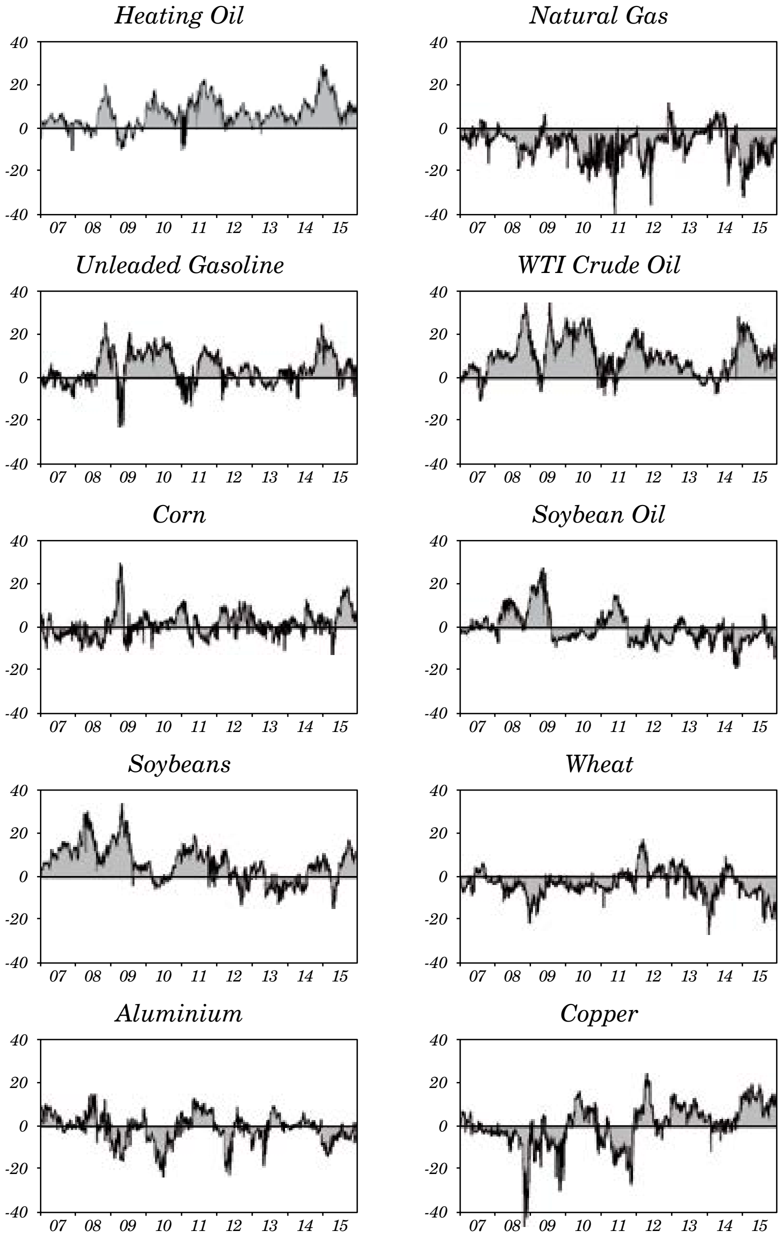
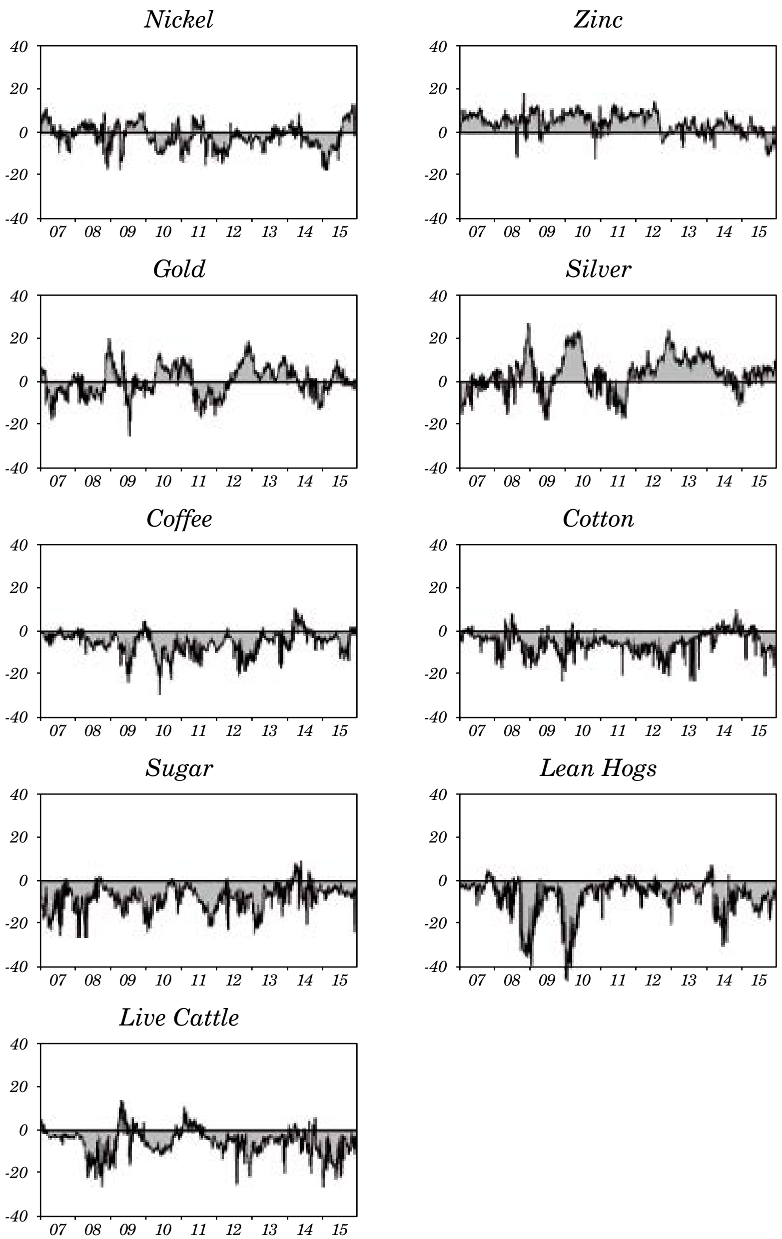


Figure 8. (continued)



As our discussion of the dynamic system-wide connectedness in the previous section showed, and as figure 8 confirms, oil played quite an important role in the commodity market connectedness. Its net connectedness is higher than all other commodities for an overwhelming majority of the rolling sub-sample windows considered. Both in earlier and later parts of the period, net connectedness of oil reached as high as a 30-35% range. The only sub-periods during which the net connectedness of crude oil was lower are the first half of 2007 and the period from the second half of 2013 to July 2014.

Starting in the first quarter of 2008, the crude oil price skyrocketed from around $60 in February 2007 to reach $141 per barrel by the first week of July 2008. Henceforth, however, the oil price started to come down as the worries about U.S. economic performance intensified, and along with slowdown signs in many countries. As the downturn started in the oil price, oil return volatility increased substantially. Along with the rising oil return volatility, system-wide volatility connectedness increased from around 40% in early July 2008 to 53% by the end of October 2008. Over the same period, net connectedness of West Texas Intermediate (WTI) crude oil increased from 10% to 35%, the highest net connectedness level generated by a commodity for all rolling subsample windows considered (figure 8).

By the end of October 2008, the crude oil price dropped to $60 per barrel. However, the downward spiral in the price of oil continued until the third week of December, with a minimum price of $31 per barrel. As the oil price lost its downward momentum, its net connectedness dropped to around 10% by the end of 2008. Once the oil price recovered to reach closer to $60 per barrel, we observe that net volatility connectedness (hence volatility) of oil returns started to increase significantly and reached to 35% by mid-July 2009.

Heating oil, soybeans, and zinc are the three commodities that followed crude oil in generating very high levels of net connectedness to other commodities over all subsamples considered. Heating oil is also in the energy commodities group. Its net connectedness to others follows a trajectory which resembles that of crude oil.

Soybeans have high net connectedness, not because they are an important consumption item for households around the world, but rather because they are used in the biofuel production. Soybeans' net connectedness reached as high as 28% in March 2008, last quarter of 2008, and first half of 2009. Unlike crude oil, soybeans' net connectedness increased during 2008: in January —exactly around the Federal Open Market Committee's (FOMC's) emergency conference-call on January 22—, late February and early March. During this period, crude oil prices were still on an upward move with a net connectedness of only around 10%. A similar asymmetric move between the net connectedness of crude oil and soybeans occurred in the first half of 2009. While crude oil's net connectedness declined from its peak of end-October 2008 to a low of -6% in the first week of April 2009, the net connectedness of soybeans increased to reach 28% level during this same period.

Zinc is actually the only commodity that generated net positive connectedness to others throughout the period from 2006 to 2016. During this period, zinc had small but positive (between 5 to 10%) net connectedness from the beginning of the sample to the end of 2012. Its net connectedness started to decline significantly in late 2012 to less than 5%, yet continued to stay on the positive side.

As for energy commodities, unleaded gasoline is the third in terms of generating net connectedness to other commodities. Again, its net connectedness followed a behavior over time quite similar to that of crude oil. The only energy commodity that is a net recipient of connectedness from others is natural gas. Natural gas is the energy market with the weakest link to the economic news flow, even when accounting for recession periods. Reflecting this fact, its connectedness to others and from others is much lower than that of other energy commodities. As such, its return volatility is likely to be affected by the return volatilities of other energy commodities. That is why its net connectedness was negative for an overwhelming majority of rolling sample windows, as shown in figure 8.

We also need to focus on the net connectedness of copper. While its net connectedness was negative from the U.S. and global financial crisis in 2007 through 2009 and during the 2011 European debt crisis, copper has generated positive net connectedness since early 2012. Copper prices declined by more than 50% since the end of 2010, from a high of $9,800 per ton to a low of $4,700 per ton at the end of 2015. The decline in the price of copper and its increasing contribution to system-wide connectedness are closely related to the Chinese slowdown in recent years. Other industrial metals, such as zinc, nickel, and aluminum also experienced significant price drops over the period, but none of them had net connectedness as high as copper. We have already covered zinc above. The other two industrial metals, aluminum and nickel, displayed both positive and negative episodes. When considered altogether, industrial metals generated positive net connectedness to other commodity groups (ranging from 5 to 20%) for almost all rolling window samples.

Among precious metals, silver has higher net connectedness than gold for most of the period covered. During the global financial crisis, in the second half of 2009 and first half of 2010, and since the end of 2011, silver's net connectedness is much higher (sometimes as high as 20%) than that of gold (figure 8).

Soft commodities (coffee, cotton and sugar) and livestock (lean hogs and live cattle) all have negative connectedness for almost all rolling sample windows, thus indicating that their prices on average are influenced by other commodities and/or commodity groups (figure 8).

4. Conclusion

We have estimated and examined the network graph for a set of major commodity sub-index volatilities. The results reveal clear clustering of commodities into groups that match traditional industry groupings, but with some notable differences. The energy sector is most important in terms of sending shocks to others, and energy, industrial metals, and precious metals are tightly interconnected within themselves.

Appendix A

A.1 Verification of Key Properties of Realized Volatility

Results for other markets like equities (Andersen and others, 2001a) and foreign exchange (Andersen and others, 2001b) indicate that daily realized volatilities are (1) generally distributed asymmetrically, with a right skew, but approximately Gaussian after taking natural logarithms, and (2) very strongly serially correlated. The economics of commodity markets are quite different from those of foreign exchange or equities, however, so here we provide an examination of fundamental distributional and dynamic properties of commodity volatilities.

Let us start with distributional aspects. As obviously revealed in the Gaussian Q-Q plots of figure A1, the distribution of realized commodity volatility is strongly skewed right. This is not surprising, because volatilities are bounded below by zero and experience occasional large bursts. The real issue is whether log commodity volatilities are approximately Gaussian, as with foreign exchange and equities. As shown in the Gaussian Q-Q plots for log returns in figure A2, the answer is mostly yes[13].

Finally, we consider dynamics. In figure A3 we show volatility autocorrelations. They decay, which is consistent with covariance stationarity, but they do so very slowly, indicating highly persistent, if nevertheless mean-reverting, dynamics.

13. The only exceptions to approximate log-normality are three industrial metals (aluminum, nickel, zinc), as clearly shown in the Gaussian Q-Q plots of figure 10. All three of them are traded on the London Metal Exchange (LME), and they are the only commodities in our data set traded on that exchange.

Figure A1. Gaussian Q-Q Plots for Realized Volatilities

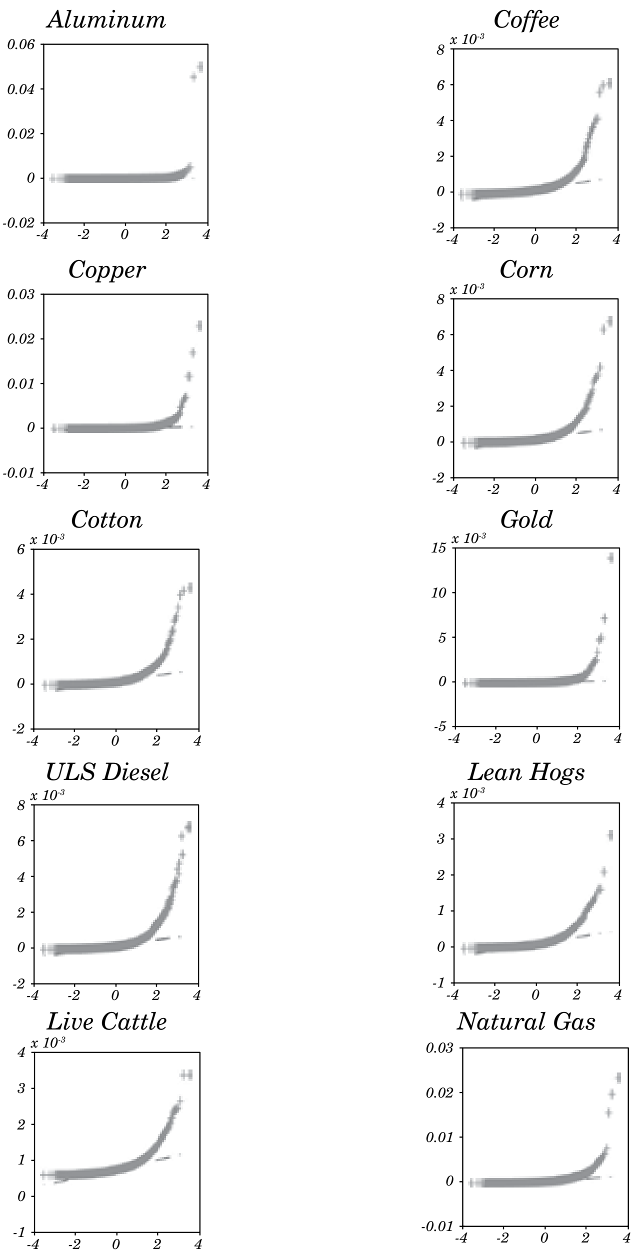


Figure A1. (continued)

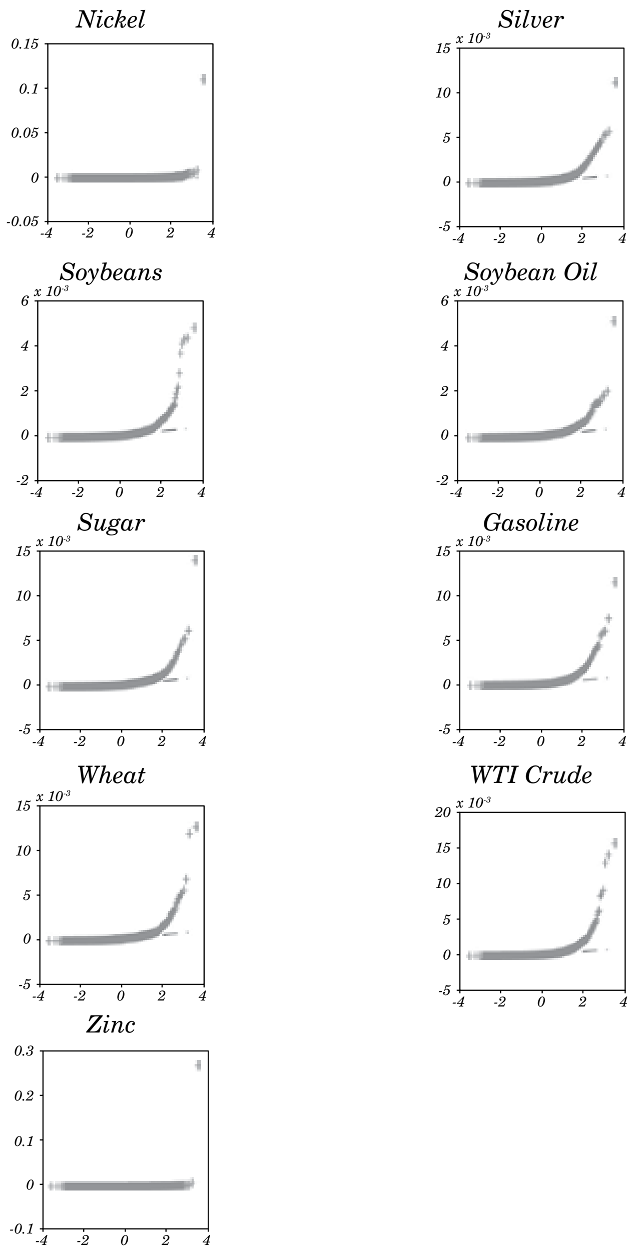


Figure A2. Gaussian Q-Q Plots for Realized Volatilities

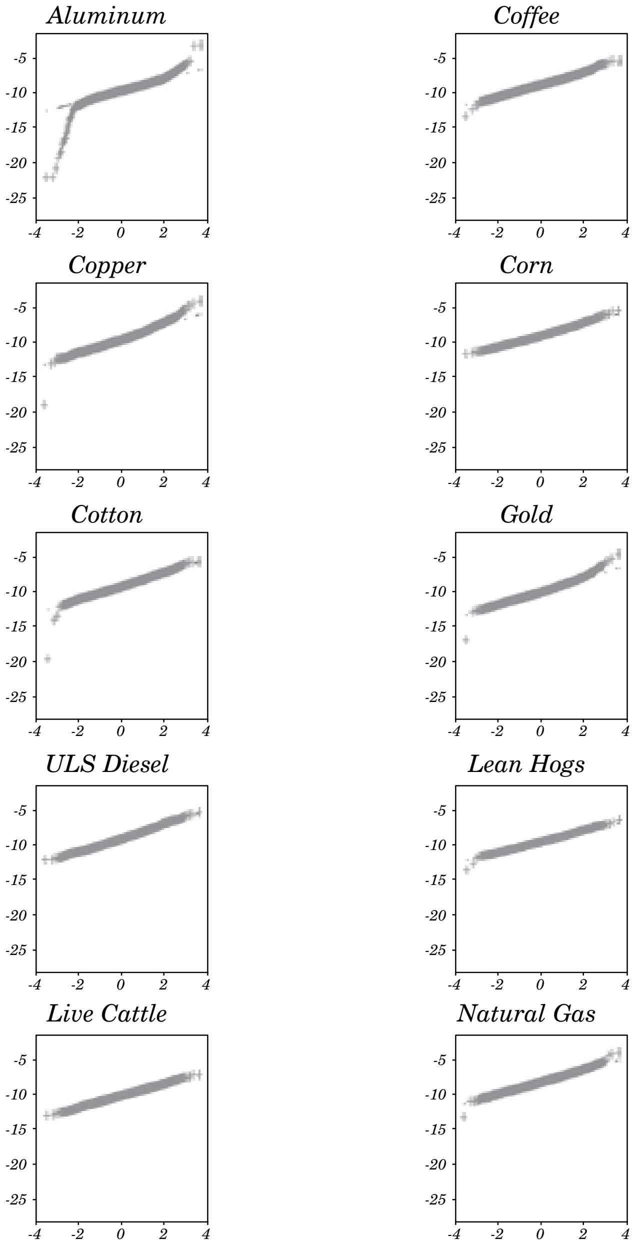


Figure A2. (continued)

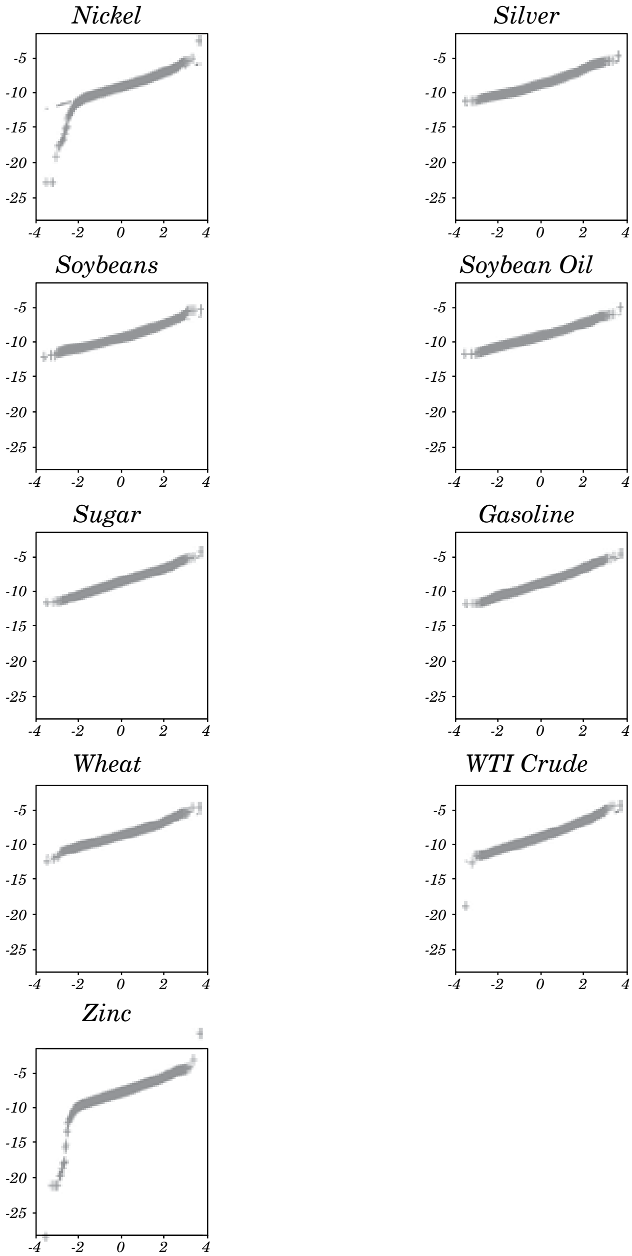
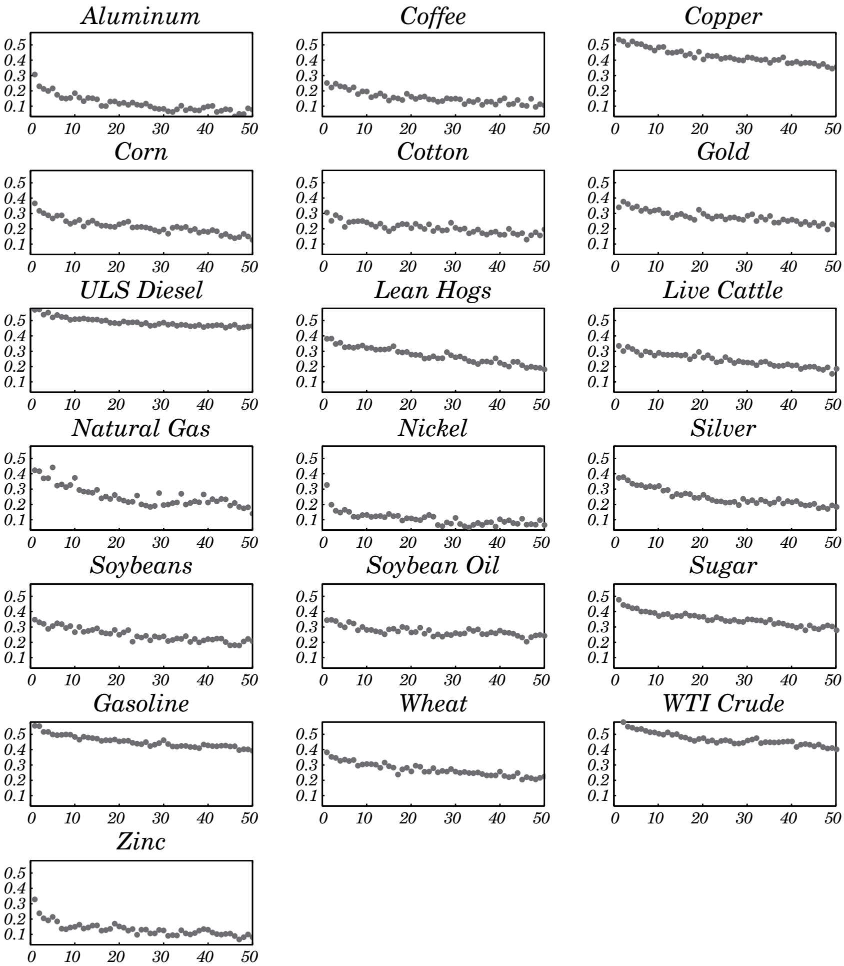


Figure A3. Sample Autocorrelation Functions of Log Realized Volatilities



Appendix B

B1. Different Horizons (Various *h*, Fixed *p* = 3)

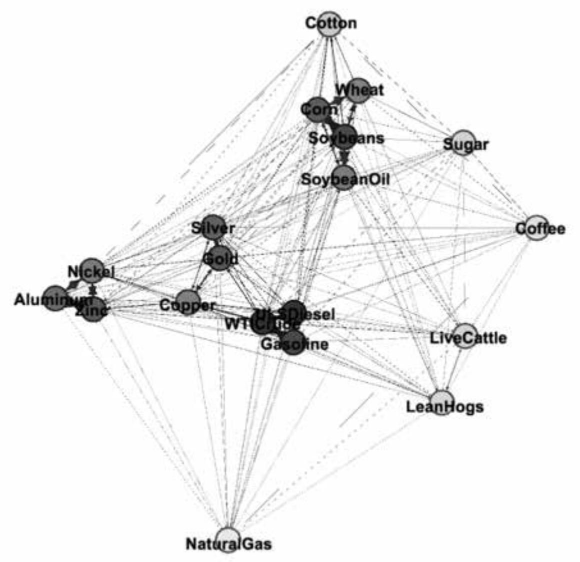
It is of interest to explore connectedness at different horizons h. On the one hand, one might hope for results robust to horizon. On the other hand, upon further consideration, it is not obvious why the results should be robust, or whether such robustness is "desirable". This point is related to different notions of network centrality; one can assess 1-step through the adjacency matrix A, 2-step through A^2, and so on to ∞-step (eigenvalue centrality).

First consider static connectedness. In figure B1, we show static (full-sample) *VAR*(3) network connectedness graphs for six variance decomposition horizons: h= 2,10,20,...,50 days. The different subgraphs are rotated to enhance multiple comparisons. The topology appears strongly robust to horizon[14].

14. The scaling, however, differs across the subgraphs; otherwise, the small-h graphs would be tiny and the large-h graphs would be huge.

Figure B1. Full-Sample Connectedness, *VAR(3)*, Different Horizons

h=2



h=10

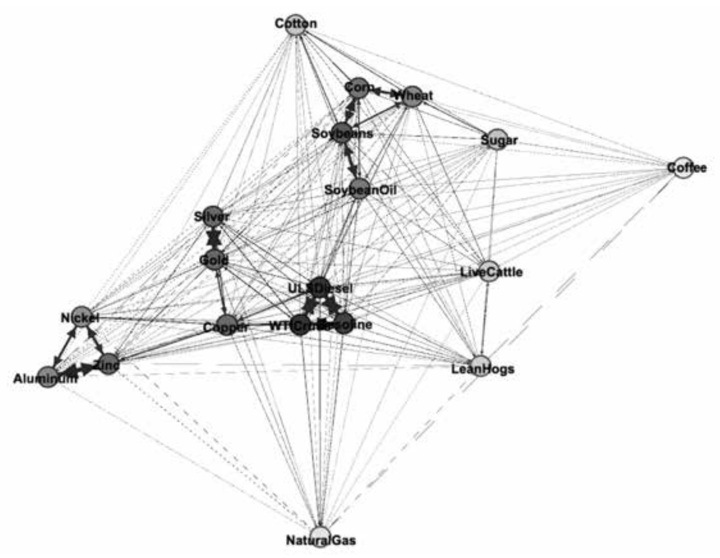
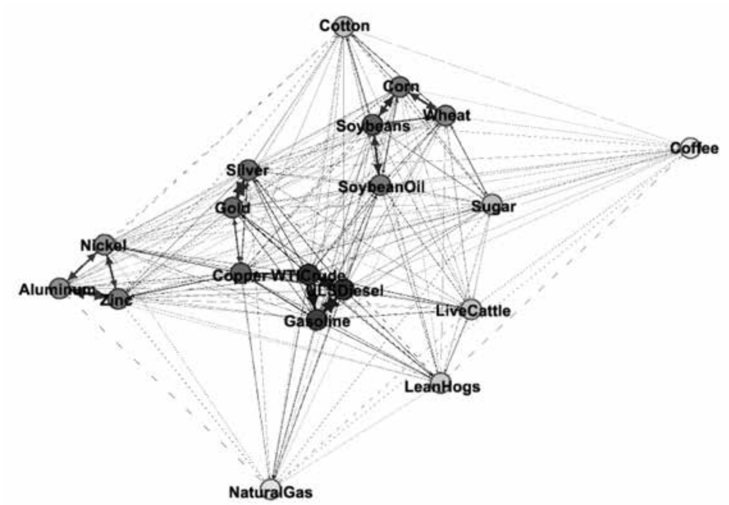


Figure B1. (continued)

h=20



h=30

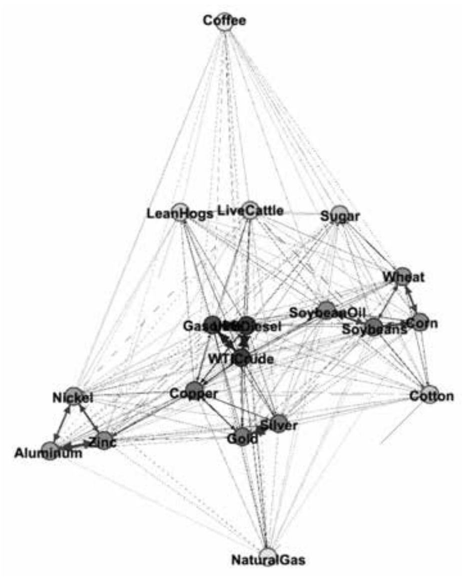
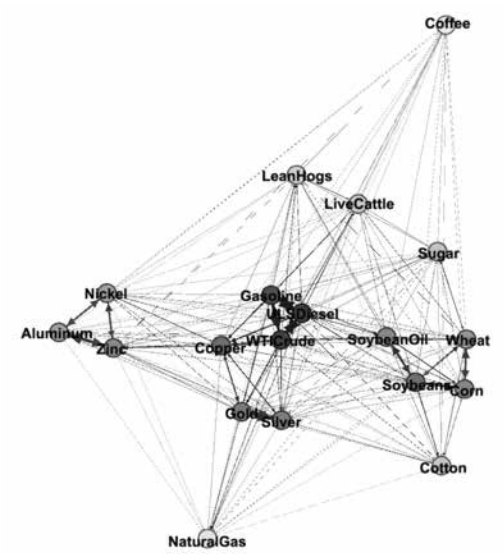
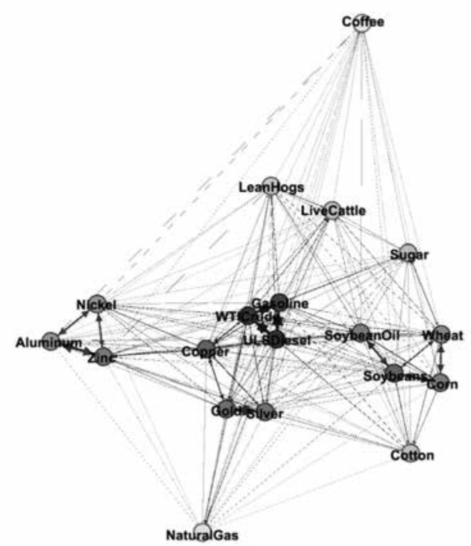


Figure B1. (continued)

h=40



h=50



Appendix C

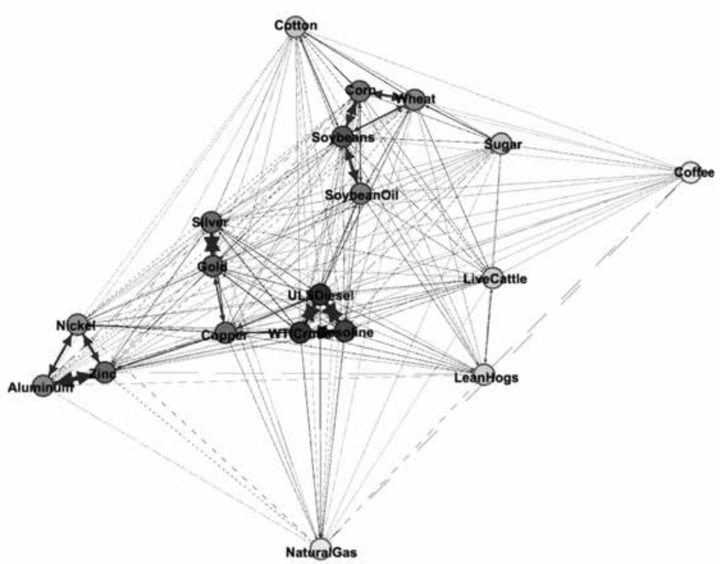
C1. Different Dynamics (Fixed *h* =10, Various *p*)

We already noted the very high persistence in commodity return volatilities, as is common across many assets and asset classes. Indeed, there may even be long memory, as emphasized in Andersen and others (2003). To allow for that possibility, we also explored a variety of higher-order approximating models, estimation of which is feasible despite profligate parameterizations, given the regularization achieved by the LASSO.

In figure C1, we show static (full-sample) h=10 network connectedness graphs for six *VAR* lag orders, p = 3,5,10,15,20,25. The different subgraphs are rotated to enhance multiple comparisons. The topology appears strongly robust to lag order.

Figure C1. Full-Sample Connectedness, Different *VAR* Orders, h = 10

VAR(3)



VAR(5)

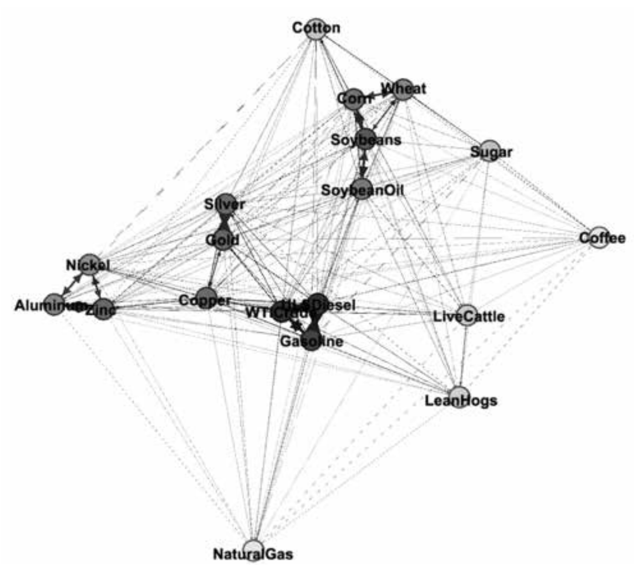
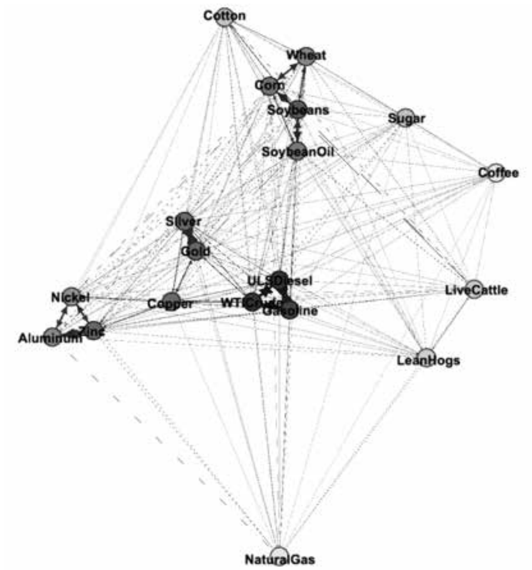


Figure C1. (continued)

VAR(10)



VAR(15)

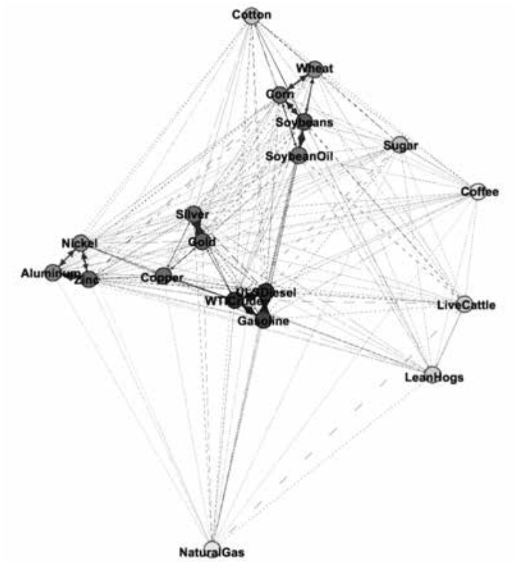
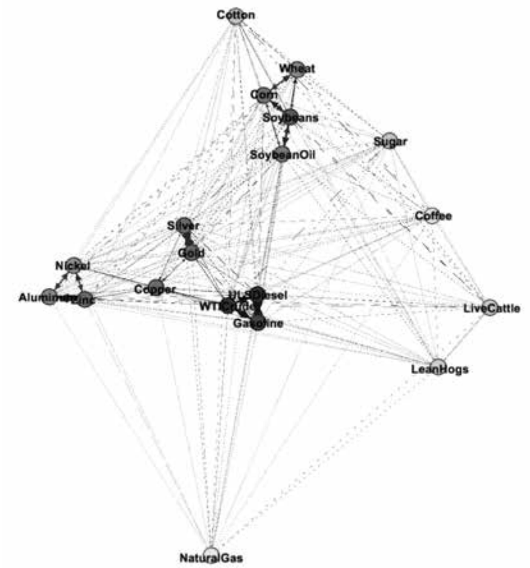
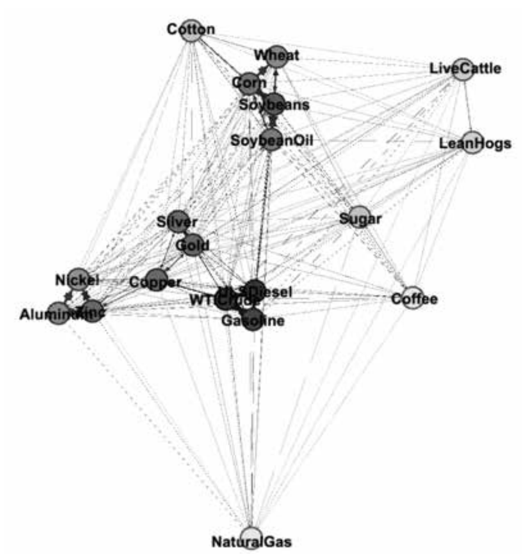


Figure C1. (continued)

VAR(20)



VAR(25)



References

Acharya, V.V., L. Pedersen, T. Philippon, and M. Richardson. 2010. "Measuring Systemic Risk." Manuscript, New York University.

Adrian, T. and M. Brunnermeier. 2016. "CoVaR." *American Economic Review* 106: 1705–41.

Alizadeh, S., M.W. Brandt, and F.X. Diebold. 2002. "Range-Based Estimation of Stochastic Volatility Models." *Journal of Finance* 57: 1047–91.

Andersen, T.G., T. Bollerslev, F.X. Diebold, and H. Ebens. 2001. "The Distribution of Realized Stock Return Volatility." *Journal of Financial Economics* 61: 43–76.

Andersen, T.G., T. Bollerslev, F.X. Diebold, and P. Labys. 2001. "The Distribution of Realized Exchange Rate Volatility." *Journal of the American Statistical Association* 96: 42–55.

————. 2003. "Modeling and Forecasting Realized Volatility." Econometrica 71: 579–625.

Billio, M., M. Getmansky, A.W. Lo, and L. Pelizzon. 2012. "Econometric Measures of Connectedness and Systemic Risk in the Finance and Insurance Sectors." *Journal of Financial Economics* 104: 535–59.

Bloomberg. 2016. "Index Methodology: The Bloomberg Commodity Index Family." Available at https://www.bbhub.io/indices/sites/2/2016/05/BCOM-Methodology-April-2016.pdf.

Bonaldi, P., A. Hortacsu, and J. Kastl. 2013. "An Empirical Analysis of Systemic Risk in the Eurozone." Manuscript, University of Chicago.

Chevallier, J. and F. Ielpo. 2013. *The Economics of Commodity Markets.* Hoboken, NJ: John Wiley & Sons.

Demirer, M., F.X. Diebold, L. Liu, and K. Yilmaz. 2017. "Estimating Global Bank Network Connectedness", *Journal of Applied Econometrics*, in press.

Diebold, F.X. and K. Yilmaz. 2009. "Measuring Financial Asset Return and Volatility Spillovers, with Application to Global Equity Markets." *Economic Journal* 119: 158–71.

————. 2012. "Better to Give than to Receive: Predictive Measurement of Volatility Spillovers (with discussion)." *International Journal of Forecasting* 28: 57–66.

————. 2014. "On the Network Topology of Variance Decompositions: Measuring the Connectedness of Financial Firms." *Journal of Econometrics* 182: 119–34.

Fernández, A., A. González, and D. Rodriguez. 2015. "Sharing a Ride on the Commodities Roller Coaster: Common Factors in Business Cycles of Emerging Economies." Inter-American Development Bank Working Paper Series No. IDB-WP-640. Available at http://www.iadb.org/en/research-and-data/publication-details,3169.html?pub_id=IDB-WP-640.

Garman, M.B. and M.J. Klass. 1980. "On the Estimation of Security Price Volatilities From Historical Data." *Journal of Business* 53: 67–78.

Kara, G.I., M.H. Tian, and M. Yellen. 2015. "Taxonomy of Studies on Interconnectedness." SSRN Working Paper No. 2704072. Available at http://ssrn.com/abstract=2704072.

Kat, H.M. and R.C.A. Oomen. 2007a. "What Every Investor Should Know About Commodities, Part I." *Journal of Investment Management* 5(1): 4–28.

———. 2007b. "What Every Investor Should Know About Commodities, Part II: Multivariate Return Analysis." *Journal of Investment Management* 5(3)_ 16–40.

Koop, G., M.H. Pesaran, and S.M. Potter. 1996. "Impulse Response Analysis in Nonlinear Multivariate Models." *Journal of Econometrics* 74: 119–47.

Pesaran, H.H. and Y. Shin. 1998. "Generalized Impulse Response Analysis in Linear Multivariate Models." *Economics Letters* 58: 17–29.

World Bank. 2015. Commodity Market Outlook, July.

World Bank. 2014. Commodity Market Outlook, October.

Global Information Spillovers

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The amount of information produced in an economy varies over time. Stock prices, in particular, are informative, but their degree of informativeness changes over time.[1] Agents do not produce the same amount of information in every macroeconomic state of the world or in anticipation of every state. Although a baseline level of information is always produced, spending additional resources on information production is not always beneficial. In fact, it is so only when the expected benefits exceed the costs. In particular, more information is produced when distinguishing between firms is more important. This is most likely when many firms may fail, as in a financial crisis. In this paper, we show how the amount of information produced varies over time. We then focus on the informational links between economies, both advanced and emerging, on a global scale. We show that: (1) stock price based measures of information produced *within a set of advanced economies* predict crises in *other advanced economies and in emerging markets*; (2) stock price based measures of information

This paper is based on a preliminary version of Chousakos et al. (2016). The results here should be viewed as tentative, since the sample currently is small, with only 24 countries, seven of which are emerging markets. Thanks to Enrique G. Mendoza, Ernesto Pastén, Diego Saravia, Yuliy Sannikov, and participants at the Annual Conference of the Central Bank of Chile for comments and suggestions. We also thank Shah Kahn and Tim Rudner for research assistance and the National Science Foundation for support.

1. The foundation for this is that stock markets are at least weakly (market) efficient; see, e.g., Fama (2014) and Grossman (1981).

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predict global imbalances, with funds flowing towards countries with more information production, thus suggesting that the reallocation of resources that occurs among economies is a result of information production; (3) global imbalances are associated with financial crises for a number of economies. These results suggest that economies are integrated via an information channel.

In Gorton and Ordoñez (2014, 2016), the macroeconomic dynamics are caused by agents producing more information about firms at certain times, but not at other times. These papers focus on collateralized debt, and the information about collaterals is not directly useful for investment purposes, but is indeed useful for credit allocations. In this paper, we shift the focus to stock prices and ask a related question: Do agents produce more information about firms at certain times rather than other times and, if so, is there any reallocation of resources in response? We find that the answer to both questions is yes. The stock price based measures of information that we propose are successful in predicting recessions with a financial crisis and reallocation of resources at a global level.

For reasons discussed in Gorton and Ordoñez (2016), and in Chousakos and others (2016), we start by proposing definitions of "recession" and "growth" periods. Our definitions are agnostic, intuitive, and ad hoc.[2] Our data set includes a list of financial crises for a panel of countries, which mostly happen during a recession. We compute and examine measures of aggregate information about the economy's fragility (defined below) prior to and during the different types of aggregate activity. In all, we define four possible states of the macroeconomy: *recession with no crisis, recession with crisis, growth*, and *normal* (which is none of the other categories). Note that these can occur in any order. In particular, growth and recession need not alternate. We validate this dating procedure for macroeconomic states by showing how information varies across these states, and by further showing that reallocation occurs as a function of the information. We focus on the information relationships between advanced and developing markets.

The information inter-linkages that we analyze in this paper relate to the phenomenon of globalization, i.e., information produced in a set of countries is important for a number of other economies.

2. But they are no more ad hoc than the choice of a smoothing parameter when detrending by using the Hodrick-Prescott filter. See Hodrick and Prescott (1997). Nor are our definitions more *ad hoc* than dating *via* peaks and troughs, which requires that peaks follow troughs and *vice versa*.

We find strong evidence in favor of global information spillovers. More specifically, by using principal component analysis (PCA), we estimate a number of common information factors across an initial set of advanced countries with a long history of stock data. We show that these information factors consistently predict instances of recessions with crises not only in the countries used in the estimation, but also in other advanced and developing economies. However, we cannot test for an informational channel running in the opposite direction, that is, from the omitted advanced economies and emerging markets to the more advanced economies. This impossibility is due to data limitations, because emerging countries' stock markets have limited histories and few listings, in general. Actually, this is itself very suggestive in that it may be a possible reason why emerging market participants may use information produced in advanced economies; however, we produce no evidence of that in this paper.

Motivated by the predictive power of information measures over recessions associated with crises, we conjecture that if these information measures are indeed informative, a reallocation of resources is likely to occur as a response to the information produced. We provide strong evidence in favor of this hypothesis. Aggregate measures of information have a significant predictive power over global imbalances. More specifically, we show that an increase in information production is associated with a higher level of domestic imbalances and with a lower level of foreign imbalances. This implies that more information is related to a higher level of domestic assets which, in turn, are funded with foreign liabilities. The relation between information production and global imbalances suggests a possible link between information production and reallocation of capital at a global level. Finally, we show that global imbalances predict instances of recessions associated with financial crises.

All this evidence combined suggests an informational narrative about international information linkages: information production in a set of advanced countries results in international capital flowing towards the country with more and better information, thus creating global imbalances. These global imbalances seem to be related to crises in other countries with outflows of funds. We finally investigate whether information production is associated with reallocation of capital within an economy. Towards that, for each country in our sample, we group companies on the basis of their Tobin's Q-ratios into quintiles and measure the fraction of companies that remain in the same bin or switch bins over two consecutive years. We find that lagged innovations in information production are weakly associated with changes in companies' Q-ratios, both in normal times and in times of recessions with crises, which implies that information production only weakly affects reallocation of resources within a given economy. This finding is in contrast to the strong relation between information production and reallocation at a global level, which suggests that the economy that generates information may face other circumstances that impede the exploitation of more and better information.

Our findings on the predictive ability of information measures on economic events are consistent with Gorton and Ordoñez (2016) and the literature that shows that economic agents can forecast when an upcoming recession will be particularly bad, i.e., one with a financial crisis. With regard to information spillovers, there are a number of papers that focus on stock market contagion, in which a stock market crash in one country causes declines in the stocks of other countries, e.g., King and Wadhwani (1990), Calvo (2004), and Calvo and Mendoza (2000). Gande and Parsley (2003) find evidence of information spillovers when one country's sovereign debt is downgraded, thus resulting in increased spreads on other countries' sovereign debt. This link has also been rationalized by Cole and others (2016) with a model of contagion in sovereign bond spreads through the incentives for information acquisition generated by an optimal portfolio reallocation across sovereign bonds. Our question is different: We ask whether the information produced in advanced economies forecasts financial crises and global imbalances in emerging markets, and whether reallocation occurs as a function of the information.

This paper is also related to work on the reallocation of resources, particularly during recessions and crises. There is a large literature on whether there are "cleansing effects" of recessions, which means that capital and labor are moved—reallocated—from low- to high-productivity firms and industries. Such reallocation is relatively less costly to do during recessions. There is a large literature on this subject, including Schumpeter (1939), Foster and others (2016), and Caballero and Hammour (1994, 1996). Reallocation involves some firms exiting, but also capital (and labor) moving between firms or sectors as well. Except for exit, reallocation may be difficult because, in a financial crisis, the banking system is damaged.

The paper proceeds as follows. Section 1 explains and summarizes the data we use, and defines aggregate economic episodes and information measures. Section 2 shows how information measures relate to macroeconomic fluctuations. Section 3 examines how our measures of information spill over across countries. Section 4 studies the reallocation of resources, both at a global level and within an economy, as a result of information production. Section 5 briefly summarizes our results and concludes.

1. Definitions and Data

In this section, we discuss the data, define the different phases of aggregate economic activity, and explain various information measures.[3]

1.1 Economic Fluctuations

We do not want to impose a great deal of preconceived structure on the data, such as detrending or defining peaks and troughs, because there is no theoretical justification for this. Instead, we define recessions and growth periods differently, as follows: To determine recession periods, at date t we look backward four years and compute the difference in the level of real GDP (*rGDP*) between date $t-4$ and all consecutive dates until date t. The measure of a recession at time t (that we denote as α_t) is defined as the minimum difference across all the above mentioned differences in *rGDP* levels over the four-year period prior to t. A *recession* period begins when α_t is less than 0.5% (this is when $\alpha_t \leq -0.5\%$), and ends when the previous peak is again attained. This definition is based on the level of real GDP. As Burns and Mitchell (1946) put it: "Aggregate [economic] activity can be given a definite meaning and made conceptually measurable by identifying it with gross national product" (p. 72). We determine *growth* periods by the same backward-looking procedure, but with a new (growth) threshold of $\alpha_t \geq 1\%$.[4]

A financial crisis may start at any date during a recession period and continue until the end of both the crisis and the recession. However, in a few cases, financial crises are not associated with a recession. In what follows we will look at predictive regressions to try to explain the starting date of recessions and the starting dates of crises.

3. For further details, see Chousakos and others (2016).

4. Our results are robust to alternative thresholds for recessions ($\alpha_t \leq -0.4\%$, or $\alpha_t \leq -0.6\%$) and growth periods ($\alpha_t \geq 0.5\%$, or $\alpha_t \geq 1.5\%$).

Note that the structure imposed on real GDP is the choice of the thresholds and the length of the look-back period. We impose the same thresholds and look-back length on all countries in our sample. Recessions fall into two types: recessions with a crisis and recessions with no crisis. We make this classification by first defining recessions and then checking against Valencia and Laeven (2012) who provide crisis dates worldwide since 1970.[5] Under our definitions, there can be a pattern of aggregate activity such as: recession, normal, recession, growth, normal, recession with a crisis, normal, and so on, where "normal" refers to a period that is neither a recession period nor a growth period; it is a normal period of economic activity. Based on the data discussed below we identify the different types of aggregate economic activity, which are shown in table 1.

The first column in table 1 shows the number of each type of episode across the countries of our sample. As expected, episodes of "normal times" predominate. There are 66 growth episodes and 68 recessions, among which 18 are associated with crises and 61 include instances of no crisis.[6] The second column shows statistics on the average duration in years of each event type. The average duration of a recession with a crisis episode is longer than that of a recession with no crisis. Growth episodes are the briefest.

Table 1. Summary Statistics - Duration of Economic Events

	Count	*Mean*	*St Dev*	*Min*	*Max*
Normal times	89	2.61	1.92	1.00	9.00
Growth	66	1.55	0.95	1.00	5.00
Recessions	68	2.84	1.39	1.00	7.00
Recessions with crisis	18	3.06	0.94	1.00	5.00
Recessions with no crisis	61	2.26	1.15	1.00	5.00

Notes: Duration in years of normal times, growth, recession, recession with crisis, and recession with no crisis episodes. The economic episodes are computed by using quarterly real GDP data from the OECD Library over a period of thirty years from 1980 until 2010.

5. Valencia and Laeven (2012) define a systemic banking crisis by two conditions: (1) There are significant signs of financial distress in the banking system, evidenced by significant bank runs, losses to banks, and/or bank liquidations. (2) There are significant banking policy interventions in response to large losses in the banking system. Interventions can include: (1) extensive liquidity support, (2) bank restructuring with gross costs of at least 3% of GDP, (3) significant bank nationalizations, (4) significant guarantees put into place, (5) significant asset purchases (at least 5% of GDP), (6) deposit freezes and/or bank holidays.

6. A number of recessions begin as recessions with no crisis and become recessions with crisis later, since a crisis might occur towards the end of a recession. In other words, there are recession episodes which include both crises and no crises episodes.

1.2 Measures of Information and Fragility

Now we propose two series of information in stock markets. One is the inverse of stock-market volatility, which is closely related to the fragility of firms (i.e., possible bankruptcy) in the economy. The other one relates to the cross-sectional dispersion (CSD) of stock price volatilities, and constitutes more direct evidence of private information acquisition, as it widens the range of beliefs about stocks.

The definition of fragility is from Atkeson and others (2013). Based on Leland's (Leland, 1994) and Merton's (Merton, 1974) structural models, these authors develop two concepts of default: Distance-to-Insolvency and Distance-to-Default. They then show that the variable one over the firm's equity volatility (1/*Vol*) is bounded between these two measures. Intuitively, when a firm's equity volatility is high, the firm is more likely to default (for given leverage). The fragility of an economy varies over time and spikes significantly during a crisis. Atkeson and others (2013) study the U.S. over 1926-2012 and show that 1932-1933, 1937, and 2008 stand out as especially fragile periods. Vassalou and Xing (2004) use the Merton (1974) model measure of default risk to show that default risk is a systematic risk and that the Fama-French asset pricing factors partially reflect such default risk.

We examine the median 1/*Vol* of each country in each year as a state variable about the *fragility* of the economy. Fragility is essentially a measure of economy-wide bankruptcy risk. There is a history of research that shows that firms are increasingly prone to bankruptcy leading up to a recession. Burns and Mitchell (1946) show that the liabilities of failed non-financial firms is a leading indicator of recession.[7] Gorton (1988) shows that, when the unexpected component of this variable spikes, there was a banking panic during the U.S. National Banking Era. There was never a panic without the threshold being exceeded; and the threshold was never exceeded without a panic.[8]

We also examine an additional measure of information in the economy which is defined as the cross-section of firms' stock-price volatilities. In particular, we look at the standard deviation of firms' volatilities: *CsVol*. In other words, this variable is a cross-section characterization. This variable is related to the cross-section of firms' average returns: *CsAvg*. These two variables are highly correlated (0.96), so we will restrict attention to *CsVol*. We label this second

7. Also see Zarnowitz and Lerner (1961).
8. See the discussion in Gorton (2012), p. 75-77.

variable *Information* because movements in this variable reflect information in stock prices. We have in mind the idea that underlying these variables are agents in the economy who are producing more or less information in reaction to the unobserved (to us) state of the economy. Based on the private information that these agents produce, they trade, and stock prices respond. This interpretation is not crucial. It could be public information, or a combination of public and private information. In a later section, we will show that it is not unreasonable to consider both these measures to be informative. We find that the proposed measures of information are associated with the reallocation of capital among economies at a global level, especially during instances of recessions with crises.

These variables are calculated as follows. By using daily stock price data, monthly return and volatility are calculated for each firm in each country of the sample. Both returns and volatilities are annualized and 1/*Vol* is computed. For each country, we find the median (1/*Vol*) and compute the cross-sectional standard deviation of firm-level volatilities. Then, these two monthly series are averaged across quarters to create quarterly series. The annual series are formed by using the last quarter observation of the quarterly series.[9]

1.3 Measures of Global Imbalances

In addition to domestic phases of macroeconomic volatility and domestic measures of information acquisition, in what follows, we examine the currency composition (domestic *versus* foreign) of assets and liabilities, and ask whether and how the currency composition changes in response to the changing information produced in advanced countries. The various assets and liabilities in a country are categorized by currency (either domestic or foreign) based on where the security was issued. For example, an asset in country A owned by nation B is classified as a foreign asset on the national balance sheet of country B, and a liability issued by country A and owned by a nation overseas is classified as a foreign liability on the national balance sheet

9. Another approach to the construction of the annual series would be to use an annual measure of our information variables, or the last month's observation. The reasons why we choose the last observation of the quarterly series is, *first*, that it captures information in a more timely fashion and exhibits more variation as compared to the annual measure, which is extremely smooth, and *second*, that it is less volatile than the monthly series, which is a significantly noisier series.

of country B. We standardize all measures by GDP levels, where the standardization is based on expressing the GDP denominator in the same currency as the numerator.[10] Global imbalances are defined as the difference between assets and liabilities denominated in the same currency. We use the following measures: *GI*(*DOM*) for imbalances in domestic currency; *GI*(*FOR*) for global imbalances denominated in foreign currencies; *GI*(*USD*) for imbalances in U.S. dollars; *GI*(*EUR*) for imbalances in euros; and *GI*(*TOT*) for total imbalances, which are the sum of global imbalances issued in domestic and foreign currency.[11] For additional details see Bénétrix and others (2015).[12]

1.4 Data Sources and Summary Statistics

Annual Real GDP is from the Penn World Tables (PWT), TFP is from Kose and others (2008), domestic credit to private sector is from the World Development Indicators, and labor productivity is constructed by using the hours-adjusted output-labor ratio from the Total Economy Database (TED). Our measures of economy-wide fragility and the level of information in the economy are constructed by using daily stock price data for the countries in our sample, as discussed above. The source of stock price data is Thomson/Reuters DataStream.[13] Data on global imbalances are from the online appendix of Bénétrix and others (2015).

10. This method guarantees that results cannot be due to currency fluctuation effects.

11. For additional details see Bénétrix and others (2015).

12. The dataset can be found on Philip Lane's website http://www.philiplane.org/BLSJIE2015data.htm.

13. Table 9 in the appendix shows the sample period of stock prices for each country.

Table 2. Summary Statistics – Annual Frequency

	Count	*Mean*	*StDev*	*Min*	*Max*
TFP	1,270	462.685	171.680	133.540	823.585
Credit/rGDP	1,004	66.306	49.441	6.325	232.097
Labor Productivity in hours	1,057	15.934	8.709	2.012	40.215
Recession Measure	637	-0	0.023	-0.161	0.061
$\Delta rGDP$	1,090	0.035	0.056	-0.313	0.591
ΔTFP	1,238	0.003	0.038	-0.180	0.236
$\Delta Credit/rGDP$	979	0.041	0.199	-0.671	2.881
Δ*Labor Productivity*	1,029	0.020	0.031	-0.179	0.196
1/Vol	665	3.296	1.151	0.921	8.067
CsVol	665	0.447	0.353	0.046	3.657
CsAvg	665	0.125	0.079	0.018	0.854
$\Delta(1/Vol)$	643	0.009	0.898	-4.210	3.403
$\Delta CsVol$	643	0.012	0.303	-1.886	2.181
$\Delta CsAvg$	643	0.003	0.069	-0.403	0.536
GI(DOM)	646	-41.078	42.345	-516.487	54.671
GI(FOR)	646	15.425	43.028	-62.745	15.291
GI(TOT)	646	-25.653	28.720	-165.921	60.271

Notes: The table reports summary statistics for *realGDPinbillion$, TFP, Credit/GDP, LaborProductivityinhours, RecessionMeasure* (*a*), $\Delta rGDP$, ΔTFP, $\Delta Credit/GDP$, Δ*LaborProductivity, 1/Vol, CsAvg, CsVol*, $\Delta(1/Vol)$, $\Delta CsVol$, $\Delta CsAvg$, *GI(DOM), GI(FOR)*, and *GI*(*TOT*). The data are from the Penn World Tables (PWT), WIPO statistics database, World Development Indicators, Total Economy Database (TED), and Thomson/Reuters (DataStream), and span a period from 1973 until 2010. "Count" label refers to country-years.

2. Information and the Macroeconomy

We now turn to the first set of results, which concerns how information fluctuates over time in a country in relation to macroeconomic fluctuations. We do this through a univariate comparison of variables prior to the different types of aggregate economic events (recession with crisis, recession with no crisis, growth, and normal). Table 3a shows a univariate comparison of key variables *four quarters prior* to the beginning of a recession with crisis episode *versus* the beginning of a recession with no crisis episode. Leading up to a recession with crisis, growth in real GDP ($\Delta rGDP$) is lower, and our recession measure (α) of the minimum difference of real GDP levels over a four-year period from the real GDP level at the beginning of the period is negative. Prior to recessions with crises, we observe a higher level of fragility (1/*Vol* is smaller). The significant difference in fragility is natural. As an economy heads towards a crisis, the distance-to-default of the average firm decreases. Leading up to a recession with a crisis, *CsAvg* and *CsVol*, i.e., the standard deviation of average returns and the standard deviation of firm level volatility, are both significantly higher. This is an indication of a higher dispersion of volatility and returns among companies, which we interpret as an increase in the information produced by agents in the economy in an attempt to distinguish between possible surviving firms and possible failures. Domestic and foreign global imbalances, which capture the difference between assets and liabilities issued by domestic and foreign investors respectively, exhibit the opposite pattern between instances of recessions with crises *versus* recessions with no crises. Domestic global imbalances are lower and foreign global imbalances are higher prior to recessions with crises episodes.

Table 3b reports the results of a univariate comparison of the same variables four quarters prior to the beginning of a recession *versus* prior to the beginning of a growth period. The only variable which is statistically different between the two events is *CsAvg* with a higher value prior to a growth episode. This suggests that the short-lived (average duration of 1.55 years) growth stage is associated with more production of information.

Table 3 shows that information measures have predictive content at a domestic level. Figure 1 in the appendix illustrates this finding. It shows plots of the two information measures averaged over recessions with a crisis and recessions with no crisis, starting *15 quarters before* the start of the average recession with a crisis and the average recession with no crisis. It is apparent that these measures of information and fragility vary depending on whether the coming recession will involve a financial crisis or not. We observe that fragility is higher and more information is produced prior to the beginning of a recession with a crisis episode.[14] We discuss the global imbalances measures below, when we separate advanced and developing economies.

14. We must remember that the economy is more fragile when Vol increases, and so 1/Vol decreases.

Table 3. Summary Statistics - 4 Quarters Prior to Economic Events (All Economies)

(a) Recessions with crises vs. recessions with no-crises

	No-Crisis	*Crisis*	*Mean Diff.*
$\Delta rGDP$	0.032	-0.005	0.037***
			(6.59)
α	0.004	-0.033	0.037***
			(13.51)
1/Vol	3.447	2.388	1.059***
			(6.57)
CsVol	0.407	0.645	-0.238***
			(-5.19)
CsAvg	0.115	0.173	-0.057***
			(-5.59)
$\Delta(1/Vol)$	0.016	-0.319	0.335*
			(2.57)
$\Delta CsVol$	0.002	0.107	-0.106*
			(-2.54)
$\Delta CsAvg$	0	0.024	-0.024*
			(-2.48)
$GI(DOM)$	-43.861	-64.154	20.293***
			(3.47)
$GI(FOR)$	20.714	35.239	-14.526*
			(-2.47)
$GI(TOT)$	-23.148	-28.915	5.767
			(1.29)
N	78	18	60

Notes: t-statistics in parentheses.
+p <0.10; * p <0.05; ** p <0.01; *** p <0.001.

Table 3. (continued)

(b) Recessions vs. growth

	Recession	*Growth*	*Mean Diff.*
$\Delta rGDP$	0.025	0.040	-0.015*** (-3.68)
α	-0.001	0.007	-0.009*** (-3.90)
1/Vol	3.384	3.223	0.161 (1.36)
CsVol	0.425	0.442	-0.017 (-0.50)
CsAvg	0.118	0.131	-0.013+ (-1.71)
Δ*(1/Vol)*	-0.055	0.136	-0.191* (-2.04)
Δ*CsVol*	0.016	-0.006	0.022 (0.74)
Δ*CsAvg*	0.004	-0.002	0.005 (0.75)
GI(DOM)	-46.459	-46.983	0.524 (0.11)
GI(FOR)	23.344	20.101	3.243 (0.66)
GI(TOT)	-23.115	-26.882	3.767 (1.01)
N	85	89	-4

Notes: *t*-statistics in parentheses.
+p <0.10; * p <0.05; ** p <0.01; *** p <0.001.

The table summarizes mean values for $\Delta rGDP$, α, 1/*Vol*, *CsVol*, Δ(1/*Vol*), Δ*CsVol*, *GI*(*DOM*), *GI*(*FOR*), and *GI*(*TOT*) four quarters prior to the event for (a) recessions with a crisis vs. recessions with no crisis and (b) recessions vs. growth. The third column reports the difference in means and the *t*-statistic of the difference.

Table 4a compares our information measures and global imbalances measures *during* recessions associated with crises *versus* recessions associated with no crises.[15] The levels of all the information variables are significantly different. Recessions with a crisis are significantly deeper in terms of the level of the real GDP decline. Fragility is significantly higher (1/*Vol* is smaller), as are both *CsAvg* and *CsVol*, i.e., the standard deviation of returns and the standard deviation of volatility. These two measures are higher, thus implying a higher dispersion of volatility and returns among companies. None of the other information-related measures are significantly different. Table 4b shows that, in terms of information production during the economic event, recession periods are not different from growth periods.

We also explore any potential differences in global imbalances between recessions with crises and recessions with no crises. Table 4a shows that in recessions with crises, as compared to recessions with no crises, there is a significant *decrease* in the domestic currency denominated component of the imbalance and a significant *increase* in the foreign denominated component of the imbalance. This hints at a possible reallocation of resources taking place among economies at a global scale during financial crises. In section 4.1 we further explore the implications of information production on global imbalances. We now turn to looking at these univariate comparisons separately for developed and emerging economies.

Tables 5 and 6 display univariate results for advanced and developing economies, respectively. These tables show that, in recessions with no crises, global imbalances of foreign issued assets and liabilities (*GI(FOR)*) are positive for both advanced and developing economies, thus suggesting a lower level of foreign issued liabilities as compared to that of foreign assets held by domestic investors. The positive foreign global imbalances are counterbalanced by negative imbalances of domestically-held assets and -issued liabilities (*GI(DOM)*) for both advanced and developing economies. However, in recessions with crises, the behavior of foreign global imbalances differs between advanced and developing economies. *GI(FOR)* increases for advanced economies and decreases for developing economies, thus reflecting shrinking foreign denominated liabilities. These results suggest a reallocation of investment with the exit of foreign assets. Such reallocation takes the form of capital outflows from developing economies, which means capital inflows to advanced economies.

15. "Global imbalances" refers to the difference between financial assets and liabilities standardized by the level of GDP of each country.

One question is whether the *GI(FOR)* results constitute a sudden stop which is usually defined as an abrupt decline or reversal of capital inflows, regardless of currency denomination.[16] It should be noted, however, that the dating of sudden stops is quite different than the dates of crises, and there are many more sudden stops than crises.

Table 4. Summary Statistics - Contemporary to Economic Events (All Economies)

(a) Recessions with crises vs. recessions with no crises

	No-Crisis	*Crisis*	*Mean Diff.*
$\Delta rGDP$	0.012	-0.005	0.017***
			(3.77)
α	-0.009	-0.042	0.033***
			(8.54)
1/Vol	3.519	2.388	1.131***
			(6.56)
CsVol	0.341	0.645	-0.304***
			(-5.70)
CsAvg	0.100	0.173	-0.073***
			(-6.18)
Δ*(1/Vol)*	0.055	0.041	0.015
			(0.10)
Δ*CsVol*	0.004	0.076	-0.072
			(-1.56)
Δ*CsAvg*	0.002	0.016	-0.014
			(-1.30)
GI(DOM)	-36.214	-72.775	36.561***
			(3.73)
GI(FOR)	11.072	41.512	-30.440***
			(-3.41)
GI(TOT)	-25.142	-31.263	6.121
			(1.04)
N	187	57	130

Notes: *t*-statistics in parentheses.
+$p < 0.10$; * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

16. See, e.g., Eichengreen and Gupta (2016).

Table 4. (continued)

(b) Recessions vs. growth

	No-Crisis	*Crisis*	*Mean Diff.*
$\Delta rGDP$	0.006	0.048	-0.042***
			(-10.95)
α	-0.019	0.017	-0.035***
			(-13.90)
1/Vol	3.267	3.223	0.043
			(0.32)
CsVol	0.410	0.442	-0.032
			(-0.82)
CsAvg	0.116	0.131	-0.015+
			(-1.67)
Δ*(1/Vol)*	0.040	-0.020	0.059
			(0.57)
Δ*CsVol*	0.033	-0.002	0.035
			(0.98)
Δ*CsAvg*	0.009	-0.001	0.010
			(1.16)
GI(DOM)	-50.171	-48.872	-1.298
			(-0.18)
GI(FOR)	23.306	20.713	2.593
			(0.39)
GI(TOT)	-26.865	-28.159	1.295
			(0.28)
N	233	134	99

Notes: *t*-statistics in parentheses.
+$p < 0.10$; * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

The table summarizes mean values for Δ*rGDP*, α, 1/*Vol*, *CsVol*, Δ(1/*Vol*), Δ*CsVol*, *GI(DOM)*, *GI(FOR)*, and *GI(TOT)* for (a) recessions with a crisis vs. recessions with no crisis and (b) recessions vs. growth. The third column reports the difference in means and the *t*-statistic of the difference.

Table 5. Summary statistics - Contemporary to economic events (Advanced Economies)

(a) Recessions with crises vs. recessions with no crises

	No-Crisis	*Crisis*	*Mean Diff.*
$\Delta rGDP$	0.012	-0.007	0.019***
			(4.58)
α	-0.008	-0.038	0.030***
			(8.15)
1/Vol	3.788	2.417	1.371***
			(7.70)
CsVol	0.312	0.686	-0.375***
			(-6.47)
CsAvg	0.089	0.177	-0.088***
			(-6.91)
Δ*(1/Vol)*	0.030	0.042	-0.012
			(-0.08)
Δ*CsVol*	0.017	0.057	-0.040
			(-0.85)
Δ*CsAvg*	0.005	0.014	-0.009
			(-0.83)
GI(DOM)	-38.632	-79.371	40.740**
			(3.20)
GI(FOR)	15.387	50.479	-35.092**
			(-3.13)
GI(TOT)	-23.245	-28.892	5.647
			(0.74)
N	148	50	98

Notes: *t*-statistics in parentheses.
+$p < 0.10$; * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

Table 5. (continued)

(b) Recessions vs. growth

	No-Crisis	*Crisis*	*Mean Diff.*
$\Delta rGDP$	0.006	0.041	-0.035***
			(-7.78)
α	-0.017	0.015	-0.032***
			(-11.57)
1/Vol	3.438	3.409	0.029
			(0.17)
CsVol	0.411	0.391	0.020
			(0.42)
CsAvg	0.112	0.113	-0.001
			(-0.11)
Δ(1/Vol)	0.032	-0.088	0.119
			(0.91)
ΔCsVol	0.032	-0.006	0.038
			(1.03)
ΔCsAvg	0.008	-0.002	0.010
			(1.17)
GI(DOM)	-56.674	-62.831	6.158
			(0.55)
GI(FOR)	31.116	29.322	1.794
			(0.18)
GI(TOT)	-25.557	-33.509	7.952
			(1.12)
N	192	88	104

Notes: *t*-statistics in parentheses.
+$p < 0.10$; * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.
The table summarizes mean values for $\Delta rGDP$, α, 1/*Vol*, *CsVol*, Δ(1/*Vol*), Δ*(CsVol)*, *GI(DOM)*, *GI(FOR)*, and *GI(TOT)* for (a) recessions with a crisis vs. recessions with no crisis and (b) recessions vs. growth. The third column reports the difference in means and the *t*-statistic of the difference.

Table 6. Summary Statistics - Contemporary to Economic Events (Developing Economies)

(a) Recessions with crises vs. recessions with no crises

	No-Crisis	*Crisis*	*Mean Diff.*
ΔrGDP	0.014	0.007	0.007
			(0.38)
α	-0.013	-0.074	0.061***
			(4.24)
1/Vol	2.478	2.182	0.296
			(0.90)
CsVol	0.454	0.350	0.104
			(0.82)
CsAvg	0.142	0.146	-0.003
			(-0.12)
Δ(1/Vol)	0.155	0.034	0.121
			(0.31)
ΔCsVol	-0.048	0.208	-0.255+
			(-1.73)
ΔCsAvg	-0.007	0.031	-0.038
			(-1.19)
GI(DOM)	-31.916	-25.658	-6.258
			(-0.86)
GI(FOR)	3.400	-22.539	25.940**
			(3.21)
GI(TOT)	-28.515	-48.197	19.681***
			(3.62)
N	39	7	32

Notes: *t*-statistics in parentheses.
+$p < 0.10$; * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

Table 6. (continued)

(b) Recessions vs. growth

	No-Crisis	*Crisis*	*Mean Diff.*
$\Delta rGDP$	0.009	0.061	-0.052***
			(-6.94)
α	-0.027	0.019	-0.047***
			(-7.74)
1/Vol	2.440	2.887	-0.447*
			(-2.20)
CsVol	0.409	0.534	-0.125+
			(-1.84)
CsAvg	0.137	0.163	-0.026+
			(-1.71)
$\Delta(1/Vol)$	0.078	0.103	-0.025
			(-0.14)
$\Delta CsVol$	0.040	0.006	0.034
			(0.35)
$\Delta CsAvg$	0.009	0	0.009
			(0.41)
GI(DOM)	-30.834	-34.913	4.080
			(1.08)
GI(FOR)	0.081	12.104	-12.022*
			(-2.25)
GI(TOT)	-30.752	-22.810	-7.943*
			(-2.27)
N	41	46	-5

Notes: *t*-statistics in parentheses.
+$p < 0.10$; * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.
The table summarizes mean values for $\Delta rGDP$, α, 1/*Vol*, *CsVol*, Δ(1/*Vol*), Δ(*CsVol*), *GI(DOM)*, *GI(FOR)*, and *GI(TOT)* for (a) recessions with a crisis vs. recessions with no crisis and (b) recessions vs. growth. The third column reports the difference in means and the *t*-statistic of the difference.

3. A Global Information Factor

Are there information spillovers across countries? To address this question, we extract principal components for the information and fragility measures, respectively, by using a number of advanced countries in our sample.[17] We first examine whether the first and second principal components of the information and fragility measures predict economic episodes (recessions and recessions with crises), and *second* explore the relation between those principal components and global imbalances (domestic and foreign).

3.1 Information Spillovers from Advanced Economies to Other Markets

In this section, we focus on the ability of the first two principal components of information and fragility measures to predict the occurrence of recessions with crises on a country-by-country basis. More specifically, for each of the countries of our sample, we regress the occurrence of a recession with a crisis on the first and second principal component of the information measure *(CsVol)* and the distance to insolvency measure (1/*Vol*), controlling for a number of macroeconomic variables ($\Delta Credit$, ΔTFP, and ΔLP).

Using principal components we are able to separate information from noise. The first two principal components of *CsVol* and 1/*Vol* summarize a large part of the variation of the *CsVol* and 1/*Vol* series among the advanced countries of our sample. Due to the nature of the methodology, we cannot actually identify the nature of the information that is summarized by the principal components. However, we know that principal components are orthogonal to each other and explain a large portion of the variability of the original series. If our measures are informative, then their principal components ought to predict economic events and global imbalances.

Figure 2 in the appendix summarizes the regression coefficients and a 95% confidence interval around the estimates for the first two principal components of the information measure and the distance to insolvency measure, along with the F-statistics and p-values of country

17. We extract the principal components by using the information and fragility measures for countries for which we have a complete time series from 1973 until 2010. The list of countries with complete time series is: Australia, Austria, Belgium, Denmark, France, the United Kingdom, Ireland, Japan, the Netherlands, and the United States.

level regressions. We observe that the results of these regressions with respect to the predictive power of the principal components of the information measure are fairly dramatic.[18] The principal components of the information measures are generally successful in predicting recessions with crises. The coefficient of the first principal component is positive, whereas that of the second is negative.

Since we employ principal components as explanatory variables, it is hard to accurately identify their nature and the fundamental information that they summarize. Nevertheless, the fact that the first two principal components of the information and the distance to insolvency measures explain the largest part of the variability of the data (figure 5 in the appendix) allows us to distinguish the relevant information from noise. We observe that the principal components, extracted from the information measures of specific countries (Australia, Austria, Belgium, Denmark, France, the United Kingdom, Ireland, Japan, the Netherlands, and the United States) with long time series for this measure, predict the occurrence of recessions with crises in other economies, both advanced (e.g., Finland, Greece, Portugal, and Spain) and developing (e.g., Argentina). This is suggestive of information spillovers from the countries of the sample to other economies.

3.2 Global Information and Global Imbalances

In the previous section we provided evidence in favor of information spillovers. Information produced by a set of advanced countries predicts recessions with crises in other advanced and developing economies. In this section we explore an additional aspect of information spillovers and their possible source: information produced by a set of countries predict global imbalances (domestic and foreign). Empirically, at a country level, we regress series of global imbalances on the first and second principal component of our information measures (1/*Vol* and *CsVol*).

Figures 3 and 4 in the appendix summarize the individual country regression coefficients and a 95% confidence interval for the estimated values. Figure 3 looks at global imbalances denominated in foreign currency. The coefficients on both principal components of the distance to insolvency measure, even though statistically significant for a number of countries, are somewhat noisy overall. However, the coefficients on the first principal component of the information measure

18. In the appendix the same figure is shown for the case of predicting recessions (see figure 6). In this figure, neither principal component appears with a statistically significant predictive power over the occurrence of recessions in the countries of our sample.

are consistently negative across the countries of our sample, while the coefficients on the second principal component are positive only for a subset of countries. Figure 4 looks at global imbalances measured in foreign currency. Here the results are reversed. Most coefficients on the first principal component of the information measure are positive, while those on the second principal component are negative. This finding is consistent with the opposite signs we document in table 7.

Table 7. Explanatory Regression - Global Imbalances (panel)

	(1) $GI(DOM)_t$	(2) $GI(FOR)_t$	(3) $GI(USD)_t$	(4) $GI(EUR)_t$	(5) $GI(TOT)_t$
$CsVol_t$	11.913***	-5.611*	-2.102	6.753	6.303*
	(3.42)	(-2.05)	(-1.23)	(1.08)	(2.50)
$CsVol_{t-1}$	6.966*	-3.337	-3.850**	1.128	3.629+
	(2.26)	(-1.31)	(-2.72)	(0.31)	(1.78)
Vol_t	2.854	-1.222	-1.339	2.344	1.633
	(0.92)	(-0.56)	(-0.76)	(0.58)	(0.67)
Vol_{t-1}	-3.472	1.484	0.811	-0.403	-1.987
	(-1.18)	(0.53)	(0.47)	(-0.11)	(-0.93)
$Credit_{t-1}$	-0.478*	0.173	0.086	-0.680*	-0.305+
	(-2.29)	(0.97)	(0.76)	(-1.98)	(-1.82)
TFP_{t-1}	0.018	0.076	0.050	0.030	0.094
	(0.19)	(0.78)	(1.23)	(0.25)	(1.07)
LP_{t-1}	-3.430	4.121	-1.517	-3.058	0.691
	(-1.09)	(1.25)	(-0.82)	(-0.55)	(0.33)
Constant	16.713	-69.858*	3.166	8.910	-53.145**
	(0.68)	(-2.46)	(0.17)	(0.23)	(-2.71)
N	449	449	449	449	449
R^2	0.72	0.80	0.75	0.61	0.69
FE (year)	YES	YES	YES	YES	YES
FE (country)	YES	YES	YES	YES	YES

Notes: *t*-statistics in parentheses.
$+p < 0.10$; * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

The table summarizes the explanatory power of *1/Vol*, *CsVol*, and their one-year lagged observations on (1) global imbalances denominated in domestic currency, (2) global imbalances denominated in foreign currency, (3) global imbalances denominated in U.S. dollars, (4) global imbalances denominated in euros, (5) total global imbalances (see, e.g., Bénétrix and others (2015)). The regression specification is: $GI_{n,t} = \alpha + \beta' X_{n,t} + \varepsilon_{n,t}$, where $X_{n,t} = (1/Vol_{n,t}, 1/Vol_{n,t-1}, CsVol_{n,t}, CsVol_{n,t-1}, Credit_{n,t-1}, TFP_{n,t-1}, LP_{n,t-1})'$. Data are from Bénétrix and others (2015) and DataStream, and span a period from 1990 until 2010. All specifications include year and country fixed effects. Robust *t-statistics* adjusted for country-level clustering are reported in parentheses.

The results in figures 3 and 4 provide additional evidence in favor of information spillovers. Global information measures predict instances of recessions with crises and also are correlated with domestic and foreign imbalances, which means that they explain the reallocation of resources among economies. This finding strengthens our interpretation of our information measures as being indeed informative.

4. Reallocation of Resources

In the previous section we provided evidence of reallocation of resources across countries as a result of information production. Here we explore this reallocation effect of information in more detail.

4.1 Reallocation of capital across countries

Do measures of information have any predictive power over global imbalances (both domestic and foreign)? We primarily focus on three measures of global imbalances: (i) imbalances denominated in domestic currency, (ii) imbalances denominated in foreign currency, and (iii) total imbalances. Changes in global imbalances reflect a reallocation of capital among countries. There is a large literature on global imbalances, a summary of which would be outside the scope of this paper.[19]

Table 7 shows regression results of the contemporaneous association and the effects of lagged information values (*1 / Vol, CsVol*), as well as lagged credit-to-private sector as a percentage of GDP (*Credit*), total factor productivity (*TFP*), and labor productivity (*LP*) separately on a number of global imbalance measures, i.e., in domestic currency (*GI*(*DOM*)), foreign currency (*GI*(*FOR*)), U.S. dollars (*GI*(*USD*)), euros (*GI*(*EUR*)) and total (*GI*(*TOT*)). Contemporaneous and lagged *CsVol* are positively related to the domestic global imbalance measure and negatively related to the foreign global imbalance measure. This means that an increase in information production is associated with a larger level of domestic assets as compared to domestic liabilities, and with a lower level of foreign assets as compared to foreign liabilities.

This finding is consistent with our conjecture that a higher level of information produced in the economy leads to a reallocation of

19. See, e.g., Gourinchas and Rey (2013).

resources among countries, and towards countries where information has been produced. More information is associated with a higher level of domestic assets which are funded with foreign liabilities. The sum of the first two columns of table 7 yields the coefficients for the total global imbalances for each country in the sample. Finally, we observe that the economy-wide solvency measure (*Vol*), as well as a number of macroeconomic variables (Credit, TFP, and LP), do not correlate with global imbalances.

Motivated by this predictive power of the information measures on global imbalances, we address the question of whether lagged measures of global imbalances (*GI(DOM)* and *GI(FOR)*, respectively) have any predictive power with respect to the occurrence of financial crises. Table 8 summarizes the results of a logit regression of the probability of a recession with a crisis on the global imbalances measures. We observe that a decrease in foreign global imbalances is associated with an increase in the probability of a recession with a crisis. More specifically, when the difference between foreign assets and liabilities decreases, recessions with crises become more likely.

In what follows, we further look into the predictive ability of global imbalances with respect to recessions with crises at a country level. Figures 7 and 8 in the appendix summarize our results. We find that lagged measures of domestic global imbalances do predict instances of recessions associated with crises in about half of the countries of our sample (Austria, Greece, Ireland, the Netherlands, Portugal, Spain, Sweden, and the United States). On the other hand, foreign global imbalances predict crises in more than half of the countries (Denmark and Mexico, in addition to the above mentioned countries). The weak results are primarily attributed to the small number of recessions associated with crises in our sample (18 observations). The documented predictive power of global imbalances on the occurrence of crises is consistent with, for example, Bernanke (2005) and Bernanke (2007).

Table 8. Predictive regressions

	(1) $GI(DOM)_t$	(2) $GI(FOR)_t$	(3) $GI(TOT)_t$
$GI(DOM)_t$	-0.006		
	(-0.63)		
$GI(FOR)_t$		-0.030*	
		(-2.11)	
$GI(TOT)_t$			-0.033+
			(-1.86)
$\Delta Credit_{t-1}$	-1.181	-1.016	-0.809
	(-0.74)	(-0.63)	(-0.70)
ΔTFP_{t-1}	-38.703*	-44.755*	-38.128*
	(-2.14)	(-2.38)	(-2.08)
ΔLP_{t-1}	13.549	15.740	7.265
	(0.71)	(0.84)	(0.35)
Constant	-1.241	0.802	-1.186*
	(-1.62)	(1.20)	(-2.18)
N	266	266	266
FE (Year)	YES	YES	YES
FE (Country)	YES	YES	YES

Notes: *t*-statistics in parentheses.
+$p < 0.10$; * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

The table summarizes the predictive power of (1) global imbalances denominated in domestic currency, (2) global imbalances denominated in foreign currency, and (3) total global imbalances (see, e.g., [4]) on the occurrence of recessions with crises. The regression specification is: $logit(E[Y_{i,t} \mid X_{i,t-1}]) = logit(p_{i,t}) = \alpha + \beta' X_{t-1} + \varepsilon_t$, where $X_{t-1} = (GI(type)_{t-1}, \Delta Credit_{t-1}, \Delta TFP_{t-1}, \Delta LP_{t-1})', type \in \{domestic, foreign, total\}$, and $p_{i,t}$ is the probability of a recession with a crisis occurring for country *i* at time *t*. Data are from [4] and DataStream, and span a period from 1990 until 2010. All specifications include year and country fixed effects. Robust *t–statistics* adjusted for country-level clustering are reported in parentheses.

4.2 Reallocation of capital within a country

We have showed that a higher level of produced information is associated with a higher level of domestic assets which are funded with foreign liabilities. This finding suggests that the production of information locally leads to a reallocation of resources across economies at a global scale. In this section we shift our focus to the domestic reallocation of resources as a result of the production of information in the economy. If our measures are actually associated with domestic reallocation, then we would expect to find a statistically significant relation between the information and fragility measures and future changes in a firm's Tobin's Q-ratio. An increase in the information produced in the economy would be expected to be followed by an increase in the Q-ratios of firms with Q-ratios less than one and a decrease in the Q-ratios of firms whose Q-ratios are more than one, thus reflecting a reallocation of resources from the firms with high Q-ratios to those with low Q-ratios.

Tables 10 and 11 in the appendix show the effect of one- and four-year lagged innovations in information production ($\Delta CsVol$), respectively, on the fraction of firms (1) remaining in the first (lowest) quintile of firms ranked on the basis of their Tobin's Q-ratio, (2) switching from the first to the second quintile, (3) switching from the first to the third quintile, (4) remaining in the fifth (highest) quintile, (5) switching from the fifth to the fourth quintile, and (6) switching from the fifth to the third quintile. We observe that an increase in the production of information prior to a financial crisis is associated with a decrease in the fraction of firms that remain in the lowest quintile of Q-ratios and a subsequent increase in the fraction of firms that switch from the first to the second and third quintiles. The absence of statistically significant coefficients for the other cases considered in the regression analysis suggests that the reallocation of resources within an economy following the production of information is rather limited.

This finding is in contrast with that of section 4.1 and implies that the reallocation of resources is more pronounced among economies as a whole, rather than among firms within a given economy. The weak reallocation of resources within an economy in periods of crises is in line with evidence of a malfunctioning financial system. On the other hand, the strong reallocation of resources among economies at a global scale indicates that the financial system operates efficiently at a global level.

5. Conclusion

Globalization is a much-discussed phenomenon, one aspect of which we study in this paper, namely: information spillovers from a set of advanced economies to a number of other advanced and developing economies. Our preliminary results provide evidence in favor of the existence of global information spillovers. We show that measures of information produced in advanced countries predict crises in other advanced and developing markets. The same information measures are also associated with global imbalances, thereby suggesting a possible mechanism through which reallocation of capital takes place at a global level and how crises are contagious in the world. More specifically, we find that more information is related to a higher level of domestic assets which are, in turn, funded with foreign liabilities, and global imbalances predict instances of recessions associated with financial crises. The results of this paper should be viewed as tentative because of the small sample of countries, particularly for emerging market economies.

References

Atkeson, A.G., A.L. Eisfeldt, and P.O. Weill. 2013. "Measuring the Financial Soundness of U.S. Firms, 1926-2012." Working Paper No. 19204, National Bureau of Economic Research.

Bernanke, B.S. 2005. "The Global Saving Glut and the U.S. Current Account Deficit." Speech delivered for the Sandridge Lecture at the Virginia Association of Economists, Richmond, March.

———. 2007. "Global Imbalances: Recent Developments and Prospects." Speech delivered at the Bundesbank, Berlin, Germany, September.

Bénétrix, A.S., P.R. Lane, and J.C. Shambaugh. 2015. "International Currency Exposures, Valuation Effects and the Global Financial Crisis." *Journal of International Economics* 96 (Supplement 1): S98–S109. 37th Annual {NBER} International Seminar on Macroeconomics.

Burns, A.F. and W.C. Mitchell. 1946. "Measuring Business Cycles, National Bureau of Economic Research, Inc.

Caballero, R.J. and M.L. Hammour. 1994. "The Cleansing Effect of Recessions." *American Economic Review* 84(5): 1350–68.

———. 1996. "On the Timing and Efficiency of Creative Destruction." *Quarterly Journal of Economics* 111(3): 805–52.

Calvo, G.A. 2004. *Contagion in Emerging Markets: When Wall Street is a Carrier.* London, U.K.: Palgrave Macmillan.

Calvo, G.A. and E.G. Mendoza. 2000. "Contagion, Globalization, and the Volatility of Capital Flows." In *Capital Flows and the Emerging Economies: Theory, Evidence, and Controversies.* NBER Chapters, National Bureau of Economic Research.

Chousakos, K., G. Gorton, and G. Ordoñez. 2016. "Aggregate Information Dynamics." Working Paper, Yale University.

Cole, H., D. Neuhann, and G. Ordoñez. 2016. "Debt Crises: For Whom the Bell Tolls." Working Paper No. 22330, National Bureau of Economic Research.

Eichengreen, B. and P. Gupta. 2016."Managing Sudden Stops." Policy Research Working Paper No. 7639, The World Bank.

Fama, E.F. 2014. "Two Pillars of Asset Pricing." *American Economic Review* 104(6): 1467–85.

Foster, L., C. Grim, and J. Haltiwanger. 2016. "Reallocation in the Great Recession: Cleansing or Not?" *Journal of Labor Economics* 34(S1): S293–S331.

Gande, A. and D. Parsley. 2003. "News Spillovers in the Sovereign Debt Market." Working Paper No. 062003, Hong Kong Institute for Monetary Research.

Gorton, G. 1988. "Banking Panics and Business Cycles." *Oxford Economic Papers* 40(4): 751–81.

————. 2012. *Misunderstanding Financial Crises: Why We Don't See Them Coming.* Oxford University Press.

Gorton, G. and G. Ordoñez. 2014. "Collateral Crises." *American Economic Review* 104(2): 343–78.

————. 2016. "Good Booms, Bad Booms." Working Paper No. 22008, National Bureau of Economic Research.

Gourinchas, P.O. and H. Rey. 2013. "External Adjustment, Global Imbalances and Valuation Effects." Technical Report, Berkeley and London Business School.

Grossman, Sanford J. 1981. "An Introduction to the Theory of Rational Expectations under Asymmetric Information." *Review of Economic Studies* 48(4): 541–59.

Hodrick, R.J. and E.C. Prescott. 1997. "Postwar U.S. Business Cycles: An Empirical Investigation." *Journal of Money, Credit and Banking* 29(1): 1–16.

King, M.A. and S. Wadhwani. 1990. "Transmission of Volatility between Stock Markets." *Review of Financial Studies* 3(1): 5–33.

Kose, M.A., E.S. Prasad, and M.E. Terrones. 2008. "Does Openness to International Financial Flows Raise Productivity Growth?" Working Paper No. 14558, National Bureau of Economic Research.

Leland, H. 1994. "Corporate Debt Value, Bond Covenants, and Optimal Capital Structure." *Journal of Finance* 49(4): 1213–52.

Merton, R. 1974. "On the Pricing of Corporate Debt: The Risk Structure of Interest Rates." *Journal of Finance* 29(2): 449–70.

Newey, W. and K. West. 1987. "A Simple, Positive Semi-Definite, Heteroskedasticity and Autocorrelation Consistent Covariance Matrix." *Econometrica* 55(3): 703–08.

Schumpeter, J.A. 1939. *Business Cycles: A Theoretical, Historical, and Statistical Analysis of the Capitalist Process.* New York, N.Y.: McGraw-Hill.

Valencia, F. and L. Laeven. 2012. "Systemic Banking Crises Database; An Update." IMF Working Paper No. 12/163.

Vassalou, M. and Y. Xing. 2004. "Default Risk in Equity Returns." *Journal of Finance* 59(2): 831–68.

Zarnowitz, V. and L.J. Lerner. 1961. "Cyclical Changes in Business Failures and Corporate Profits." In *Business Cycle Indicators*, volume 1. Cambridge, Ma: National Bureau of Economic Research.

APPENDIX A

Table A1. Equity data - Start and end dates at a country level

Country	*Start Date*	*End Date*
Argentina	1993	2010
Australia	1973	2010
Austria	1973	2010
Belgium	1973	2010
Brazil	1996	2010
Chile	1995	2010
Colombia	2000	2010
Denmark	1973	2010
Finland	1987	2010
France	1973	2010
Greece	1988	2010
India	1996	2010
Ireland	1973	2010
Israel	1995	2010
Japan	1973	2010
Mexico	1988	2010
Netherlands	1973	2010
New Zealand	1987	2010
Portugal	1988	2010
Spain	1986	2010
Sweden	1973	2010
Turkey	1988	2010
United Kingdom	1973	2010
United States	1973	2010

Notes: The table summarizes the start and end dates for equity data used to compute the measures of distance to insolvency ($1/Vol$) and information ($CsVol$). The data are from WorldScope.

Table A2. Predictive Regression - Reallocation at a Country Level

	(1)	(2)	(3)	(4)	(5)	(6)
	Q1→Q1	Q1→Q2	Q1→Q3	Q5→Q5	Q5→Q4	Q5→Q3
ΔCsVolt	0.071	0.009	-0.007	0.064	0.002	-0.008
	(0.57)	(0.27)	(-0.56)	(0.85)	(0.06)	(-0.37)
ΔCsVolt x1t(Crisis)	-0.479*	0.093	0.131+	-0.085	-0.095	0.043
	(-2.45)	(1.48)	(1.69)	(-0.44)	(-1.17)	(0.52)
Δ(1/Vol)t	0.018	-0.017	-0.005	0.003	-0.018	0.001
	(0.27)	(-0.82)	(-0.43)	(0.09)	(-1.03)	(0.10)
Δ(1/Vol)t x1t(Crisis)	-0.074	0.026	-0.023	-0.024	0.051	0.003
	(-0.51)	(0.41)	(-0.44)	(-0.23)	(1.00)	(0.15)
ΔCsVolt-1	0.073	-0.018	0.024	0.098	0.043	-0.003
	(0.41)	(-0.51)	(1.25)	(0.94)	(0.81)	(-0.08)
ΔCsVolt-1 x1t(Crisis)	-0.533	0.123*	-0.123	-0.260	-0.054	0.090
	(-1.60)	(2.50)	(-1.46)	(-1.28)	(-0.47)	(1.26)
1/Vol t-1	-0.043	0.007	-0.007	-0.009	-0.001	-0.001
	(-0.64)	(0.39)	(-0.62)	(-0.18)	(-0.03)	(-0.09)
1/Volt-1 x1t(Crisis)	0.010	0.002	0.018+	0.004	0.004	-0.009
	(0.27)	(0.17)	(1.75)	(0.22)	(0.48)	(-1.18)
Constant	1.016**	0.253**	0.175***	0.562*	0.261+	0.075
	(3.43)	(2.80)	(4.62)	(2.13)	(1.94)	(1.01)
N	215	213	213	225	219	220
R^2	0.35	0.52	0.58	0.43	0.42	0.54
Cluster (Country)	YES	YES	YES	YES	YES	YES
FE (Time)	YES	YES	YES	YES	YES	YES
FE (Country)	YES	YES	YES	YES	YES	YES

Notes: *t*-statistics in parentheses.
+p < 0.10; * p < 0.05; ** p < 0.01; *** p < 0.001.

The table summarizes the predictive power of 1/*Vol*, Δ1/*Vol*, cross-sectional volatility (*CsVol*), change in cross-sectional volatility (Δ*CsVol*), and their interaction with a dummy indicating a crisis on the fraction of firms (1) remaining in quintile 1, (2) switching from quintile 1 to quintile 2, (3) switching from quintile 1 to quintile 3, (4) remaining in quintile 5, (5) switching from quintile 5 to quintile 4, and (5) switching from quintile 5 to quintile 3. All fractions are computed for a single economic episode (recession with crisis, recession with no-crisis, normal periods, growth periods). The regression specification is: $fr(Qx_{start} \rightarrow Qy_{end})_{n,t} = \alpha_n + \beta' X_{n,t-1} + \gamma' X_{n,t-1} 1(Crisis)_{n,t} + \varepsilon + n,t$, where $X_{n,t} = (CsVol_{n,t-1}, \Delta CsVol_{n,t}, 1/Vol_{n,t-1}, \Delta(1/Vol)_t)'$ and $x, y \in \{1,\ldots,5\}$. Data are from WorldScope and span a period from 1980 until 2010. All specifications include year and country fixed effects. Robust *t–statistics* adjusted for country-level clustering are reported in parentheses.

Table A3. Predictive Regression - Reallocation at a Country Level

	(1)	(2)	(3)	(4)	(5)	(6)
	Q1→Q1	Q1→Q2	Q1→Q3	Q5→Q5	Q5→Q4	Q5→Q3
$\Delta CsVol_{t-4}$	0.066	0.012	-0.027*	0.046	-0.027	-0.012
	(0.87)	(0.45)	(-2.44)	(0.94)	(-1.62)	(-0.84)
$\Delta CsVol_{t-4}$ $x1_t(Crisis)$	-0.244**	0.085*	0.070	-0.002	-0.035	0.053+
	(-3.49)	(2.46)	(1.63)	(-0.02)	(-0.91)	(1.73)
$\Delta(1/Vol)_{t-4}$	0.050	-0.025	-0.003	-0.005	0.005	-0.001
	(0.99)	(-1.41)	(-0.40)	(-0.11)	(0.40)	(-0.05)
$\Delta(1/Vol)_{t-4}$ $x1_t(Crisis)$	-0.011	-0.036	-0.050	-0.027	0.012	0.021
	(-0.12)	(-0.87)	(-1.61)	(-0.29)	(0.36)	(1.03)
$\Delta CsVol_{t-5}$	-0.036	-0.008	-0.007	-0.029	-0.001	0.022
	(-0.33)	(-0.27)	(-0.43)	(-0.43)	(-0.04)	(1.07)
$\Delta CsVol_{t-5}$ $x1_t(Crisis)$	-0.186	0.075	-0.025	-0.029	0.032	0.039
	(-1.15)	(1.05)	(-0.57)	(-0.23)	(0.49)	(1.01)
$1/Vol_{t-5}$	0.001	0.001	-0.002	0.001	-0.001	0.008
	(0.01)	(0.03)	(-0.24)	(0.03)	(-0.08)	(0.98)
$1/Vol_{t-5}$ $x1_t(Crisis)$	-0.068*	-0.011	0.009	-0.033	-0.019	-0.002
	(-2.17)	(-0.78)	(0.75)	(-1.04)	(-0.99)	(-0.35)
Constant	0.993*	0.303*	0.156**	0.567**	0.290***	0.051+
	(2.16)	(2.49)	(3.37)	(3.43)	(4.24)	(1.81)
N	170	169	168	180	175	175
R^2	0.43	0.56	0.71	0.51	0.54	0.69
Cluster (country)	YES	YES	YES	YES	YES	YES
FE (time)	YES	YES	YES	YES	YES	YES
FE (country)	YES	YES	YES	YES	YES	YES

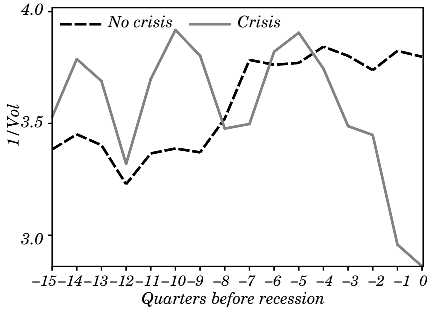
Notes: *t*-statistics in parentheses.
$+p < 0.10$; * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

The table summarizes the predictive power of 1/*Vol*, Δ1/*Vol*, cross-sectional volatility (*CsVol*), change in cross-sectional volatility (Δ*CsVol*), and their interaction with a dummy indicating a crisis on the fraction of firms (1) remaining in quintile 1, (2) switching from quintile 1 to quintile 2, (3) switching from quintile 1 to quintile 3, (4) remaining in quintile 5, (5) switching from quintile 5 to quintile 4, and (5) switching from quintile 5 to quintile 3. All fractions are computed for a single economic episode (recession with crisis, recession with no crisis, normal periods, growth periods). The regression specification is: $fr(Qx_{start} \rightarrow Qy_{end})_{n,t} = \alpha_n + \beta' X_{n,t-4} + \gamma' X_{n,t-4} 1(Crisis)_{n,t} + \varepsilon + n,t$, where $X_{n,t-4} = (CsVol_{n,t-5}, \Delta CsVol_{n,t-4}, 1/Vol_{n,t-5}, \Delta(1/Vol)_{t-4})'$ and $x, y \in \{1,\ldots,5\}$.
Data are from WorldScope and span a period from 1980 until 2010. All specifications include year and country fixed effects. Robust *t–statistics* adjusted for country-level clustering are reported in parentheses.

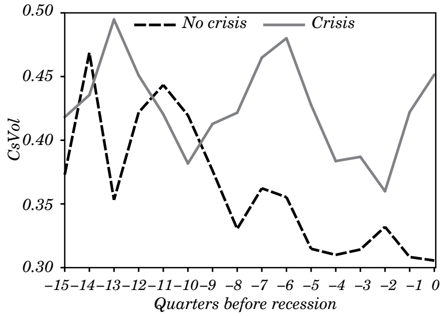
Appendix B

Figure B1. Average Distance to Insolvency and Cross-Sectional Volatility

(a) 1/Volatility



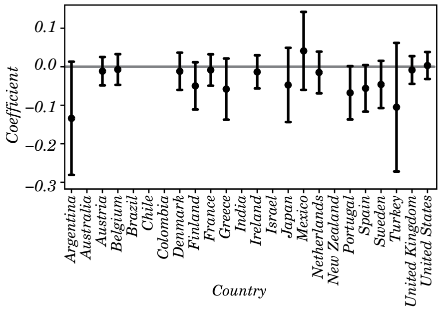
(b) Cross-sectional Volatility



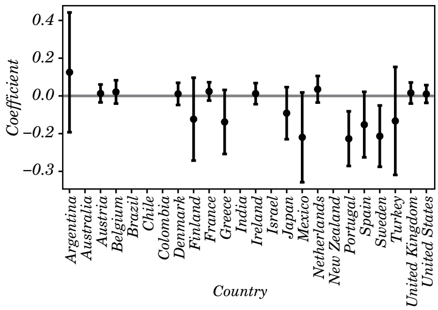
Notes: Average Distance to Insolvency and Cross-Sectional Volatility over 15 quarters before the beginning of: (*a*) a recession with a crisis, and (*b*) a recession with no crisis.

Figure B2. Predictive Regressions - Recessions with Crises

(a) PC1 1/Volatility



(b) PC2 1/Volatility



(c) PC1 Cross-Sectional Volatility

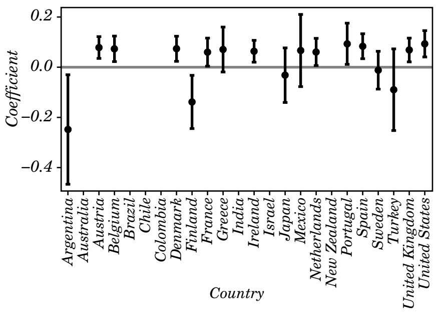
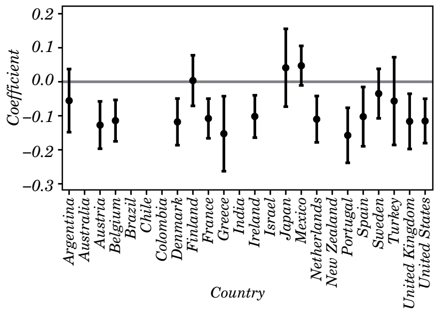
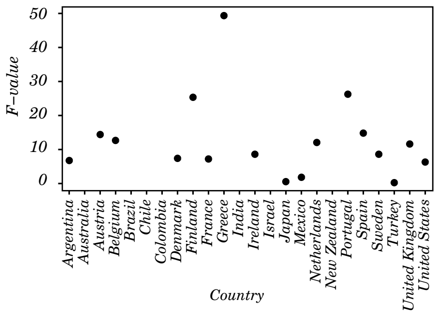


Figure B2. (continued)

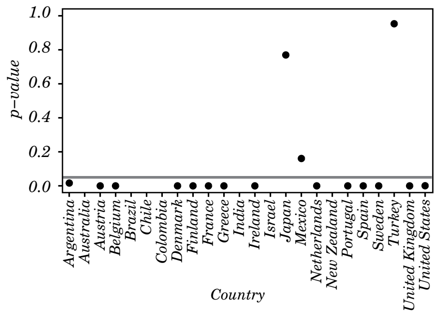
(d) PC2 Cross-Sectional Volatility



(e) F-statistic



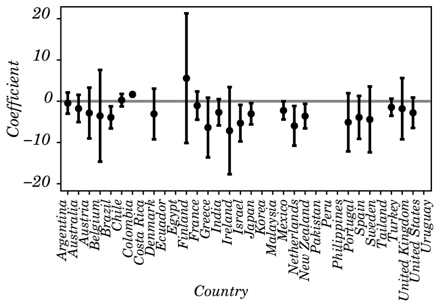
(f) p-value



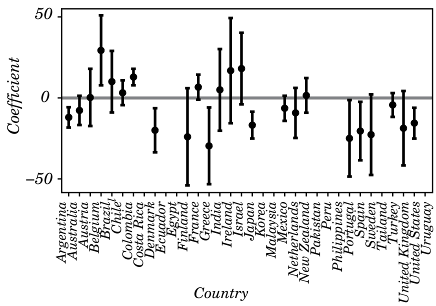
Notes: Figures (a) through (d) summarize the predictive power of the first two principal components of 1/*Vol* and *CsVol* on the occurrence of recessions with crises. The figures show the point estimates of the regression coefficients along with a 95% confidence interval around the point estimates. Figures (e) and (f) report the *F–statistic* and the *p–value* of the regressions, respectively. All regressions are performed at the country level and standard errors are corrected using Newey and West (1987) with one lag. The regression specification is: $\mathbb{1}_t(Recession \cap Crisis) = \alpha + \beta' X_{t-1} + \varepsilon_t$, where $X_{t-1} = (PC1(1/Vol_{t-1}), PC2(1/Vol_{t-1}), PC1(CsVol_{t-1}), PC2(CsVol_{t-1}), \Delta Credit_{t-1}, \Delta TFP_{t-1}, \Delta LP_{t-1},)'$.

Figure B3. Predictive Regressions - Domestic Global Imbalances (Country Level)

PC1 1/Volatility



(b) PC2 1/Volatility



(c) PC1 Cross-Sectional Volatility

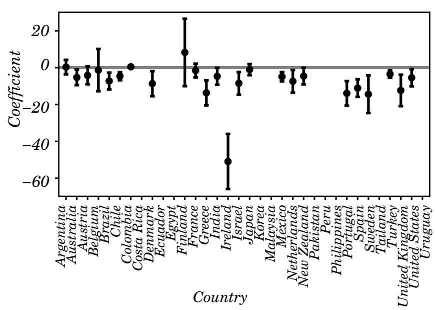
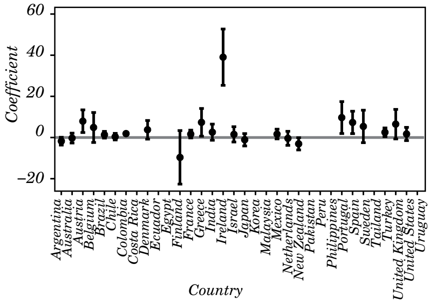
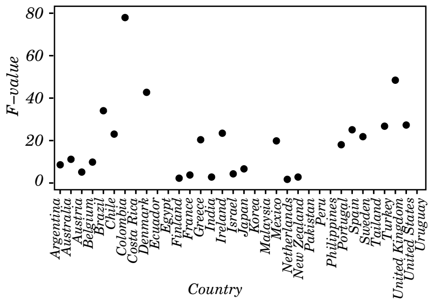


Figure B3. (continued)

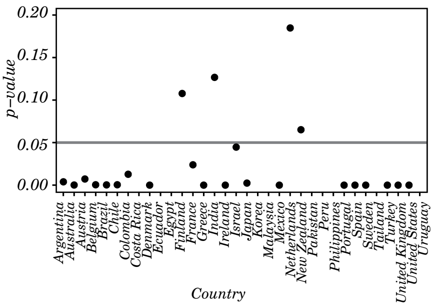
(d) PC2 Cross-Sectional Volatility



(e) F-statistic



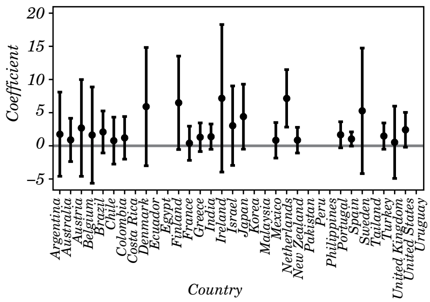
(f) p-value



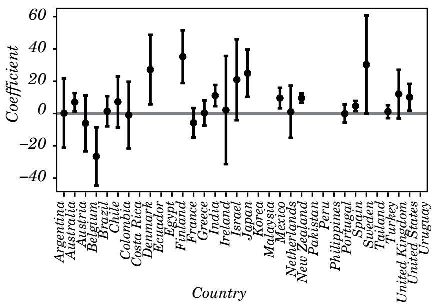
Notes: Figures (a) through (d) summarize the predictive power of the first two principal components of *1/Vol* and *CsVol* on global imbalances denominated in domestic currency. The figures show the point estimates of the regression coefficients along with a 95% confidence interval round the point estimates. Figures (e) and (f) report the *F–statistic* and the *p–value* of the regressions, respectively. All regressions are performed at the country level and standard errors are corrected by using Newey and West (1987) with one lag. The regression specification is: $GI(DOM)_t = \alpha + \beta' X_{t-1} + \varepsilon_t$, where $X_{t-1} = (PC1(1/Vol_{t-1}), PC2(1/Vol_{t-1}), PC1(CsVol_{t-1}), PC2(CsVol_{t-1}))'$.

Figure B4. Predictive regressions - Foreign global imbalances (country level)

(a) PC1 1/Volatility



(b) PC2 1/Volatility



(c) PC1 Cross-Sectional Volatility

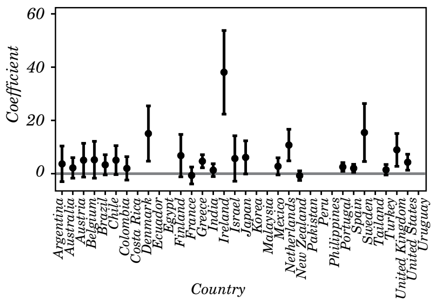
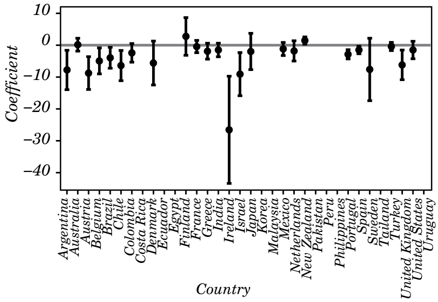
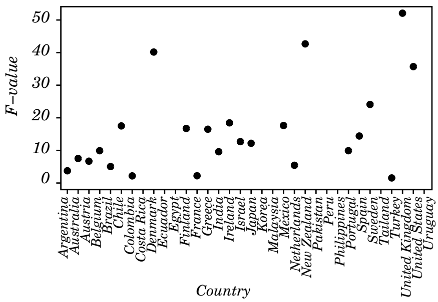


Figure B4. (continued)

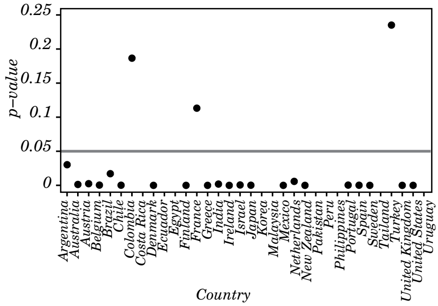
(d) PC2 Cross-Sectional Volatility



(e) F-statistic



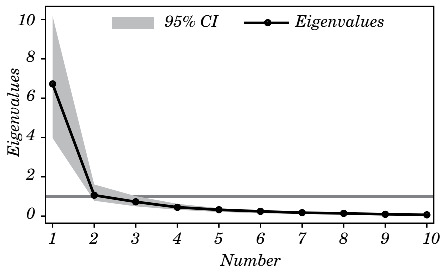
(f) p-value



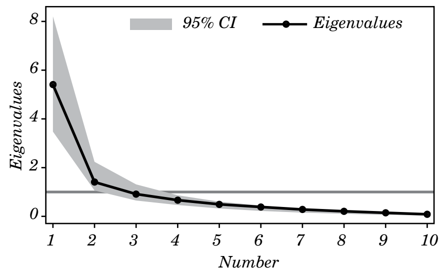
Notes: Figures (*a*) through (*d*) summarize the predictive power of the first two principal components of $1/Vol$ and *CsVol* on global imbalances denominated in foreign currency. The figures show the point estimates of the regression coefficients along with a 95% confidence interval round the point estimates. Figures (*e*) and (*f*) report the *F–statistic* and the *p–value* of the regressions, respectively. All regressions are performed at the country level and standard errors are corrected by using Newey and West (1987) with one lag. The regression specification is: $GI(FOR)_t = \alpha + \beta' X_{t-1} + \varepsilon_t$ where $X_{t-1} = (PC1(1/Vol_{t-1}), PC2(1/Vol_{t-1}), PC1(CsVol_{t-1}), PC2(CsVol_{t-1}))'$.

Figure B5. Principal Component Analysis - Eigenvalues

(a) 1/Volatility



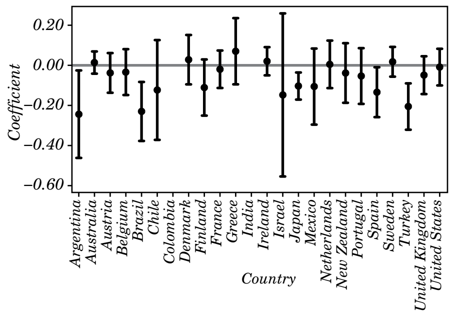
(b) Cross-Sectional Volatility



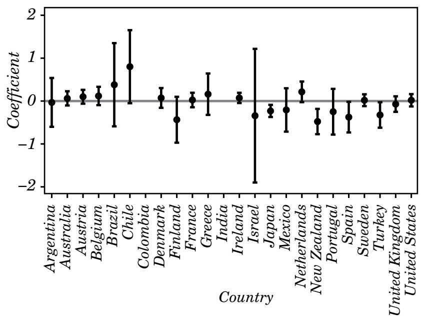
Note: The figure summarizes the eigenvalues of the first ten principal components along with a 95% confidence interval for 1/*Vol* and *CsVol*.

Figure B6. Predictive Regressions - Recessions

(a) PC1 1/Volatility



(b) PC2 1/Volatility



(c) PC1 Cross-Sectional Volatility

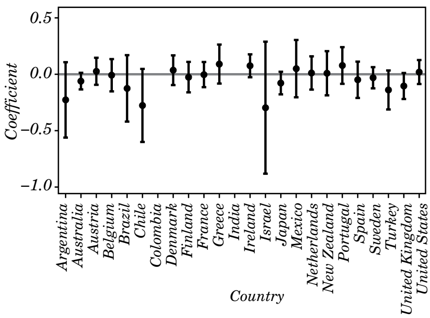
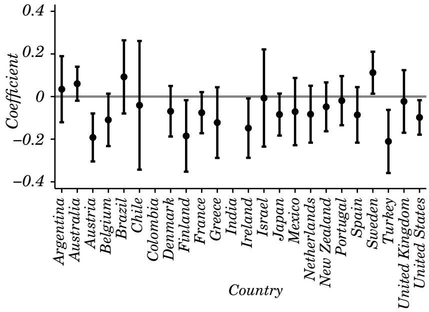
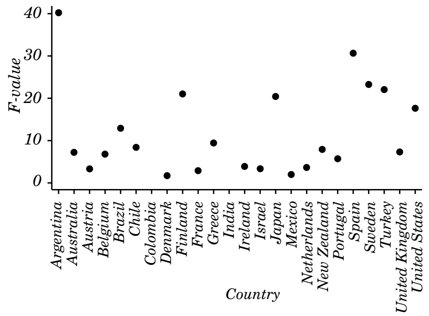


Figure B6. (continued)

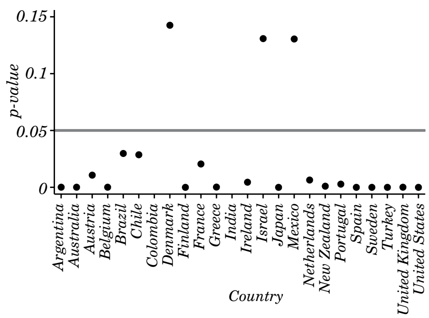
(d) PC2 Cross-Sectional Volatility



(e) F-statistic

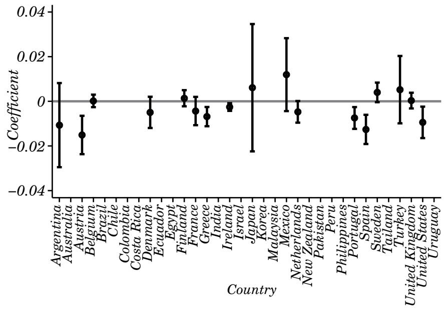


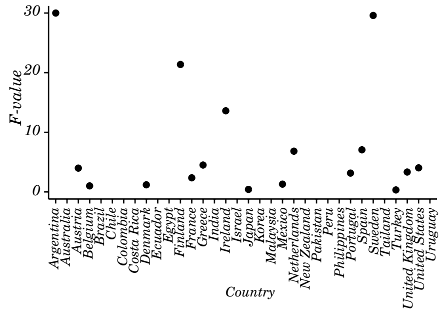
(f) p-value

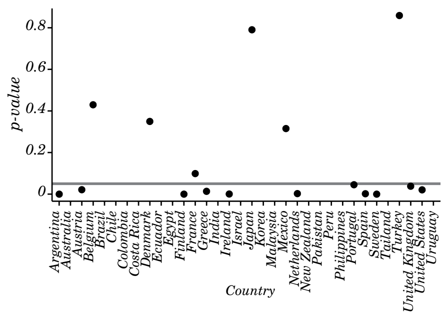


Notes: Figures (*a*) through (*d*) summarize the predictive power of the first two principal components of 1/*Vol* and *CsVol* on the occurrence of recessions. The figures show the point estimates of the regression coefficients along with a 95% confidence interval round the point estimates. Figures (*e*) and (*f*) report the *F–statistic* and the *p–value* of the regressions, respectively. All regressions are performed at the country level and standard errors are corrected by using Newey and West (1987) with one lag. The regression specification is: $1_t(Recession) = \alpha + \beta' X_{t-1} + \varepsilon_t$ where $X_{t-1} = (PC1(1/Vol_{t-1}), PC2(1/Vol_{t-1}), PC1(CsVol_{t-1}), PC2(CsVol_{t-1}), \Delta Credit_{t-1}, \Delta TFP_{t-1}, \Delta LP_{t-1},)'$.

Figure B7. Predictive Regressions - Domestic Imbalances and Recessions with Crises

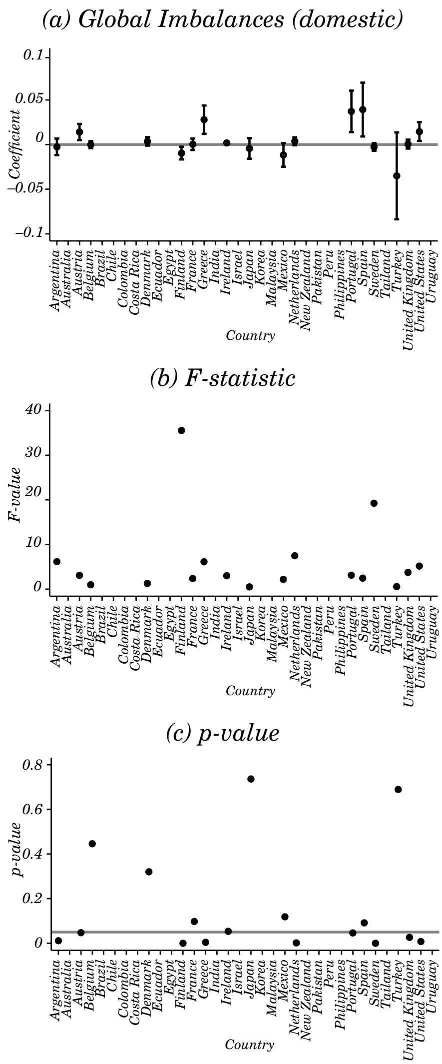






Notes: Figure (*a*) summarizes the predictive power of global imbalances denominated in domestic currency on the occurrence of recessions with crises. The figure shows the point estimates of the regression coefficients along with a 95% confidence interval round the point estimates. Figures (*b*) and (*c*) report the *F–statistic* and the *p–value* of the regressions, respectively. All regressions are performed at the country level and standard errors are corrected by using Newey and West (1987) with one lag. The regression specification is: $1_t(Recession \cap Crisis) = \alpha + \beta' X_{t-1} + \varepsilon_t$, where $X_{t-1} = (GI(DOM)_{t-1}, \Delta Credit_{t-1}, \Delta TFP_{t-1}, \Delta LP_{t-1},)'$.

Figure B8. Predictive Regressions - Foreign Imbalances and Recessions with Crises



Notes: Figure (a) summarizes the predictive power of global imbalances denominated in foreign currency on the occurrence of recessions with crises. The figure shows the point estimates of the regression coefficients along with a 95% confidence interval round the point estimates. Figures (b) and (c) report the *F–statistic* and the *p–value* of the regressions, respectively. All regressions are performed at the country level and standard errors are corrected by using Newey and West (1987) with one lag. The regression specification is: $1_t(Recession \cap Crisis) = \alpha + \beta' X_{t-1} + \varepsilon_t$, where $X_{t-1} = (GI(FOR)_{t-1}, \Delta Credit_{t-1}, \Delta TFP_{t-1}, \Delta LP_{t-1})'$

Monetary Policy Responses to External Spillovers in Emerging Market Economies

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Despite the remarkable progress made in many emerging and middle-income economies over the last few decades, the continuing liberalization in financial markets, and the integration into the global financial system, these countries remain highly vulnerable to real and financial shocks coming from the U.S. and other advanced economies. Particularly in the aftermath of the financial crisis, emerging economies have been subject to rapid buildups and reversals of international capital flows and large real exchange rate fluctuations. This experience is partially responsible for a new debate on the relevance of the open economy policy 'trilemma' as applied to emerging market economies (Rey, 2013, 2015). If the standard toolkit of macroeconomic policy levers is not adequate for emerging market economies in a global financial system with damaging macroeconomic spillovers, perhaps these countries need to slow down or reverse the momentum of financial openness in order to manage their economies.

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In particular, if an emerging economy is exposed to large spillovers from advanced economy shocks, having a flexible exchange rate may provide little policy independence, and the best option for shielding the economy from damage may be to employ controls on international capital inflows.

Our paper is motivated by this recent debate. We follow a theoretical approach to modeling financial crises in emerging market economies, and combine this with the standard analysis of monetary policy from the New Keynesian literature.[1] Our contribution is to blend these two frameworks together, in order to investigate the extent to which standard prescriptions for monetary policy are muted or circumscribed in small economies with financial frictions and endogenous financial crises. In particular, we ask to what degree the exchange rate system is important in dealing with financial crises, and whether an active or an accommodating monetary policy should be used, in contrast to a simple inflation-targeting policy as is prescribed for advanced economies. We also ask whether monetary policy should operate in a 'macro-prudential' fashion, in an attempt to reduce the risk of future financial crises by leaning against the wind. Finally, we explore how the monetary and exchange rate system itself effects the frequency and severity of financial crises.

As we mentioned, our model represents a combination of two main approaches. The first one, championed by Mendoza and others,[2] models financial crises as occurrences of 'occasionally binding collateral constraints', in which a financial crisis leads to a collapse in asset prices and further tightening of constraints through a financial accelerator effect. The second approach is the standard open-economy New Keynesian model.[3] The synergies involved in blending these two frameworks allow us to provide a comprehensive evaluation of the role of monetary policy in the incidence of and response to emerging market financial crises.

We introduce a simple small open economy model with sticky prices and collateral constraints which depend on asset prices, where shocks to world interest rates or leverage limits may throw the economy into a crisis. We compare three different monetary systems within this

1. Our paper reviews and extends some material from Devereux and Yu (2016), and Devereux, Young, and Yu (2015).

2. See, e.g., Bianchi and Mendoza (2010).

3. See, e.g., Gali and Monacelli (2005).

model: a flexible exchange-rate system with pure inflation targeting, an optimal discretionary monetary policy with flexible exchange rates, and a strict exchange rate peg. We find that, when the model is calibrated to emerging economy data, there is little difference between the three systems in the absence of financial crises. But, in a crisis, an exchange rate peg does much worse than the rest, since it requires a costly deflation and a large spike in real interest rates. Moreover, a pegged exchange rate puts severe constraints on the range of external debt over which the economy is vulnerable to a crisis.

During 'normal times,' i.e., outside of crises, the model implies that macro volatility is sufficiently contained and that there is no need for a large real exchange rate adjustment. A substantial part of adjustment can take place through movements in the price level, since, while prices are sticky in the model, the price level can evolve over time through price adjustment. But in crisis times, the economy requires a large and rapid real exchange rate depreciation. In the absence of nominal flexibility, this is very costly, since it involves a large deflation and a substantial increase in the output gap.

The comparison between the policy with pure inflation targeting and an optimal time-consistent monetary policy is far less extreme. We find that there is little difference between these two monetary policies, both of which actively exploit the flexibility of the nominal exchange rate. Outside of crises, the optimal discretionary policy in fact follows a pure inflation target. In a crisis, the optimal policy is more expansionary, but the net effect of this relative to pure inflation targeting is minimal.

As a corollary, this model implies that there is no macro-prudential role for monetary policy. An optimal monetary policy does not adjust to the likelihood of future crises, but adjusts only upon the occurrence of a crisis. While this feature is somewhat specific to the form of the financial friction facing borrowers in our model, it is noteworthy, nonetheless, that the possibility of large periodic sudden stops in capital flows does not necessarily justify a departure from an inflation-targeting monetary rule.

Different monetary stances also affect the frequency of crises. Surprisingly, we find that crises may be less frequent in a (successful) pegged exchange rate regime. This is due to the fact that pegged exchange rates tend to have less volatile real exchange rates and, on balance, tend to incur less external liabilities due to a higher level of precautionary current account surpluses.

1. Related Literature

Our paper is related to a growing recent literature along several dimensions, which we decompose as described below.

1.1 Macroprudential Capital Controls

Since the global financial crisis, there has been a surge of interest in capital flow regulations. Bianchi (2011) studies an endowment economy with tradable and non-tradable sectors. Private agents do not internalize the effects of their borrowing on asset prices in a crisis, which leads to an *ex-ante* overborrowing. Bianchi and Mendoza (2010) develop state-contingent capital inflow taxes to prevent overborrowing. This state-contingent taxation can be understood as Pigouvian taxation, as in Jeanne and Korinek (2010). Schmitt-Grohe and Uribe (2012) investigate a model with downward wage rigidity, to explain the large and protracted slump in the Eurozone. On the other hand, when there exist *ex-post* adjustments of production between tradable and non-tradable sectors, private agents may engage in underborrowing, as shown in Benigno, Chen, Otrok, Rebucci, and Young (2013).

Schmitt-Grohe and Uribe (2016b) study a Bianchi (2011)-type model and optimal capital controls from the perspective of boom-bust cycles, rather than the narrow-defined crisis scenarios. They show that over-borrowing and amplification are small, and that optimal capital control policy is not countercyclical and, hence, not macroprudential. Their model differs from ours in a number of dimensions, but one of the key distinctions is that they focus on a borrowing constraint which depends upon current relative non-traded goods prices, while we posit a collateral constraint which depends on expected future prices of capital as in Kiyotaki and Moore (1997).

Korinek (2011), Lorenzoni (2015), and Engel (2015) provide comprehensive reviews on borrowing and macroprudential policies during financial crises. As regards the description of optimal policy, Bianchi and Mendoza (2013) explore a time-consistent macroprudential policy. Devereux, Young, and Yu (2015) focus on time-consistent monetary and capital control policies in a flexible exchange rate regime. Capital controls, in their case, are welfare-reducing, because of a key time consistency involved in the valuation of collateral.

1.2 Monetary Policy and Effects of Capital Controls on Monetary Policy

Rey (2013), and Passari and Rey (2015) show that volatile capital flows can lead to substantial economic dislocation, even under a flexible exchange rate regime, while Georgiadis and Mehl (2015) still support the view of the traditional 'trilemma' case in favor of floating exchange rates. Based on the experience of the Eurozone, Schmitt-Grohe and Uribe (2016a) show that various types of taxes can be used to reduce the severity of financial crisis if the nominal exchange rate cannot be adjusted. Fornaro (2013a) extends Bianchi's model (Bianchi, 2011) to a Gali-Monacelli type of small open economy (Gali and Monacelli, 2005) and shows that debt deleveraging may generate a world-wide recession in a monetary union. In a similar vein, Fornaro (2013b) investigates the trade-off between price and financial stability in a small open economy with sticky wages and credit constraints. Building upon Schmitt-Grohe and Uribe (2016a), Ottonello (2015) studies exchange rate policy and capital controls in a small open economy. Policymakers in his model have to balance the tension between unemployment and value of collateral caused by exchange rate movements. In a similar vein but in a different framework, Devereux, Young, and Yu (2015) show that monetary policy should stabilize domestic inflation in normal times, but should dramatically deviate from the target in sudden stop scenarios in order to stimulate domestic aggregate demand. Liu and Spiegel (2015) explore optimal capital controls and monetary policy in a small open economy around its deterministic steady state. They focus on imperfect asset substitutability between domestic and foreign bonds. Optimal policy is to stabilize the domestic economy and to increase risk sharing across borders.

The most related works are Farhi and Werning (2012, 2013). They explore optimal capital controls and monetary policy in a Gali-Monacelli type of small open economy model and illustrate that capital controls can help regain monetary autonomy in a fixed exchange rate regime and work as terms of trade manipulation in a flexible exchange rate regime. They make use of risk premium shocks to break the uncovered interest rate parity condition. Our work is quite different from theirs. First, we investigate a fully-fledged small open-economy New Keynesian model with occasionally binding collateral constraints. Risk premia are endogenous in our model. Second, our model can capture both the normal time business cycle properties and also sudden stop scenarios. A policy affects not only the variability of macroeconomic variables but, more importantly, it changes the first moment (mean) of variables.

1.3 Currency Manipulation and Currency Wars

It has long been recognized that even in a small economy, monetary authorities can manipulate their currency in favor of domestic households. Costinot, Lorenzoni, and Werning (2014) show how capital controls and foreign exchange interventions can be used as intertemporal terms of trade manipulation. The choice of an exchange rate regime may reflect the intention of currency manipulation, as in Hassan, Mertens, and Zhang, 2015. Market frictions and incompleteness of policy tools are also roots of currency manipulation and even currency wars (Korinek, 2015). Our paper is related to this literature in the sense that monetary and fiscal authorities may have incentives to manipulate the value of domestic currency to enhance domestic welfare at the expense of the rest of the world. But, as described below, we assume that fiscal measures are in place so as to avoid the use of monetary or capital control policy for terms of trade manipulation.

The paper is organized as follows: Section 2 describes the details of the small open economy model. Section 3 discusses the calibration assumption. Section 4 briefly explains the solution method. Section 5 presents the main results. Section 6 presents some brief conclusions.

2. The Model

All the analysis in this paper will be based on a prototype model of a small open economy. The baseline model structure is mostly taken from Devereux, Young, and Yu (2015), which in turn builds upon Cespedes, Chang, and Velasco (2004), and Mendoza (2010). In the domestic economy, we assume that there exist infinitely lived firm-households with a unit measure. Households consume, invest in domestic capital and foreign bonds, and supply labor. Domestic firms are owned by households. International financial markets are incomplete. Domestic households trade assets across borders only in foreign currency denominated non-state contingent bonds. There are two types of domestic stand-in producers: competitive wholesale goods producers and monopolistically competitive final goods producers.

The latter assumption allows for sticky prices. Wholesale producers combine imported intermediate inputs, domestic labor, and physical capital in competitive factor markets with production technology as follows:

$$M_t = A_t Y_{F,t}^{\alpha_F} L_t^{\alpha_L} K_t^{\alpha_K}, \tag{1}$$

with $\alpha_F + \alpha_L + \alpha_K \leq 1$. M_t denotes wholesale good production, A_t is a country-specific exogenous technological shock, $Y_{F,t}$ is imported intermediate inputs, L_t is labor demand, and K_t is physical capital.

Imported intermediate inputs are differentiated into a unit mass of individual imported varieties. Since prices of intermediate inputs in the rest of world are exogenously given, we can abstract away from the pricing decision of foreign intermediate suppliers. We assume that foreign currency denominated prices of all intermediate varieties are identical and normalized to unity.

As is further described below, wholesale goods produced in the domestic economy are themselves combined to produce a final consumption good which is sold to both domestic households and foreign consumers. Let us assume that the foreign demand function for the domestic consumption composite, X_t, can be written as

$$X_t = \left(\frac{P_t}{E_t P_t^*} \right)^{-\rho} \zeta_t^*, \tag{2}$$

where P_t is the price of the domestic composite good, and E_t is the nominal exchange rate (price of foreign currency). The term ζ_t^* stands for foreign demand, while $\rho > 1$ is the elasticity of substitution between imports and locally produced goods in the foreign consumption basket. The share of expenditures in the foreign country (the rest of world) on imports from the domestic country is assumed to be negligible, and can thus be ignored as a component of the foreign CPI. Hence, we normalize the consumer price index in the foreign country to unity $P_t^* = P_{F,t}^*(i) = 1$.

2.1 Domestic Firm-Households

In the domestic economy, the representative infinitely lived firm-household has preferences given by

$$E_0 \sum_{t=0}^{\infty} \beta^t U(c_t, l_t), \tag{3}$$

where E_0 represents the expectation conditional on information up to date 0. We assume that the household is impatient relative to the rest of the world, so that the subjective discount factor is constrained by $\beta R^*_{t+1}<1$. This ensures that in a deterministic steady state, the small economy remains a net debtor. Current utility function takes a GHH (Greenwood, Hercowitz, and Huffman, 1988) form.[4]

$$U(c_t, l_t) = \frac{\left(c_t - \chi \frac{l_t^{1+\nu}}{1+\nu}\right)^{1-\sigma} - 1}{1-\sigma}. \tag{4}$$

Similar to Mendoza (2010), households borrow from abroad to finance both imported intermediate inputs and final goods consumption. All borrowing is denominated in foreign currency. In addition, total borrowing from abroad requires physical capital k_{t+1} as collateral. There are many approaches to rationalizing such a constraint. The most immediate motivation is to assume the presence of agency costs associated with imperfect contract enforcement. Hence the collateral (or borrowing) constraint can be written as

$$\vartheta(1+\tau_{N,t})Y_{F,t} - B^*_{t+1} \leq \kappa_t E_t \left\{ \frac{Q_{t+1}k_{t+1}}{E_{t+1}} \right\}, \tag{5}$$

where B^*_{t+1} stands for domestic household's foreign currency bond holdings at the end of period t, $\tau_{N,t}$ is an import tax, ϑ measures the fraction of imported inputs $(1+\tau_{N,t})Y_{F,t}$ which is financed in advance, and Q_{t+1} is the nominal capital price in domestic currency.[5] The parameter κ_t captures the maximal loan-to-value ratio according to Kiyotaki and Moore (1997). We assume that this is stochastic and follows a random process which will be described below.

4. This form of preference makes the computational procedure easier, but does not play a key role in the qualitative analysis.

5. The import tax $\tau_{N,t}$ is applied for technical reasons. The foreign demand function (2) implies that the small economy collectively has market power over its export good. The import tax is set at the steady state value which ensures that this market power is maximized at the 'optimal tariff' level. This is done so as to eliminate the incentive for the monetary policymaker to conflate the policy problem associated with nominal rigidities and the collateral constraint with the exploitation of market power in the terms of trade of the economy. We note that this constraint is not developed from first principles, although it can be given a micro-founded rationale (see Devereux, Young, and Yu, 2015). It would be interesting to explore a deeper theory of financing constraints which allowed for a role for financial institutions (e.g., Holmstrom and Tirole, 1997) within a model of occasional crises.

Households own domestic firms equally. Each household makes identical decisions in a symmetric equilibrium. The representative firm-household faces the following budget constraint

$$P_t c_t + Q_t k_{t+1} + \frac{B_{t+1}}{R_{t+1}} + \frac{B^*_{t+1} E_t}{R^*_{t+1}} \leq W_t l_t + k_t (R_{K,t} + Q_t) + B_t + B^*_t E_t + T_t \tag{6}$$

$$+ \left[P_{M,t} M(Y_{F,t}, L_t, K_t) - (1 + \tau_{N,t}) Y_{F,t} E_t - W_t L_t - R_{K,t} K_t \right] + D_t .$$

The left-hand side of the this constraint represents domestic consumption expenditure, $P_t c_t$; capital purchases, $Q_t k_{t+1}$; domestic bond holdings, B_{t+1}/R_{t+1}; and bond holdings in foreign currency, $B^*_{t+1} E_t / R^*_{t+1}$. The right-hand side of (6) consists of labor income, $W_t l_t$; gross return on capital, $k_t (R_{K,t} + Q_t)$; gross return on domestic currency bond holdings, B_t, and foreign bond holdings, $B_t^* E_t$; lump-sum transfers from government, T_t; profits from wholesale good producers, $P_{M,t} M_t - (1 + \tau_{N,t}) Y_{F,t} E_t - W_t L_t - R_{K,t} K_t$; and profits from the rest of the domestic economy, D_t. The wholesale good production M_t is given by equation (1). As in Bianchi and Mendoza (2013), we assume that working capital incurs no interest rate payments.

Let $\mu_t e_t$ be the Lagrange multiplier for the borrowing constraint (5). A lower case price variable denotes a real price, so that $q_t = Q_t / P_t$, $w_t = W_t / P_t$. The consumer price index inflation rate is defined as $\pi_t = P_t / P_{t-1}$. The real exchange rate (which in our case is also the terms of trade) is $e_t = E_t P^*_t / P_t$. Higher et implies a real exchange rate depreciation.

We may summarize the household's optimality decisions as those where the optimal labor supply decision satisfies

$$w_t = \chi l_t^{\nu} . \tag{7}$$

With these preferences, household's labor supply is independent of wealth effects.

The optimality conditions for the household's choice of capital is given by the Euler equation

$$q_t = \mu_t \kappa_t E_t \left\{ \frac{q_{t+1} e_t}{e_{t+1}} \right\} + E_t \left\{ \beta \frac{U_c(t+1)}{U_c(t)} (r_{K,t+1} + q_{t+1}) \right\} . \tag{8}$$

The benefit of holding one more unit of domestic capital comes from the increased collateral value of capital, which relaxes the borrowing constraint in the case $\mu_t > 0$, as well as the usual direct return on capital from the rental rate plus the future price, discounted by the household's stochastic discount factor, where $U_c(t)$ stands for the marginal utility of consumption.

The household's choice of domestic bonds is unaffected by the collateral constraint, and described by

$$1 = E_t\left\{\beta\frac{U_c(t+1)}{U_c(t)}\frac{R_{t+1}}{\pi_{t+1}}\right\}. \tag{9}$$

Finally, the choice of foreign currency bonds leads to the following condition:

$$1 = \mu_t R^*_{t+1} + E_t\left\{\beta\frac{U_c(t+1)}{U_c(t)}\frac{e_{t+1}}{e_t}R^*_{t+1}\right\} \tag{10}$$

As in the capital Euler equation, the benefit of holding an additional unit of the foreign currency bond is enhanced if the collateral constraint (5) is binding. The term $\mu_t R^*$ represents an 'external finance premium,' indicating that the cost of borrowing abroad is effectively higher than the world cost of funds when the economy is constrained by (5). The size of the external finance premium represents a measure of the degree of financial frictions in the domestic economy. As we see below, the external finance premium will depend in a critical way upon the monetary rule and the exchange rate regime.

We note that the combination of (9) and (10) implies that uncovered interest rate parity will not hold in this model when $\mu_t > 0$, even up to a first order approximation. Moreover, the external finance premium will vary according to the degree to which the constraint binds. As we show below, this external finance premium may differ systematically between alternative monetary policy regimes. In particular, we will show that in a crisis, domestic interest rates may be much higher in a pegged exchange rate regime than under a floating regime.

The household-firm's choice of imported inputs, labor and capital are expressed as

$$p_{M,t}\frac{\alpha_F M_t}{Y_{F,t}} = e_t\left(1+\vartheta\mu_t\right)(1+\tau_{N,t}), \tag{11}$$

$$p_{M,t}\frac{\alpha_L M_t}{L_t} = w_t \tag{12}$$

$$p_{M,t}\frac{\alpha_K M_t}{K_t} = r_{K,t}. \tag{13}$$

where w_t denotes the cost of labor.

Note that condition (11) implies that a binding collateral constraint increases the effective costs of imported intermediate goods for the firm. Thus, as in Mendoza (2010), there is a direct negative effect of a binding constraint on the firm's production and employment of labor.

The complementary slackness condition related by (5) is written as

$$\mu_t\left[\kappa_t E_t\left(\frac{q_{t+1}k_{t+1}}{e_{t+1}}\right)+b^*_{t+1}-\vartheta Y_{F,t}(1+\tau_{N,t})\right]=0, \tag{14}$$

where we have replaced nominal bond B^*_{t+1} with real bonds $b^*_{t+1}=B^*_{t+1}/P^*_t$.

2.2 Final Good Producers

There is a continuum of monopolistically competitive final good producers with measure 1. Each producer differentiates wholesale goods into a variety of final goods, where each variety is an imperfect substitute for the other varieties, thus implying that final good producers have monopoly power. Varieties are then aggregated into a consumption composite, which has a constant elasticity of substitution (Dixit and Stiglitz, 1977) form of

$$Y_t=\left(\int_0^1 (Y_t(i))^{\frac{\theta-1}{\theta}}di\right)^{\frac{\theta}{\theta-1}},$$

where Y_t is total demand for consumption composites and $Y_t(i)$ is demand for variety i in period t. The parameter $\theta > 1$ represents the elasticity of substitution between varieties. Let $P_t(i)$ be the nominal price of variety $Y_t(i)$. Cost minimization implies

$$P_t=\left(\int_0^1 (P_t(i))^{1-\theta}di\right)^{\frac{1}{1-\theta}},$$

and the demand for variety $Y_t(i)$,

$$Y_t(i)=\left(\frac{P_t(i)}{P_t}\right)^{-\theta}Y_t. \tag{15}$$

Each variety producer makes use of a linear technology through the use of the wholesale good as an input

$$Y_t(i)=M_t(i). \tag{16}$$

Firms set prices in local currency and can reset their prices each period, but resetting price incurs a cost. We follow Rotemberg (1982) in positing a quadratic price adjustment cost. Firm *i*'s profits in each period equal total revenues net of wholesale prices and of price adjustment costs. These can be written as

$$D_{H,t}(i) \equiv (1+\tau_H)P_t(i)Y_t(i) - P_{M,t}Y_t(i) - \phi\left(\frac{P_t(i)}{P_{t-1}(i)}\right)Y_tP_t.$$

Here τ_H denotes a subsidy rate by the fiscal authority so as to offset the monopoly power of price setters. Following Varian (1975) and Kim and Ruge-Murcia (2009), we assume an asymmetric price adjustment function $\phi\left(\frac{P_t(i)}{P_{t-1}(i)}\right)$ given by

$$\phi\left(\frac{P_t(i)}{P_{t-1}(i)}\right) \equiv \phi_P \frac{\exp\left(\gamma\left(\frac{P_t(i)}{P_{t-1}(i)} - \pi\right)\right) - \gamma\left(\frac{P_t(i)}{P_{t-1}(i)} - \pi\right) - 1}{\gamma^2}.$$

Here π is the inflation target. In the cost function $\phi(\cdot)$, ϕ_p characterizes the basic Rotemberg price adjustment cost and γ captures the asymmetry of the price adjustment cost. When $\gamma < 0$, the price adjustment displays a pattern of downward rigidity.

Firm *i* faces the following problem:

$$\max_{\{P_t(i),Y_t(i)\}} E_h\left(\sum_{t=h}^{\infty}\Lambda_{h,t}\frac{P_h}{P_t}D_{H,t}(i)\right),$$

subject to demand for variety *i* (15) and production technology (16). The household's stochastic discount factor used by the firm is given by $\Lambda_{h,t} = \beta^{t-h}U_c(t)/U_c(h)$ with $h \le t$.

In a symmetric equilibrium, all firms choose the same price, $P_t(i) = P_t$. As a result, the supply of each variety will be identical to $Y_t(i) = Y_t$ in equilibrium. The optimality condition for price-setting can be simplified as

$$Y_t\left[(1+\tau_H) - \theta(1+\tau_H - p_{M,t})\right] - \varphi_P Y_t \pi_t \frac{\exp(\gamma(\pi_t - \pi)) - 1}{\gamma} + E_t\left[\Lambda_{t,t+1}\varphi_P \pi_{t+1} Y_{t+1}\frac{\exp(\gamma(\pi_{t+1} - \pi)) - 1}{\gamma}\right] = 0. \tag{17}$$

Real profits from intermediate producers are

$$d_{H,t} \equiv \frac{D_{H,t}}{P_t} = (1+\tau_H)Y_t - p_{M,t}Y_t - \phi(\pi_t)Y_t \tag{18}$$
$$= Y_t\left[(1+\tau_H) - p_{M,t} - \phi(\pi_t)\right]$$

with

$$\phi(\ _t) = \phi_P \frac{\exp(\gamma(\pi_t - \pi)) - \gamma(\pi_t - \pi) - 1}{\gamma^2}.$$

In the absence of price adjustment costs, $\phi_p = 0$ and with the appropriate production subsidy $\tau_H = 1/(\theta - 1) > 0$, production markets are frictionless, so that $p_{M,t} = 1$.

Markets clear at the end of each period, and we impose that $l_t = L_t$, $c_t = C_t$. We are assuming that domestic bonds are only held by domestic agents. Abstracting away from government bond issuance, this means that $b_{t+1} = 0$ in the aggregate. Also, in the aggregate, the capital stock is fixed. We normalize then so that $K_{t+1} = k_{t+1} = 1$. Profits from final good producers yield $d_t = d_{H,t}$. The wholesale goods market clearing condition reads

$$\int_0^1 Y_t(i)di = \int_0^1 M_t(i)di = M_t. \tag{19}$$

The composite final good is either consumed by domestic households or exported to the rest of world

$$Y_t\left[1 - \phi(\pi_t)\right] = C_t + X_t. \tag{20}$$

2.3 Government Policy

The government doesn't issue bonds, but makes lump-sum transfers to domestic households

$$T_t = -\tau_H Y_t P_t - \frac{\tau_{c,t} b^*_{t+1} e_t}{R^*_{t+1}} P_t + \tau_{N,t} Y_{F,t} e_t P_t. \tag{21}$$

As noted above, we also assume that the government sets a production subsidy τ_H to offset the monopoly power of price setting. The central bank conducts monetary policy under either a fixed or a flexible exchange rate regime. Under the latter, monetary policy takes the form of either a strict inflation-targeting policy or an optimal, welfare-maximizing monetary policy rule. Under either the fixed exchange rate regime or the strict inflation-targeting regime, the monetary rule can be defined by[6]

$$R_{t+1} = R\left(\frac{\pi_t}{\pi}\right)^{\alpha_\pi}\left(\frac{Y_t}{Y}\right)^{\alpha_Y}\left(\frac{e_t}{e}\right)^{\alpha_e}. \tag{22}$$

A variable without a superscript denotes the value at the deterministic steady state. The response coefficients $\alpha_\pi > \alpha_\gamma > 0$ and are interpreted in the usual manner. In the fixed exchange rate regime, domestic inflation must equal the sum of foreign inflation and the change in the real exchange rate, so that

$$\pi_t = \frac{e_{t-1}}{e_t}\pi_t^* = \frac{e_{t-1}}{e_t}. \tag{23}$$

Note that the fixed exchange rate regime implies that inflation has a backward-looking element, depending on the lagged real exchange rate.

2.4 Optimal Monetary Policy

As an alternative to the strict inflation-targeting policy on the one hand, and the exchange rate peg on the other, we will explore the case where the monetary authority solves a Ramsey planner's problem to maximize a representative household's lifetime utility. The optimal policy is implemented only by a monetary policy instrument; e.g., the nominal interest rate. Under optimal monetary policy, we must implicitly assume a regime of flexible exchange rates. In addition, we will focus on the time-consistent optimal policy under discretion and look for a Markov perfect equilibrium. This is a situation where the current planner (or monetary authority) takes as given the decisions of future planners, but still internalizes how the choices of future planners will depend on the future debt level b^*_{t+1}which is implicitly chosen by the current planner.

6. Note that the change in the nominal exchange rate is a function of the change in the real exchange rates and inflation, $\varepsilon_t/\varepsilon_{t-1} = \pi_{t,}\ e_t/e_{t-1}$. Therefore, stabilizing nominal exchange rates and inflation is equivalent to stabilizing both inflation and the real exchange rate.

Let the value function for a representative domestic firm-household be $V(b_t^*, Z_t)$, where Z_t represents the set of exogenous state variables. Under the time-consistent Ramsey optimum, the problem faced by the monetary authority can be represented as

$$V(b_t^*, Z_t) = \max_{\{\Xi\}} U(\tilde{C}_t) + \beta E_t V(b_{t+1}^*, Z_{t+1}), \text{with} \tilde{C}_t \equiv C_t - \chi \frac{L_t^{1+\nu}}{1+\nu}$$

with

$$\Xi \equiv \{L_t, C_t, Y_t, Y_{F,t}, b_{t+1}^*, q_t, \mu_t, r_{K,t}, e_t, p_{M,t}, \pi_t\},$$

subject to the set of competitive equilibrium conditions.[7]

2.5 Aggregate Market Clearing

Combining the firm-households' budget constraints (6) with the relevant market clearing conditions and taxation policy (21), yields the country level resource constraint

$$C_t + \left(\frac{b_{t+1}^*}{R_{t+1}^*} - b_t^* \right) e_t = Y_t \left(1 - \varphi(\pi_t)\right) - e_t Y_{F,t}. \tag{24}$$

Equivalently, condition (24) implies that trade surpluses are used to finance external debt

$$X_t - e_t Y_{F,t} = \left(\frac{b_{t+1}^*}{R_{t+1}^*} - b_t^* \right) e_t. \tag{25}$$

2.6 A Recursive Competitive Equilibrium

A recursive competitive equilibrium consists of a sequence of allocations $\{L_t, C_t, Y_{F,t}, Y_t, K_{t+1}, b_{t+1}^*\}$, and a sequence of prices $\{w_t, q_t, \pi_t, \mu_t, r_{K,t}, e_t, p_{M,t}\}$, for $t = \ldots, 0, 1, 2, \ldots$, given production subsidy τ_H, import tax $\tau_{N,t}$, capital inflow tax $\tau_{c,t}$ and monetary policy R_{t+1}, such that (a) allocations solve households' and firms' problems given prices and public policies and (b) prices clear corresponding markets.

7. A more complete account of this optimal monetary policy problem in a related context is given in Devereux, Young, and Yu (2015).

3. Calibration

The model period is one quarter. Table 1 lists parameter values in the baseline model. The preference parameters are quite standard and taken from the literature. In normal times without a binding constraint, optimal inflation equals its target. Therefore, domestic nominal interest rates reflect domestic real interest rates. We set the subjective discount factor $\beta = 0.975$, in line with the literature for emerging economies (Uribe and Yue, 2006; Aguiar and Gopinath, 2007), thus implying an annual real interest rate of 10%. Relative risk aversion is set to $\sigma = 2$ and the inverse of Frisch labor supply elasticity is $\nu = 1$.

The leverage shock κ_t determines the borrowing capacity in a country. We take a two-state Markov chain to capture the leverage shock: $\kappa_L = 0.35$ and $\kappa_H = 0.5$. These two states are consistent with the leverage change from pre-crisis period to crisis period for U.S. nonfinancial corporations (Graham, Leary, and Roberts, 2015) and the corporate leverages in Asian emerging economies (IMF, 2014).[8] The transition matrix is given by

$$\Pi_l = \begin{bmatrix} p_{L,L} & 1 - p_{L,L} \\ 1 - p_{H,H} & p_{H,H} \end{bmatrix}.$$

We set $p_{L,L} = 0.775$ and $p_{H,H} = 0.975$ such that the duration of a high leverage regime equals quarters and the unconditional probability of a low leverage regime is (Bianchi and Mendoza, 2013), thus implying that a typical leverage crisis will happen every ten years.

8. Mendoza (2010) uses a similar leverage $\kappa_t = 0.2$ and $\kappa_t = 0.3$ in his analysis.

Table 1. Parameter values

Parameter		*Value*
Preference		
β	Subjective discount factor	0.975
σ	Relative risk aversion	2
ν	Inverse of Frisch labor supply elasticity	1
χ	Parameter in labor supply	0.4
Production		
α_F	Intermediate input share in production	0.13
α_L	Labor share in production	0.57
α_K	Capital share in production	0.03
ϑ	Share of working capital	1.3
ϕ_P	Price adjustment cost	76
γ	Asymmetry of price adjustment cost	-100
θ	Elasticity of substitution among imported varieties	10
ρ	Elasticity of substitution in the foreign countries	10
ζ	Steady state of foreign demand shock	0.101
R^*	Steady state of world interest rate	1.015
A	Steady state of TFP shock	1
ρ_A	Persistence of TFP shocks	0.95
σ_A	Standard deviation of TFP shocks	0.008
ρ_R	Persistence of foreign interest rate shocks	0.6
σ_R	Standard deviation of foreign interest rate shocks	0.00623
$p_{H,H}$	Transitional probability of high leverage to high leverage	0.975
$p_{L,L}$	Transitional probability of low leverage to low leverage	0.775
Policy variables		
$\alpha_\pi, \alpha_Y, \alpha_e$	Coefficients in the Taylor rule	
τ_H	Subsidy to final goods producers	$\frac{1}{\theta-1}$
$\tau_{N,t}$	Gross subsidy to exports	$\frac{1}{\rho-1}$

Parameters in the production function are set to match imports share (15% of GDP, see Hanson, 2012), labor share (65% of GDP, see Mendoza, 2010) and the external debt-GDP ratio (40%) in emerging economies before the global financial crisis.[9] Given the leverage specification above and relevant ratios, we set $\alpha_F = 0.13, \alpha_L = 0.57$ and $\alpha_\kappa = 0.03$. Parameter ϑ is set to 1.3, thus implying a share of working capital of 20% of GDP (Mendoza, 2010).[10] The equilibrium labor supply in normal times (without credit constraints) is normalized to be 1, which implies that $\chi = 0.4$.

Nominal rigidity is introduced through a Rotemberg price adjustment cost. Price adjustment takes around four quarters. We set $\phi_p = 76$ as in Aruoba and Schorfheide (2013), and assume a small downward price rigidity $\gamma = -100$.[11] Following the New Keynesian literature (Christiano, Eichenbaum, and Evans, 2005; Gali, 2015), we set the elasticity of varieties in both domestic and foreign consumption baskets as $\theta = \rho = 10$, thus implying a price markup of 11%.

The real exchange rate is normalized to be 1 in a deterministic steady state when the collateral constraint binds, which requires $\zeta_t^* = 0.101$. Domestic productivity and foreign interest rate, each follows an AR(1) process:

$$\ln(A_{t+1}) = (1-\rho_A)\ln(A) + \rho_A \ln(A_t) + \varepsilon_{A,t+1}$$

$$\ln(R_{t+1}^*) = (1-\rho_R)\ln(R^*) + \rho_R \ln(R_t^*) + \varepsilon_{R,t+1}$$

where mean productivity is normalized to be 1, $A = 1$, and the world quarterly real interest rate, $R^* = 1.015$ (Mendoza, 2010). We assume that the local productivity shock is uncorrelated with the global

9. Data from World Development Indicators show that, just before the onset of the global financial crisis, many emerging economies accumulated a large amount of external debt stocks, around 40% of their gross national income. Data source: World Development Indicators with indicator code: DT.DOD.DECT.GN.ZS.

10. Note that ϑ captures the role of working capital only when credit constraints bind. This value is higher than Mendoza (2010) and Bianchi and Mendoza (2013), but is consistent with Uribe and Yue (2006).

11. The Rotemberg price adjustment cost relates to the Calvo price stickiness via $\phi_p = \alpha(\theta-1)/((1-\alpha)(1-\alpha\beta))$ in an economy without collateral constraints (Khan, 2005). $1-\alpha$ measures the probability of Calvo style price adjustment in each period. Empirical evidence shows that prices rise faster than they fall (Peltzman, 2000) and small price increases occur more frequently than small price decreases for price changes (Chen, Levy, Ray and Bergen, 2008).

liquidity shock.[12] Following the literature (i.e., Backus, Kehoe, and Kydland, 1992), we set the standard deviation of the productivity shock to $\sigma_A = 0.008$ and its persistence, to $\rho_A = 0.95$. The standard deviation of the foreign interest rate is set to $\sigma_R = 0.00623$ and its persistence, to $\rho_R = 0.60$ (Rudebusch, 2002, 2006). We then discretize the continuous AR(1) process into a two-state Markov chain, based on Tauchen and Hussey (1991) in the computation of the model.[13] Thus, in the solution algorithm, there are eight states in the Markov chain, associated with the three exogenous shocks.

4. Model Solution

We solve the model by using a global solution method. This allows us to analyze both 'normal' business cycles and 'crises,' when the small economy is limited by the borrowing constraint. For the competitive equilibrium under strict inflation targeting, and the pegged exchange rate regime, we make use of a policy function iteration approach to solve the model. For the optimal monetary policy solution, we apply the algorithm developed by Schittkowski (2014) to solve the model. More solution details can be found in Devereux and Yu (2014), and Devereux, Young, and Yu (2015).

5. The Effects of Alternative Monetary Policy Rules

5.1 The Steady-State Conditions

It is instructive at this point to describe the workings of the model in simple terms. One immediate property of this set of assumptions is that the domestic agent is on average a borrower, since our calibration implies that in the steady state $\beta R^* < 1$; i.e., households are impatient relative to the rest of the world. As a result, in a steady state, the collateral constraint will bind, since households in the small economy will borrow up to their limit implied by (5). In a steady state, price stickiness is absent. Then, from (10), we can establish that in the steady state the Lagrange multiplier on the collateral constraint is

12. Allowing for correlated shocks would slightly change households' precautionary saving, but would not alter the main messages in this paper.

13. Adding additional states into the Markov chain alters the quantitative answers, but not the qualitative ones.

given by $\mu = \dfrac{1-\beta R^*}{R^*}$. From (7), (11), and (12), we can derive a negative relationship between the steady-state real exchange rate and the steady-state demand for intermediate imports Y_F. A rise in e raises the cost of intermediate inputs, thus reducing Y_F, which also reduces the marginal product of labor. Let us denote this equilibrium relationship $Y_F(e)$. Likewise, it is easy to see that, from the optimality condition for capital (8), we can derive a negative relationship between the capital price q and the real exchange rate, denoted $q(e)$ in the steady state. A higher real exchange rate reduces both employment and intermediate imports, which in turn reduces the marginal product of capital in the steady state, thus reducing q. Putting these parts together gives a steady-state collateral constraint

$$\vartheta(1+\tau_N)Y_F(e) - b^* = \kappa \frac{q(e)k}{e}. \tag{26}$$

This represents an implicit relationship between external debt $-b^*$ and the real exchange rate. In principle this may be a positive or negative relationship. A real depreciation (rise in e) will reduce Y_F and reduce the need for intra-period borrowing, thus easing the collateral constraint and allowing higher external debt. But a real depreciation will also unambiguously reduce the real value of capital $\dfrac{q(e)}{e}$ in terms of foreign currency, and tighten the collateral constraint. For our calibration, we find that the latter effect is predominant, so that (26) gives a negative relationship between $-b^*$ and e.

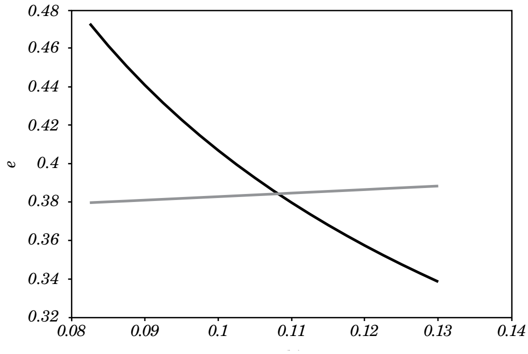
A second link between external debt and the real exchange rate is given by the steady-state balance of payments condition (25)

$$e^{\rho-1}\zeta^* - Y_F(e) = -b^* \frac{R^*-1}{R^*} \tag{27}$$

A rise in e increases foreign demand for domestic final goods, and reduces the demand for imported inputs. As a result, a higher trade balance increases the steady-state sustainable foreign debt $-b^*$.

Figure 1 illustrates the determination of e and $-b^*$ in the steady state. A permanent easing of the collateral constraint (a rise in κ) will shift up the locus representing (26), thus raising both e and $-b^*$. A higher domestic productivity will shift up both (26) and (27), and for our calibration, will lead to a rise in the steady state e and $-b^*$. Hence, for these two shocks, in the steady state, we find that higher net external debt is associated with a higher (more depreciated) real exchange rate.

Figure 1. Steady State Real Exchange Rate and External Debt



Notes: Debt and Real Exchange Rate determination in the steady state. The black (downward sloping) locus is the steady-state financial constraint. The gray (upward sloping) locus is the steady-state balance of payments condition.

In a stochastic equilibrium, it is no longer necessarily the case that the collateral constraint binds. But, as suggested by the steady-state analysis, we will find that a binding constraint is associated with a higher external debt and a higher real exchange rate.

5.2 Price Stability versus Ramsey Optimal Monetary Policy

The characteristics of the model in a stochastic equilibrium are very different from those in the steady state. In general, the collateral constraint may or may not bind. As shown in Devereux and Yu (2014), for a similar constraint, agents will in general engage in precautionary saving, so that external debt is lower than that implied by the steady state, and the collateral constraint may not bind over a large part of any given sample period. In fact, for our calibration, we find that the degree of precautionary saving is strong enough that the constraint is slack for almost all the time. Nevertheless, as we see below, episodes when the constraint binds display substantially different dynamic properties than when the constraint is slack. We describe episodes with binding constraints as 'crisis events'.

We begin by outlining the characteristics of the basic sticky price model under flexible exchange rates, and comparing a monetary policy which follows a policy of strict price stability with an optimal (time-consistent) monetary rule derived in the manner described above.

The solution algorithm generates decision rules, or 'policy functions', representing mappings from the state of the system to all the endogenous variables at any time period. The model has only one endogenous state variable, the level of net foreign assets b_t^*, and three exogenous states, represented by the shocks (κ_t, α_t and R_t^*). We illustrate the equilibrium policy functions in figure 2. The figure gives the mapping from the level of net foreign debt $-b^*$ to output, the price of capital, the rate of inflation, the interest rate, and the real exchange rate. Since there are eight possible exogenous states of the world in the Markov chain over the three shocks, there is a separate mapping for all eight possible outcomes. For clarity, we show the mapping for the 'worst state,' representing the lowest value for κ_t, the lowest productivity state, and the highest state for the foreign interest rate (state 1), and the 'best state,' representing the alternative for all three exogenous shocks (state 8).

Figure 2. Equilibrium Policy Functions for the Regime of Price Stability and Ramsey Optimal Policy

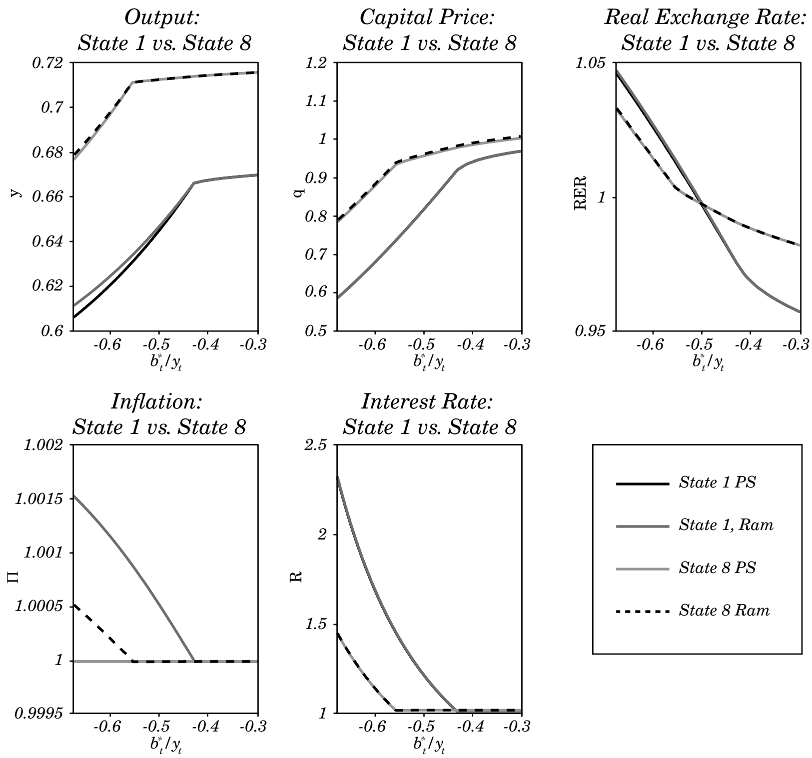


Figure 2 indicates that there is a kink in the policy functions that occurs when the collateral constraint begins to bind at a critical level of net external debt. This occurs at different levels of debt, depending on the state of the exogenous shocks. At low levels of debt, the collateral constraint is slack. Output and capital prices are higher in state 8 than in state 1, and are identical for the policy of price stability and the Ramsey optimal policy. The real exchange rate is higher, given a higher level of output under both monetary policy regimes. Inflation is set equal to zero for the Ramsey policy, while the nominal interest rate is fixed and equal to the world interest rate. As debt rises, but before the collateral constraint binds, the real exchange rate depreciates in both states 1 and 8, the capital price falls, and GDP falls as well. Intuitively, the higher external debt depresses domestic consumption demand, thus leading to a rise in the real exchange rate and reducing the purchase of intermediate imports, which in turn leads to a fall in domestic production and, through a fall in the return on capital, reduces the price of capital itself.

A further rise in net external debt leads the collateral constraint to bind and, thus, the economy enters the crisis zone. This occurs at a debt-to-GDP ratio of in state 1 and in state 8. With the binding constraint, the kink in the policy rules indicates that the price of capital falls more quickly as net external debt rises. This further tightens the collateral constraint, thus raising the external finance premium and leading to a sharp fall in intermediate imports and GDP, with a large real exchange rate depreciation. As the threshold debt level for state 1 is much less than that for state 8, we see a non-monotonicity in the real exchange rate across states. The real exchange rate depreciation in state 1 is large enough that e may be higher in state 1 than state 8 for intermediate levels of debt for which there is a crisis in state 1 but not in state 8.

How does optimal Ramsey monetary rule respond to the crisis? Panel 4 indicates that the policymaker allows inflation to increase as debt hits the threshold and the collateral constraint binds. The rise in inflation allows for a slightly higher real exchange rate and partially cushions the fall in GDP. Obviously, under the price stability rule, inflation is unchanged as the economy moves into a crisis. But panel 5 of figure 2 indicates that the nominal interest rate rises as the collateral constraint binds. Moreover, this occurs approximately equally under both the price stability rule and the optimal monetary rule. Note that the rise in the nominal interest rate is equivalent to a rise in the real rate under price stability. Comparing (9) and (10), we see that a binding collateral constraint opens up a gap between the domestic and world interest rate, given the path of the real exchange rate. Thus, as the economy enters the crisis zone, the domestic real interest rate rises, and this requires a rise in the policy rate required to maintain price stability. So under either alternative monetary rule, the policy interest rate must rise in a crisis, despite that the economy is operating under a flexible exchange rate.

While the Ramsey optimal policy allows for a rise in inflation in response to the crisis, we see from the policy function for output that this has little consequence for the path of GDP, conditional on external debt and the state of the exogenous shock processes. The rise in inflation allows for a higher level of output and employment through the channel of the New Keynesian Phillips curve (17), thus leading to a higher level of intermediate imports due to a greater real exchange rate appreciation. But this effect is very slight, intuitively because the degree of effective price rigidity is quite small in this model, given the forward-looking inflation dynamics in the economy.

The policy functions indicate that there is a zone of vulnerability in the levels of debt-to-GDP for which a crisis may occur, depending on the outcome of the exogenous shocks to leverage, productivity, and the world interest rate. For debt levels between 43% and 56% of GDP, there will be a crisis with probability 1 in the worst state of the world (state 1), but a crisis may not occur in other states. Given this, it might be expected that an optimal policy would take action to prevent the economy from entering this zone of vulnerability. But a key feature of figure 2 is that it establishes that there is no 'macroprudential' element in an optimal monetary policy. Outside of the crisis zone, the Ramsey optimal monetary policy strictly adheres to the price stability rule. It is only when the crisis occurs, conditional on the level of debt and the state of the exogenous shocks, that inflation is allowed to rise. The optimal policy does not involve a rise in policy rates at any levels of debt that occur 'near to' the crisis threshold levels.[14]

14. This finding is tied to the form of financial friction in the model, and is explained for a wider class of policies in Devereux, Young, and Yu (2015). In Bianchi and Mendoza (2010), a macroprudential role for capital taxes arises from the planner's desire to influence the current period asset price. Given the nature of the collateral constraint (5) in our model, it is the future period asset price that is the critical determinant of the degree to which the constraint binds. As a result, it is always better for the planner to wait until the collateral constraint binds to depart from a policy of strict inflation targeting.

5.3 Moments

Tables 2 and 3 describe the first and second moments from the model simulations, under the two alternative regimes: strict inflation targeting, and optimal monetary policy (we discuss the pegged exchange rate case below). Each table contains two panels. The first panel reports moments for the whole sample simulation, including both 'crisis' and normal times, while the second panel reports moments computed only during a 'crisis,' where the collateral constraint binds.

Comparison of sample means shows there is little difference between the optimal monetary rule and the regime of price stability, as suggested by the policy functions described above. Outside of a crisis, the outcomes are essentially identical, since as we have seen, the two monetary rules are identical when the collateral constraint does not bind. In crisis times, output is slightly higher under the optimal monetary rule.

The comparison of standard deviations across the two regimes is similar. In normal times, the standard deviation of output, the real exchange rate and consumption are equal. During crisis episodes, output and consumption volatility is slightly lower under the optimal monetary policy, while real exchange rate and inflation volatility is higher. The optimal policy deviates from the pure price stability objective in crisis times, but the volatility of inflation is still extremely low.

Overall, the moment comparison supports the message from the policy functions discussed above—a Ramsey optimal policy is very close to a pure price stability rule, despite the presence of financial frictions and recurrent financial crises.

5.4 The Pegged Exchange Rate

We now turn to an analysis of the pegged exchange rate regime. Under an exchange rate peg, there is an additional state variable, in the form of the lagged real exchange rate as described in equation (23). Thus, the policy functions must be represented in the form of two dimensional mappings from the state $\{b_t^*, e_{t-1}\}$ to the endogenous variables, for each exogenous state of the world. Figures 3 and 4 illustrate the policy functions for states 1 and 8, where the states are as described above. The figures show the mapping from the endogenous states $\{b_t^*, e_{t-1}\}$ to output, the price of capital, the real exchange rate and inflation, the interest rate, and in addition, for clarity, we show the value of the Lagrange multiplier μ, which makes it easier to identify the points in the state space where the collateral constraint begins to bind.

The characteristics of the policy functions under the peg are mainly similar to those in the flexible exchange rate. As debt increases, output falls, the capital price falls, and there is a real exchange rate depreciation. But there are two key differences. The first one is that the policy rules depend on the predetermined real exchange rate e_{t-1}. In the case of the output function, for instance, a higher value of e_{t-1} leads to a higher level of output, for any given value of debt. From (23), we see that for a given e_t, a higher lagged real exchange rate implies a higher level of inflation, *ceteris paribus*. Panel 4 of figure 3 illustrates the positive relationship between e_{t-1} and inflation, conditional on $-b^*_t$.

Figure 3. Equilibrium Policy Functions for the Pegged Exchange Rate Regime in State 1

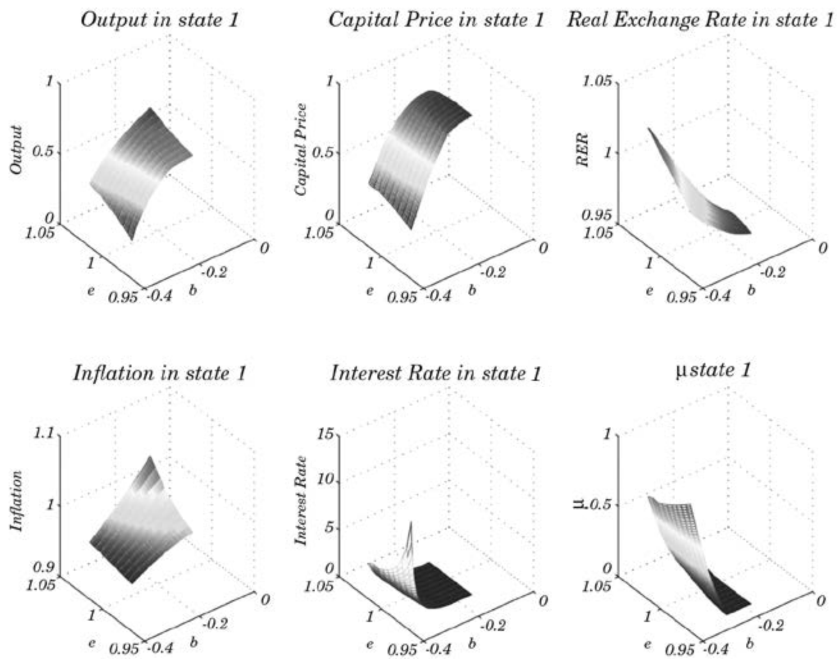
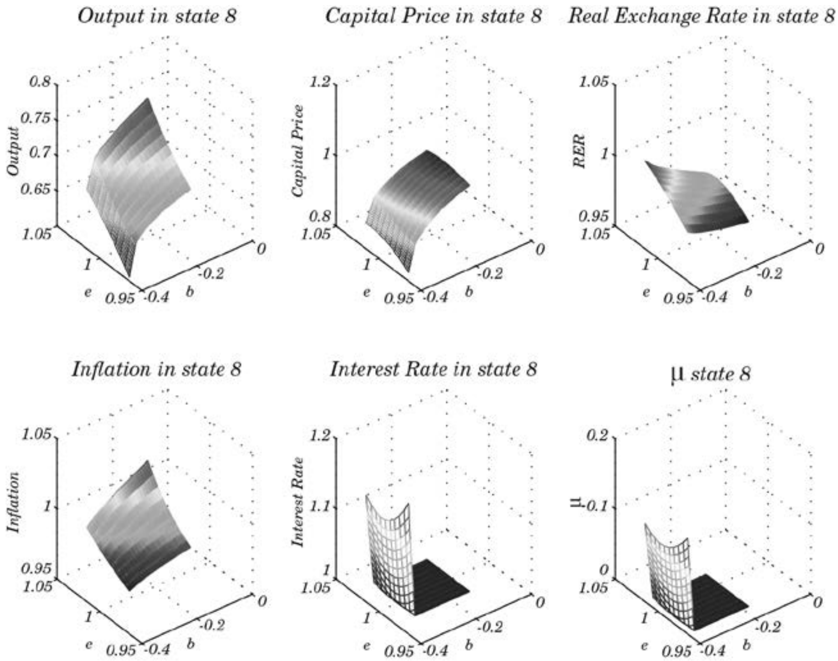


Figure 4. Equilibrium Policy Functions for the Pegged Exchange Rate Regime in State 8



More importantly, however, we see from panel 4 that the process for inflation under the pegged exchange rate is critically different from that of the optimal floating exchange rate rule. In general, inflation is non-zero, even away from crisis states. For low levels of debt, inflation tends to be positive, particularly for high lagged values of e_{t-1}, as discussed in the preceding paragraph. But when the collateral constraint begins to bind, the inflation stance is reversed, and the pegged exchange rate rule leads to a deflation, as the policymaker must generate a real exchange rate depreciation through falling prices. Thus, the behavior of domestic inflation in a crisis under a pegged exchange rate is exactly the opposite of that in the optimal floating exchange rate regime.

Figure 5 projects the policy functions for the pegged exchange rate regime by restricting the functions to be defined over the mean of the exchange rate states, so as to be more easily comparable with the one-dimensional policy functions for the floating exchange rate regime.

The figure compares the outcomes for the exogenous state 1 described earlier, and contrasts the policy mappings under the optimal monetary policy with those from the pegged exchange rate. Outside of the crisis state, output is slightly higher under the pegged exchange rate, but output falls by much more when the collateral constraint binds. It is clear that the major contrast with the floating regime is the behavior of the inflation rate. Under the floating exchange rate with optimal monetary policy, inflation is zero outside of the crisis zone, and rises in the crisis. Under the peg, inflation is positive outside of the crisis, and falls below zero in the crisis zone. During a crisis, in order to facilitate a real exchange rate depreciation in the absence of nominal exchange rate flexibility, the policymaker needs to generate deflation.

Figure 5. Policy Function Projection for the Pegged Exchange Rate, Compared to the Ramsey Optimal Policy Function

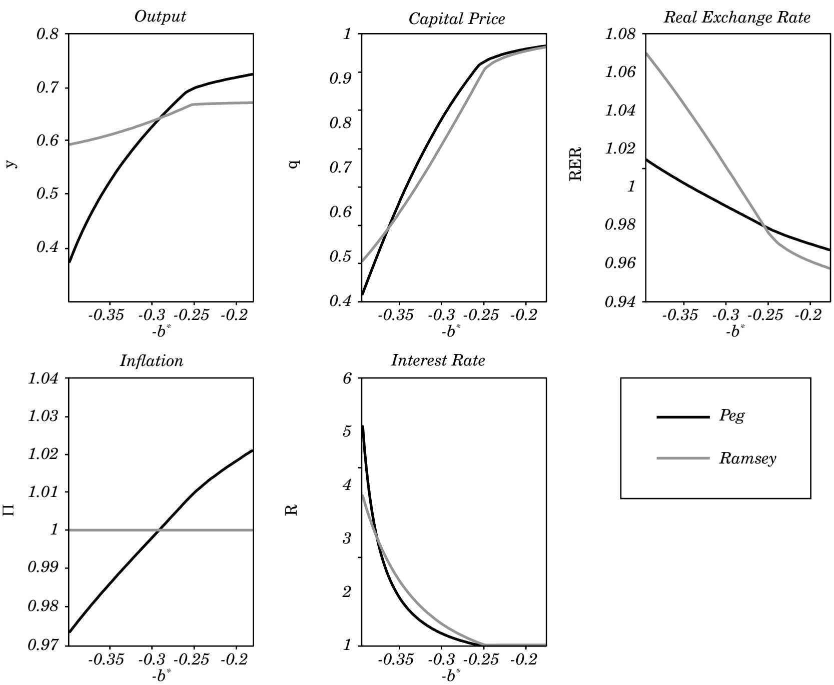
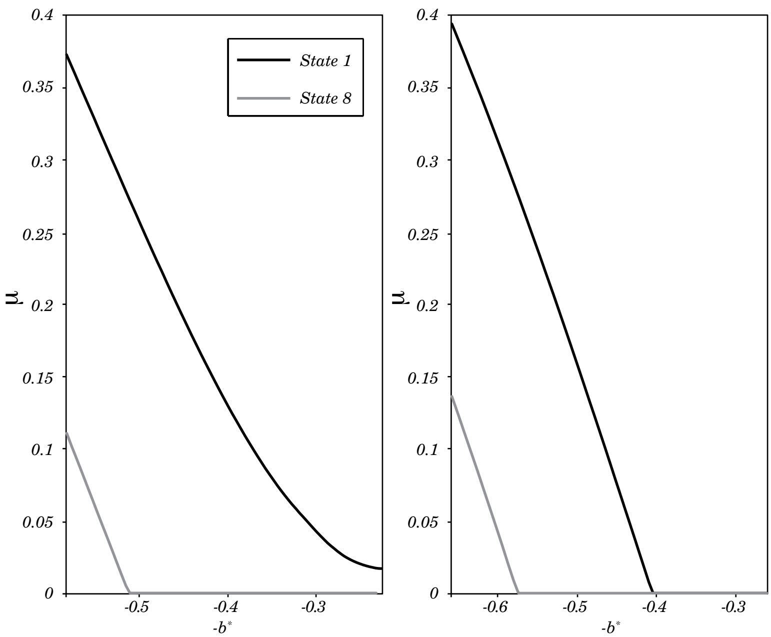


Figure 6 plots the range of values for debt-to-GDP for which the country is in the zone of vulnerability to crises. As before, the figure illustrates the lowest value of debt-to-GDP for which the crisis will occur (which happens if state 1 occurs) and the highest value of debt-to-GDP for which the crisis will occur (which happens when state 8 occurs). But now, the zone of vulnerability depends critically on the predetermined real exchange rate e_{t-1}. The left hand panel shows the range of debt-to-GDP values which will precipitate a crisis for the highest value of e_{t-1} (i.e., most depreciated real exchange rate), while the right hand panel illustrates the equivalent range for the lowest (most appreciated) value of e_{t-1}. For high real exchange rates, the crisis is much more likely. The range of debt-to-GDP ratios goes from 0.2 to 0.5. With the lowest value of e_{t-1}, the range of crisis vulnerability is much smaller.

Figure 6. Debt Zone of Crisis Vulnerability for High and Low Real Exchange Rate States in the Pegged Exchange Rate Regime



Hence, we see that, while the risk of crises under a flexible exchange rate may be summarized by the level of debt-to-GDP (as well as the exogenous states of the world), under the pegged exchange rate, crisis risk depends both on the real exchange rate and the debt-to-GDP ratio. Moreover, the model implies that a pegged exchange rate may impose more severe limits on the range of permissible debt levels necessary to avoid a crisis. For a high real exchange rate, crises may occur for much lower levels of debt than in a flexible exchange rate regime.

Tables 2 and 3 compare the pegged exchange rate regime to the floating regimes in terms of the simulated mean and volatility. Over the whole sample, there is little difference between the inflation-targeting regime (or optimal monetary policy) and the pegged regime. In terms of means, output is effectively identical across these regimes. Net external debt is slightly lower under the peg. This occurs due to the greater degree of precautionary saving undertaken by households in a pegged exchange regime. Precautionary saving is higher because consumption volatility is substantially higher in crisis outcomes under a pegged regime (as we see below).

The domestic interest rate and the external finance premium are identical across the three regimes. When we look at volatilities during normal times, there is more of a contrast between the peg and the inflation-targeting regime. The real exchange rate is significantly more volatile in the latter case, as the nominal rate is free to move, while under the peg, the real exchange rate can move only through costly domestic price adjustment. Output volatility is in fact lower under a peg.[15] However, consumption volatility is higher, due to the absence of the exchange rate as a stabilizing mechanism.

When the country enters a crisis, the impact is much greater in the pegged regime. The reversal in the current account is more extreme, since in the absence of rapid real exchange rate adjustment, domestic interest rates rise much more under the peg, thus leading to a substantially greater fall in domestic absorption. The mean level of external debt during a crisis is 10% lower in a fixed exchange rate environment than under either alternative floating regime. Interest rates in floating and fixed exchange rate regimes are identical outside of crises, but they diverge sharply when the country is borrowing-

15. This is due to the presence of productivity shocks, as when the exchange rate is fixed and prices are sticky, productivity shocks have less of a short-run impact on domestic production. See Devereux and Yu, 2016 for a further explanation.

constrained. In a crisis, the average domestic interest rate rises to 10% under the floating regimes, but it rises to 17% under the peg. Note that domestic and foreign interest rate differentials during a crisis are driven by a combination of anticipated exchange rate movements (as implied by uncovered interest rate parity) and the presence of the external finance premium, since it becomes much more expensive to borrow abroad when the country is collateral-constrained. The interest rate differential under the peg fully reflects the much greater external finance premium, as shown in table 2.

The lack of nominal exchange rate variation leads to much greater volatility of consumption and output under the peg than under either flexible exchange rate regime, when volatility is measured over episodes of a binding collateral constraint. In crisis times, the standard deviation of output under the peg is well over twice that in the floating regimes. The standard deviation of consumption is twice that in the floating regime. This accounts for the increased precautionary saving associated with the peg.

The tables also indicate that under the price stability regime, the crisis frequency is 11%. The Ramsey optimal policy does slightly reduce the crisis frequency to 10.7%. Surprisingly, under the pegged exchange rate, the crisis frequency is significantly lower, at 6.8%. Partly this is due to the lower average debt-to-GDP ratio in the peg, given the higher precautionary saving. But the composition of shocks also matters. This result is further explored in Devereux and Yu (2016). There, it is shown that the lower frequency of crises under a peg is tied to the presence of domestic productivity shocks. Under an exchange rate peg, the price of capital is less volatile in the face of productivity shocks and, hence, crisis frequency may be lower. Despite this, conditional welfare is lower under an exchange rate peg, as shown in table 2.[16]

The model therefore implies that the impact of 'sudden stop' financial crises in emerging markets is critically dependent upon the monetary policy stance being followed by each country. Whatever the monetary policy in place, when countries are hit by binding borrowing constraints, crises are associated with sharp downturns and a process of deleveraging. But the depth of the downturn is crucially linked to the exchange rate regime. If the policymaker maintains a pegged exchange rate when a crisis hits, it has a much more damaging effect.

16. Interestingly, Domac and Martinez-Peria (2003) show that adopting a fixed exchange rate regime can reduce the likelihood of banking crises for developing countries during 1980-1997.

Table 2. Model Moments: Price Stability, Ramsey Optimum, Pegged Exchange Rate

		Mean	
	Price Stability	*Ramsey*	*Peg*
Probability of crisis	11.1	10.6	6.8
Conditional welfare	0.3898288	0.388289	0.3893
Panel A: the whole sample			
Output	0.6877	0.6877	.6877
Debt-GDP	0.3185	0.3183	0.3163
Capital Price	0.9364	0.9364	0.9338
Domestic Interest Rate	1.025	1.025	1.025
External Finance Premium	$0.74.e^{-2}$	$0.74.e^{-2}$	$0.73.e^{-2}$
Panel B: the subsample with binding constraints			
Output	0.6645	0.6652	0.6492
Debt-GDP	0.461	0.458	0.427
Capital Price	0.8738	0.8734	0.860
Domestic Interest Rate	1.11	1.11	1.17
External Finance Premium	$0.67.e^{-1}$	$0.64.e^{-1}$	$1.07.e^{-1}$

Notes: The moments are generated by a simulation of 210,000 periods with dropping the first 10,000 periods. A crisis scenario is defined as a binding collateral constraint.

Table 3. Model Moments: Price Stability, Ramsey Optimum, Pegged Exchange Rate

		Standard Deviation	
	Price Stability	*Ramsey*	*Peg*
Panel A: the whole sample			
Output	1.8	1.79	1.65
Consumption	1.59	1.57	1.71
Real Exchange Rate	0.69	0.7	0.3
Inflation	0	0.01	0.3
Capital Price	3.43	3.42	3.05
Panel B: the subsample with binding constraints			
Output	1.82	1.79	4.49
Consumption	2.53	2.51	4.9
Real Exchange Rate	1.14	1.18	0.52
Inflation	0	0.03	0.6
Capital Price	5.7	5.79	7.72

Notes: The moments are generated by a simulation of 210,000 periods with dropping the first 10,000 periods. A crisis scenario is defined as a binding collateral constraint.

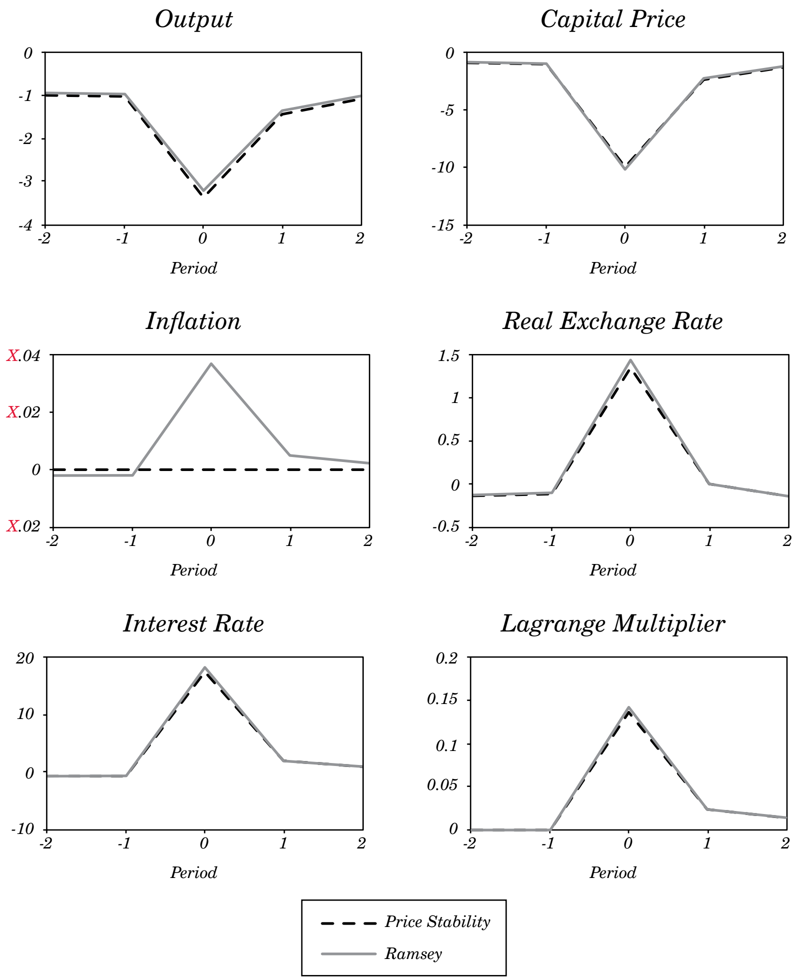
5.5 Crisis Events

To see more clearly what happens in a typical financial crisis, we illustrate the model simulations in terms of an event analysis. We define an 'event' in the simulations as a situation where the collateral constraint is non-binding for two periods, and then becomes binding for at least one period following this. Then we average the responses of all macroeconomic variables across all such events.

Figure 7 reports the response of output, the price of capital, the real exchange rate, inflation and interest rates, and the Lagrange multiplier (which gives a measure of the response of the External Finance Premium) for the comparison of the two flexible exchange rate regimes (price stability *versus* Ramsey optimal monetary policy). As suggested by the policy functions and the moment analysis above, there is only a slight difference in the crisis experience between the two monetary policy regimes. Inflation rises in a crisis under the Ramsey policy, thus leading to a greater real exchange rate depreciation and a slightly smaller reduction in output.

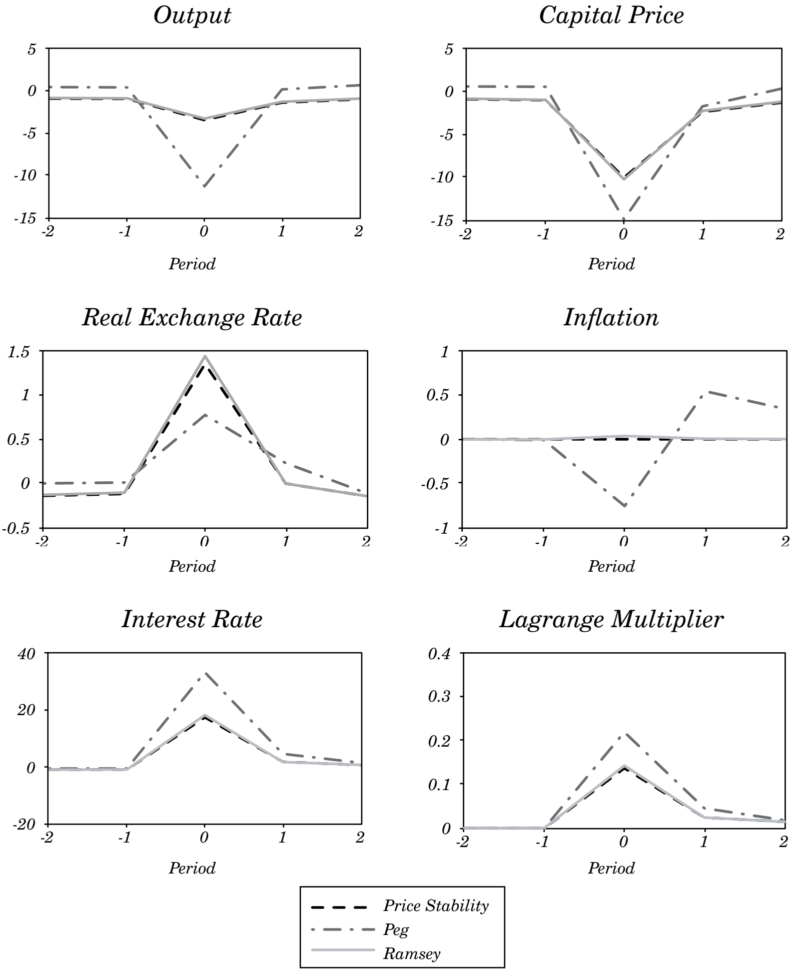
Figure 8 compares the crisis response under a peg to that of the two floating exchange rate regimes. Clearly, the response under a peg is substantially greater in most dimensions. The multiplier jumps much more under the peg, which indicates a much greater rise in the external finance premium. This is reflected in a larger increase in the domestic interest rate. The interest rate rises to 18% in the floating regimes, but to almost twice as much in the peg. Thus, the crisis is associated with a large temporary deviation from interest parity. We can equivalently think of this as the necessary interest rate defence required to maintain a peg in face of a capital market crisis.

Figure 7. Crisis Events for the Price Stability Regime and the Ramsey Optimal Policy



While the real exchange rate depreciates in both regimes, there is a much larger depreciation under the floating exchange rate regime. Because of the inverse relationship between inflation and real exchange rate, under the pegged exchange rate, the real exchange rate depreciation requires a substantial deflation on impact and then a dramatic inflation following the impact period. The large deflation required to maintain the peg has significant consequences for the real economy. Output falls by 10% under the peg compared with approximately 3% in the floating regime. The rapid deflation and the spike in the domestic interest rate lead to a much larger fall in the price of capital under the peg, thus further increasing the external finance premium through the 'financial accelerator' process.

Figure 8. Crisis Events for the Price Stability Regime, the Ramsey Optimal Policy, and the Pegged Exchange Rate Regime



Finally, the figures also establish that, while an optimal monetary policy differs from the strict inflation-targeting regime during a crisis, in practice, there is little difference between the two policies, even in a crisis. In contrast to the strict inflation-targeting regime, we see that there is a jump in inflation during a crisis under an optimal monetary policy. But this is much smaller than the (negative) response of inflation in the peg and has little effect on the overall response of the real economy, as compared to that under the strict inflation-targeting regime. Also, as discussed above, the event figure for inflation under optimal monetary policy in the floating regime shows that monetary policy only reacts to disturbances in crisis and doesn't serve as a macroprudential policy.

6. Conclusion

This paper explores the ways in which a small, emerging market country that suffers from financial vulnerabilities can utilize monetary and exchange rate policy to avoid macro spillovers from external shocks. The paper combines the literature on sudden stops in financial markets with the New Keynesian literature on nominal wage and price rigidities. We find that, while the benefit of monetary policy in dealing with financial crises depends on the degree of nominal rigidity, the effect of crises under pegged exchange rates may be very costly. Thus, even in the presence of large spillover effects from the rest of the world`s financial fragilities which generate recurrent crises, there remains an important policy 'trilemma' for emerging market economies that are committed to capital market openness.

References

Aguiar, M. and G. Gopinath. 2007. "Emerging Market Business Cycles: The Cycle Is the Trend." *Journal of Political Economy* 115: 69–102.

Aruoba, S.B. and F. Schorfheide. 2013. "Macroeconomic Dynamics Near the ZLB: A Tale of Two Equilibria." Working Paper 13-29, Federal Reserve Bank of Philadelphia.

Backus, D.K., P.J. Kehoe, and F.E. Kydland. 1992. "International Real Business Cycles." *Journal of Political Economy* 100(4): 745–75.

Benigno, G., H. Chen, C. Otrok, A. Rebucci, and E.R. Young. 2013. "Financial Crises and Macro-Prudential Policies." *Journal of International Economics* 89(2): 453–70.

Bianchi, J. 2011. "Overborrowing and Systemic Externalities in the Business Cycle." *American Economic Review* 101(7): 3400–26.

Bianchi, J. and E.G. Mendoza. 2010. "Overborrowing, Financial Crises and 'Macroprudential' Taxes." Working Papers 16091, National Bureau of Economic Research, Inc, June

————. 2013. "Optimal Time-Consistent Macroprudential Policy." Working Paper 19704, National Bureau of Economic Research.

Cespedes, L.F., R. Chang, and A. Velasco. 2004. "Balance Sheets and Exchange Rate Policy." *American Economic Review* 94(4): 1183–93.

Chen, H., D. Levy, S. Ray, and M. Bergen. 2008. "Asymmetric Price Adjustment in the Small." *Journal of Monetary Economics* 55(4): 728–37.

Christiano, L.J., M. Eichenbaum, and C.L. Evans. 2005. "Nominal Rigidities and the Dynamic Effects of a Shock to Monetary Policy." *Journal of Political Economy* 113(1): 1–45.

Costinot, A., G. Lorenzoni, and I. Werning. 2014. "A Theory of Capital Controls as Dynamic Terms-of-Trade Manipulation." *Journal of Political Economy* 122(1): 77–128.

Devereux, M.B. and C. Yu. 2014. "International Financial Integration and Crisis Contagion." Working Paper 20526, National Bureau of Economic Research.

————. 2016. "Exchange rate adjustment in financial crises"

Devereux, M.B., E.R. Young, and C. Yu. 2015. "A New Dilemma: Capital Controls and Monetary Policy in Sudden Stop Economies." Working Paper 21791, National Bureau of Economic Research.

Dixit, A.K. and J.E. Stiglitz. 1977. "Monopolistic Competition and Optimum Product Diversity." *American Economic Review* 67(3): 297–308.

Domac, I. and M.S. Martinez-Peria. 2003. “Banking Crises and Exchange Rate Regimes: Is There a Link?” *Journal of International Economics* 61(1): 41–72.

Engel, C. 2015. “Macroprudential Policy in a World of High Capital Mobility: Policy Implications from an Academic Perspective.” Working Paper 20951, National Bureau of Economic Research.

Farhi, E. and I. Werning. 2012. “Dealing with the Trilemma: Optimal Capital Controls with Fixed Exchange Rates.” Working Paper 18199, National Bureau of Economic Research.

————. 2013. “Dilemma Not Trilemma? Capital Controls and Exchange Rates with Volatile Capital Flows.” Working Paper 133566, Harvard University OpenScholar.

Fornaro, L. 2013a. “International Debt Deleveraging.” Economics Working Paper 1401, Department of Economics and Business, Universitat Pompeu Fabra.

————. 2013b. “Financial Crises and Exchange Rate Policy.” Economics Working Paper 1431, Department of Economics and Business, Universitat Pompeu Fabra.

Gali, Jordi. 2015) Monetary Policy, Inflation, and the Business Cycle: An Introduction to the New Keynesian Framework (the Second Edition, Princeton University Press).

Gali, J. and T. Monacelli. 2005. “Monetary Policy and Exchange Rate Volatility in a Small Open Economy.” *Review of Economic Studies* 72(3): 707–34.

Georgiadis, G. and A. Mehl. 2015. “Trilemma, Not Dilemma: Financial Globalisation and Monetary Policy Effectiveness.” Globalization and Monetary Policy Institute Working Paper 222, Federal Reserve Bank of Dallas.

Graham, J.R., M.T. Leary, and M.R. Roberts. 2015. “A Century of Capital Structure: The Leveraging of Corporate America.” *Journal of Financial Economics* 118(3): 658–83.

Greenwood, J., Z. Hercowitz, and G.W. Huffman. 1988. “Investment, Capacity Utilization, and the Real Business Cycle.” *American Economic Review* 78(3): 402–17.

Hanson, G.H. 2012. “The Rise of Middle Kingdoms: Emerging Economies in Global Trade.” *Journal of Economic Perspectives* 26(2): 41–64.

Hassan, T.A., T.M. Mertens, and T. Zhang. 2015. “Currency Manipulation.” Manuscript, University of Chicago.

Holmstrom, B. and J. Tirole. 1997. “Financial Intermediation, Loanable Funds and the Real Sector.” Quarterly Journal of Economics 112(3): 663–91.

International Monetary Fund. 2014. *Regional Economic Outlook: Asia and Pacific World Economic and Financial Surveys*. Washington, D.C.: IMF.

Jeanne, O. and A. Korinek. 2010. "Excessive Volatility in Capital Flows: A Pigouvian Taxation Approach." *American Economic Review* 100(2): 403–07.

Khan, H. 2005. "Price-Setting Behaviour, Competition, and Markup Shocks in the New Keynesian Model." *Economics Letters* 87(3): 329–35.

Kim, J. and F.J. Ruge-Murcia. 2009. "How Much Inflation Is Necessary to Grease the Wheels?" *Journal of Monetary Economics* 56(3): 365–77.

Kiyotaki, N. and J. Moore. 1997. "Credit Cycles." *Journal of Political Economy* 105(2): 211–48.

Korinek, A. 2011. "The New Economics of Prudential Capital Controls: A Research Agenda." *IMF Economic Review* 59(3): 523–61.

————. 2015. "Currency Wars or Efficient Spillovers?" Manuscript, Johns Hopkins University.

Liu, Z. and M.M. Spiegel. 2015. "Optimal Monetary Policy and Capital Account Restrictions in a Small Open Economy." *IMF Economic Review* 63(2): 298–324.

Lorenzoni, G. 2015. "Chapter 12 - International Financial Crises." In *Handbook of International Economics*, vol 4, edited by K. Rogoff, E. Helpman, and G. Gopinath, Elsevier.

Mendoza, E.G. 2010. "Sudden stops, Financial Crises, and Leverage." *American Economic Review* 100(5): 1941–66.

Ottonello, P. 2015. "Optimal Exchange Rate Policy under Collateral Constraints and Wage Rigidity." Manuscript, University of Michigan.

Passari, E. and H. Rey. 2015. "Financial Flows and the International Monetary System." *Economic Journal* 0(584): 675–98.

Peltzman, S. 2000. "Prices Rise Faster than They Fall." *Journal of Political Economy* 108(3): 466–502.

Rey, H. 2013. "Dilemma Not Trilemma: The Global Cycle and Monetary Policy Independence." Proceedings - Economic Policy Symposium - Jackson Hole.

————. 2015. "International Channels of Transmission of Monetary Policy and the Mundellian Trilemma." CEPR Discussion Paper 11027.

Rotemberg, J.J. 1982. "Monopolistic Price Adjustment and Aggregate Output." *Review of Economic Studies* 49(4): 517–31.

Rudebusch, G.D. 2002. “Term Structure Evidence on Interest Rate Smoothing and Monetary Policy Inertia.” *Journal of Monetary Economics* 49(6): 1161–87.

———. 2006. “Monetary Policy Inertia: Fact or Fiction?” *International Journal of Central Banking* 2(4): 85–135.

Schittkowski, K. 2014. “NLPQLP: A Fortran Implementation of a Sequential Quadratic Programming Algorithm with Distributed and Non-Monotone Line Search—User’s Guide, version 4.2.” Report, Department of Computer Science, University of Bayreuth.

Schmitt-Grohe, S. and M. Uribe. 2012. “Prudential Policy for Peggers.” CEPR Discussion Paper 8961.

———. 2016a. “Downward Nominal Wage Rigidity, Currency Pegs, and Involuntary Unemployment.” *Journal of Political Economy*, 124: 1466-1514.

———. 2016b. “Revisiting Macroprudential Policy in Open-Economy Models with Financial Frictions.” Manuscript, Columbia University.

Tauchen, G. and R. Hussey. 1991. “Quadrature-Based Methods for Obtaining Approximate Solutions to Nonlinear Asset Pricing Models.” *Econometrica* 59(2): 371–96.

Uribe, M. and V.Z. Yue. 2006. “Country Spreads and Emerging Countries: Who Drives Whom?” *Journal of International Economics* 69(1): 6–36.

Varian, H.R. 1975. “A Bayesian Approach to Real Estate Assessment.” Studies in Bayesian Econometrics and Statistics in Honor of Leonard J. Savage.

Appendix A. Measures of Welfare

The lifetime utility for a representative household in the small economy, conditional on the initial debt level and exogenous shocks can be written as

$$Wel(b_0^*, Z_0) \equiv E_0 \left\{ \sum_{t=0}^{\infty} \beta^t U(\tilde{C}_t) \right\} = E_0 \left\{ \sum_{t=0}^{\infty} \beta^t \frac{\tilde{C}_t^{1-\sigma} - 1}{1-\sigma} \right\}. \qquad \text{(A-1)}$$

We define a certainty equivalence of effective consumption $\tilde{C}(b_0^*, Z_0)$ in a policy regime conditional on an initial state (b_0^*, Z_0) as

$$Wel(b_0^*, Z_0) = E_0 \left\{ \sum_{t=0}^{\infty} \beta^t \frac{\tilde{C}(b_0^*, Z_0)^{1-\sigma} - 1}{1-\sigma} \right\} = \frac{\tilde{C}(b_0^*, Z_0)^{1-\sigma} - 1}{1-\sigma} \frac{1}{1-\beta}.$$

Rearranging the equation yields

$$\tilde{C}(b_0^*, Z_0) = \left[Wel(b_0^*, Z_0)(1-\sigma)(1-\beta) + 1 \right]^{\frac{1}{1-\sigma}}. \qquad \text{(A-2)}$$

We will use $\tilde{C}(b_0^*, Z_0)$ to measure conditional welfare in the main text.

The unconditional welfare *Wel* is measured in a similar way except that the welfare Wel is a weighted average of conditional welfare $Wel(b_t^*, z_t)$ over the whole domain in the stationary equilibrium.

Macroprudential Policy: Promise and Challenges

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The developments that led to the 2008 global financial crisis raised a new awareness amongst central banks and financial regulators in advanced economies about the need to approach financial regulation and surveillance from a macroeconomic (i.e., systemic) and prudential (i.e., pre-emptive) perspective. Policymakers in several emerging economies learned this lesson a decade earlier, in the aftermath of the 1990s emerging markets crises, and authorities in Chile learned this lesson even earlier, with the massive banking crisis that engulfed the country in 1982. The practice of macroprudential policy, however, has marched well ahead of theoretical and quantitative research that could provide a solid foundation for it, comparable with the foundation that neokeynesian dynamic stochastic general equilibrium (DSGE) models provide for the conduct of monetary policy. The goal of watching for and containing the emergence of economy-wide credit booms and balance-sheet imbalances in financial intermediaries is widely agreed upon, based on the recurrent observation that, in the years leading to financial crises, credit grows "too fast," and often accompanied by maturity and/or currency mismatches. But taking this notion into

This paper was prepared for the 20th Annual Conference of the Central Bank of Chile, 10-11 Nov 2016. The arguments presented here draw from various projects with several co-authors I have had the privilege of collaborating with, particularly Javier Bianchi, Emine Boz, Julio Carrillo, Bora Durdu, Juan Hernández, Victoria Nuguer, Vincenzo Quadrini, Jessica Roldán, Katherine Smith, and Marco Terrones. I also benefitted from interactions with other authors in the literature on quantitative models with financial frictions, particularly: Gianluca Benigno, Markus Brunnermeier, Larry Christiano, Mick Devereux, Nobu Kiyotaki, Mark Gertler, Matteo Iacoviello, Alessandro Rebucci, Pablo Ottonello, Chris Otrok, Stephanie Schmitt-Grohe, Martin Uribe, and Eric Young.

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practice has been largely a learning-by-doing exercise, given the lack of sound quantitative models that can capture financial crises dynamics, provide market-failure arguments to justify policy intervention, and facilitate the design and evaluation of macroprudential policies.

This paper reviews a class of dynamic macro models with financial frictions that is contributing to fill these gaps, namely models with Fisherian collateral constrains (i.e., constraints limiting borrowing capacity to a fraction of the market value of assets or goods posted as collateral). Quantitative studies show that these models can replicate key stylized facts of financial crises, and that the optimal macroprudential policy of an ideal constrained-efficient financial regulator can reduce significantly the severity and frequency of financial crises. On the other hand, as this paper argues, macroprudential policy remains a difficult task. In particular, this paper highlights three major challenges:

Complexity: Optimal macroprudential policy rules feature significant and nonlinear variation over time and across states of nature in response both to traditional domestic factors and to global spillovers, in the form of shifts in global liquidity, news about global fundamentals, and recurrent waves of financial innovation and structural/regulatory change in world financial markets. Macroprudential regulation can be implemented with rules simpler than the optimal rules, but this requires careful design and quantitative evaluation, because otherwise it can be counterproductive and reduce welfare, even relative to a *status-quo* without policy intervention.

Lack of credibility: Under commitment, macroprudential policymakers have incentives to be time-inconsistent and thus deviate from pre-announced policy rules. The argument is subtle but, at its core, it has similar features to those of the the well-known time-inconsistency arguments that undermine the credibility of optimal monetary and fiscal policies under commitment.

Coordination failure: Macroprudential policy needs to be carefully balanced with monetary policy. If, instead of implementing separate financial policy rules, monetary policy rules are simply expanded with a financial mandate, their efficacy in terms of financial stability is weakened by the lack of sufficient policy instruments (i.e., Tinbergen's rule is violated). With separate rules, it is important that monetary and financial authorities coordinate, so as to prevent strategic interaction from undermining the effectiveness of both policies.

This paper draws from the findings of a large and growing research program encompassing macroeconomic models of financial crises and their normative analysis. This program originated in the international macro field in the 1990s, motivated by the emerging markets crises and building on classic models of financial transmission (as in Bernanke and Gertler, 1989, and Kiyotaki and Moore, 1997), and then became dominant in the broader macro field after the 2008 global financial crisis. The arguments developed here focus in particular on a branch of this literature that studies quantitative models with Fisherian collateral constraints[1], and also, to some extent, on the large literature incorporating financial frictions into neokeynesian DSGE models (e.g., Bernanke and others, 1999, and Christiano and others, 2014).

The rest of this paper is organized as follows. The next section develops a general argument about the aim of macroprudential policy and the relevance of global, nonlinear methods in developing quantitative models to implement it. Section 2 provides a benchmark framework to characterize the market failure present in Fisherian models and the optimal policy response. Section 3 demonstrates the effectiveness and complexity of optimal financial policy using a variant of a framework widely used in the literature, in which income from the nontradables sector serves as collateral for debt denominated in units of tradable goods (i.e., a "liability dollarization" framework). Section 4 documents similar features in the findings reported by Bianchi and Mendoza (2017) by using a model in which assets are used as collateral (i.e., a "collateral assets" framework), and also discusses time-inconsistency of the optimal policy under commitment and the quantitative implications of optimal, time-consistent policy. Section 5 examines the quantitative relevance of Tinbergen's rules and policy coordination failure resulting from the interaction of monetary and financial policies in the setup proposed by Carrillo and others (2016). Section 6 concludes.

1. A General Case for Nonlinear Models of Financial Crises and Macroprudential Policy

The appeal of macroprudential policy derives from the consensus formed around the view that credit booms, albeit infrequent, should be prevented because they end in deep, protracted crises. This view is consistent with the findings of empirical studies. For instance,

1. See, for example, Bianchi, 2011; Bianchi and Mendoza, 2010; Bianchi and others, 2016; Jeanne and Korinek, 2010; Benigno and others, 2013; Mendoza and Quadrini, 2010; Ottonello, 2015.

the event analysis of credit booms by Mendoza and Terrones (2012) shows that credit booms occur with a frequency of only 2.8 percent in a sample of 61 industrial and emerging economies for the 1960-2010 period but conditional on a credit boom, the probability of banking or currency crises is 1/3rd.[2] The downswings of credit booms are also typically accompanied by sudden stops, defined as sharp current account reversals (i.e., a sudden halt to financing from the rest of the world). After credit booms peak, the median current account reversals are roughly 2.5 and three percentage points of GDP in annual terms for advanced and emerging economies, respectively. Recessions in the aftermath of credit booms are large and long-lasting. Three years after credit booms peak, the median GDP *per capita* is five and eight percent below trend in advanced and emerging economies, respectively.

The task of macroprudential policy—as originally described by Borio (2003) or, in a more recent description, by Bernanke (2010)—is to enrich financial regulation and financial policies with a macroeconomic, rather than a microeconomic, approach to credit dynamics and systemic risk, aiming at stopping credit booms at their early stages as a prudential measure to prevent them from turning into macro crises. While this task is clear, work on producing useful quantitative models to design and evaluate macroprudential policies has only progressed slowly, largely because our understanding of how financial policies influence the transmission mechanism driving financial crises is still developing and incorporating this mechanism into quantitative dynamic macroeconomic models has proven difficult.

The neokeynesian DSGE models, that are commonplace in central banks today, have been used very successfully to evaluate monetary policy scenarios and implement inflation targeting. A comparable quantitative tool for macroprudential policy does not yet exist. Unfortunately, DSGE models have been less successful at accounting for the dynamics of financial crises and the transition from credit boom events to financial crashes, even when the models have been extended to introduce financial mechanisms (by, for example, introducing a financial accelerator along the lines of the Bernanke-Gertler-Gilchrist, BGG, setup). Several studies (e.g., Gertler and others, 2007, Christiano and others, 2014) show how financial transmission can be a significant factor driving macroeconomic dynamics in response to financial shocks, but modeling financial crises without relying on financial shocks in

2. Mendoza and Terrones identify a country to be in a credit boom if the cyclical component of real credit is in the 95 percentile of that country's distribution.

this class of models remains difficult. From a technical standpoint, this limitation is due in part to the fact that the quantitative methodology that DSGE models typically follow is based on perturbation methods, which have inherent limitations for capturing accurately the non-linear nature of the financial transmission mechanism that drives credit booms and triggers financial crises. These limitations extend into limitations for quantifying the crucial equilibrium interaction between prudential policy measures taken in good times, the optimal intertemporal plans of economic agents, and the probability and magnitude of financial crises.

The rest of this section provides intuitive arguments about the importance of non-linear dynamics for developing quantitative frameworks to study financial crises and macroprudential policy that apply to a large class of models, in addition to the Fisherian models that this paper emphasizes.[3] Consider a function relating the yield of a financial instrument to the aggregate liability position in that instrument (for example, mortgage debt of households in an advanced economy, short-term, foreign-currency denominated debt of corporations in an emerging economy, sovereign debt, etc.). It is reasonable to think that this function should be increasing and convex, like the function denoted "theoretical pricing function" in figure 1. The convexity of this function is easier to understand by looking at the vertical intercept and asymptote. If the liability position is negligible, which means that the probability of financial distress is also negligible, the yield should be roughly the risk-free rate (i.e., the vertical intercept). The vertical asymptote exists because, since wealth in the aggregate and for a mass of agents of any size is finite, there must exist a level of indebtedness such that the likelihood of non-repayment approaches 100% as that debt level is reached (i.e., the debt is so large that agents are almost certain to be unable to repay, regardless of economic conditions). The vertical asymptote can therefore be thought of as a rationing threshold, at which the yield goes to infinity as the price of the liability goes to zero because repayment is a zero-probability event. In between the vertical intercept and the rationing threshold, the yield increases with the liability position, and the spread between the yield on the financial liability and the riskless

3. Robert Merton made similar arguments about the importance of nonlinearities in modeling financial stress in terms of option pricing in his 2009 Robert A. Muh Alumni Award Lecture, "Observations on the Science of Finance in the Practice of Finance," delivered on 3 May 2009).

rate widens. The yield and the spread grow at an increasing rate (i.e., the theoretical pricing function is convex), because the increase in the probability of non-repayment in response to an increase in debt of a given amount is much larger when debt is high than when it is low.

Several models used to introduce financial frictions into macroeconomic models embody convex yield functions like the one above. The list includes the Eaton and Gersovitz (1981) model of sovereign default, the financial accelerator model of Bernanke and Gertler (1989), the Kiyotaki and Moore (1997) model of collateral constraints, the classic Merton models of option pricing, and several others. Note also that, for the relationship to be convex, we do not require default to be explicitly modeled or that it occurs as an equilibrium outcome. In the Kiyotaki-Moore model, for example, there is no default.

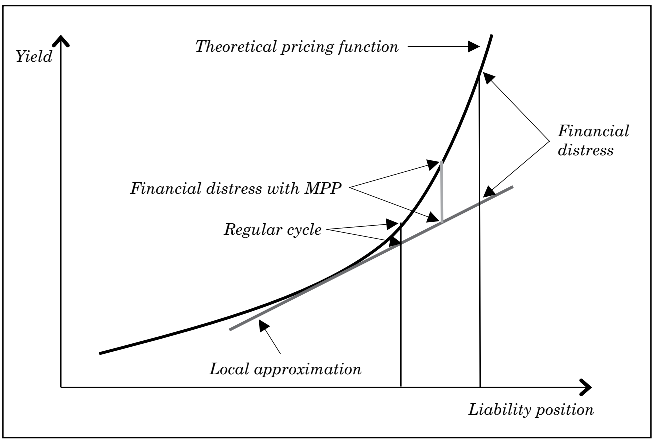
The typical DSGE model with financial frictions focuses on a linear, or low-order, perturbation around a point in figure 1, in an area in which financial markets are stable (i.e., spreads are small). This point is often the deterministic stationary equilibrium. As the figure suggests, if the approximation point is in a relatively flat segment of the curve, the errors implied by the gaps between the "true" yields and those implied by the local approximation are small and, therefore, of little consequence. This could be interpreted as suggesting that the perturbation method does a good job at capturing the effects of the financial transmission mechanism over the regular business cycle, in which fluctuations around cyclical averages are relatively small. But periods of financial distress are very different, because these are points in the steep region of the theoretical pricing function and, in that region, the errors of the local approximation are large. The data could be producing yields as predicted by the theoretical pricing function but, to a modeler working with the local approximation, it may look as if those outcomes are due to large, unexpected shocks (i.e., outcomes that cannot be explained within the model).[4] Merton (2009) made a similar argument and concluded that: "*Things are not conceptually out of control, this is not some mystery black swan we don't understand*

4. A higher-order approximation can of course make the local results of the perturbation method more accurate at tracking the curvature of the pricing function, but to be close to the global solution, it is necessary to use an approximation point that corresponds to the global equilibrium solution, otherwise a higher-order approximation does not make the solutions of local methods a good approximation to the solutions obtained using global methods (see de Groot and others, 2016).

and we need to rewrite all the paradigms because all the modeling is wrong. If people are acting using a linear model, what looks like a ten-sigma event can actually be a two-sigma event..."

An important step in the modeling of financial crises is to be able to explain the transitions across the regular business cycle region and the region with financial distress, so that financial crises do not appear as large, unexpected shocks. Hence, instead of modeling crises as resulting from financial shocks, the aim is to model crises as resulting from financial *amplification*, defined as larger adverse effects on macroeoconomic aggregates caused by shocks of standard magnitudes when financial frictions are more active. Again in Merton's words: "*Most of the models in credit, in trading desks, in macro models, do quite well locally, the problem is when you stop being locally, nonlinearities are really quite large,…If you want to see what happened in AIG…they wrote a whole lot of credit default swaps…the assets underlying them went down not one shock, not two shocks, not three shocks, but over and over. Each time the same size shock is going to create something even larger…*"

Figure 1. Theoretical Pricing Function of Financial Liabilities



The dynamics are non-linear locally, because for local approximations, small variations in liability positions around the steep segment of the pricing function produce large changes in spreads and also globally, since modeling the transitions between regular cycles (i.e., when financial amplification is innocuous) and financial crises (i.e., when financial amplification is large) requires capturing equilibrium dynamics across the flat and steep segments of the function. This is critically important for developing quantitative models of macroprudential policy, because the policy's stated goal is to manage financial policy tools in "good times" in the flat region of the theoretical pricing function, so as to reduce the frequency of transitions into the financial instability region, and the severity of the crises that occur when those transitions do happen. This is illustrated by the shift to the liability position marked as "Financial distress with MPP" in figure 1. Hence, the quantitative framework that policymakers aiming to conduct this policy need is one that captures accurately the effects of financial policy tools on the incentives of credit-market participants in goods times, and that explicitly models the connection between these effects and the transitional dynamics between normal times and crisis times.

Of the agents' incentives that the framework needs to capture, precautionary savings is perhaps the most important, and this also requires a global approach. How does, for example, a regulatory loan-to-value ratio on mortgages with a given size and cyclical co-movement alter mortgage borrowing decisions, household leverage and the frequency and magnitude of financial crises? The answer hinges critically on how borrowing decisions change as the loan-to-value (LTV) requirement changes, and this response is in part determined by how the policy alters the borrowers' incentives to build buffer stock of savings (i.e., disincentives to accumulate debt), which is in turn determined by the equilibrium histories of possible future income and consumption streams that borrowers see themselves exposed to, not just one or two periods ahead, but across the entire stochastic steady state of the economy (and particularly in those low-but-positive probability financial crisis events).

Figure 1 is just a heuristic abstraction, at a high level of generality, of what an ideal model of macroprudential policy should produce. The remainder of this paper focuses on Fisherian models as one class of macro-finance models that so far has produced promising quantitative results in terms of both capturing the nonlinear dynamics of financial crises and providing a framework for studying macroprudential policy.

In addition, Fisherian models provide a theoretical justification for macroprudential policy, because they embody collateral constraints that cause market failure in the form of pecuniary externalities.

2. Pecuniary Externalities as a Rationale for Macroprudential Policy in Fisherian Models

The defining feature of Fisherian models is an occasionally-binding collateral constraint that limits the borrowing capacity of economic agents to a fraction κ of the market value of the goods or assets pledged as collateral. Whether this constraint binds or not is a state-contingent equilibrium outcome, which depends on the agents' optimal plans, the realizations of shocks and the values of aggregate variables, particularly equilibrium prices.[5] These models are labeled "Fisherian" because, when the constraint binds, they display dynamics driven by the classic debt-deflation mechanism first proposed in the seminal work of Fisher (1933). We focus on models in which this constraint is imposed directly on the optimization problems of agents, rather than modeled as an endogenous outcome of a contractual relationship between borrowers and lenders explicitly included in the models. This is common practice in a branch of the macro literature on financial frictions (e.g., Kiyotaki and Moore, 1997; Aiyagari and Gertler, 1999). There are, however, studies of Fisherian models in which the collateral constraint is derived from a contractual setup, typically as a result of a limited enforcement or costly state verification problem (e.g., Bianchi and Mendoza, 2017; Mendoza and Quadrini, 2010). In addition, the pecuniary externality argument developed below applies to a wider class of financial frictions models, in which market-determined prices determine borrowing capacity. For instance, the classic Bernanke-Gertler financial accelerator model, in which borrowers pay an external financing premium as a function of their net worth that emerges endogenously as an outcome of an optimal contract, features a similar pecuniary externality, because net worth is valued at market prices and borrowers do not internalize the effect of their actions on those prices.

5. Nothing guarantees that the constraint may actually bind along an equilibrium path. In fact, since credit constraints strengthen precautionary savings incentives, these models have a self-correcting mechanism that reduces the probability that the constraint binds, potentially even to zero.

In generic form, the Fisherian collateral constraint is:

$$\frac{b_{t+1}}{R_t} \geq -\kappa_t f(p_t)\,, \tag{1}$$

b_{t+1} is an agent's position in a one-period, non-state-contingent discount bond (i.e., the agent borrows when $b_{t+1}<0$), with a price equal to the reciprocal of its gross return R_t; κ_t is the possibly time-varying fraction of goods or assets pledgeable as collateral; p_t represents the market-determined price of collateral; and $f(.)$ is an exogenous (usually linear) function of p_t.

The quantitative applications reviewed in this paper focus mostly on two specific functional forms of the collateral function $f(.)$. First, the "liability dollarization" setup for an economy in which debt is denominated in units of tradables and collateral is posted in terms of the income from tradable and nontradable sectors, y_t^T and y_t^N, respectively. This setup originated in Mendoza (2002) and has been used widely in models of macroprudential policy (e.g., Bianchi, 2011; Benigno and others, 2013; Korinek, 2011; Bianchi and others, 2016). In this case, b_{t+1} is in units of tradables and $f(.)=y_t^T + p_t^N y_t^N$, where p_t^N is the relative price of nontradable goods to tradable goods. Hence, debt cannot exceed a fraction $_t$ of total income in units of tradables, and the price determining the value of collateral is p_t^N. Second, the "collateral assets" setup, in which an asset k_{t+1} (e.g., land, houses, a firm's physical capital) serves as collateral and $f(.)= q_t k_{t+1}$, where q_t is the market price of the asset in units of consumption goods. Hence, in this case κ_t represents an upper bound on the loan-to-value ratio. These models are similar in structure to Kiyotaki and Moore (1997) and Aiyagari and Gertler (1999), and have been used in quantitative studies of financial crises, such as those by Mendoza and Smith (2006) and Mendoza (2010), and in studies of macroprudential policy by Bianchi and Mendoza (2010, 2017), and Jeanne and Korinek (2010).

There are several variations of the above Fisherian collateral constraint in the literature. One case we will examine later extends debt to include both intertemporal debt and within-period debt in the form of working capital financing used by producers to pay for inputs. There are also formulations that allow for endogenous production, capital accumulation, asset trading and financial intermediation. In liability dollarization models with production, the Fisherian deflation of p_t^N affects aggregate supply by reducing demand for inputs in the nontradables sector (e.g., Durdu and others, 2009). If labor income is included in the pledgeable collateral, the constraint increases the effective returns to labor supply, since additional labor income enhances borrowing capacity (e.g., Mendoza, 2002; Benigno and others, 2013). In models with capital accumulation, the Fisherian deflation hits Tobin's Q and thus has both supply and demand effects, because it causes a collapse in investment and thus in future physical capital (e.g., Mendoza, 2010). Models in which assets are traded internationally have a similar feature that triggers asset fire sales and price collapses when the constraint binds, but since the assets are sold to foreign investors, the response of the equilibrium price depends on additional financial frictions, such as trading costs and short-selling constraints[6]. Mendoza and Quadrini (2010) study a model in which banks subject to a mark-to-market capital requirement intermediate funds between heterogeneous households and a representative firm with a collateral constraint.

In the remainder of this section, the goal is to develop the market-failure argument that justifies macroprudential policy when collateral constraint (1) is present. The essence of the argument is that the fact that collateral is valued at market prices in the right-hand side of (1) creates a pecuniary externality. Pecuniary externalities are generally benign, because they do not distort allocations, but in models of this class they do. Of particular interest for macroprudential policy (since it is a pre-emptive policy) is a state of nature in which the collateral constraint does not bind at date t, but can bind with some probability at t+1. In this case, agents make borrowing decisions equating the marginal cost and benefit of the additional unit of debt they take on at date t, but in the marginal cost they do not internalize the response of collateral values at t+1 if the credit constraint becomes binding. As a result, private and social marginal costs of borrowing differ.

The above argument can be articulated more formally as follows. In general equilibrium, the market value of collateral corresponds to marginal rates of substitution in consumption and/or marginal rates of technical substitution in production. Because this is a general equilibrium outcome, individual borrowers do not internalize the effects of their own borrowing decisions on the aggregate variables that pin down the value of collateral *via* these equilibrium conditions, but a social planner does, because the planner internalizes that prices depend on allocations. Thus, from the planner's perspective, prices in the collateral function are actually a function of aggregate allocations. In the standard liability dollarization setup with endowment incomes,

6. See Mendoza and Smith, 2006, 2014.

the relevant marginal rate of substitution for the value of collateral is that between consumption of tradables and nontradables, and since nontradables are usually an endowment, we can re-write the collateral function as $f(p_t(C_t^T))$, where C_t^T is the aggregate value of consumption of tradables. In the collateral assets setup, the relevant marginal rate of substitution is the intertemporal one (or the stochastic discount factor), so the collateral function can be expressed as $f(p_t(C_t, C_{t+1}))$. Notice a subtle difference in these two collateral functions: In the liability dollarization model, the function depends only on date-*t* aggregate variables, whereas in the collateral assets model, it depends on date-*t* and date *t*+1 variables. This difference has crucial implications for time-consistency and credibility of optimal macroprudential policy that we will highlight later in this paper.

In general, dynamic macroeconomic models with Fisherian collateral constraints have in common that, in a decentralized equilibrium without policy intervention, the households' Euler equation for bond holdings takes the following form:

$$u'(t) = \beta R_t E\left[u'(t+1)\right] + \mu_t \,. \tag{2}$$

The non-negative Lagrange multiplier on the collateral constraint (μ_t) enters as a wedge that represents the fact that the effective cost of borrowing exceeds R_t when the constraint binds.

Optimal policy problems for Fisherian models are typically written following the "primal approach," as constrained-efficient problems in which a regulator chooses bond holdings directly internalizing the dependency of the value of collateral on consumption and borrowing choices. Optimality conditions for these problems take different forms depending on the particular structure of models, and especially on whether prices in the collateral function depend on contemporaneous and/or future aggregate variables. Differences along these lines yield different implications as to whether the social planner problem calls for policy intervention when the collateral constraint binds and/or before it becomes binding. To characterize the macroprudential pecuniary externality, however, we abstract from the former by assuming a state of nature in which the collateral constraint does not bind at date *t*. In this case, the planner's Euler equation for bonds typically takes this form:

$$u'(t) = \beta R_t E\left[u'(t+1) + \mu^*_{t+1}\kappa_{t+1} f'(t+1)\frac{\partial p_{t+1}}{\partial \tilde{C}_{t+1}}\frac{\partial \tilde{C}_{t+1}}{\partial b_{t+1}}\right], \tag{3}$$

where μ_t^* is the multiplier of the collateral constraint in the planner's problem and $\tilde{C}_{t+1}$ is the relevant aggregate variable for determining prices in the collateral function. The second term inside the brackets in the right-hand side of this expression reflects the planner's assessment of the effect of the date-t's borrowing choice b_{t+1} on $\tilde{C}_{t+1}$, which in turn determines the value of collateral and borrowing capacity at t+1. This assessment is only relevant in states of nature in which the constraint is expected to bind (i.e., if $\mu^*_{t+1}>0$). This is an externality because it captures price effects that are the aggregate result of individual choices and, as such, are not internalized by private agents. Clearly, since we are assuming that the constraint does not bind at t, it follows from condition (2) that the *private* marginal cost of borrowing is only $\beta R_t E[u'(t+1)]$ and hence, as long as $f'(t+1)(\partial p_{t+1}/\partial \tilde{C}_{t+1})(\partial \tilde{C}_{t+1}/\partial b_{t+1})>0$, the *social* marginal cost of borrowing is higher. In other words, agents in the economy without policy intervention have the incentive to overborrow because they undervalue the marginal cost of borrowing.

The property that $f'(t+1)(\partial p_{t+1}/\partial \tilde{C}_{t+1})(\partial \tilde{C}_{t+1}/\partial b_{t+1})>0$ is critical for the above argument. The positive sign of $f'(p_{t+1})$ can be safely imposed by assumption, since the form of $f(.)$ is chosen exogenously and is generally linear in the value of collateral. In the liability dollarization setup $f'(p_{t+1})=y_t^N>0$, and in the asset pricing setup $f'(p_{t+1})=K_{t+1}>0$, where K_{t+1} is the aggregate supply of assets in the economy, and in both of these setups y_t^N and K_{t+1} are often modeled as exogenous endowments. Also, $\partial \tilde{C}_{t+1}/\partial b_{t+1}>0$ follows from standard budget constraints and, in fact, in both liability dollarization and collateral asset models, $\partial \tilde{C}_{t+1}/\partial b_{t+1}=1$.[7] On the other hand, since prices are general equilibrium outcomes, the sign of $\partial p_{t+1}/\partial \tilde{C}_{t+1}$ is also an equilibrium outcome, and thus $\partial p_{t+1}/\partial \tilde{C}_{t+1}>0$ cannot be assumed, instead, it needs to be established as a property of the equilibrium. As it turns out, in relatively simple variants of both the liability dollarization and collateral assets setups, this property of the equilibrium pricing function holds because of the concavity of utility functions. The equilibrium pricing function derivatives in the liability dollarization and collateral assets models, respectively, are:[8]

7. For example, the standard resource constraint for consumption of tradables in the liability dollarization setup is $c_t^T=y_t^T-q_t b_{t+1}+b_t$, so that $\partial c_t^T/\partial b_t=1$.

8. In these expressions, p_{t+1} is replaced with the relevant price from each model, and we simplify to obtain prices in the numerators by using the optimality conditions for sectoral allocation of consumption in the liability dollarization setup and the Euler equation for assets, in the collateral assets setup.

$$\frac{\partial p_{t+1}^{N}}{\partial C_{t+1}^{T}} = \frac{-p_{t+1}^{N} u_{c^T c^T}(t+1)}{u_{c^T}(t+1)} > 0 \tag{4}$$

$$\frac{\partial q_{t+1}}{\partial C_{t+1}} = \frac{-q_{t+1} u_{cc}(t+1)}{u_{c}\ (t+1)} > 0\ . \tag{5}$$

The optimal allocations of the social planner produced by the so-called primal approach are generally decentralized in the literature by using a state-contingent tax on debt (sometimes referred to as a Pigouvian tax) with the revenues rebated as a lump-sum transfer. The optimal macroprudential tax on debt τ_t is defined as the one that makes private agents in the decentralized equilibrium with the tax face the same marginal cost of borrowing as the social planner in states of nature in which $\mu^*_t = 0$ and $E_t[\mu^*_{t+1} > 0]$. Hence, the optimal τ_t levied on the decentralized economy with taxes is simply the one that matches the value of the pecuniary externality in the planner's optimality condition (3) (i.e., a tax schedule such that the right-hand side of (3) and that of the corresponding Euler equation in the decentralized economy with taxes yield identical values). The optimal macroprudential debt tax is:

$$\tau_t = \frac{E_t\left[\ \mu^*_{t+1}\kappa_{t+1} f'(t+1)\frac{\partial p_{t+1}}{\partial \tilde{C}_{t+1}}\frac{\partial \tilde{C}_{t+1}}{\partial b_{t+1}}\ \right]}{E_t\left[u'(t+1)\right]}\ . \tag{6}$$

This tax is strictly positive, because it inherits the sign of the pecuniary externality, and thus, once it is established that $\partial p_{t+1} / \partial \tilde{C}_{t+1} > 0$, it follows that the τ is strictly positive when $E_t[\mu^*_{t+1} > 0]$.

Taxes are a natural way of decentralizing the optimal policy because we are dealing with an externality. In practice, however, financial regulators rarely operate with standard tax instruments, and, in the conduct of macroprudential policy, what we tend to see more generally is the use of instruments, such as regulatory loan-to-value (LTV) and loan-to-income (LTI) ratios, rules for banks' liquidity coverage or capital buffers with a countercyclical element. It is straightforward to see that the optimal macroprudential policy can be decentralized in terms of regulatory LTV or LTI ratios instead of taxes. In this case, the aim would be to adjust the value of the "unregulated" collateral coefficient κ_t with a time- and state-contingent adjustment that does not let private agents borrow above the amount indicated by the social planner's decision rules. Bianchi (2011) shows how the optimal policy can also be decentralized with capital requirements.

Four important caveats to the case for macroprudential policy presented here should be noted: First, alternative formulations of the collateral constraint can yield underborrowing and debt subsidies (e.g., Benigno and others, 2013). Second, depending on model structure and parameter values, there can be multiple competitive equilibria, if there are more than one value of b_{t+1} that satisfy the collateral constraint with $\mu_t > 0$[9]. Third, also depending on model structure, the social planner may have incentives to intervene not just with macroprudential policy (i.e., policy that applies when $\mu_t^* = 0$ and $E_t[\mu_{t+1}^* > 0]$), but also with *ex-post* policy (i.e., policy that applies when $\mu_t^* > 0$). For instance, in a liability dollarization model with production, the planner would like to reallocate inputs from nontradables to tradables production when $\mu_t^* > 0$, because this props up the value of collateral and makes the constraint less binding[10]. Fourth, if collateral values at date t are determined jointly by date-t and date-t+1 allocations, the optimal plans of the social planner can be time-inconsistent under commitment[11]. This fourth issue is particularly relevant for policy evaluation, because time-inconsistency undermines the credibility of the policy, and will be discussed in section 5.

3. Complexity of the Optimal Policy in a Liability Dollarization Setup

This section uses a specific quantitative example based on the liability dollarization setup to illustrate two points. First, Fisherian models produce financial crises with realistic features, because they embody a strong financial amplification mechanism. Second, these models yield very favorable results about the effectiveness of optimal macroprudential policy, because of large pecuniary externalities. The specific formulation of the liability dollarization model is based on Hernández and Mendoza (2017), which in turn follows from Bianchi and others (2016).

9. See Schmitt-Grohe and Uribe, 2017, and Mendoza, 2005.
10. See Hernández and Mendoza, 2017.
11. See Bianchi and Mendoza, 2017.

3.1 A Liability Dollarization Model with Production and Unconventional Shocks

Consider a small open economy in which agents produce and consume tradable and nontradable goods. A representative household chooses sequences of b_{t+1}, c_t^T, and c_t^N so as to solve the following optimization problem:

$$\max E_0\left[\sum_{t=0}^{\infty}\beta\frac{c_t^{1-\gamma}}{1-\gamma}\right], \qquad c_t = \left[\omega(c_t^T)^{-\eta} + (1-\omega)(c_t^N)^{-\eta}\right]^{-\frac{1}{\eta}} \tag{7}$$

subject to:

$$q_t b_{t+1} + c_t^T + p_t^N c_t^N + A^T + p_t^N A^N = b_t + \pi_t^T + \pi_t^N \tag{8}$$

$$q_t b_{t+1} \geq -\kappa\left(\pi_t^T + \pi_t^N\right). \tag{9}$$

Preferences are standard, with a CRRA utility function and a CES consumption aggregator of consumption of tradables and nontradables ($1/(1+\eta)$ is the elasticity of substitution across the two). In the right-hand side of the budget and borrowing constraints, π^T and π^N are profits from production in the tradables and nontradables industries. A^T and A^N are autonomous spending constants that correspond to investment and government purchases, so as to allow the model to be calibrated to observed consumption-output ratios.

Representative firms produce tradables and nontradables by using intermediate goods, m_t^T and m_t^N in each industry respectively, as the only variable input in standard neoclassical production functions. These intermediate goods are tradable goods with a constant world-determined relative price of p^m in units of the tradable consumer goods. Firms choose their demand for inputs so as to maximize profits:

$$\max_{m_t^T} \pi_t^T = z_t^T\left(m_t^T\right)^{\alpha^T} - p^m m_t^T \tag{10}$$

$$\max_{m_t^N} \pi_t^N = p_t^N z_t^N\left(m_t^N\right)^{\alpha^N} - p^m m_t^N. \tag{11}$$

Notice that, because profit maximization will require equating the value of the marginal product of inputs in each sector with p^m, total profits at equilibrium (which are the collateral for debt) are given by $\pi_t^T + \pi_t^N = (1-\alpha^T) z_t^T \left(m_t^T\right)^{\alpha^T} + (1-\alpha^N) p_t^N z_t^N \left(m_t^N\right)^{\alpha^N}$. Hence, at equilibrium, the borrowing constraint of this economy depends on p^N, even though it does not enter explicitly in the collateral constraint that households "see."

As in Bianchi and others (2016), the model includes three types of shocks. First, standard total-factor productivity (TFP) shocks hitting both producers, z_t^i for i=N,T. Second, noisy news about future fundamentals in the form of a signal s_t received at date t about the date-t+1 TFP in the tradables sector z_{t+1}^T. Third, shifts in global liquidity, modeled as regime-switches in the world interest rate, which is the inverse of q_t. The rationale for introducing these two "unconventional" shocks is to capture effects from conditions in global markets (e.g., commodity price news, Shin's (2013) "phases of global liquidity") by which shocks and policy decisions from the rest of the world spillover into domestic financial stability conditions and macroeconomic fluctuations.

Noisy news are modeled as in Durdu and others (2013). The signals have the same number N of realizations as the TFP shocks and they satisfy the following condition:

$$p(s_t = i \mid z_{t+1}^T = l) = \begin{cases} \theta & if\ i = l \\ \dfrac{1-\theta}{N-1} & if\ i \neq l \end{cases}. \tag{12}$$

The parameter θ determines the precision of the signals. News are perfectly precise if θ=1, because in that case the particular TFP signal received at t is exactly the realization observed at t+1. At the other extreme, news are perfectly uninformative if θ =1/N, because a particular TFP signal received at t has an equal probability of being associated with all possible TFP realizations at t+1. Agents use these signals to improve their (Bayesian) rational expectations of the evolution of TFP in the tradables sector (for details, see Bianchi and others, 2016).

Global liquidity shifts are modeled as a standard Hamilton-style Markov switching process across two regimes, one with a low world real interest rate (high bond price, q^H) and one with a high interest rate (low bond price, q^L). The one-step transitional probabilities of continuation of each regime are F_{HH} and F_{LL}, and the mean durations of high and low liquidity regimes are therefore $1/(1–F_{LL})$ and $1/(1–F_{HH})$.

Noisy news and liquidity shifts are important to consider in models of financial transmission. For example, good news received at date about commodity prices at date t+1 is akin to a form of optimism that induces agents to borrow more and to expect higher future borrowing capacity. If at t +1 the realized prices are actually low, the economy can become financially fragile, as it will be carrying higher debt and leverage than in the absence of the noisy news. Similarly, if the world is in a high liquidity regime (e.g., following commitments to quantitative easing by central banks in advanced economies), agents also have the incentive to take on more debt, so when a shift to low liquidity occurs it can trigger financial instability both directly, because of the sudden large reversal in liquidity, and indirectly, because agents will be carrying higher debt and leverage than in the case in which the interest rate is constant or modeled as a smooth time-series process.

When the collateral constraint becomes binding in the decentralized competitive equilibrium of this economy, tradables consumption falls because access to credit is limited. This, in turn, causes the market-clearing price of nontradables to drop. This reduces the value of the marginal product of inputs in the N sector, causing a drop in demand for inputs and in production from this sector, which also implies that profits from this sector fall. The Fisherian deflation occurs because, as both the price and profits from the N sector fall, the collateral constraint hitting the household becomes more binding, causing a feedback loop by which tradables consumption falls more; the price, production and profits from nontradables fall more; and the collateral constraint binds more.[12]

The optimal financial policy in this economy is characterized by the allocations that solve the following recursive constrained-efficient planner's problem (using ε to represent a set of realizations of each shock, $\varepsilon=(z^T,z^N,s,q)$:

$$V(b,\varepsilon)=\max_{b',c^T,c^N,m^T,m^N}\left[\frac{\left(\left[\omega(c^T)^{-\eta}+(1-\omega)(c^N)^{-\eta}\right]^{-\frac{1}{\eta}}\right)^{1-\gamma}}{1-\gamma}+\beta EV(b',\varepsilon')\right] \quad (13)$$

12. Note that since production of nontradables falls, for the relative price to fall, the effect of the collateral constraint reducing tradables consumption must be larger than the decline in nontradables consumption implied by the fall in output of nontradables. In addition, there is the possibility of equilibrium multiplicity if a condition that requires κ to be relatively high compared to the product of $(1+\eta)$ and the ratio of profits from nontradables to consumption of tradables holds.

subject to:

$$c^T + A^T + p^m(m^T + m^N) + qb' = b + z^T(m^T)^{\alpha^T} \tag{14}$$

$$c^N + A^N = z^N(m^N)^{\alpha^N} \tag{15}$$

$$qb' \geq -\kappa\left[(1-\alpha^T)z^T(m^T)^{\alpha^T} + (1-\alpha^N)p^N z^N(m^N)^{\alpha^N}\right] \tag{16}$$

$$p^N = \left(\frac{1-\omega}{\omega}\right)\left(\frac{c^T}{c^N}\right)^{1+\eta} \tag{17}$$

Constraints (14) and (15) are the resource constraints in the T and N sectors, respectively. Constraint (16) is the collateral constraint as faced by the planner, which internalizes that profits at equilibrium correspond to the share $(1–\alpha^i)$, for i=N,T. of each sector's output in units of tradables. Constraint (17) is an implementability constraint that corresponds to the optimality condition for sectoral consumption allocations in the competitive equilibrium. Intuitively, the planner, when recognizing the connection between the price of nontradables and borrowing capacity, takes into account that its optimal plans must be consistent with prices that can be supported as a market outcome in which markets remain private and competitive.

Following the arguments from the previous section, we can conclude that this economy features the same pecuniary externality according to which the planner internalizes the effect of today's borrowing choice on tomorrow's value of collateral when the collateral constraint binds. Deriving the optimality conditions of the decentralized equilibrium and the planner's problem, and comparing them in the light of the arguments of section 1, we can obtain the following expression for the planner's Euler equation for bonds:

$$q_t u_{c^T}(t) = \beta E_t\left[u_{c^T}(t+1) + \mu^*_{t+1}\kappa(1+\eta)\frac{p_t^N(1-\alpha^N)z_t^N(m_t^N)^{\alpha^N}}{c_t^T}\right] \tag{18}$$

The second term in the brackets in the right-hand side of this expression corresponds to this model's pecuniary externality when the constraint does not bind today, but can bind tomorrow in some states of nature. Again following the arguments in section 1, this externality yields the following optimal macroprudential debt tax:

$$\tau_t^b = \frac{E_t\left[\mu_{t+1}^*\kappa(1+\eta)\frac{p_t^N(1-\alpha^N)z_t^N(m_t^N)^{\alpha^N}}{c_t^T}\right]}{E_t\left[u_{c^T}(t+1)\right]} \tag{19}$$

In this economy, however, there is not only macroprudential (i.e., *ex-ante*) policy, but also financial policy in a broader sense, because the planner also has the incentive to intervene when the collateral constraint is binding at date t. In particular, when the constraint binds, the planner finds it optimal to introduce wedges in the factor allocation conditions as follows:

$$\alpha^N p_t^N z_t^N (m_t^N)^{\alpha^N-1} = p^m\left[\frac{\lambda_t}{\lambda_t + \mu_t^*\kappa(1-\alpha^N)\left(1-\left(\frac{p_t^N c_t^N + c_t^T}{c_t^T}\right)\left(1+\frac{A^T}{c_t^N}\right)\right)}\right] \tag{20}$$

$$\alpha^T z_t^T (m_t^T)^{\alpha^T-1} = p^m\left[\frac{\lambda_t}{\lambda_t + \mu_t^*\kappa(1-\alpha^T)}\right] \tag{21}$$

In these expressions, λ denotes the Lagrange multiplier on the resource constraint for tradables. The wedge in the factor allocation condition of the N sector—the term in square brackets in condition (20)—is smaller than one, because the second term in the denominator is negative. The wedge in the factor allocation of the T sector—the term in square brackets in condition (21)—is greater than one, because the second term in the denominator is positive. Hence, the social marginal cost of allocating inputs to produce N (T) goods is higher (lower) than the private marginal cost (p^m), because the planner realizes that, by reallocating inputs and production in this way, it can prop up the value of collateral, which is socially valuable when the collateral constraint binds. These socially optimal factor allocations can be decentralized by imposing the following time- and state-contingent taxes τ_t^N (subsidies s_t^T) on the N (T) sector:

$$\tau_t^N = \left[\frac{\lambda_t}{\lambda_t + \mu_t^*\kappa(1-\alpha^N)\left(1-\left(\frac{p_t^N c_t^N + c_t^T}{c_t^T}\right)\left(1+\frac{A^T}{c_t^N}\right)\right)}\right] - 1 \tag{22}$$

$$s_t^T = 1 - \left[\frac{\lambda_t}{\lambda_t + \mu_t^* \kappa (1 - \alpha^T)} \right] \tag{23}$$

The government budget constraint in this setup is $Tr_t = -\frac{\tau q_t b_{t+1}}{1+\tau} + \tau_t^N m_t^N - s_t^T m_t^T$, where Tr_t is a lump-sum tax (if negative) or transfer (if positive) to individuals. Notice that if Tr_t<0, the assumption of lump-sum taxation can be troublesome because it gives the government a distortion-free mechanism to reallocate resources. In such a case, it would be more sensible to require the government to raise the revenue needed to pay for the optimal financial policies using distortionary taxes, and take this additional distortion into consideration when designing the optimal policy. This is only an issue here in states when the collateral constraint binds and if the revenue raised by the macroprudential debt tax and the nontradables producers tax is less than the cost of the subsidy to tradables producers.

3.2 Quantitative Findings

Hernández and Mendoza (2017) calibrate the model by using data for Colombia (previous applications of the liability dollarization model have used data for Mexico and Argentina). The parameter values are listed in table 1, and the details of the calibration are available in their paper. They solve the model by using nonlinear global methods (a time-iteration algorithm with the occasionally binding constraint, news shocks, and regime-switching in the interest rate adapted from the work of Bianchi and others, 2016). We are interested in two features of the results. First, the Fisherian amplification mechanism produces financial crises with realistic features. Second, the optimal financial policy (both macroprudential and *ex-post* intervention) is very effective at reducing the frequency and magnitude of crises and increasing social welfare.

Table 2 reports key moments that summarize financial-crises features of both the decentralized equilibrium without policy intervention (DE) and the social planner's equilibrium with the optimal financial policy (SP), together with additional results for simpler policy rules, which will be discussed later. Let us first consider the features of financial crises in the DE. Crises occur with a 2.8 percent probability, as an implication of the calibration target for the value of κ. On average, when a financial crisis hits (defining financial crises as in empirical studies, in terms of changes exceeding two standard deviations in the credit flow, which in this case is also the current account), the impact effects are: a six percent decline in consumption, an eight percent decline in the real exchange rate, and a reversal of the current account of nearly 800 basis points. Thus, financial amplification produces crises with realistic features in terms of responses of consumption and of the current account, as compared with actual features of sudden stops in emerging economies[13].

Global spillovers *via* regime switches in the interest rate and/ or noisy news about the future productivity of the tradables sector (or future terms of trade), play an important role in these results. In particular, as previously documented in the results of Bianchi and others (2016), in all the financial crises events included in the model, the realization of z_t is low, but the signal about this realization is average or good in about 1/3rd of the crises. Hence, positive news about global fundamentals that turn out to be "false optimism" *ex-post* is a source of financial instability.

Table 1. Calibration of Liability Dollarization Model

Parameter		*Value*	*Target*
Risck aversion	γ	2.000	Standard value
Elasticity of subs.	η	0.205	Bianchi et al. (16)
Consumption aggregator	ω	0.415	Share of tradable output
New precision	θ	2/3	Bianchi et al. (16)
T input % in T sector	α_T	0.420	Avg. % of T input /*T* gross out.
T input % in NT sector	α_N	0.158	Avg. % of T input /*NT* gross out.
Autocorr. T prod.	ρ_z^T	0.845	Output autocorrelation
SD T prod.	σ_z^T	0.016	Output volatility
Low liq. real int. rate	R^h	1.013	Bianchi et al. (16)
High liq. real int. rate	R^l	0.992	Bianchi et al. (16)
Low liq. cont. prob.	F_{hh}	0.983	Bianchi et al. (16)
High liq. cont. prob.	F_{ll}	0.900	Bianchi et al. (16)
Discount factor	β	0.989	Avg. colombian NFA/GDP
Assets Pledgeable (%)	κ	0.850	Crisis probability

13. See Mendoza, 2010.

Table 2. Comparison of Equilibria with and without Financial Policies

Long-run moments	(1) *DE*	(2) *SP*	(3) *CT@Opt.*	(4) *CT@SPag*
$\mathbb{E}\,(B/Y)$	77.35%	74.95%	70.86%	75.7%
$\sigma\,(CA/Y)$	0.023	0.009	0.019	0.022
Welfare gain	n.a.	1.38%	0.9%	0.4%
Prob. of crisis	2.80%	0.00%	1.39%	2.48%
$Pr\ (\mu_t > 0)$	15.57%	4.95%	11.92%	14.60%
Financial crisis moments				
ΔC	−6.03%	−1.57%	−5.24%	−5.42%
ΔTCR	−7.99%	−1.08%	−7.93%	−7.35%
$\Delta CA/Y$	7.70%	−0.31%	3.42%	6.43%
$\mathbb{E}\,[\tau]$ *pre crisis*	n.d.	0.1%	0.1%	0.3%
$\mathbb{E}\,[s^T]$ *pre crisis*	n.d.	0.1%	0.0%	0.0%
$\mathbb{E}\,[\tau^N]$ *pre crisis*	n.d.	0.8%	0.0%	0.0%

Notes: (1) Decentralized equilibrium without policy intervention. (2) Social planner's equilibrium with the optimal financial policy. (3) Optimized constant taxes. (4) Taxes are simply set at the averages of the optimal policy.

Comparison of the DE v. the SP in table 2 (columns 1 and 2) shows that the optimal policy is very effective in this setup. Crises are completely removed (i.e., changes in the current account of magnitudes comparable to those in the DE become zero probability events). When faced with shocks of the same magnitudes as the DE economy in the crisis states, the responses of consumption and the real exchange rate are much smaller, and the current account is nearly unchanged. Social welfare, measured as a compensating variation in consumption that renders agents indifferent between the DE and DP in terms of expected lifetime utility, is 1.4 percent higher in the SP economy, which is a significant welfare gain.

The average of the macroprudential debt tax and the subsidy on tradables production is about 0.1 percent (in the year before financial crises hit in the DE economy to make them comparable), while the tax on nontradables production is 0.8 percent. Debt taxes are used more frequently, with a long-run probability of almost 12 percent, while the long-run probability of using the production tax and subsidy, which are states in which $\mu_t > 0$, is roughly five percent.

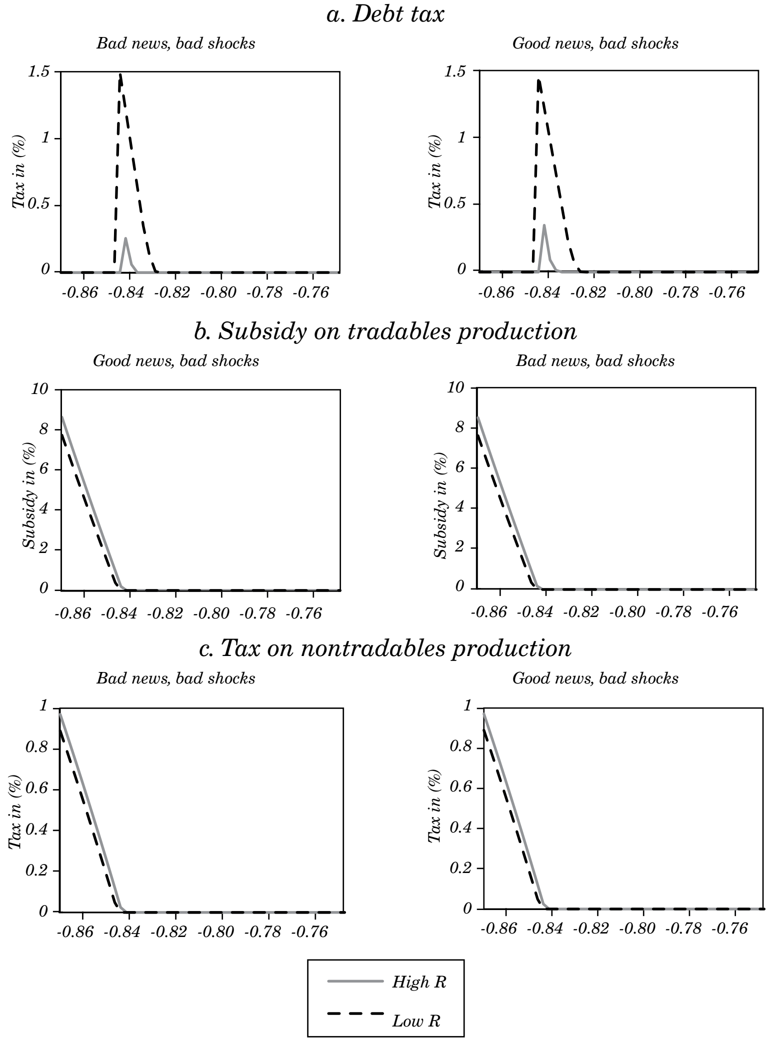
Hernández and Mendoza (2017) and Bianchi and others (2016) document in detail the complexity of the optimal policies by studying the variation of the optimal taxes, both in the time-series dimension and in the schedules of taxes across values of debt and realizations of the various shocks. Figure 2 illustrates some of this complexity by showing the optimal policy schedules as functions of the value of b for regimes with high (continuous curves) and low (dashed curves) world interest rates, in pairs of panels for each tax that correspond to bad news and good news in s, both coinciding with bad realizations of z.

The optimal policies embody large and nonlinear variations. When b is sufficiently high for the collateral constraint to be of little relevance, all three wedges in the planner's optimality conditions are zero and all taxes are zero. When the value of b is sufficiently low for the constraint to bind at t+1 with some probability (for the debt tax) or at t (for the production tax and subsidy), the policy instruments are activated, and their values increase as b falls (as debt rises). Optimal debt taxes can be as high as 1.4 percent, optimal subsidies on tradables producers can reach a little over one percent, and optimal taxes on nontradables producers can be as high as ten percent.

In light of the complexity of the optimal policy, consider instead simpler policy rules in the form of constant taxes. First, column (3) of table 2 shows results for the case in which the taxes are "optimized," in the sense of finding the triple (τ, s^T,τ^N) that attains the highest social welfare by using a simplex routine starting from the average taxes of the optimal policy. Since this is computationally intensive, column (4) presents results for the case in which the taxes are simply set at the averages of the optimal policy.

The results for these two simple rules show the significant risks embodied in the use of financial policy instruments, and the importance of developing reliable quantitative models to evaluate these policies. These two rules are less effective than the optimal policy by sizable margins, but in particular the effectiveness of the simplest rule set to the averages of the optimal policy is minimal. Relative to the DE without policy in column (1), the crisis frequency falls from 2.8 to 2.5 percent, the welfare gain is only 0.4 percent, and the magnitudes of the impact effects on consumption, real exchange rate and current account when a crisis hits are only slightly weaker. Moreover, there are many triples of values of policy instruments that can actually turn welfare losses, so that the economy is better off when exposed to the 2.8 percent risk of financial crises than with suboptimal constant taxes.

Figure 2. Complexity of the Optimal Policy



4. Credibility and Optimal Time-Consistent Policy in a Collateral Assets Setup

In this section, we provide a quantitative example of the collateral assets setup. Drawing from results obtained by Bianchi and Mendoza (2017), we document that again in this environment, Fisherian models produce financial crises with realistic features. In addition, the authors demonstrate that optimal financial policy under commitment is time-inconsistent—and therefore its credibility is an issue—but that the optimal, time-consistent policy of a financial regulator that cannot commit to future policies can still be very effective. Complexity, however, is again a hurdle, and there is a large set of "simple financial policy rules" that are much less effective than the optimal policy, and that can actually be welfare-reducing relative to the decentralized economy without regulation.

4.1 The Bianchi-Mendoza Model and the Time-Inconsistency of Financial Policy

Let us consider again a small open economy with access to world credit markets, but now let us assume that private agents use a physical asset in fixed supply (e.g., land or housing) as collateral. To allow the collateral constraint to affect aggregate supply, we assume that agents operate a production technology that again requires intermediate goods priced at a world-determined price, but now the constraint matters for production, because a fraction of the cost of inputs needs to be paid in advance with working capital loans, and these loans are also subject to the collateral constraint. Without loss of generality, we combine the optimization problems of households and firms into the optimization problem of a representative "firm-household."

The representative agent chooses sequences of consumption and bond holdings as in the model of section 2, but in addition, they also choose sequences of asset holdings, k_{t+1}, labor supply, h_t, and intermediate goods, m_T, so as to solve the following constrained optimization problem:

$$\max E_0 \left[\beta^t \frac{\left(c_t - \chi \dfrac{h^{1+\omega}}{1+\omega} \right)^{1-\sigma}}{1-\sigma} \right], \qquad \omega > 0, \sigma > 1 \tag{24}$$

subject to:

$$q_t k_{t+1} + c_t + \frac{b_{t+1}}{R_t} = q_t k_t + b_t + \left[z_t k_t^{\alpha k} m_t^{\alpha m} h_t^{\alpha h} - p^m m_t \right], \tag{25}$$

$$\alpha k, \alpha m, \alpha h \geq 0, \alpha k + \alpha m + \alpha h \leq 1$$

$$\frac{b_{t+1}}{R_t} - \theta p^m m_t \geq -\kappa_t q_t k_t, \qquad 0 \leq \theta \leq 1\,. \tag{26}$$

The utility function is again constant relative risk aversion (CRRA), but now its argument is the Greenwood, Hercowitz and Huffman (1988) utility function, which removes the wealth effect on labor supply by making the marginal rate of substitution between consumption and labor depend only on the latter. The parameter ω determines the Frisch elasticity of labor supply. The left-hand side of the budget constraint (25) states that the representative firm-household uses income to purchase assets (at price), consumption goods, and bonds. The right-hand side states that the sources of income are the value of current asset holdings, the payment on current bond holdings, and the profits from production (gross output minus the cost of intermediate goods). The gross production function uses assets, intermediate inputs and labor to generate output. The production function is standard: $F(k_t, m_t, h_t) = k_t^{\alpha k} m_t^{\alpha m} h_t^{\alpha h}$. Inputs are bought in global markets at a constant price p^m. Since the same representative agent supplies and demands labor, labor income is included in gross production and the wages bill washes out with the wage income in constraint (25).

The collateral constraint (26) states that total debt, including one-period debt and within-period working capital financing, cannot exceed the fraction κ_t of the current value of collateral assets. Working capital is needed to pay in advance for a fraction θ of the total cost of intermediate goods. Notice the timing of working capital is different from the standard Fuerst (1992) working capital setup, in which the net interest rate enters as debt service on working capital and thus becomes part of the price of inputs. This would enhance the financial transmission at work in the model by linking directly the interest rate with the cost of inputs. Instead, here working capital loans are obtained and paid within the production period, so unless the collateral constraint binds, working capital is neutral.

This model has three shocks. Standard domestic TFP shocks on gross production, z_t, and two shocks that capture the effects of global spillovers, namely: world real interest rate shocks, R_t, and shocks to the ability to collateralize assets into debt, κ_t. Interest rate shocks are modeled as a standard stationary Markov process that is fitted to U.S. time-series data on short-term real interest rates, and hence can be viewed as a proxy for the mechanism driving spillover effects from changes in U.S. monetary policy. Shocks to κ_t are set following the same approach to model global liquidity shocks, as in the liability dollarization examples. Hence, κ_t follows a two-point ($\kappa^h > \kappa^l$) regime-switching Markov process, with κ^h corresponding to the high liquidity regime. Notice that, as shown in section 3 and elsewhere in the literature (e.g., Mendoza, 2010), shocks to κ are not required for Fisherian models to have strong amplification and produce financial crises in quantitative applications. They are used in this collateral assets setup to capture the effects of observed fluctuations in credit availability and LTV ratios driven by global capital markets.

The aggregate supply of capital is K=1. If follows, then, that the competitive equilibrium satisfies the Euler equation (2) and, in addition, the following conditions:

$$z_t F_h(1, h_t, m_t) = \chi h_t^{\omega} \tag{27}$$

$$z_t F_m(1, h_t, m_t) = p^m \left(1 + \theta \mu_t / u_c(t)\right) \tag{28}$$

$$q_t u_c(t) = \beta E_t \left[u_c(t+1)(d_{t+1} + q_{t+1}) + \kappa_{t+1} \mu_{+1} q_{t+1} \right], \tag{29}$$

$$d_{t+1} \equiv z_{t+1} F_k(1, h_{t+1}, m_{t+1}).$$

If the collateral constraint does not bind at t and t+1, $\mu_t = \mu_{t+1} = 0$ and the above conditions would be standard. Condition (27) equates the marginal product of labor with the marginal disutility of labor, which is also the real wage. Condition (28) equates the marginal product of intermediate goods with p^m. Condition (29) reduces to a standard Euler equation for assets, equating the marginal cost and benefit of buying an extra unit of assets.

If μ>0, the collateral constraint effectively increases the marginal cost of intermediate goods in condition (28) by the amount $\theta\mu_t/u_c(t)$, which reduces demand for inputs and hence results in adverse effects on factor allocations and production when the constraint binds. In these states, financial amplification hits aggregate supply because, even if R_t and κ_t are unchanged, a TFP shock of a given size has a more negative effect on demand for inputs and production if the constraint binds than if it does not.

If $\mu_{t+1}>0$, the marginal benefit of accumulating assets rises because, if the constraint is expected to bind the next period, the representative agent takes into account that holding more assets enhances borrowing capacity. Notice this is different from internalizing the price effects of optimal plans, because this relates to the effect of holding more k_{t+1} on the collateral constraint at t+1, not the effects on asset prices either at t or t+1.

How are asset prices affected by binding collateral constraints? This is harder to explain, because of the forward-looking nature of asset pricing. Following Bianchi and Mendoza (2017), if we apply the standard mathematical treatment of equilibrium asset pricing models to the optimality conditions in order to obtain expressions for the forward solution of asset prices and the equity premium, we can obtain the following results:

$$q_t = E_t \sum_{j=0}^{\infty} \left[\prod_{i=0}^{j} E_{t+i}\left(R^q_{t+1+i} \right) \right]^{-1} d_{t+1+j}, \quad R^q_{t+1+i} \equiv \frac{d_{t+1+i} + q_{t+1+i}}{q_{t+i}} \tag{30}$$

$$E_t\left[R^q_{t+1} - R_t\right] = \frac{1}{E_t\left(sdf_{t+1}\right)}\left[\frac{\mu_t}{u_c(t)} - E_t\left(\phi_{t+1} sdf_{t+1}\right) - \text{cov}_t\left(R^q_{t+1}, sdf_{t+1}\right)\right] \tag{31}$$

$$sdf_{t+1} = \frac{\beta u_c(t+1)}{u_c(t)}, \quad \phi_{t+1} \equiv \kappa_{t+1} \frac{\mu_{t+1}}{u_c(t)} \frac{q_{t+1}}{q_t}.$$

In these expressions, *sdf* is the stochastic discount factor between dates t and t+1, and ϕ is a term that captures the effect of capital gains on the marginal value of collateral when the constraint binds.

Equation (30) looks like a standard forward solution for asset prices: The asset price equals the expected present discounted value of dividends discounted by using the rate of return on equity. The dividend rates and the equity returns, however, are affected by the collateral constraint. The effects on the dividend streams are the result of the higher marginal cost of inputs when the collateral constraint binds, as explained earlier. The effects on the equity returns can be inferred from the equity premium expression (31). If the collateral constraint binds, the equity premium reduces to the standard expression determined by $\text{cov}_t\left(R^q_{t+1}, sdf_{t+1}\right)$. But when the collateral constraint binds at date t and is expected to bind at least in some states of nature at t+1, excess returns respond with three effects defined by each of the three terms in the square brackets in the right-hand side of (31), as identified by Bianchi and Mendoza (2017). The first term represents a "liquidity effect," because assets will command a higher premium when the constraint binds at date , due to the additional borrowing capacity (i.e., liquidity) they provide in that same period. This effect always rises expected excess returns when the constraint binds. The second term represents a "collateral effect," in terms of the benefit that buying more assets at date t provides by improving borrowing capacity at t+1 if the constraint binds then (notice ϕ_{t+1} is positive only if $\mu_{t+1}>0$). This effect lowers excess returns. The third effect is a second-order effect operating via the conditional covariance between asset returns and marginal utility. This effect can contribute to increasing or reducing excess returns. On one hand, expecting the collateral constraint to bind at t+1 makes consumption smoothing harder, thus making the covariance "more negative." On the other hand, with the constraint already binding at t, the covariance may rise as the constraint tightens.

The net effect of the above three effects on excess returns is ambiguous, but in quantitative applications the liquidity premium generally dominates, pushing asset returns sharply higher when the constraint binds. Higher returns in turn imply heavier discounting of dividends, which in turn imply a fall in q_t. This feeds back into a tighter constraint as the value of collateral is falling, following the Fisherian deflation dynamics. It is also important to note that, unlike in the liability dollarization setup, since asset prices are forward looking, q_t is affected by expectations of the constraint becoming binding (i.e., equity returns becoming higher) at any future date along the equilibrium path, not just at date t or t +1.

The social planner's problem of a constrained efficient regulator in this setup can be written as follows, again using ε to indicate a vector of the realizations of the three shocks $\varepsilon=(z,R,\kappa)$ for simplicity:

$$V(b,\varepsilon) = \max_{c,b',h,m} \left[\frac{\left(c - \chi \frac{h^{1+\omega}}{1+\omega} \right)^{1-\sigma}}{1-\sigma} + \beta E\left[V(b',\varepsilon') \right] \right] \quad (32)$$

$$c + \frac{b'}{R} = b + \left[z 1^{\alpha k} m^{\alpha m} h^{\alpha h} - p^m m \right] \quad (33)$$

$$\frac{b'}{R} - \theta p^m m \geq -\kappa q \quad (34)$$

$$qu_c\left(c-\chi\frac{h^{1+\omega}}{1+\omega}\right)=\beta E\left[u_c\left(\hat{c}'-\chi\frac{\hat{h}'^{1+\omega}}{1+\omega}\right)\left(z'F_k(1,\hat{m}',\hat{h}')+\hat{q}'\right)+\kappa'\hat{\mu}'\hat{q}'\right].\quad(35)$$

The planner is benevolent, so it maximizes private utility. It faces the economy's resource constraint (eq. 33) and the aggregate equivalent of the collateral constraint (eq. 34). In addition, just as in the liability dollarization setup we had the optimality condition for sectoral allocation of consumption as an implementability constraint, here we have the Euler equation for asset holdings of the representative firm-household as an implementability constraint.

The implementability constraint in the above problem indicates that the planner chooses the socially-optimal allocations taking into account that the collateral values that determine borrowing capacity need to be supported as equilibrium asset prices in private competitive markets. How the planner deals with this requirement is a subtle but fundamentally important aspect of the characterization of planning problems in collateral assets models, and it is the reason why the arguments in the right-hand side of constraint (35) are written with a "^," as explained in the paragraphs below.

Formulations of the planning problems for collateral assets models like those originally proposed by Bianchi and Mendoza (2010) and Jeanne and Korinek (2010) imposed assumptions that, while maintaining the pecuniary externality highlighted in section 2, and thus the incentive to internalize the effect of the debt choice made at date t on asset prices at t+1, effectively prevented the social planner from internalizing the effects of that same debt choice on asset prices at date t.[14] This is a drawback, because of course whether the planner may or may not find it optimal to use its debt choice to alter date-t, asset prices should be an endogenous outcome. In fact, Bianchi and Mendoza (2017) show that indeed the planner will have incentives to do so. But more importantly, as will become evident below, forcing the planner to ignore these incentives imposes time-consistency of the optimal policy in an *ad-hoc* way.

14. In Bianchi and Mendoza (2010), the planner does not face constraint (35) and instead is required to support the same asset pricing function from the decentralized competitive equilibrium without policy. In Jeanne and Korinek (2010), the Euler equation for assets is entered as a constraint but with the pricing function modeled as a "reduced form" that allows the government to internalize the effects of b' on q' but not on q. In both formulations, by construction, when the planner is at any state (b,ε) the price $q(b,\varepsilon)$ is independent of the choice of b'.

Once we allow the planner to be subject to the implementability constraint (35), the next key assumption to make is whether the planner is able to commit to future policies or not. If the planner can commit, the variables with "^" can be replaced with their usual forms without "^," which reflects the planner's ability to commit.[15] Unfortunately, when this is the case, it turns out that the planner's optimal plans display time inconsistency, and this time inconsistency relates directly to the incentives to affect asset prices contemporaneously with the debt choice when the constraint binds. Formally, the planner's optimality conditions for consumption and asset prices under commitment are:

$$\lambda_t^* = u_c(t) - \xi_t^* u_{cc}(t) q_t + \xi_{t-1}^* u_{cc}(t)\left[z_t F_k(t) + q_t + \kappa_t \mu_t q_t \right] \tag{36}$$

$$\xi_t^* = \xi_{t-1}^* \left[1 + \kappa_t \mu_t \right] + \frac{\kappa_t (\mu_t \nu_t^* + \mu_t^*)}{u_c(t)} \tag{37}$$

where λ^*, μ^*, and ξ^* are the planner's Lagrange multipliers with respect to the budget, borrowing and implementability constraints respectively; ν^* is the multiplier on the planner's complementary slackness condition; and μ is the multiplier on the borrowing constraint for private agents. From (37), it is clear that the multiplier ξ^* follows a positive, non-decreasing process which increases every time that the collateral constraint binds. From (36), the planner values how increasing c_t creates a tradeoff by which the collateral constraint weakens at date t but tightens in the previous period. The combination of these two features produces time inconsistency. The intuition is that, if the collateral constraint binds at date t, the planner acting under commitment promises that future consumption will be *lower*, because *via* the *sdf* in the valuation of q_t, lower expected c_{t+1} props up q_t and thus enhances borrowing capacity at t. But at t+1, if the planner is given the option to deviate, it will find it suboptimal to stick to that promise. In short, the optimal financial policy that emerges from models in which assets serve as collateral is time-inconsistent, and therefore lacks credibility.

In light of the above, Bianchi and Mendoza (2017) characterize and solve for the optimal policies of a regulator who cannot commit (i.e.,

15. The problem under commitment also needs, as constraints, the optimality conditions for the allocations of labor and intermediate goods, and the complementary slackness conditions. In principle, the problem without commitment also needs them, but it is possible to demonstrate that these constraints are not binding in this case (see Proposition II in the appendix to Bianchi and Mendoza, 2016). For the same reason, these constraints were omitted from the formulation of the planner's problem in this paper.

optimal, time-consistent financial policies). In this case, the variables with "^" in constraint (35) are replaced with recursive functions that represent conjectures of the regulator about the optimal plans of future regulators: $\hat{c}' = C(b',\varepsilon')$, $\hat{h}' = H(b',\varepsilon')$, $\hat{q}' = Q(b',\varepsilon')$, $\hat{m}' = M(b',\varepsilon')$, $\hat{\mu}' = \mathrm{M}(b',\varepsilon')$.

The regulator's recursive equilibrium becomes a Markov perfect equilibrium that satisfies the Markov stationarity condition, which states that the recursive functions that characterize the optimal choices of the regulator must match the regulator's conjectured functions for the optimal plans of future regulators.

This setup is more complex than the stylized framework of section 2 and the liability dollarization model of section 3, but proceeding with the same logical steps (i.e., deriving the optimality conditions of the time-consistent planner's problems, comparing them with the optimality conditions of the decentralized equilibrium without policy, and solving for a schedule of debt taxes that supports the planner's allocations as a decentralized equilibrium with policy) yields the following expression for the optimal debt tax:

$$\tau_t = \frac{E_t\left[-\kappa_{t+1}\mu^*_{t+1}\dfrac{u_{cc}(t+1)}{u_c(t+1)}Q_{t+1} + \dfrac{\kappa_t\mu^*_t}{u_c(t)}\Omega_{t+1}\right]}{E_t\left[u_c(t+1)\right]} + \frac{\kappa_t\mu^*_t\dfrac{u_{cc}(t)}{u_c(t)}q_t}{\beta R_t E_t\left[u_c(t+1)\right]} \qquad (38)$$

where Ω_{t+1} is short notation for a term that collects all the terms by which the planner's choice of b_{t+1} affects q_t *via* the derivatives of the functions that represent the choices of future planners in the right-hand side of the implementability constraint (35). See Bianchi and Mendoza (2017) for the full expression and the analysis showing that the sign of Ω_{t+1} is ambiguous, but in quantitative applications it is generally negative.

The optimal financial policy implied by this tax has again both macroprudential and *ex-post* intervention components. The macroprudential component of the debt tax (τ_t^{MP}) levied at date t is the one associated with the expectation that the collateral constraint may bind at t+1:

$$\tau_t^{MP} = \frac{E_t\left[-\kappa_{t+1}\mu^*_{t+1}\dfrac{u_{cc}(t+1)}{u_c(t+1)}Q_{t+1}\right]}{E_t\left[u_c(t+1)\right]} \qquad (39)$$

Notice this tax is exactly of the form derived in the more general framework of section 2 (use equation (5) in (6), taking into account that by Markov stationarity $q_{t+1}=Q_{t+1}$). Hence, the planner wants to tax debt contracted at date t when the constraint has positive probability of becoming binding at t+1, in order to bring the private marginal cost of borrowing in line with the social marginal cost, because of the incentive to overborrow produced by the pecuniary externality. Any tax revenue is rebated as a lump-sum transfer, as indicated in section 2.

The *ex-post* intervention component of financial policy (τ_t^{FP}) is given by the other two components of the optimal tax:

$$\tau_t^{FP} = \frac{E_t\left[\frac{\kappa_t \mu_t^*}{u_c(t)}\Omega_{t+1}\right]}{E_t\left[u_c(t+1)\right]} + \frac{\kappa_t \mu_t^* \frac{u_{cc}(t)}{u_c(t)} q_t}{\beta R_t E_t\left[u_c(t+1)\right]} \tag{40}$$

The sign here is ambiguous because the sign of Ω_{t+1} is ambiguous, but since in the quantitative applications $\Omega_{t+1}<0$, and since the second term of this tax is always negative, again because of the concavity of the utility function, we can "safely" assume that, as in section 3, the *ex-post* intervention element of the financial policy calls for subsidizing debt when the collateral constraint is already binding. The first term in the above expression indicates that, assuming $\Omega_{t+1}<0$ when the collateral constraint binds, the planner affects the actions of future planners so as to generate an increase in q_t by borrowing more (lowering b_{t+1}). The second term states that, by borrowing more when the constraint binds, the planner can also prop up the asset price because higher current consumption reduces the denominator of the *sdf* and thus increases q_t. The numerator of this term is isomorphic in absolute value to the one that determines the macroprudential tax (i.e., it reflects the shadow value of the increase in borrowing capacity that the additional unit of debt generates through its effects on the value of collateral), except that it is evaluated as of date t. With the constraint already binding at date t, borrowing *more* at t helps prop up the value of collateral by increasing consumption at t, while if the constraint does not bind at t but can bind at t+1 with some probability, borrowing *less* at date t props up the value of collateral at t+1 if the constraint binds by increasing consumption at t+1.

As in the liability dollarization setup, if the two financial policy instruments result in a net subsidy (i.e., $\tau_t<0$), the government is assumed to pay for it with lump-sum taxes, which raises the concern noted earlier about the possibility that the subsidy would have to be paid with distortionary taxes. The potential for an overall debt subsidy arises only in states in which the collateral constraint binds and either $E_t[\mu^*_{t+1}=0]$, in which case $\tau_t<0$ for sure since we are still assuming $\Omega_{t+1}<0$, or $E_t[\mu^*_{t+1}>0]$ but the revenue from the macroprudential debt tax is not enough to pay for the *ex-post* intervention subsidies, which would imply $\tau_t<0$.

4.2 Quantitative Findings

Bianchi and Mendoza (2017) examine several features of the quantitative predictions of this model, both in terms of the dynamics of macro-aggregates and asset pricing variables, and in terms of comparing solutions without policy v. solutions with optimal policy with and without commitment, and v. solutions with simple macroprudential policy rules. We focus here on only three key results of their work: First, showing financial amplification in the Fisherian collateral assets model is strong and produces financial crises with realistic features. Second, the optimal, time-consistent policy (i.e., taking into account the planner's inability to commit to future policies) is still effective at reducing the frequency and magnitude of crises. Third, the optimal policy is again a complex time- and state-contingent schedule, and simpler policies, in the form of constant taxes or what Bianchi and Mendoza labeled a "macroprudential Taylor rule," are much less effective and can even be welfare-reducing.

The model was calibrated to annual data (1984-2012) for OECD economies. A subset of the parameters is determined directly by drawing from actual data and estimates from the literature, and a second subset is determined by model simulation to match targets from the data. The parameters that are set with the latter are the variability and persistence of TFP, the share of assets in production, the subjective discount factor, and the regime-switching probabilities of κ. A summary of the calibration is provided in table 3[16]. The corresponding targets are the variability and persistence of HP-detrended GDP (averages for OECD countries), loan-to-value and net foreign asset-GDP ratios of the U.S., a frequency of crises of four percent, and a mean duration of crises of one year.

Figure 3 illustrates both the effects of Fisherian financial amplification on macroeconomic dynamics and the effectiveness of the optimal, time-consistent policy at reducing the magnitude of crises. The

16. See Bianchi and Mendoza, 2017, for full details.

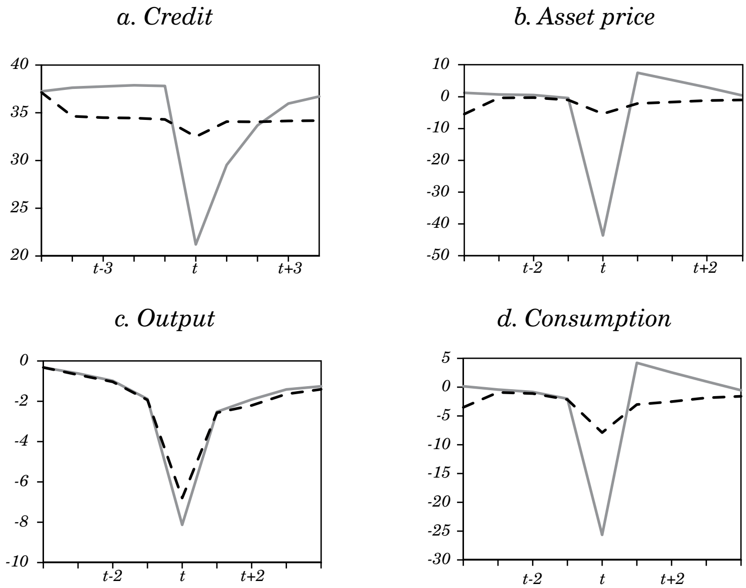
figure shows four event windows for financial crises events identified in a long (100,000 periods) time-series simulation of the model. The windows cover nine years, starting five years before a financial crisis hits. Financial crises are defined by using the methodology proposed by Forbes and Warnock (2012) (the linearly-detrended current account-GDP ratio is two standard deviations above its mean).

The continuous curves in the event windows of figure 3 show the strong Fisherian amplification effects that produce large declines in credit, asset prices production and consumption during financial crises. The magnitudes of the declines in asset prices and output are roughly in line with the OECD data, while the declines in consumption and credit are in fact much larger (partly because all intertemporal debt is one-year debt in the model, so the credit constraint forces a large adjustment in consumption).

Table 3. Bianchi-Mendoza Calibration for Collateral Assets Model

Parameters set independently	*Value*	*Source / Target*
Risck aversion	$\sigma = 1$	Standard value
Share of inputs in gross output	$\alpha_v = 0.45$	Cross country average OECD
Share of labor in gross output	$\alpha_v = 0.45$	OECD GDP labor share =0.64
Labor disutility coefficient	$X = 0.45$	Normalization to yield average h=1
Frisch elasticity	$1/\omega = 2$	Keane and Rogerson (2012)
Working capital coefficient	$\theta = 0.16$	U.S. Working capital/ GDP ratio=0.133
Tight credit regime	$\kappa^L = 0.75$	U.S. post-crisis LTV ratios
Normal credit regime	$\kappa^H = 0.90$	U.S. pre-crisis LTV ratios
Interest rate	$R = 1.1\%$. $\rho_R = 0.68$ $\sigma_R = 1.86\%$	U.S. 90-day T-Bills
Parameters set by simulation	*Value*	*Target*
TFP shock	$\rho_z = 0.78$, $\sigma_\varepsilon = 0.01\%$	OECD average for std. and autoc. of GDP
Share of assets in gross output	$\alpha_k = 0.008$	Value of collateral matches total credit
Discount factor	$\beta = 0.95$	NFA = –25 percent
Transition prob. κ^H to κ^L	$P_{H,L} = 0.1$	4 crises every 100 years (see appendix F.2)
Transition prob. κ^L to κ^L	$P_{L,L} = 0$	1 yearduration of crises (see appendix F.2)

Figure 3. Crisis Dynamics with and without Optimal Policy



The dashed curves in figure 3 represent the dynamics of the optimal, time-consistent financial policy. The policy reduces sharply the declines in credit, asset prices, and consumption, and it also weakens the fall in output, although by less than in the other cases. This is because financial crises coincide on average with periods of low TFP and a shift to κ^l, and these two exogenous shocks have large adverse effects on production that are independent of policy intervention. In addition, unlike the case of the *ex-post* financial policy of the planner in section 4, the planner without commitment of the collateral assets model does not have wedges to tackle in the factor allocation conditions. When the collateral constraint binds, the marginal cost of inputs rises for both private agents and planner, but the optimality conditions of the two have the same form. Still, since the planner's μ^* differs from the private agents' μ, the planner may want to intervene in factor markets when the constraint binds, but as Bianchi and Mendoza (2017) proved, the optimality conditions for factor allocations of private agents are non-binding constraints for the social planner without commitment.

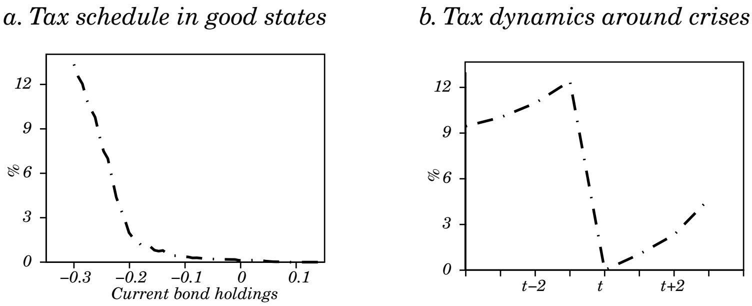
The optimal policy is also very effective at reducing the frequency of crises, and it yields a nontrivial welfare gain. Financial crises have an endogenous probability of 4 percent in the competitive equilibrium without policy v. only 0.02 percent with the optimal, time-consistent policy. The optimal policy yields an average welfare gain of 0.30 percent.

Since the collateral constraint binds infrequently, but the expectation that it may bind at t+1 when it does not bind at t is a frequent event (with 94 percent probability in the stochastic steady state with the optimal policy), the quantitatively relevant element of the policy is the macroprudential debt tax (τ_t^{MP}). The complexity of this tax under the optimal time-consistent policy is illustrated in figure 4. Panel (a) shows how the tax varies with the bond position of the economy in "good" states of nature. The tax varies nonlinearly between 0 and 13 percent. Panel (b) shows the time-series dynamics of the tax around crises. The tax rises in the pre-crisis years, from nine percent five years before the crisis, to about 12 percent one year before, then it goes to zero, and then rises again to about five percent by the fourth year after the crisis.

Given the complexity of the optimal policy, Bianchi and Mendoza (2017) examined the performance of two alternative simpler rules. First, a constant (time- and state-invariant) debt tax. Second, a "macroprudential Taylor rule," according to which the debt tax evolves as a log-linear function of the gap between the debt position and a target value of debt with a given elasticity parameter, and it applies only if the implied tax is positive (if the rule returns a subsidy, the tax is set to zero). Bianchi and Mendoza examined alternative formulations of this rule by adding other variables from the model. These formulations perform only marginally better and, since the rule with just the debt is more parsimonious, they focus on this case. The constant tax and the elasticity of the macroprudential Taylor rule are both "optimized," in the sense that the authors identified parameters for each that yield the largest welfare gain. For the constant tax, they identified the one that yields the largest welfare gain in the zero to two percent interval. For the Taylor rule, they searched over pairs of the elasticity and the target debt.

The results show that the constant debt tax, which has an optimized value of 0.6 percent (v. 3.6 percent for the average of the optimal, time-consistent tax), is almost completely ineffective at reducing the magnitude and frequency of crises. Crises occur with 3.6 percent probability (v. 0.02 percent with the optimal policy), and the drops in credit, asset prices, output, and consumption during crises are about the same as without policy. The optimized fixed tax yields a negligible welfare gain of only 0.03 percent, 1/10th the size of the gain under the optimal policy.

Figure 4. Optimal, Time-Consistent Macroprudential Debt Tax



But constant taxes can do much worse. Constant taxes larger than 1.1 percent are actually welfare-reducing, thus indicating that agents are better off in the economy without regulation, living with a four percent probability of a financial crisis than with a permanent debt tax of 1.1 percent. A tax set at the average of the optimal, time-consistent tax would cause a welfare loss of nearly -0.3 percent.

The macroprudential Taylor rule performs better than the constant debt tax, but is still less effective than the optimal policy. It reduces the probability of crisis to 2.2 percent (a little more than half of the crisis probability without policy, but much higher than the 0.02 percent under the optimal policy), it mitigates the drops in macro variables and asset prices more, and it yields a welfare gain of nearly 0.1 percent (v. 0.3 percent under the optimal policy and 0.03 percent with the best constant tax). The average debt tax under this rule is one percent, and it has a correlation with leverage of 0.3, while the optimal, time-consistent tax has a mean of 3.6 percent and a sharply higher correlation with leverage of 0.7. As with constant taxes, however, there are several combinations of the debt target and the elasticity of this rule that reduce social welfare relative to the equilibrium without policy.

The reason why both of these simple rules can be so harmful when their parameter structure is not "optimized" is twofold. First, they can call for taxes that remain in place when they are not needed (i.e., when credit is tight and the credit constraint is binding or almost binding). Second, they can also call for taxes that remain in place or are too high in "very good times," when the constraint can bind only in the distant future, so hampering access to debt is suboptimal. The rationale for these two effects is straightforward, but the magnitude of the quantitative findings is striking. For instance, changing the constant tax from 0.6 to 1.1 percent turns a constant debt tax into a welfare-reducing policy. Hence, these results highlight the relevance of evaluating simple macroprudential rules carefully by using models and solution methods that can capture well the global, nonlinear features of financial amplification.

5. Interactions between Financial and Monetary Policy

A critical issue in the implementation of financial policy in general, and macroprudential policy in particular, is the interaction with monetary policy. Even if financial authorities can construct relatively simple, time-consistent policy rules that seem effective in models of the class we have examined, their actual effectiveness hinges crucially on how monetary policy responds. The instruments that each policy uses have effects on the variables that each policy targets (e.g., management of credit conditions affects inflation, while adjustments of short-term nominal interest rates affect credit conditions), and since the objective functions of monetary and financial authorities generally differ (e.g., monetary authorities focus on inflation, financial authorities focus on credit growth, and both may focus also on the output gap), the potential for inefficiencies resulting from violations of Tinbergen's rule or strategic interaction is evident.

This is an issue regardless of institutional arrangements. In some countries, monetary and financial policies are largely designed and implemented by the central bank, either through a single committee (as in the United States) or separate committees (as in the United Kingdom); in others, the monetary and financial authorities are separate entities (as in Chile); and in others, the central bank is in charge of some but not all of the financial policy decisions (as in Mexico). Regardless of the arrangement, considering the interaction of the two policies is important, because even when both are set within the central bank, the areas or committees in charge of the two policies differ.

The dominant approach to design and evaluate monetary policy in many central banks is to use quantitative neokeynesian DSGE models, typically to conduct inflation targeting with a Taylor rule for a short-term nominal interest rate (the "policy rate"). There are also variants of these models that incorporate financial frictions, often using the Bernanke-Gertler financial accelerator framework following the well-known BGG model proposed by Bernanke and others (1999). As explained in section 1, these models are solved with perturbation methods using first- or second-order local approximations, which can be problematic because important features of the financial amplification mechanism and the design of optimal financial policies that hinge on global, nonlinear effects of financial frictions are not accurately captured. On the other hand, Fisherian models are by necessity parsimonious, because the curse of dimensionality hampers our ability to apply global, nonlinear methods to large-scale models like the central banks' DSGE models. Hence, in this section of the paper, we draw from the work of Carrillo and others (2016) to discuss the interaction of monetary and financial policies by using a variant of the BGG neokeynesian DSGE model with financial shocks proposed by Christiano and others (2014). We acknowledge that the magnitude of the financial amplification created by the Bernanke-Gertler accelerator, and thus the effects of both financial frictions and financial policies, would not match the results of a global solution of the same model, but we make this tradeoff to shed light on the quantitative implications of the interaction between monetary and financial policies.

5.1 Analytical framework

The model used by Carrillo and others (2016) is in the vein of the BGG-DSGE setup with "risk shocks" proposed by Christiano and others (2014). Hence, the model features two sources of inefficiency: First, nominal rigidities in the form of Calvo staggered pricing of differentiated intermediate goods produced under monopolistic competition; second, costly state verification of entrepreneurs returns by financial intermediaries. Risk shocks enter as shocks to the variance of the entrepreneurs' investment projects. These shocks are viewed as "financial shocks" because they have first-order effects on the interest rate that financial intermediaries charge to entrepreneurs, which in turn affects allocations, prices, and welfare *via* the BGG financial accelerator. Carrillo and others (2016) provide the full details of the model structure, so the discussion here focuses on the aspects of the model that drive the interaction between monetary and financial policies, and the quantitative implications for the role of Tinbergen's rule and strategic interaction between the two policies.

For simplicity, Carrillo and others (2016) focus on monetary and financial policies that follow isoelastic rules. The monetary policy literature has studied conditions under which rules of this form can be consistent with optimal Ramsey policy problems or with the optimal policy for policymakers with quadratic loss functions. These conditions are generally violated in monetary policy applications of DSGE models, but still we focus on isoelastic rules because of their prevalent use in policymaking. On the monetary policy side, consider a simple Taylor rule driving the evolution of the policy interest rate:

$$(1+i_t) = (1+i)\left(\frac{1+\pi_t}{1+\overline{\pi}}\right)^{a_\pi} \tag{41}$$

where i is the long-run nominal interest rate, $\overline{\pi}$ is the inflation target and a_π is the elasticity of the Taylor rule with respect to deviations of inflation from its target.

On the financial policy side, the optimality conditions of the optimal contract for the supply of capital to entrepreneurs in the BGG model (corresponding to the problem of maximizing the entrepreneurs expected returns subject to participation constraints of intermediaries for each realization of the risk shock), yield the familiar external financing premium or credit spread. Introducing financial policy into the model, the external financing premium takes this form:

$$E_t\left[\frac{r^k_{t+1}}{R_t}\right] = s\left(\frac{q_t k_t}{n_t}, \sigma_{\omega,t}\right)(1-\tau_{f,t}) \tag{42}$$

In this expression, $r^k{}_{t+1}$ is the real rate of return on capital, R_t is the opportunity cost of investing (the gross real interest rate), q_t is the price of capital, k_t is the aggregate capital of entrepreneurs, n_t is their aggregate net worth (the sum of their aggregate equity plus any labor income they are paid), $\sigma_{\omega,t}$ is the date-t variance of idiosyncratic shocks to the return of entrepreneurs' investment projects (the risk shock), $\tau_{f,t}$ is a subsidy (if positive) or tax (if negative) on the intermediaries' expected returns on loans to entrepreneurs, and $s(.)$ represents the pre-tax external financing premium at which entrepreneurs borrow from financial intermediaries under the optimal Bernanke-Gertler contract. The function $s(.)$ is increasing and convex in the leverage ratio $(q_t k_t / n_t)$, and increasing in $\sigma_{\omega,t.}$

The financial policy rule is given by the following iso-elastic function:

$$\tau_{f,t} = \tau_f\left[E_t\left(\frac{r^k_{t+1}}{R_t}\right)\Big/\left(\frac{r^k}{R}\right)\right]^{a_r} \tag{43}$$

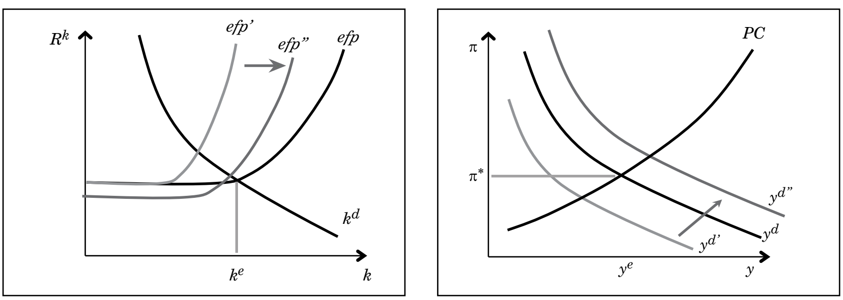
where R is the long-run real interest rate that satisfies $R=(1+i)/(1+\bar{\pi})$, r^k is the long-run gross real of return on capital, and τ_f is a long-run value of the financial tax consistent with attaining the long run value of r^k. The intuition is that with $a_r>0$, increases in the credit spread above its long-run value (in response, for example, to a positive risk shock) induce an increase in the financial subsidy, which results in increases in credit and investment demand to offset the adverse effects of the risk shock.

The interaction between monetary and financial policies can be characterized intuitively with graphs as follows. The essential role of the neokeynesian side of the model is to produce an upward-sloping Phillips curve, which, together with aggregate demand, generates the equilibrium inflation rate and output gap. This is illustrated in panel (a) of figure 5. *PC* is the Phillips curve and y^d is the aggregate demand curve. On the financial side of the model, the Bernanke-Gertler financial accelerator distorts the credit market and the demand for capital goods from entrepreneurs. Their demand for capital follows from a similar Euler equation for assets as the one studied in section 3 which, taking as given asset prices, yields a downward sloping demand curve, because of the decreasing marginal product of capital. The financial intermediaries' supply of funds to entrepreneurs in this market is determined by the BGG external financing premium. These two curves generate the equilibrium capital allocation and rate of return on capital, as illustrated in panel (b) of figure 5. The curve labeled *efp* (external financial premium) represents the supply of capital provided by the funding from financial intermediaries. The curve k^d is the entrepreneurs demand for capital.

Figure 5. Monetary and Financial Policy Interactions

a. Aggregate supply and demand

b. Entrepreneurs capital supply and demand



Assume that a risk shock hits the economy. The financial intermediaries' supply curve shifts inward to *efp*, because of the effect of the higher variance of idiosyncratic shocks to entrepreneurs' returns on the optimal credit contract. This reduces the equilibrium allocation of capital and increases its rate of return. In turn, the lower demand for capital shifts aggregate demand inward to $y^{d'}$, thus reducing inflation and output. Therefore, the financial shock has effects on all macroeconomic aggregates, including those that monetary and financial policies target.

If monetary policy is implemented without financial policy, the aim would be to reduce i so as to offset the declines in inflation and output. Ideally, the policy would seek to return output and inflation to their targets, but for some arbitrarily-specified Taylor rule the idea would be to shift aggregate demand outward, say to $y^{d''}$. Because of the Bernanke-Gertler costly-state-verification friction, however, the lower i and higher expected inflation reduce the real interest rate, and this shifts the supply of capital outward to *efp"*, and thus alters equilibrium in the capital market and the credit spread, which the financial authority cares for. On the other hand, if financial policy is implemented without monetary policy, financial policy would be relaxed (i.e., $\tau_{f,t}$ rises) so as to shift the supply of funds outward. Ideally, the policy would seek to restore the target spread and capital levels, but for an arbitrary elasticity of the financial tax rule, the shift is to *efp"* (to keep the plots simple, we assume it is the same shift as in the monetary policy example). As investment demand rises, however, aggregate demand shifts outward (again for simplicity it is also a shift to $y^{d''}$) and the equilibrium inflation and output, which the monetary authority cares for, change. In short, since $E_t\left(r_{t+1}^k/R_t\right)/\left(r^k/R\right)$ and $(1+\pi_t)/(1+\overline{\pi})$ are general equilibrium outcomes that depend on $(i_t,\tau_{f,t})$, the actions of one policy authority affect the target variable and payoff of the other.

The above arguments raise two key issues. First, assuming that the goal is to maximize social welfare, Tinbergen's rule applies, i.e., using two separate instruments (i_t and $\tau_{f,t}$) to target two variables (inflation and the credit spread) should be at least as good as using a single instrument to target both variables. Intuitively, there are two inefficiencies in the economy, sticky prices and costly state-verification, and using one policy instrument to tackle each should be (weakly) better than a single instrument trying to tackle both. Second, if monetary and financial authorities have different payoff functions, a suboptimal policy mix will result, because of inefficient strategic interaction. Hence, a cooperative equilibrium with coordination of financial and monetary authorities dominates a non-cooperative regime. Analytically, the two issues are straightforward applications of standard findings from the literature on Tinbergen's rule and strategic interaction in economic policy. The main concern is whether these are quantitatively relevant issues.

5.2 Quantitative Findings

We omit the full details of the model structure, functional forms, and parameter calibration of the model, which are provided in the Carrillo and others (2016) study. The calibration was done for the United States, at a quarterly frequency, and several parameter values were taken from the model estimation in the work of Christiano and others (2014), with the parameters of the financial accelerator structure taken from Bernanke and others (1999). It is also important to note that the model is solved with a second-order approximation in order to obtain more accurate welfare assessments. The emphasis in the discussion below is on the main results related to Tinbergen's rule and strategic interaction of financial v. monetary policies.

In order to evaluate these two issues quantitatively, we need to define the welfare effects of alternative policy regimes. As in the previous exercises measuring the welfare effects of debt taxes, we follow again the standard Lucas approach to measure welfare as a compensating (time- and state-invariant) change in consumption that equates welfare under a policy regime v. a baseline benchmark. In this case, we define the benchmark as the deterministic stationary state of the economy, because by construction, this steady state is independent of the elasticities of the monetary and financial policy rules. Moreover, by parameterizing the intercept coefficients of the policy rules, the deterministic steady state is constructed so that the real effects of the nominal rigidities and the financial friction wash out, and this makes the deterministic steady state Pareto efficient. Thus, the welfare effect of a particular policy regime is the percentage increase in consumption needed to make individuals indifferent between expected lifetime utility under that policy regime and lifetime utility in the deterministic steady state. Larger increases indicate larger welfare losses.

To examine the quantitative relevance of Tinbergen's rule, the goal is to compare an environment with separate monetary and financial policy rules as described earlier, with one in which there is only a monetary policy rule but augmented to include financial stability considerations. In particular, this monetary rule takes this form:

$$(1+i_t) = (1+i)\left(\frac{1+\pi_t}{1+\bar{\pi}}\right)^{\hat{a}_\pi}\left[E_t\left(\frac{r^k_{t+1}}{R_t}\right)\Big/\left(\frac{r^k}{R}\right)\right]^{-\hat{a}_r}. \tag{44}$$

Notice that, in this rule, the coefficient on the credit spread, $\hat{a}_r$, enters with a negative sign, indicating that when the spread rises, the interest rate falls to help offset the adverse effect on aggregate demand due to the fall in investment.

Carrillo and others (2016) computed the elasticity pairs under the two-rule regime (a_π,a_r) with policy rules (41) and (43), and under the one-rule regime ($\hat{a}_\pi, \hat{a}_r$) with policy rule (44), that minimize the social welfare loss relative to the deterministic steady state. The resulting elasticities are (a_π, = 1,2 a_r = 1,6) v. ($\hat{a}_\pi = 1{,}25, \hat{a}_r = 0{,}26$), and social welfare is 34 percent higher under the two-rule regime than under the one-rule regime. Notice that both monetary and financial policies are “too tight” under the latter, with a response to inflation that increases the interest rate by more than under the two-rules regime and a response to the spread that does not relax financial conditions enough.[17] Financial policy in particular is significantly tighter. These differences result in significant differences in impulse response functions in response to a risk shock[18]. In particular, comparing the one-rule regime v. the two-rule regime, output (investment) at its trough falls 30 (115) basis points below the deterministic steady state v. less than 20 (50) basis points, equity prices fall 200 basis points v. less than 100 basis points, and the time series dynamics of consumption are significantly smoother with the two rules. In short, aiming to expand the Taylor rule to target the credit spread together with inflation targeting results in a quantitatively significant violation of Tinbergen’s rule.

Consider next the quantitative implications of strategic interaction. To this end, we need to spell out the payoff functions of policy authorities. If financial and monetary authorities have the same payoff function

17. The elasticity coefficients on the credit spread in (43) and (44) are comparable because condition (42) can be rewritten as $E_t[r^k{}_{t+1}]E_t[1+\pi_{t+1}]=s(t)(1-\tau_{f,t})(1+i_t)$, so increasing the financial subsidy or reducing the interest rate have isomorphic effects on the supply-of-capital condition. The connections between policy instruments and targets of monetary and financial policies are also evident in this expression.

18. See figure 3 in Carrillo and others, 2016.

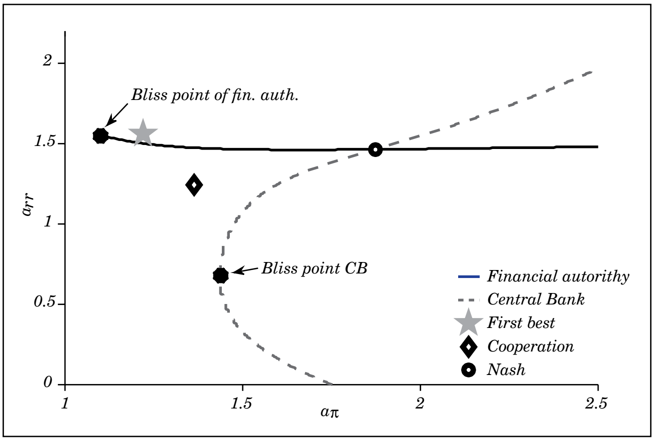
(whether social welfare or minimizing a common loss function), there is obviously no conflict, in the sense that a Nash game in which each policy authority chooses the elasticity of its rule taking as given the elasticity of the rule of the other authority yields the same outcome as a cooperative equilibrium.[19] When the payoff functions differ, however, the results are very different as documented below.

Define the payoff functions following Williams (2010), so that each policy authority aims to minimize a loss function defined by the sum of the variances of their target and instrument variables (i.e., for the central bank, the sum of the variances of inflation and the policy interest rate; for the financial authority, the sum of the variances of the credit spread and the financial tax). Carrillo and others (2016) compute reaction functions in the (a_π, a_r) space, with the central bank choosing the Taylor elasticity coefficient that minimizes its loss function for a given value of the financial subsidy elasticity, $a_\pi^*(a_r)$, and the financial authority choosing the financial subsidy elasticity that minimizes its loss function for a given value of the Taylor elasticity, $a_r^*(a_\pi)$. The Nash equilibrium is the intersection of these reaction curves, and the cooperative equilibrium is the pair (a_π, a_r) that minimizes the equally-weighted sum of the two loss functions. Figure 6 shows the reaction curves of the monetary authority (dashed curve) and of the financial authority (continuous curve), together with the Nash and cooperative equilibria, and in addition it shows the bliss points of each authority and the "first best" point at which social welfare is maximized (instead of the joint loss function minimized as in the cooperative equilibrium).

The Nash equilibrium yields a welfare loss of -7.26 percent relative to the first best, while the welfare loss in the cooperative equilibrium is -1.31 percent. Hence, failure to coordinate policies has a large social cost. The social benefit of cooperation by monetary and financial authorities is roughly six percentage points. Moreover, as the figure indicates, the Nash equilibrium yields policies that are "too tight" relative to the cooperative equilibrium. In the former, the elasticities of the monetary and financial rules are $(a_\pi = 1.9, a_r = 1.4)$, while in the latter they are $(a_\pi = 1.35, a_r = 1.25)$.

19. The games Carrillo and others (2016) solve are one-shot games in which payoffs are defined by the welfare costs of choices of the policy rule elasticities (i.e., the payoffs take into account the short- and long-run effects of changing the elasticities on equilibrium prices and allocations).

Figure 6. Reaction Curves, Cooperative and Nash Equilibria



It is also important to note that the nonlinear shape of the reaction curves is indicative of shifting preference by the policy authorities for adjusting the elasticities of their policy rules as strategic complements v. strategic substitutes. In particular, the reaction curve of the monetary rule changes from adjusting a_{π} as a strategic substitute for a_r if $a_r < 0.7$, to adjusting it as a strategic complement if a_r rises above 0.7. The reaction curve of the financial authority is slightly convex but always consistent with strategic substitutes.

6. Conclusions

Macroprudential policy holds the promise of becoming a powerful and effective tool to reduce the magnitude and frequency of financial crises, thereby increasing social welfare. This is a theoretical and quantitative prediction that follows from several studies based on Fisherian models of financial crises (i.e., models in which borrowing capacity is linked to market-determined collateral values *via* occasionally binding credit constraints). Financial amplification, defined as larger responses of macroeconomic aggregates to shocks of standard magnitudes when the collateral constraint binds, is significant, and results in model-generated financial crises broadly consistent with actual financial crises. Market failure, in the form of pecuniary externalities because private agents do not internalize the effect of their borrowing choices on collateral values, justifies policy intervention in order to bring private marginal costs of borrowing in line with social marginal costs. Quantitatively, optimal financial policies designed to maximize social welfare taking these externalities into account reduce the probability and severity of financial crises sharply. Hence, in calibrated Fisherian models, optimal macroprudential policies have proven to be very effective.

In practice, however, effective implementation of Fisherian policies has to cope with three important limitations discussed in this paper:

- The optimal policy in Fisherian models is a complex time- and state-contingent policy that follows a non-linear pattern of adjustment depending on the phase of the credit cycle and on the size of domestic and external shocks hitting the economy. In particular, optimal financial policies vary widely across values of external shocks in the form of fluctuations in world interest rates, global liquidity conditions, and news about global fundamentals.
- If collateral values hinge on expectations of future outcomes, the optimal policy under commitment is time-inconsistent, and hence the credibility of financial authorities is called into question. Fisherian models can be upgraded to design and evaluate optimal, time-consistent policies. The resulting policies are again very effective but also very complex. Simple policy rules optimized to generate the largest welfare gain are much less effective than the optimal policies, and setting the parameters of simple rules without optimizing them in this way can result in significant welfare losses that make agents worse off than in an economy left to suffer deep financial crises with low probability and no policy intervention.
- The interaction of monetary and financial policies in the determination of equilibrium allocations and prices that the authorities in charge of each policy care about raises well-known issues related to Tinbergen's rule and strategic interaction. These issues are quantitatively significant. Using monetary policy with a Taylor rule augmented with financial stability considerations is significantly inferior to using separate monetary and financial policy rules. Strategic interaction in the setting of elasticities of separate financial and monetary rules results in equilibria that are significantly inferior to cooperative equilibria. Both the use of an augmented monetary rule and the non-cooperative setting of separate financial and monetary rules produce environments in which policies are too tight relative to optimal or cooperative regimes.

There are other important obstacles that the design of effective macroprudential policy still has to face and that this paper did not examine. Heterogeneity in borrowers and lenders is a critical issue. The research discussed in this paper is all based on representative-agent settings. In practice, the financial conditions and the vulnerability to shocks varies widely across lenders and borrowers of various types. The optimal policy, therefore, is very likely to display additional complexity, as it will need to vary across the cross-section of agents. For the same reason, simple rules present additional challenges, because even if rules are made time-varying, they can still be inefficient and welfare-reducing because of large adverse effects for subsets of agents. Other important issues include interactions with other financial frictions in addition to Fisherian collateral constraints (e.g., moral hazard or informational frictions) and international implications such as the optimal design of financial policies that apply to domestic v. external credit relationships (e.g., capital controls) and the international coordination of financial policies.

References

Aiyagari, S.R. and M. Gertler. 1999. "'Overreaction' of Asset Prices in General Equilibrium." *Review of Economic Dynamics* 2(1): 3–35.

Benigno, G., H. Chen, C. Otrok, A. Rebucci, and E.R. Young. 2013. "Financial Crises and Macro-Prudential Policies." *Journal of International Economics* 89(2): 453–70.

Bernanke, B. 2010. "Causes of the Recent Financial and Economic Crisis, before the Financial Crisis Inquiry Commission." September 2, 2010. Washington, DC: Board of Governors of the Federal Reserve System.

Bernanke, B. and M. Gertler. 1989. "Agency Costs, Net Worth, and Business Fluctuations." *American Economic Review* 79(1): 14–31.

Bernanke, B., M. Gertler, and S. Gilchrist. 1999. "The Financial Accelerator in a Quantitative Business Cycle Framework." *Handbook of Macroeconomics*, vol. 1, edited by J.B. Taylor and M. Woodford.

Bianchi, J. 2011. "Overborrowing and Systemic Externalities in the Business Cycle." *American Economic Review* 101(7): 3400–26.

Bianchi, J., C. Liu, and E.G. Mendoza. 2016. "Fundamentals News, Global Liquidity and Macroprudential Policy." *Journal of International Economics* 99(1): 2–15.

Bianchi, J. and E.G. Mendoza. 2010. "Overborrowing, Financial Crises and 'Macroprudential' Policy." NBER Working Paper No. 16091, *http://www.sas.upenn.edu/~egme/wp/w16091.pdf*.

———. 2017. "Optimal Time-Consistent Macroprudential Policy." Forthcoming, *Journal of Political Economy*, *http://www.sas.upenn.edu/~egme/wp/w19704.pdf*.

Borio, C. 2003. "Towards a Macroprudential Framework for Financial Supervision and Regulation?." *CESifo Economic Studies* 49(2): 181–216.

Carrillo, J., E.G. Mendoza, V. Nuguer, and J. Roldán-Peña. 2016. "Tight Money-Tight Credit: Tinbergen's Rule and Strategic Interaction in the Conduct of Monetary and Financial Policies." Unpublished Manuscript, Bank of Mexico.

Christiano, L.J., R. Motto, and M. Rostagno. 2014. "Risk Shocks." *American Economic Review* 104(1): 27–65.

De Groot, O., B. Durdu, and E.G. Mendoza. 2016. "Global v. Local Methods in the Quantitative Analysis of Open-Economy Models with Incomplete Markets." Unpublished Manuscript, University of Pennsylvania.

Durdu, C.B., E.G. Mendoza, and M.E. Terrones. 2009. "Precautionary Demand for Foreign Assets in Sudden Stop Economies: An Assessment of the New Merchantilism." *Journal of Development Economics* 89(2): 194–209.

Durdu, C.B., R. Nunes, and H. Sapriza. 2013. "News and Sovereign Default Risk in Small Open Economies." *Journal of International Economics* 91(1): 1–17.

Eaton, J. and M. Gersovitz. 1981. "Debt with Potential Repudiation: Theoretical and Empirical Analysis." *Review of Economic Studies* 48(2): 289–309.

Fisher, I. 1933. "The Debt-Deflation Theory of Great Depressions." *Econometrica* 1(4): 337–57.

Forbes, K.J. and F.E. Warnock. 2012. "Capital Flow Waves: Surges, Stops, Flight and Retrenchment." *Journal of International Economics* 88(2): 235–51.

Fuerst, T.S. 1992. "Liquidity, Loanable Funds, and Real Activity." *Journal of Monetary Economics* 29(1): 3–24.

Gertler, M., S. Gilchrist, and F.M. Natalucci. 2007. "External Constraints on Monetary Policy and the Financial Accelerator." *Journal of Money, Credit, and Banking* 39(2-3): 295–330.

Greenwood, J., Z. Hercowitz, and G. Huffman. 1988. "Investment, Capital Utilization and the Real Business Cycle." *American Economic Review* 78(3): 402–17.

Hernández, J. and E.G. Mendoza. 2017. "Optimal v. Simple Financial Policy Rules in a Production Economy with 'Liability Dolarization'." Forthcoming, *Ensayos Sobre Política Económica*.

Jeanne, O. and A. Korinek. 2010. "Managing Credit Booms and Busts: A Pigouvian Taxation Approach." NBER Working Paper No. 16377.

Kiyotaki, N. and J. Moore. 1997. "Credit Cycles." *Journal of Political Economy* 105(2): 211–48.

Korinek, A. 2011. "Excessive Dollar Borrowing in Emerging Markets: Balance Sheet Effects and Macroeconomic Externalities." Unpublished manuscript, University of Maryland.

Mendoza, E.G. 2002. "Credit, Prices, and Crashes: Business Cycles with a Sudden Stop." *Preventing Currency Crises in Emerging Markets*, edited by S. Edwards and J. Frankel, NBER: University of Chicago Press.

———. 2005. "Real Exchange Rate Volatility and the Price of Nontradable Goods in Economies Prone to Sudden Stops." *Economia,* Fall.

———. 2010. "Sudden Stops, Financial Crisis, and Leverage." *American Economic Review* 100(5): 1941–66.

Mendoza, E.G. and V. Quadrini. 2010. "Financial Globalization, Financial Crises and Contagion." *Journal of Monetary Economics* 57: 24-39.

Mendoza, E.G. and K.A. Smith. 2006. "Quantitative Implications of a Debt-deflation Theory of Sudden Stops and Asset Prices." *Journal of International Economics* 70(1): 82–114.

———. 2014. "Financial Globalization, Financial Crises, and the External Portfolio Structure of Emerging Markets." *Scandinavian Journal of Economics* 116(1): 20–57.

Mendoza, E.G., and M.E. Terrones. 2012. "An Anatomy of Credit Booms and Their Demise." NBER Working Paper No. 18379.

Merton, R.M. 2009. "Observations on the Science of Finance in the Practice of Finance." Muh Award Lecture, Massachusetts Institute of Technology, Cambridge, MA., March.

Ottonello, P. 2015. "Optimal Exchange-Rate Policy under Collateral Constraints and Wage Rigidity." Unpublished Manuscript, University of Michigan.

Schmitt-Grohe, S. and M. Uribe. 2017. "Multiple Equilibria in Open Economy Models with Collateral Constraints: Overborrowing Revisited." Forthcoming, *Ensayos Sobre Política Económica*.

Shin, H.S. 2013. "The Second Phase of Global Liquidity and Its Impact on Emerging Economies." Mimeographed, Princeton University.

Williams, J.C. 2010. "Monetary Policy in a Low Inflation Economy with Learning." *FRBSF Economic Review*: 1–12.

Monetary Policy Transmission in Emerging Markets: An Application to Chile

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A critical question for emerging-market policymakers is how to adjust to monetary policy changes in the center. A core tenet of modern macroeconomic theory is that countries should let their exchange rate float when financial conditions abroad change. This allows the nominal and real exchange rates to absorb the brunt of the required adjustment. This is the standard Mundell-Fleming prescription for floating exchange rates. Accordingly, when the U.S. Federal Reserve tightens its policy, a country like Chile should let its currency depreciate. Under the standard analysis, the Fed tightening slows down economic activity in the U.S., thus depressing the demand for Chilean exports. The depreciation of the peso offsets partly, or even fully, this negative impulse, thus helping to prop up the Chilean economy.

A number of policymakers and academics have recently challenged that view. On the policy side, some emerging-market decision makers have complained about the effect of U.S. monetary policy on their economy. When, on August 27, 2010, Chairman Bernanke announced that the Federal Reserve would pave the way for a second round of quantitative easing, capital flows to emerging markets surged and their currencies strongly appreciated. Policymakers in these countries

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feared, not that their economy would enter a recession, but instead that it would overheat. Conversely, when, on May 22, 2013, Chairman Bernanke announced that the Federal Reserve would take a step down in the pace of asset purchases (the so-called tapering), markets also reacted strongly, with capital flowing out of many emerging-market economies whose currencies depreciated precipitously. Again, instead of expecting a domestic boom driven by a surge in exports, policymakers in the region worried that their economy would slump.

On the theory side, the excellent work of Hélène Rey in her Jackson Hole lecture (Rey, 2013) and subsequent writings, has pushed forward the idea that flexible exchange rates cannot insulate economies from the global financial cycle. In her analysis, the appreciation of the currency that follows a monetary easing at the center strengthens domestic balance sheets, encourages leverage and credit growth, thus boosting economic activity in the periphery. Conversely, the depreciation that follows a monetary tightening at the center weakens domestic balance sheets, forces deleveraging and limits credit growth, thus weakening economic activity in the periphery. Currency movements and capital inflows reinforce each other, leading to potentially excessive credit cycles in emerging-market economies. In such an environment, monetary impulses originating in the center amplify the global financial cycle and transmit it positively to the periphery: tighter U.S. monetary policy is contractionary abroad too.

What should emerging-market policymakers do? Clearly, if depreciations are contractionary and appreciations expansionary, a floating currency may not provide much insulation. Yet, it does not follow that a fixed exchange rate is preferable to a floating one. The reason is that a fixed exchange rate, under capital mobility, requires a domestic monetary policy stance that mimics the center. But the transmission of a *domestic* monetary policy impulse to the domestic economy may still operate as usual. In that case, the best response to a tightening in the center that causes a recession in the periphery is to ease monetary policy. The fact that the domestic currency depreciate even more as a byproduct is irrelevant. What does matter is the net transmission of domestic monetary policy. If, instead, domestic authorities peg their currency, they will be forced to mimic the contractionary policy of the center, which will result in a domestic recession.

The above argument would break down if a domestic monetary tightening were instead expansionary. In that case, the optimal response to the tightening in the center would be a tightening in the periphery, as the latter would counteract the contractionary impulse from the center. A number of policymakers, e.g., Gudmundsson (2017) or Başçı and others (2008) make such a claim. Such a “perverse” transmission of monetary policy could occur if financial spillovers from asset prices and currency movements were so strong as to overcome the usual channels of monetary policy: as monetary authorities tighten policy, the induced capital inflows, the appreciation of the domestic currency, and the relaxation of borrowing constraint would lead to an expansion of economic activity, despite higher real interest rates.

The purpose of this paper is to clarify these issues in two steps. First, section 1 presents a simple Mundell-Fleming-inspired model of a small open economy with financial spillovers. It describes the different channels through which a monetary impulse in the center, or in the country, is transmitted to the economy. Conceptually, the model highlights three different channels through which U.S. monetary policy affects the domestic economy. First, when the U.S. tightens monetary policy, the demand for home goods falls because U.S. aggregate demand declines. Second, under floating rates, a tightening of U.S. monetary policy causes a depreciation of the domestic currency against the U.S. dollar. Under the usual conditions, this depreciation stimulates domestic aggregate demand. Third, the depreciation may reduce the collateral value of domestic assets, and tighten the balance sheet of domestic financial intermediaries, thus leading to a sequence of develeraging and decline in credit, which adversely affects economic activity in the periphery.

Within this very stylized model, the paper establishes that the sign of the transmission of monetary policy (both center and periphery) depends on the strength of the financial spillovers. When financial spillovers are moderate or nil, the model boils down to the standard Mundell-Fleming framework: a Fed tightening is expansionary abroad, as in Krugman (2014)’s analysis. When financial spillovers are intermediate, U.S. monetary policy is transmitted positively: everything else equal, a Fed tightening causes a recession abroad due to the interaction between U.S. monetary policy and the financial cycle. But domestic monetary policy, while less effective, still operates in a normal way. In order to stabilize output, it is optimal to lower domestic policy rates, i.e., to let the domestic currency depreciate even further. Thus, in this intermediate case, the classic trilemma still operates in the sense that flexible exchange rate are optimal. Finally, when financial spillovers are sufficiently severe, the transmission of domestic monetary policy becomes “perverse”: a domestic tightening is expansionary. In that case, stabilizing output requires limiting currency fluctuations.

Which case is the relevant one for an emerging-market economy? Sections 2 and 3 attempt to answer this question. Section 2 presents a standard New Keynesian model of a small open economy that allows for financial spillovers: in the model, some households face a borrowing limit that depends on the level of the real exchange rate. An appreciation of the domestic currency, by increasing the collateral of domestic agents, raises this borrowing limit. The model also features a working capital constraints, so that increases in interest rates raise the marginal cost of production for firms, as well as dominant currency pricing, in the sense of Casas and others (2016) and a commodity sector dedicated to exports, as is the case for many emerging-market economies such as Chile. The model validates the insights from the simple Mundell-Fleming set-up: the transmission of both U.S. and domestic monetary policy depends on the strength of the financial spillovers.

Section 3 estimates the previous model with Bayesian techniques using data for Chile between 1999 and 2015. The key question of interest is: how strong are financial spillovers? The answer, at least for the case of Chile and through the lens of this particular model, is that financial spillovers are intermediate. It follows that the concern of emerging-market policymakers is valid: a tightening in the center transmits a contractionary impulse to their country, via the depreciation of their currency and the amplification via the global financial cycle. But this finding does not overturn the basic conclusion of the Mundell-Fleming analysis: the transmission of domestic monetary policy is not perverse and, therefore, flexible exchange rates remain the primary line of defense against foreign monetary policy and global financial cycles alike.

This paper touches upon a number of literatures. First, there is an abundant literature on financial spillovers in emerging-market economies, the global financial cycle and the Mundellian trilemma/dilemma. Recent contributions include Borio and Zhu (2012), Bruno and Shin (2014, 2015), Farhi and Werning (2014), Aoki and others (2015), Blanchard (2016), Devereux and others (2015), Rey (2013), and Taylor and Obstfeld (2017). The paper also borrows from the literature on open economy New Keynesian models and estimation of these models with Bayesian methods. Key references include Galí (2008), Galí and Monacelli (2005), Iacoviello (2015), Mendoza (2010), Gourinchas and others (2016), and An and Schorfheide (2007). Finally, the paper borrows from the recent literature on the dominant currency paradigm, e.g., Casas and others (2016), Gopinath (2015), Gopinath and Itskhoki (2010), and Devereux and others (2007).

Section 1 presents the simple Mundell-Fleming-style model. Section 2 presents the full fledged New Keynesian model of a small open emerging-market economy. Section 3 estimates the model for Chile and section 4 concludes.

1. A Simplified Model in the Spirit of Mundell-Fleming

This section explores the different channels of transmission of domestic and U.S. monetary policy using a deliberately old-fashioned Mundell-Fleming framework, modified to allow for financial spillovers and risk premia. The model is similar to Blanchard (2016) and Bernanke (2017). The pros and cons of such a simplified model are well-known: what it lacks in micro-foundations and intertemporal trade-offs, we hope to gain in simplicity and clarity of exposition. This is perfect for our purpose, which is to build intuition for the different channels of transmission of U.S. and domestic monetary policy. The next section performs a fuller investigation by using a state-of-the-art dynamic stochastic general equilibrium model, estimated with Bayesian methods on Chilean data.

The model has two countries: a small domestic economy and a large foreign country (the U.S.). Foreign variables are denoted by a star. Domestic and foreign output are determined by the following system of equations:

$$Y = A + NX \tag{1a}$$

$$A = \xi - cR - fE \tag{1b}$$

$$NX = a(Y^{*} - Y) + bE \tag{1c}$$

$$Y^{*} = A^{*} = \xi^{*} - cR^{*} \tag{1d}$$

$$E = d(R^{*} - R) + \chi \tag{1e}$$

Domestic output Y is equal to the sum of domestic absorption A and net exports NX. Domestic absorption depends on an aggregate demand shifter ξ, which includes, among other things, the stance of fiscal policy. It also depends (negatively) on the domestic policy rate R. We assume that absorption is also negatively impacted by a depreciation of the nominal exchange rate E.[1] This captures any *financial spillover* that arises via movements in the exchange rate. For instance, a depreciation of the domestic currency could tighten collateral constraints by reducing the foreign currency value of domestic assets, thus inducing a domestic credit crunch. It could also impact aggregate demand via a decline in domestic wealth, relative to foreign wealth. The parameter $f \geq 0$ captures, in a simple way, the strength of these spillovers, with $f = 0$ corresponding to the usual Mundell-Fleming case.

Net exports NX depend positively on U.S. output Y^*, negatively on domestic output Y, and positively on the exchange rate E. U.S. output is determined similarly, with the modification that the U.S. is assumed large relative to the foreign country and can therefore be treated as a closed economy: U.S. output equals U.S. absorption A^*, which depends positively on the U.S. aggregate demand shifter ξ^* and negatively on the U.S. policy rate R^*.

Finally, as in Blanchard (2016), we assume that the exchange rate depends on the difference between the foreign and domestic policy rates $R^* - R$, as well as on a risk premium shock χ. The first term captures the determinants of the exchange rate under Uncovered Interest Parity (UIP). The second captures deviations from UIP due to changes in risk premia. A higher U.S. policy rates relative to the domestic rate tends to depreciate the domestic currency, with the coefficient d measuring the expected duration of the interest rate differential. An increase in domestic risk premium χ also forces an immediate depreciation of the currency. In line with the recent literature on the role of U.S. monetary policy for the global financial cycle, we assume that χ is positively correlated with the U.S. policy rate R^*. We make this dependency explicit by writing $\chi(R^*) = gR^* + \chi$ With $g > 0$ and χ representing autonomous movements in risk premia.

All coefficients $a \ldots g$ are weakly positive. Absent shocks, all variables, including output, the trade balance, the policy rates, and the exchange rate, are normalized to zero. Solving the model yields the following expression for domestic output as a function of the demand shocks (ξ and ξ^*), the risk premium χ, domestic and U.S. policy rates R and R^*.

$$Y = \frac{1}{1+a}\left[\left(\xi + a\xi^*\right) + (b-f)\chi + ((f-b)d - c)R + ((b-f)(d+g) - ac)R^*\right] \quad (2)$$

1.We adopt the convention that an increase in E represents a depreciation of the domestic currency.

1.1 The International Transmission of U.S. Monetary Policy

Equation (2) encapsulates the various channels through which U.S. monetary policy affects the domestic economy. Consider first the standard Mundell-Fleming case $f = g = \chi = 0$. Whether a U.S. monetary policy tightening is expansionary or contractionary at home depends on the sign of $bd–ac$. The intuition is simple: bd captures the effect of a U.S. monetary tightening via the depreciation of the domestic currency, which stimulates the trade balance (the "trade channel" of exchange rates); ac captures the effect of the U.S. tightening via lower U.S. aggregate output, which depresses domestic exports. Thus, $bd–ac$ captures the effect of a U.S. tightening on the domestic trade balance. As is well-known, it is possible, within the traditional Mundell-Fleming framework, for a U.S. tightening to be contractionary at home (i.e., to contract the domestic trade balance), if the effect of lower economic activity in the U.S. dominates the effect of a more depreciated domestic currency.

U.S. monetary policy has two additional effects on domestic output when f or g are strictly positive. First, the term $-fd$ captures the negative impact of the depreciation of the domestic currency on absorption via financial spillovers. This is the "financial channel" of exchange rates, opposite in sign to the trade channel bd. Second, the term $(b - f)g$ reflects the impact of rising risk premia due to the U.S. tightening (risk off): a higher risk premium depreciates the exchange rate, with a stimulative direct effect bg via the trade balance. This is the effect emphasized by Krugman (2014): absent financial spillovers, an increase in risk premia is good news for domestic output. The terms $-fg$ represents the offsetting effect due to financial spillovers. It is immediate from (2) that the effect of U.S. monetary policy on the global financial cycle ($g > 0$) simply amplifies the role of U.S. monetary policy on domestic output from d to $d + g$.

The overall effect of U.S. monetary policy on home output depends on the strength of financial spillovers. To fix ideas, suppose that $bd - ac > 0$, so that a U.S. monetary policy tightening would expand domestic output in a Mundell-Fleming world. It is immediate to verify that the same U.S. monetary tightening becomes contractionary at home if $f > \underline{f}$ where

$$\underline{f} = b - \frac{ac}{d+g} > 0. \tag{3}$$

That condition is less likely to be satisfied the stronger the impact of U.S. rates on exchange rates (d) and the stronger the global financial cycle (g). For future use, we define $\phi_{R^*} \equiv \partial Y / \partial R^* = ((b-f)(d+g)-ac)/(1+a) = (d+g)(\underline{f}-f)/(1+a)$ as the partial response of output to U.S. policy rates.

1.2 The (Perverse) Transmission of Domestic Monetary Policy

Let us now consider the transmission of domestic monetary policy to the home economy. The analysis is simpler, since a change in the stance of domestic monetary policy has no effect abroad, under our small open economy assumption. According to (2), an increase in the domestic policy rate R affects domestic output through three channels. First, it directly reduces domestic absorption ($-c$). Second, the domestic currency appreciates, which dampens further aggregate demand via the trade balance ($-db$). Lastly, the appreciation stimulates aggregate demand via financial spillovers (fd).

While the first two effects are contractionary, the last one is expansionary. Could the net effect also be expansionary, i.e., could a monetary policy tightening be "perversely" expansionary? For this to be the case, financial spillovers need to be strong enough to overcome the usual channels of transmission of domestic monetary policy. In that scenario, a central bank tightening its policy rate would find itself faced with a wave of net capital inflows, a strongly appreciating currency, and an increase in aggregate demand...

In recent years, the possibility that monetary policy transmission may indeed be "perverse" has been more than a theoretical curiosum. Many policymakers in small open economies have complained that attempts to cool their economy by raising the policy rate were thwarted and ultimately counterproductive: higher domestic rates attracted foreign capital, appreciating the currency, increasing domestic wealth, relaxing borrowing constraints, and pushing the economy ahead. Gudmundsson (2017) for Iceland, or Başçı and others (2008) for Turkey essentially make this point.

Within the context of our simple model, a perverse transmission of domestic monetary policy occurs when $f > \overline{f}$ where

$$\overline{f} = b + \frac{c}{d}. \tag{4}$$

This condition is more likely to hold the more responsive exchange rates are to interest rates (higher d) and the lower the aggregate demand effect of monetary policy is (lower c). Further, a direct comparison of (3) and (4) reveals that $\bar{f} > \underline{f}$. It follows immediately that the transmission of domestic monetary policy can only be perverse if a U.S. monetary tightening has a contractionary impact on the domestic economy ($f > \bar{f}$ implies $f > \underline{f}$), while the reverse is not true. For future use, we define $\phi_R \equiv \partial Y / \partial R = ((f - b)d - c) / (1 + a) = d(f - \bar{f}) / (1 + a)$ as the partial response of domestic output to the domestic policy rate. Note that $\phi_R < 0$ under "standard" monetary policy transmission while $\phi_R > 0$ under a "perverse" monetary transmission.

1.3 Optimal Monetary Policy

Let us assume that home cares about output deviations from steady state, and may also care about the trade balance as in Bernanke (2017). Specifically, let us consider the following ad-hoc loss function:

$$L \equiv \frac{1}{2}\mathbb{E}Y^2 - \alpha\mathbb{E}NX \qquad (5)$$

where $\mathbb{E}$ denotes the expectation operator. The coefficient $\alpha > 0$ measures the importance of a possible "mercantilist" motive, i.e., the weight given by the small open economy policymaker to the trade balance above and beyond its effect on aggregate demand. Given our small country assumption, we assume that the domestic policymaker takes U.S. shocks and policies (ξ^*, R^*) and output Y^* as given when setting its own policy rate R so as to minimize L.

Under perfect foresight, the optimal level of output satisfies:

$$Y^o = -\alpha\left[a + \frac{bd}{\phi_R} \right]. \qquad (6)$$

When $\alpha = 0$, it is immediate that $Y^0 = 0$, i.e., the policymaker does not distort output away from its potential value. When $\alpha > 0$ the policymaker typically distorts output in order to enjoy a larger trade surplus. Whether this will be associated with a higher or lower level of output depends on the response of output to the domestic policy rate, i.e., on the nature of the transmission of monetary policy. In the standard case where $\phi_R < 0$, the desire to run trade surpluses will push output above potential ($Y^o > 0$): stimulating the trade balance requires depreciating the currency by cutting the policy rate which stimulates output.[2] When monetary policy transmission is "perverse" ($\phi_R > 0$),

2.This is true when $bd - ac > 0$, as was assumed above.

stimulating the trade balance still requires depreciating the currency by cutting the policy rate, but this now negatively affects output ($Y^o < 0$).

From equation (2) and (6), we can solve for the optimal policy rate:

$$R^o = \frac{1}{\phi_R}\left[Y^o - \frac{\xi + a\xi^*}{1+a} - \frac{b-f}{1+a}\chi - \phi_{R^*} R^* \right]. \qquad (7)$$

The first term inside the brackets captures the impact of the mercantilist motive on the policy rate. Because, as discussed above, Y^o and ϕ_R have opposite signs, a mercantilist motive always leads to lower policy rates: $Y^o/\phi_R < 0$. On the other hand, the optimal policy response to aggregate demand shocks ($\xi + a\xi^*$), risk premium shocks (χ), and foreign policy rate (R^*) depends on whether the transmission of monetary policy is "standard" ($\phi_R < 0$) or "perverse" ($\phi_R > 0$). In particular, the optimal pass-through from center policy rate R^* to domestic policy rate R satisfies $\partial R^o / \partial R^* = -\phi_{R^*} / \phi_R$. Importantly, this pass-through is non-monotonous as we vary the strength of financial spillovers. We can distinguish three cases:

a. Weak financial spillovers ($f \leq \underline{f}$). In the limit $f = 0$, this corresponds to the traditional Mundell-Fleming case. When financial spillovers are weak, a tightening in the center is expansionary abroad ($\phi_{R^*} > 0$), while domestic monetary policy operates in the usual way ($\phi_R < 0$). It follows that the optimal response to a tightening abroad is a domestic tightening: $\partial R/\partial R^* > 0$.[3]

b. Intermediate financial spillovers ($\underline{f} < f < \overline{f}$). A tightening at the center is contractionary at home ($\phi_{R^*} < 0$). Since domestic monetary policy transmission operates in the "standard" way ($\phi_R < 0$), the optimal response is to cut the domestic policy rate: $\partial R/\partial R^* < 0$. This case is interesting, since it suggests that the optimal response to changes

3. Whether the passthrough of foreign rates to domestic ones is larger or smaller than one depends on the impact of U.S. monetary policy on risk premia (g). When g is low, one can show that $0 < \partial R/\partial R^* < 1$. To see why, consider the case with $g = 0$. If $R = 0$, a U.S. monetary tightening is expansionary at home. Suppose, instead, that domestic authorities set $R = R^*$. This prevents the depreciation of the domestic currency and, therefore, mutes the trade channel of exchange rates. However, both the domestic and the foreign tightening impact negatively on domestic aggregate demand via their effect on domestic absorption and export demand. It follows that it is optimal to tighten, but less than one for one, and to let the currency depreciate. If the impact of U.S. monetary policy on risk premia is large, then domestic policy rates may have to rise significantly to counter the increase in risk premia, thus yielding a passthrough in excess of one. Still, in that case the exchange rate depreciates.

in the center's monetary policy stance is in the opposite direction. Tightening U.S. monetary policy requires easing abroad, and vice versa. A direct implication is that the domestic currency needs to depreciate in response to a U.S. monetary tightening.

c. Strong financial spillovers ($\overline{f} < f$). A U.S. tightening is contractionary at home, and this requires raising policy rates to stabilize output. Furthermore, since $-\phi_{R^*}/\phi_R = (d+g)/d(f-\underline{f})\,/\,(f-\overline{f}) > 1$ when $f > \overline{f}$, it follows that $\partial R/\partial R^* > 1$: the passthrough of center policy rates to domestic ones is always in excess of one.[4] A direct implication is that the domestic currency now needs to *appreciate* in response to a U.S. tightening.

Substituting R^o into equation (1e) and using the definition of ϕ_R, ϕ_{R^*}, $\underline{f}$ and $\overline{f}$, we can solve for the optimal exchange rate:

$$E^o = -\frac{(d+g)(\overline{f}-\underline{f})}{f-\overline{f}}R^* - \frac{c/d}{f-\overline{f}}\chi - \frac{d}{\phi_R}\left(Y^o - \frac{\xi + a\xi^*}{1+a}\right) \tag{8}$$

As discussed above, equation (8) tells us that the optimal response of the exchange rate depends on the strength of financial spillovers. In particular, under a "standard" transmission, the domestic currency *depreciates* when R^* increases. Conversely, in the case of a "perverse" transmission, the domestic currency *appreciates* following a tightening in the center.

1.4 Exchange Rate Regime and the Trilemma/Dilemma Debate

As equations (7) and (8) illustrate, the optimal policy consists in setting $R = R^o$ or, equivalently, $E = E^o$. It follows, somewhat trivially, that a fixed exchange rate is never optimal. But this misses a larger question: whether the exchange rate plays a stabilizing or a destabilizing role on the domestic economy. It is well known that a country cannot simultaneously let capital flow freely, set its own monetary policy, and stabilize its exchange rate. This is known as

4. Again, the reason is quite intuitive. Consider a tightening in the center. If $R = 0$, this is contractionary at home. Suppose now that $R = R^*$. This mutes the trade channel of exchange rates. As before, the domestic and foreign tightening still impact aggregate demand negatively via domestic absorption and export demand, so this remains contractionary at home. Stimulating the economy requires raising interest rates, $R > R^*$, so as to appreciate the currency.

the Mundellian trilemma. Indeed, equation (1e) characterizes the equilibrium exchange rate that is obtained given the configuration of domestic and foreign policy rates and risk premia when capital is freely mobile. Under the trilemma, floating exchange rates free monetary policy to pursue domestic objectives.

A question arises naturally: to what extent, under floating exchange rates, do currency movements hinder or facilitate the adjustment of the domestic economy? This question is intimately related to the recent trilemma/dilemma debate.

The policy trilemma has been challenged recently, most forcefully in Rey (2013, 2016). In her 2013 Jackson Hole piece, Rey argues that the deep interrelations between monetary policy at the center (the U.S.), global capital flows, and leverage in the financial sector can render domestic monetary policy ineffective in small open economies, even under a floating exchange rate regime. In a financially globalized world, conventional monetary policy may be swamped by global capital inflows and outflows, themselves driven in turn by global factors. Instead of a trilemma, these economies may face a dilemma: either to control capital flows (or to regulate the domestic financial sector via macro-prudential tools), or to lose the capacity to conduct independent monetary policy, regardless of the exchange rate regime. This global financial cycle could impact the domestic economy in a variety of ways. For instance, it may impart large movements in risk premia (χ in equation (1e)) as global markets swing from risk-on to risk-off, and vice versa. Alternatively, increased financial globalization often means larger mismatched cross-border gross positions. This amplifies the impact of changes in currency values on the balance sheet of financial and non-financial corporate entities, with potentially large effects on domestic absorption (f in equation (1b)). Both channels are present in the simple model presented above.

To further explore this question, let us assume that all fluctuations arise from foreign monetary policy (R^*) or exogenous shifts in risk premia (χ), and that both shocks are independent with mean 0 and variance $\sigma_{R^*}^2$ and σ_χ^2, respectively. Consider the following two regimes: a floating regime (f), where the domestic policy rate is constant ($R = 0$). This captures the idea that domestic policy may be constrained for reasons outside the model and allows us to evaluate directly the (de) stabilizing effect of exchange rates. The other regime is a currency peg (p), where the policy rate is set so as to maintain a constant exchange rate: $R = (1+g/d)R^* + \chi/d$, according to UIP condition (1e).

We can evaluate the loss function (5) under both regimes, denoted L^f and L^p, respectively:[5]

$$L^f = \left(\frac{b-f}{1+a}\right)^2 \sigma_\chi^2 + \left(\frac{(d+g)(f-\underline{f})}{1+a}\right)^2 \sigma_{R^*}^2 \tag{9}$$

$$L^p = \left(\frac{b-\overline{f}}{1+a}\right)^2 \sigma_\chi^2 + \left(\frac{(d+g)(\overline{f}-\underline{f})}{1+a}\right)^2 \sigma_{R^*}^2 . \tag{10}$$

If floating (with R = 0) is preferred to a peg in the absence of financial spillovers (f = 0), then it is easy to check that floating remains preferred to a peg as long as financial spillovers are not strong:[6]

$$L^f < L^p \Leftrightarrow f < \overline{f}.$$

There are two important implications of this result. First, the mere existence of financial spillovers and risk premia is not enough to overturn the Mundellian trilemma. When financial spillovers are intermediate (i.e., $\underline{f} < f < \overline{f}$), it is still preferable to let the currency float (even if the policy rate is constant) rather than to adopt a peg. The reason is that the "shock-absorbing" properties of the exchange rate still insulate the domestic economy reasonably well against the global financial cycle. Second, and more importantly, the model says that it is only when the transmission of monetary policy is "perverse" –in the sense that a tightening is expansionary– that a peg becomes preferable to a floating regime. In other words, the dilemma's intuition that exchange rates may not be insulating when financial spillovers are strong enough is correct, but it requires financial spillovers strong enough to overturn how monetary policy works.

The policy implications of living in such an environment would be considerable and would require a radical re-thinking of the way in which monetary policy is transmitted to the domestic economy and how monetary policy should be conducted. In a world with $\phi_r < 0$,

5. This is obtained by substituting equilibrium output Y from (2) into the loss function. Observe that since the shocks are centered, the "mercantilist" term drops out since $\mathbb{E}NX$=0.

6. It is easy to check that floating is preferred to a peg when f = 0 if and only if $b < c/d$. This is a reasonable benchmark since it corresponds to the usual Mundell-Fleming environment.

equation (7) tells us that policy rates need to be increased aggressively in response to increases in risk premia (χ) or in foreign policy rates (R^*). Equation (7) conveys a stronger message: policy rates also need to be *tightened* when the economy slows down ($\partial R^o/\partial\xi > 0$). If this is indeed the world we live in, it will require a major retooling of the monetary policy framework for small open economies.

Casual observation may lead to some skepticism. One would imagine that monetary authorities would have long ago figured out that, whenever they tightened their policy rate, their economy seemed to grow faster, not more slowly. Similarly, one presumes that central banks following an inflation-targeting rule would have noted, with some alarm, that raising policy rates pushed domestic price inflation up, not down, as the economy picked up speed.[7] Ultimately, though, this is an empirical question: are financial spillovers sufficiently large to overturn the usual transmission of monetary policy? This is the question to which we turn in the next two sections.

2. Model

We now present a small open economy model with financial spillovers. In the next section, the model is estimated using data for Chile. The small open economy, denoted H (for Home) trades goods and assets with the rest of the world, denoted U (for the U.S.). U is large and we take its dynamics as exogenous from the perspective of H. In particular, we will assume that the foreign price level is constant.

The model is a standard New Keynesian macro model in the spirit of Galí (2008) and Casas and others (2016): Home's manufacturing sector produces differentiated goods for the domestic and export market, with prices that are sticky in the currency in which they are invoiced. Domestic households consume domestic manufactured goods and imported ones. The model departs from the canonical New Keynesian framework along the following dimensions:

- Dominant currency pricing: Most goods sold on foreign markets are invoiced in U's currency (the dollar), whether produced by U or not.
- Strategic complementarities: The elasticity of substitution between varieties is not constant, so optimal markups vary as in Kimball (1995).

7.The effect on consumer price inflation could be more muted thanks to the effect of the appreciation of the currency on imported goods.

- Financial spillovers: There are two types of households, savers and borrowers, who differ according to their rate of time preference. Borrowers face a borrowing limit that varies with the exchange rate.
- Working capital: Firms need to fund a fraction of their input cost with an intra-period loan.
- Copper: The domestic economy is endowed with a commodity (copper) entirely destined to the export market. The dollar value of the commodity output fluctuates exogenously. This shifts *H*'s resource constraint and affects the equilibrium exchange rate.

2.1 Households

2.1.1 Preferences and Heterogeneity

We introduce financial spillovers in the model via household balance sheets. There is a unit measure of households. Households are heterogenous in their rate of time preference as in Eggertsson and Krugman (2012) and Gourinchas and others (2016). A measure $1-\chi$ of households is patient. These households will be saver in equilibrium. We index them with $i = s$ and denote their discount factor $\beta_b = \beta$. The remaining measure χ is impatient. They will be borrowers in equilibrium. We index them with $i = b$ and denote their discount factor $\beta_b < \beta$. Household i consumes a bundle of traded manufactured goods C_t^i, supplies a differentiated variety of labor N_t^i at wage W_t^i and maximizes lifetime preferences given by:

$$U^i = \mathbb{E}_0 \sum_{t=0}^{\infty} \beta_i^t \left(\frac{(C_t^i)^{1-\sigma_c}}{1-\sigma_c} - \frac{(N_t^i)^{1+\varphi}}{1+\varphi} \right), \tag{11}$$

where $\sigma_c > 0$ is the household's coefficient of relative risk aversion and $\varphi > 0$ is the inverse of the Frisch elasticity of labor supply.

Each household maximizes (11) subject to the following budget constraint:

$$P_t C_t^i = W_t^i N_t^i + \Pi_t + B_t^i - (1+i_t) B_{t-1}^i + \varepsilon_t COP_t \tag{12}$$

In (12), P_t denotes the price index for the domestic consumption basket C_t, Π_t are the (per capita) nominal profits from the domestic manufacturing sector rebated back to households, B_t^i denotes one-period domestic risk-free debt (or savings when $B_i^t < 0$) issued at time t, i_t is the domestic nominal interest rate in period t, COP_t denotes the exogenous dollar revenues (per capita) from the commodity sector (copper), and ε_t denotes the nominal exchange rate defined as the local currency value of the dollar, so that an increase in ε_t represents a depreciation of the domestic currency.

2.1.2 Strategic Complementarities

We follow Casas and others (2016) and assume that the consumption aggregator C is implicitly defined by a Kimball (1995) homothetic demand aggregator:

$$\sum_{j\in\{H,U\}} \frac{1}{|\Omega_j|} \int_{\omega\in\Omega_j} \gamma_j \Upsilon\left(\frac{|\Omega_j| C_j(\omega)}{\gamma_j C}\right) d\omega = 1. \tag{13}$$

where $C_j(\omega)$ denotes the consumption of variety ω produced in country j, γ_j is the mass of varieties produced in j, Ω_j is a taste parameter that captures home bias in consumption with $\Sigma_j \gamma_j = 1$, and where the function $\gamma(.)$ satisfies $\gamma(1) = 1$, $\gamma'(.) > 0$, and $\gamma''(.) < 0$.

The domestic price index P_t satisfies:

$$P_t C_t = \sum_j \int_{\Omega_j} P_{j,t}(\omega) C_{j,t}(\omega) d\omega$$

We later specialize the demand structure to the Klenow and Willis (2006) specification:

$$C_{j,t} = \gamma_j \left(1 - \in \ln \frac{\sigma z_{j,t}}{\sigma - 1}\right)^{\sigma/\in} C_t$$

where $z_{j,t} = (P_{j,t} / P_t) D_t$ and $D_t \equiv \sum_j \int_{\Omega_j} \Upsilon' \left(\frac{|\Omega_j| C_{j,t}(\omega)}{\gamma_j C_t}\right) \frac{C_{j,t}(\omega)}{C_t} d\omega.$ These preferences collapse to the standard CES representation when $\in = 0$. With this specification, the elasticity of demand for goods from country j, $\tilde{\sigma}_{j,t}$, and the elasticity of the markup $\Gamma_{j,t}$ are controlled by σ and $\in$:

$$\tilde{\sigma}_{jt} = \frac{\sigma}{1 - \in \ln \frac{\sigma z_{j,t}}{\sigma - 1}}$$

$$\Gamma_{j,t} = \frac{\in}{\sigma - 1 + \in \ln \frac{\sigma z_{j,t}}{\sigma - 1}}$$

In a symmetric steady state, $\tilde{\sigma} = \sigma$ and $\Gamma = \in /(\sigma - 1)$.

2.1.3 Wage Dynamics

Households are subject to a Calvo friction when setting wages in local currency: in any given period, they adjust their wage with probability 1 – δ_w, and maintain the previous-period nominal wage otherwise. As we will see, each household faces a downward sloping demand for the specific variety of labor they supply given by, $N_t^i = \left(\frac{W_t^i}{W_t}\right)^{-\vartheta} N_t$, where $\vartheta > 1$ is the constant elasticity of labor demand and W_t is the aggregate wage rate. As is well known, optimal wage setting gives rise to a standard wage-inflation equation (see Galí , 2008):

$$\pi_t^w = \beta \mathbb{E}_t \pi_{t+1}^w - \lambda_w \left(w_t - \sigma_c c_t - \varphi n_t - \mu^w \right), \tag{14}$$

where π^w denotes domestic nominal wage inflation, w = ln (W/P) is the (log) real wage, c and n are (log) aggregate consumption and labor supply, μ^w is the steady state (log) wage markup, and $\lambda_w = (1 - \delta_w)(1 - \beta\delta_w) / (\delta_w(1 + \vartheta\varphi))$ is derived from the Calvo wage-setting process.

2.2 Output

2.2.1 The Manufacturing Sector

Each home manufacturer produces a unique variety ω that is sold both domestically and internationally. The production function uses only labor N_t:

$$Y_t^m(\omega) = e^{a_t} N_t(\omega), \tag{15}$$

Where a_t is an aggregate productivity shock that follows:

$$a_t = (1 - \rho_a)\overline{a} + \rho_a a_{t-1} + \sigma^a \varepsilon_t^a \tag{16}$$

with ε^a i.i.d., mean zero, and unit variance.

The labor input N_t is a CES aggregator of the individual varieties supplied by each household i,

$$N_t = \left[\int_0^1 \left(N_t^i \right)^{(\vartheta-1)/\vartheta} di \right]^{\vartheta/(\vartheta-1)}$$

with $\vartheta>1$. Given our assumptions, the demand for each labor variety satisfies:

$$N_t(i) = \left(\frac{W_t(i)}{W_t} \right)^{-\vartheta} N_t, \tag{17}$$

with

$$W_t = \left[\int \left(W_t^i \right)^{1-\vartheta} di \right]^{\frac{1}{1-\vartheta}}.$$

Markets are segmented so firms can set different prices in each market. The firm's per-period profits are then given by:

$$\Pi_t = P_{H,t} Y_{H,t}^m + P_{U,t} Y_{U,t}^m - MC_t Y_t^m \quad , \tag{18}$$

where Y_{jt}^m denotes the demand for h goods from country j, $P_{j,t}$ the price of domestic goods sold in market j expressed in domestic currency, and MC_t the nominal marginal cost. Market clearing for each manufactured good requires $Y_{H,t}^m + Y_{U,t}^m = Y_t^m$.

2.2.2 Total Output

Nominal gross domestic product $P_t^y Y_t$ consists of nominal manufacturing output $P_{H,t} Y_{H,t}^m + P_{U,t} Y_{U,t}^m$ and output from the copper sector $\varepsilon_t COP_t$, where P_t^i denotes the GDP deflator. We assume that the dollar endowment of copper follows:

$$\ln COP_t = \rho^{co} \ln COP_{t-1} + \sigma^{co} \varepsilon_t^{co}, \tag{19}$$

where ε_t^{co} is an i.i.d. shock with mean zero and unit variance.

2.3 Price Setting

Manufacturing firms choose the price at which they sell their variety at home and abroad. As in Galí (2008) we make the Calvo pricing assumption that firms are randomly chosen to reset their prices with probability $1 - \delta_p$. In addition, we follow Casas and others (2016), and assume that most firms sets their prices in dollars on exports markets (whether *H* or *U*), while they set prices in local currency in their domestic market.

If we denote θ_{ij}^{k} the fraction of firms from country *i* selling in market *j* in currency *k*, we adopt the following parametrization based on data available from the Central Bank of Chile:

$$\theta_{UH}^{U} = 0.8627 \quad ; \quad \theta_{HU}^{U} = 0.9434.$$

Under our assumptions, and following the derivations in Galí (2008), and Casas and others (2016), we obtain the following generic Phillips curve:

$$\pi_{ij,t}^{k} = \beta\,\mathbb{E}_t \pi_{ij,t+1}^{k} + \frac{\lambda_p}{1+\Gamma}(\mathrm{mc}_{ij,t}^{k} + \Gamma(p_{j,t}^{k} - p_{ij,t}^{k}) + \mu^{p}) \tag{20}$$

where $\pi_{ij,t}^{k}$ is the inflation rate for goods from country *i* sold in country *j* in currency *k*, and $\mathrm{mc}_{ij,t}^{k} = \ln(MC_t^i / (\varepsilon_{i,t}^{k} P_{ij,t}^{k}))$ is the ratio of nominal marginal cost of production in country *i* to the price of goods of these goods sold in country *j* in currency *k*, $P_{ij,t}^{k}$ (in currency *k*), converted into *i*'s currency with the nominal exchange rate between *k* and *i*, $\varepsilon_{i,t}^{k}$.[8] In other words, $mc_{ij,t}^{k}$ is the opposite of the (log) markup for goods from *i* sold in *j* in currency *k*. $\lambda_p = (1-\beta\delta_p)(1-\delta_p)/\delta_p$ is derived from the Calvo price-setting process. According to (20), strategic complementarities (Γ>0) dampen the responsiveness of the inflation rate to markup costs, and increase the responsiveness of the inflation rate to export prices, relative to the destination price index, since firms optimally prefer to keep their price close to their competitors'.

2.4 Financial Frictions

2.4.1 Household Balance Sheet

We assume that borrowers are subject to the following borrowing limit

$$B_t \leq \frac{\bar{B}_t}{\chi}. \tag{21}$$

8.With our assumptions, $\varepsilon_{i,t}^{i} = 1$, while $\varepsilon_{H,t}^{U} = \varepsilon_t$.

In the equilibrium of the model, impatient households are the borrowers since $\beta_b < \beta$. We assume that they are sufficiently impatient so as to hit their borrowing constraint in all periods:

$$B_t^b = \frac{\overline{B}_t}{\chi}.$$

In our notation, B_t^b is the per capita level of debt of impatient borrowers, while $\chi B_t^b = \overline{B}_t$ is the aggregate lending capacity of the financial sector to households. We introduce financial spillovers by assuming that this lending capacity $\overline{B}_t$ fluctuates over time and is directly affected by the exchange rate. Specifically, we postulate the following process:

$$\overline{b}_t \equiv \ln(\overline{B}_t / P_t) = \overline{b} + \rho_b(\overline{b}_{t-1} - \overline{b}) - \psi_{be}(e_t - \overline{e}) + \zeta_t^b \tag{22}$$

where $\psi_{be} \geq 0$ denotes the intensity of the financial spillovers and $e_t = \ln(\varepsilon_t / P_t)$ is the (log) of the real exchange rate, with $\overline{e}$ its steady state value. This assumption captures the fact that the domestic financial sector needs to intermediate foreign capital into domestic loans, and its capacity to do so varies with the exchange rate. A real depreciation of the domestic currency (an increase in e relative to its steady state $\overline{e}$) limits the ability of the domestic financial sector to originate loans in domestic currency when $\psi_{be} > 0$. Different values of ψ_{be} correspond to different degrees of tightness of the financial constraint described in section 1 (the coefficient f in that model). ζ_t^b captures exogenous shifts in the borrowing constraint and is assumed to follow:

$$\zeta_t^b = \rho^b \zeta_{t-1}^b + \sigma^b \varepsilon_t^b,$$

where ε_t^b is an i.i.d. mean zero unit variance shock.

2.4.2 Working Capital

We assume that firms need to pay a share $0 \leq \psi_{wc} \leq 1$ of their production costs in advance of production via an intra-period loan funded at rate i_t. The nominal marginal cost of production is thus

$$MC_t = \frac{W_t}{e^{a_t}}(1 + \psi_{wc} i_t). \tag{23}$$

This provides a simple and quite general way through which a tightening of funding conditions affects firms' marginal costs.

2.5 Interest Rates and World Demand

We close the model by assuming the following specification for domestic and foreign interest rates. First, domestic nominal interest rate follow an inflation-targeting Taylor rule (in logs) with inertia:

$$i_t = \bar{i} + \rho_{iH}(i_t - \bar{i}) + (1 - \rho_{iH})(\phi_{pH}\pi_t^h + \phi_{yH}(y_t - \bar{y})) + \zeta_t^{mH} \quad (24)$$

In (24), ϕ_{pH} represents the sensitivity of policy rates to domestic price inflation π_t^H, while ϕ_{yH} represents the sensitivity to the output gap $y_t - \bar{y}$. $\bar{i}$ is the target nominal interest rate, equal to the steady state real interest rate $1/\beta - 1$. ζ_t^{mH} denotes an innovation to *H*'s monetary policy and is assumed to follow:

$$\zeta_t^{mH} = \rho^{mH}\zeta_{t-1}^{mH} + \sigma^{mH}\varepsilon_t^{mH},$$

where ε_t^{mH} is an i.i.d. zero mean unit variance shock.

The domestic nominal interest rate i_t and the dollar funding cost r_t^* are related by the uncovered interest rate parity relationship (UIP) which takes the following (log-linearized) form:

$$i_t = r_t^* + \mathbb{E}_t(e_{t+1} - e_t + \pi_{t+1}) \quad (25)$$

The funding costs r_t^* denotes the rate at which domestic financial intermediaries can obtain dollar funding from abroad. As is common in the literature, we assume that this dollar funding rate increases with the amount of net external debt NFA_t, so as to ensure stationarity of the log-linearized small open economy problem, as in Schmitt-Grohe and Uribe (2003), and can also be subject to sudden stops:

$$r_t^* = i_t^U - \psi_b(e^{NFA_t - \overline{NFA}} - 1) + \zeta_t^{rp} \quad (26)$$

where i_t^U is the dollar policy rate, ψ_b is a small strictly positive number, and ζ_t^{rp} captures exogenous risk premium shocks that follow:

$$\zeta_t^{rp} = \rho^{rp}\zeta_{t-1}^{rp} + \sigma^{rp}\varepsilon_t^{rp}$$

where ε_t^{rp} is an i.i.d. mean zero unit variance shock.

Finally, we assume that *U*'s monetary policy and output can be captured by the following (block-exogenous) log-linear representation:

$$i_t^U = \bar{i} + \rho_{iU}(i_{t-1}^U - \bar{i}) + (1-\rho_{iU})\phi_{yU}(y_t^U - \bar{y}^U) + \zeta_t^{mU} \quad (27a)$$

$$y_t^U = \bar{y}^U + \rho_{yU}(y_{t-1}^U - \bar{y}^U) - (1-\rho_{yU})\phi_{iU}(i_t^U - \bar{i}) + \zeta_t^{yU} \quad (27b)$$

Equation (27a) states that *U*'s monetary authorities follow a targeting rule with inertia. Since we assume that the price level in *U* is stabilized, this policy rule targets *U*'s output deviations $y_t^U - \bar{y}^U$. Equation (27b) states that U.S. output responds to U.S. monetary policy. This allows *U*'s monetary policy to impact Home via both the trade channel of exchange rates, but also via slower/faster growth in *U* (the terms *bd* and *ac* in the simplified model of the previous section). ζ_t^{mU} and ζ_t^{yU} respectively denote the exogenous components of *U*'s monetary policy and *U*'s aggregate demand. We assume they follow:

$$\zeta_t^{mU} = \rho^{mU}\zeta_{t-1}^{mU} + \sigma^{mU}\varepsilon_t^{mU}$$
$$\zeta_t^{yU} = \rho^{yU}\zeta_{t-1}^{yU} + \sigma^{yU}\varepsilon_t^{yU}$$

where ε_t^{mU} and ε_t^{yU} are i.i.d. mean zero unit variance shocks.

Equations like (27a)-(27b) are often estimated for the U.S., for instance, in Rudebusch and Svensson (1999).

2.6 Equilibrium and Discussion

Given the above assumptions, we can now define a competitive equilibrium:

A competitive equilibrium of the small open economy H *consists of:*

a) Both types of households maximizing utility over consumption and labor supply, subject to the borrowing constraint (4).
b) Manufacturing firms maximizing profits over labor demand and prices in each market.
c) Markets for labor and domestic manufacturing goods clearing.
d) Exogenous shocks to *H* and *U*'s monetary policy, ε_t^{mH} and ε_t^{mU}, copper revenue ε_t^{co}, productivity ε_t^{a}, risk premia ε_t^{rp}, borrowing limit ε_t^{b}, and *U*'s aggregate demand ε_t^{yU}.

The model features a number of channels through which *U*'s monetary policy can affect *H*'s economy. The increase in policy rate i^U slows down economic activity in *U*, according to (27b). This decreases the demand for *H*'s exports. The increase in i^U also raises *H*'s dollar funding cost, which depresses *H*'s real exchange rate according to (25). This increases the price of *H*'s imports (priced in dollars) relative to *H*'s domestic manufactures, and stimulates *H*'s economy (Casas and others, 2016) emphasize that under dominant currency pricing, the expenditure switching motive operates mostly via imports). Next, the depreciation of the local currency increases the value of the endowment of commodities $\varepsilon_t COP_t$, which stimulates aggregate demand. Finally, the depreciation of the domestic currency tightens the borrowing limit $\bar{B}_t$ of impatient households according to (22). This forces borrowers to de-lever, thus contracting aggregate demand.

The approach adopted in this paper is similar to Gourinchas and others (2016): rather than micro-founding all the channels, it presents a more flexible and pragmatic representation that hopes to capture the important trade-offs. This is not without limitations. Most obviously, the use of some reduced-form relationships, such as eq. (22), or (27a)-(27b) is subject to a Lucas critique: the relevant parameters may not be invariant to policy change. This is particularly relevant for Ψ_{be}, the parameter that captures the strength of the financial spillovers from the exchange rate to the balance sheet of the private sector. Different models would undoubtedly have different predictions in terms of the specific linkages between capital flows, currency value, and domestic aggregate demand. The stronger micro-foundations of many of these models also come at a cost: they may be too restrictive. In the absence of a canonical macro-finance model, we view the "pragmatic approach" as one that balances the need for rigorous theoretical formulation and the need for intellectual flexibility.

3. Financial Spillovers: the Case of Chile

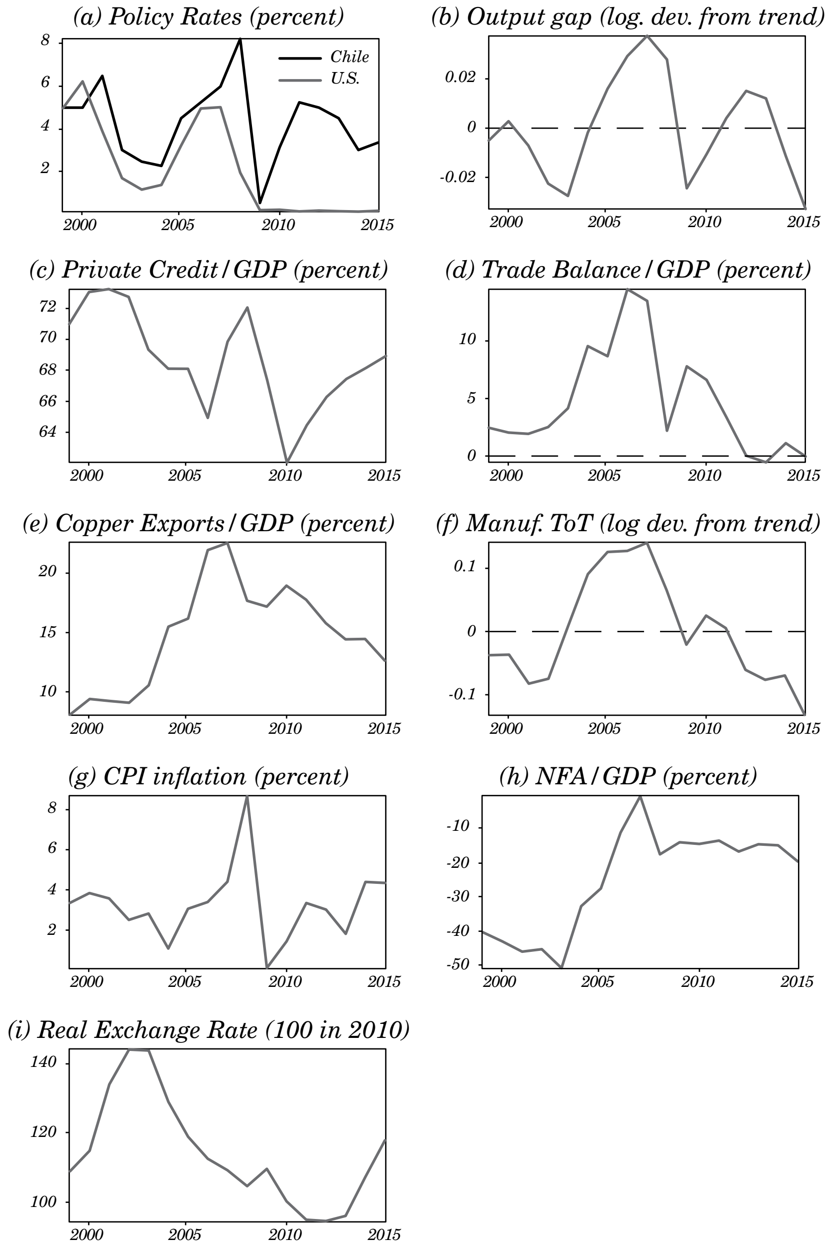
This section describes how we estimate the model by using data on the Chilean economy between 1999 and 2015. The model features seven shocks, which we list here for convenience: shocks to the policy rates in *H* and in *U* (ε^{mH} and ε^{mU}), to dollar copper revenues (ε^{co}), to manufacturing productivity (ε^{a}), to the risk premium (ε^{rp}), to the borrowing limit (ε^{b}), and to global demand (ε^{yU}). We estimate the model using standard Bayesian techniques. To do so, we feed into the model seven observable series: the Chilean and U.S. policy rates, the ratio of Chile's copper exports to its output, the ratio of Chile's trade balance to output, the terms of trade in the manufacturing sector, the ratio of Chile's credit to the non-financial sector to output, and an estimate of

Chile's output gap. Each series is detrended and described in detail in the appendix.

Figure 1 reports these seven variables, together with Chile's consumer price inflation, the ratio of its net foreign assets to output, and the peso-USD real exchange rate. The latter variables will be used to assess the external validity of the estimated model. Over the period we consider, Chile's copper exports increased substantially, from 9% of GDP in 2002 to 22.6% in 2007 (panel e). This was driven by a strong increase in the dollar price of copper, from $1,560 per metric ton to $7,131 over the same period. The overall trade balance is dominated by copper exports and shows a similar pattern, improving from 2.3% of GDP to 13.2% (panel d). The net foreign asset position steadily improves over the same period, from a large debtor position of -44 percent of output to 0 (panel h). Output increases substantially over the same period, with the estimated output gap moving from -2.2% to +3.7% (panel b). The rise in copper prices induces a 28 percent real appreciation of the peso against the dollar (panel i), and the non-copper trade balance deteriorates from -6.7 to -9.4 percent of GDP. The global financial crisis of 2008 shows up in the data with a sharp slowdown of the Chilean economy in 2009, the output gap decreasing by more than 5% (panel b), a collapse in trade (both manufactures and commodities) (panel d), and an aggressive policy response both in Chile and in the United States (panel a). Because we are interested in estimating the strength of financial spillovers, we directly include a measure of the private credit to GDP (filtered) in the series we feed into the model. Through the lens of the model, this corresponds to the debt of impatient households $\overline{B_t}$ (panel c). This measure indicates that global financial conditions were improving rapidly right before the crisis followed by a sharp contraction in the borrowing limit in 2009 and 2010. It is interesting to note that, at least for Chile, the unconditional correlation between private credit to GDP and the real exchange rate is not very strong, which indicates that financial spillovers arising from movements in the exchange rate may not play a critical role. After a sharp decline during the crisis, Chile's CPI inflation rebounded in 2011 (panel g) prompting the monetary authorities to raise the policy rate (panel a).[9]

9.Since 1999, the Central Bank of Chile follows an inflation-targeting regime. The inflation target rate has been about 3% ± 1% for most of that period.

Figure 1. Observables: Filtered Data



Detailed description and sources in appendix (A.1 and A.2).

We use a combination of calibration and estimation. We calibrate parameters that affect steady-state variables. Most of the calibrated parameters take standard values for small open economies and are reported in appendix A.3. We estimate the remaining 17 parameters (the persistence ρ^i and volatility σ^i of the seven shocks, plus the strength of the financial spillovers as measured by Ψ_{be}, χ_{wc} and ϕ_b) by using standard Bayesian estimation techniques as in An and Schorfheide (2007).

3.1 Impulse Responses

We begin by illustrating, in the context of the model, how the strength of financial spillovers shapes the transmission of U.S. and domestic monetary policy impulses to Chilean output. Figure 2 reports the impulse response function to a U.S. monetary policy tightening, at the estimated parameter values, but with $\Psi_{be} = 0$, i.e., when the balance sheet channel is turned off. As in the textbook Mundell-Fleming model described in section 1, the tightening of U.S. monetary policy is expansionary in Chile. The currency depreciates, which pushes CPI inflation up and triggers a domestic monetary tightening. Higher domestic interest rates depress the consumption of patient households, but impatient households' consumption increases, due to the higher wealth. The manufacturing terms of trade are largely unresponsive, since both exports and import prices are mostly set in dollars, as documented extensively by Casas and others (2016).

Let us contrast this result with the one that is obtained when financial spillovers are intermediate. Our simple Mundell-Fleming analysis suggested that a U.S. monetary tightening could become contractionary as the balance sheet of domestic agents would be adversely impacted by the depreciation of the local currency. Figure 3 shows that this is indeed the case in the full-fledge model. The impulse responses are estimated for an intermediate level of financial spillovers, in this case $\Psi_{be} = 3$. The depreciation of the local currency tightens the borrowing constraint of impatient households, thus forcing them to delever. Aggregate consumption now contracts, thus pushing the home economy into a recession. The optimal local response to the U.S. tightening is to reduce policy rates.

Figure 2. Impulse Response to a U.S. Monetary Tightening, Low Spillovers (ψ_{be} = 0)

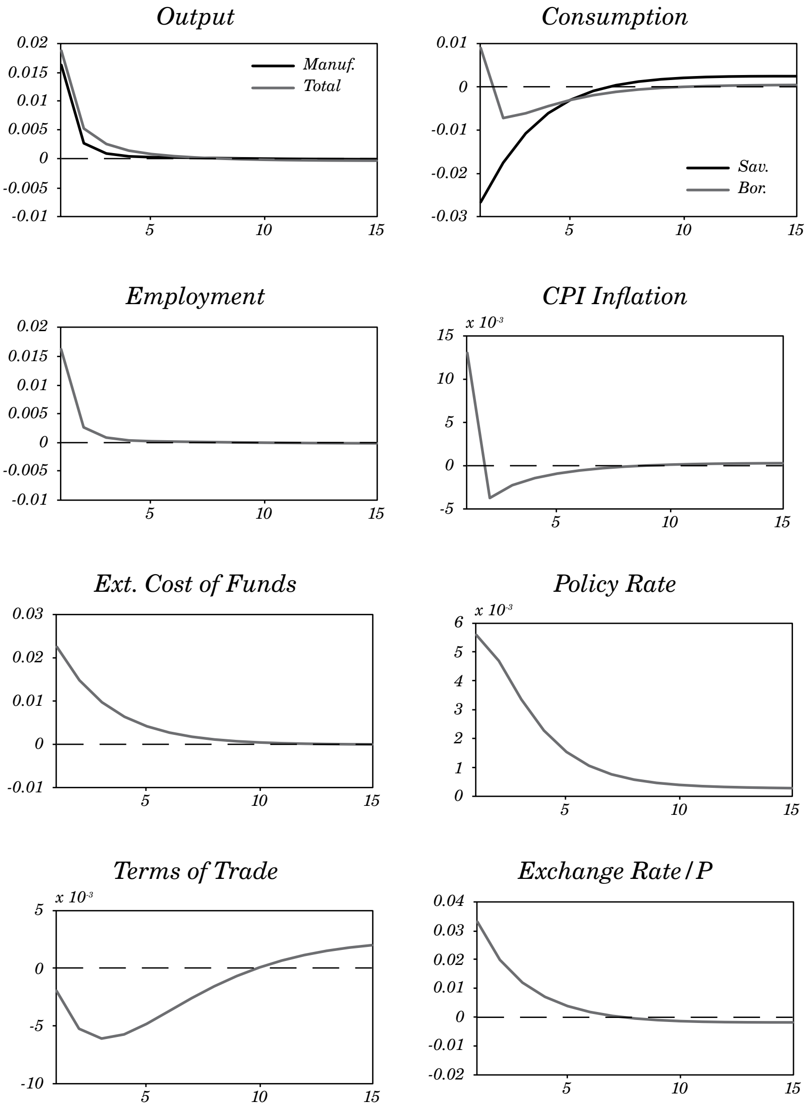


Figure 3. Impulse Response to a U.S. Monetary Tightening, Intermediate Spillovers (ψ_{be} = 3)

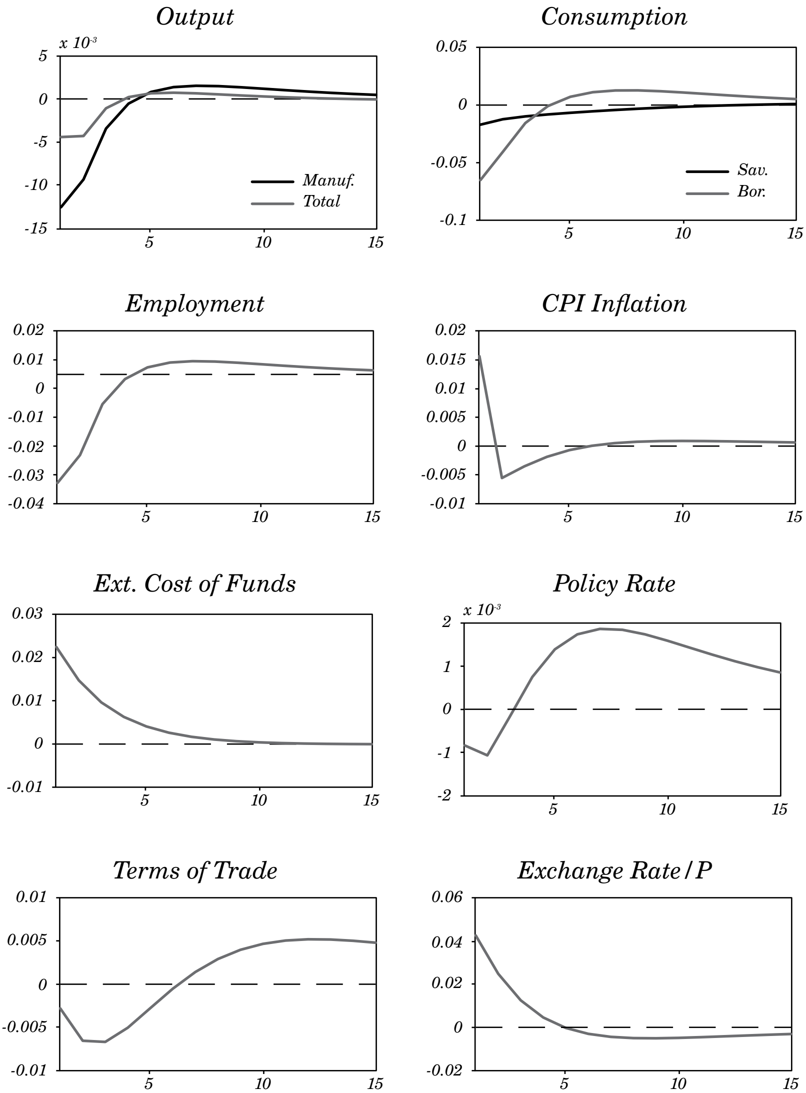
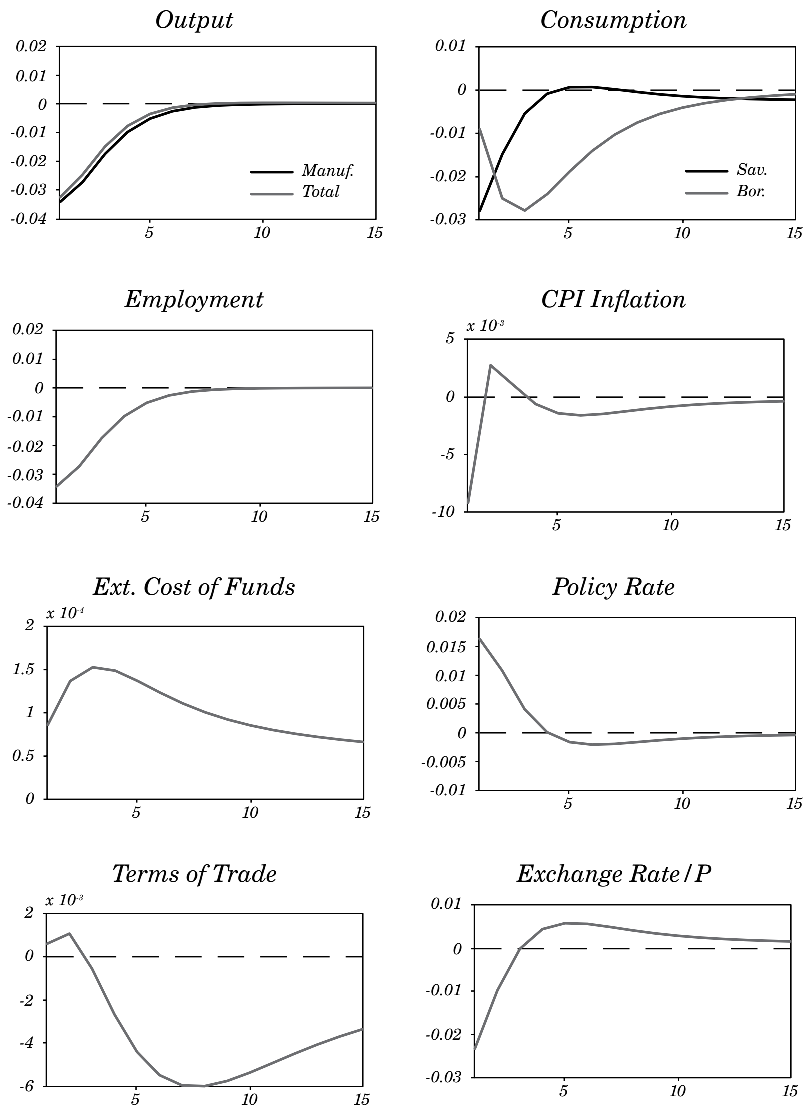


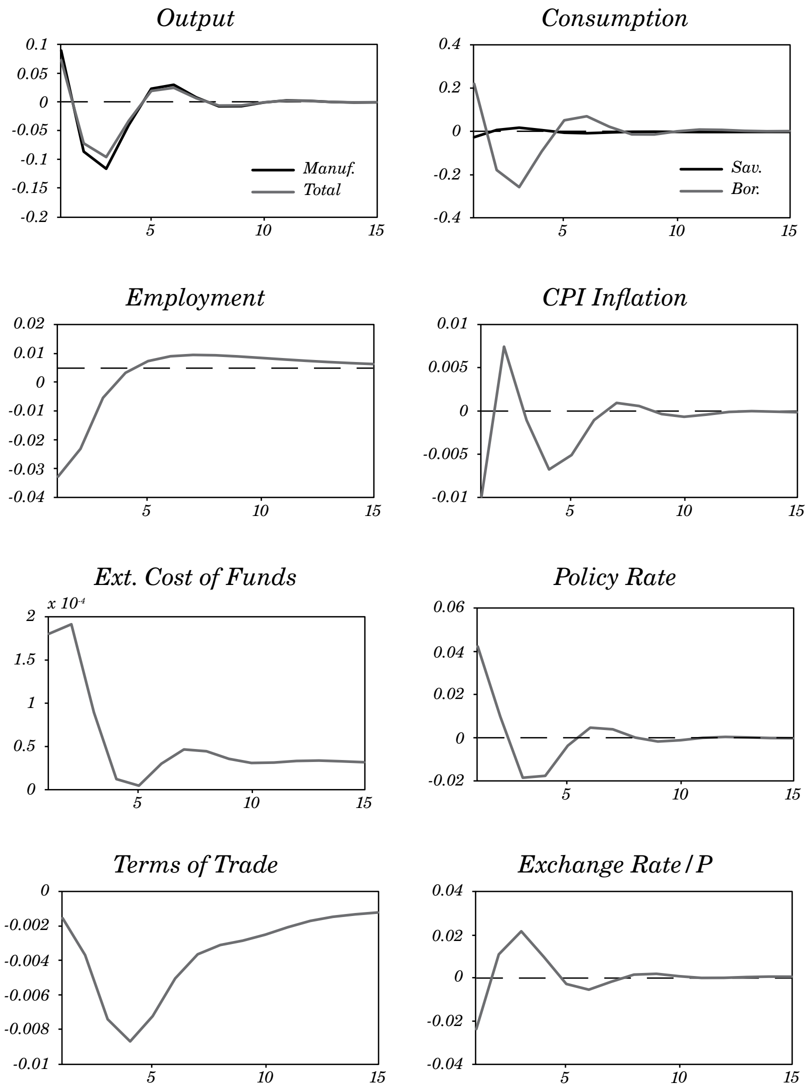
Figure 4. Impulse Response to a Local Monetary Tightening, Intermediate Spillovers (ψ_{be} = 3)



While financial spillovers are now strong enough to overturn the transmission of foreign monetary policy, they are not sufficient to overturn the transmission of domestic monetary policy. Figure 4 reports the impulse response to a domestic monetary policy tightening under the maintained assumption that spillovers are intermediate. As expected, the tightening leads to an appreciation of the domestic currency. This appreciation relaxes the borrowing constraint of impatient households, but this effect is not sufficient to stimulate aggregate demand, so output and employment decline.

Contrast this last result with the case where the financial spillovers are strong (i.e., $\Psi_{be} = 20$). Figure 5 shows the results. We now observe that output briefly increases with a domestic tightening, driven by the consumption of impatient agents who enjoy a relaxation of their borrowing constraint. The fuller model is thus able to capture the three different regimes described in section 1. First, when financial spillovers are weak, the model functions like a standard Mundell-Fleming model: U.S. monetary tightening are expansionary. In turn, when financial spillovers are intermediate, a tightening at the center is contractionary—thanks to the contraction in borrowers' balance sheet—, but home monetary policy remains expansionary. Finally, when financial spillovers are strong, the model indicates that the transmission of domestic monetary policy becomes perverse: a domestic tightening, via the appreciation of the domestic currency, becomes expansionary.

Figure 5. Impulse Response to a Local Monetary Tightening, Strong Spillovers (ψ_{be} = 20)



3.2 Estimation

We solve the model by log-linearization methods around a zero inflation steady state. The estimation results, along with our choice of priors, are described in table 2 in appendix A.4. As the previous discussion illustrates, a key parameter is the strength of financial spillovers, Ψ_{be}. We estimate $\Psi_{be} = 4.96$ with a 90% confidence interval between 3.39 and 6.54.

Figures 6 through 9 report the Bayesian impulse response functions at the estimated parameters for four shocks: a U.S. and local monetary policy tightenings, a funding cost shock, and a shock to the dollar value of copper revenues. Looking at the first two figures, it is immediate that the results are consistent with the case of "intermediate" financial spillovers: both a U.S. or a local monetary policy tightening are contractionary. This results suggest that, for Chile at least, the textbook prediction that a tightening in the U.S. will be expansionary at home is incorrect. Nevertheless, this finding does not overturn the general logic of the Mundell-Fleming framework. In particular, floating exchange rate remains highly desirable since the optimal response to a U.S. tightening may be a reduction in policy rates at home. Figure 8 reports the response to the external risk premium ε^{rp}. The increase in risk premia triggers a real depreciation that tightens the borrowing constraint, thus forcing impatient households to delever and pushing the economy into a recession. Hence, our estimates also indicate that a risk-off episode can be quite contractionary for the local economy, even if exchange rates are floating, unlike Krugman (2014)'s analysis.

Finally, figure 9 presents the response to a shock to copper revenues in U.S. dollars, which can be interpreted as an increase in the price of copper. Higher copper prices lead to an appreciation of the currency, as is often documented for commodity currencies. It is well known that the dollar exchange rate of small commodity exporters (such as Chile) is strongly correlated with the dollar price of the main commodities (see Chen and others, 2010): an increase in the dollar price of copper represents an exogenous improvement in the terms of trade of these countries, which often impacts a large fraction of their exports. The increase in resources translates into a real appreciation. This appreciation relaxes the borrowing constraint of the borrowers, who in turn increase their consumption further. While total output increases, manufacturing output declines due to the increased competition from foreign manufacturing output, and manufacturing employment declines.

Figure 6. Bayesian IRF: U.S. Monetary Policy

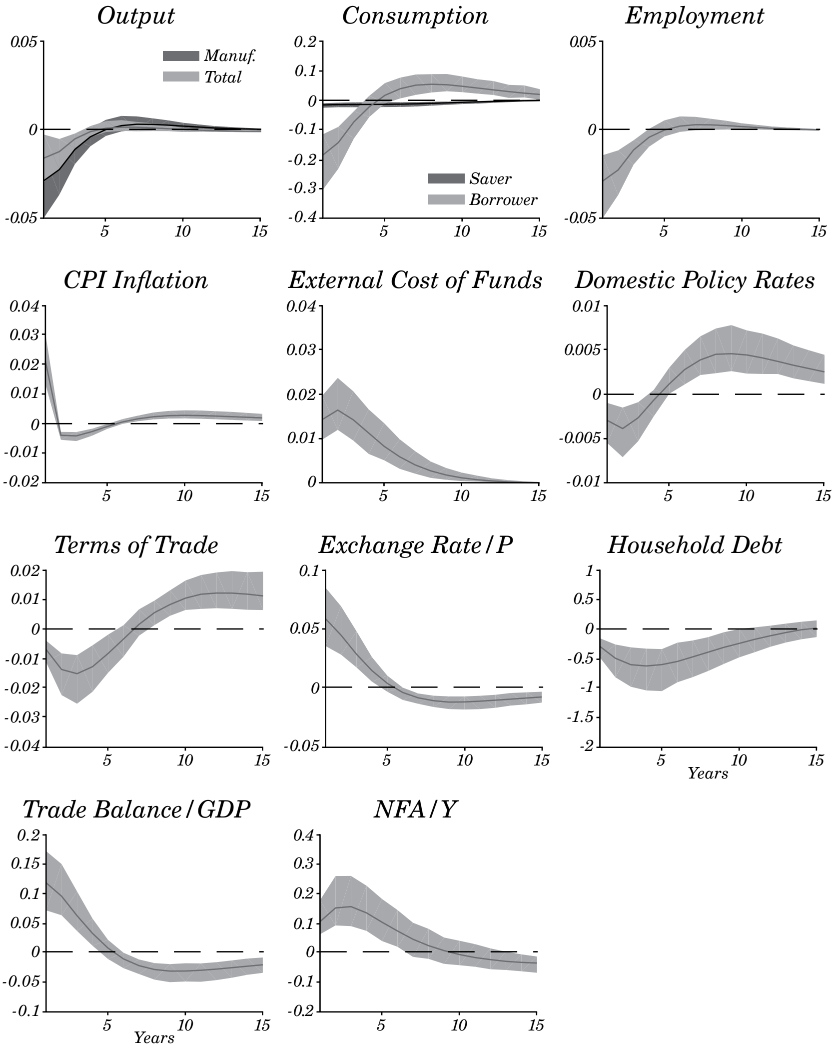


Figure 7. Bayesian IRF: Chile Monetary Policy

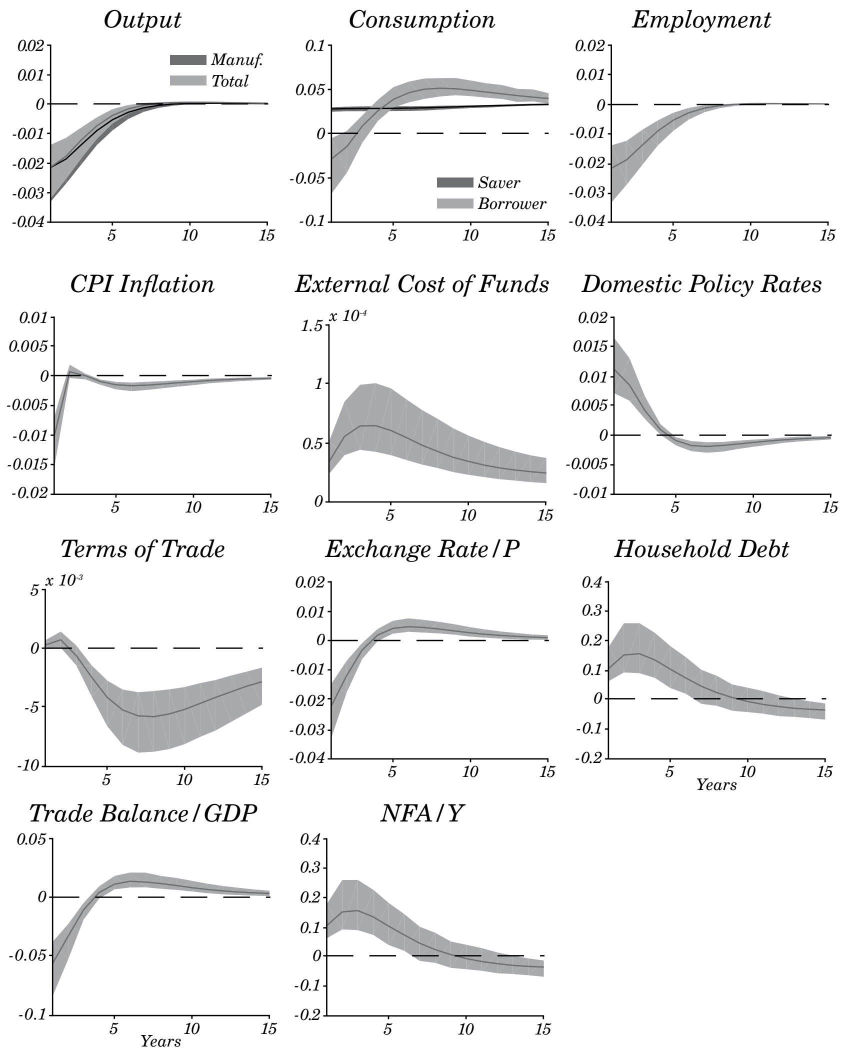


Figure 8. Bayesian IRF: External Risk Premium

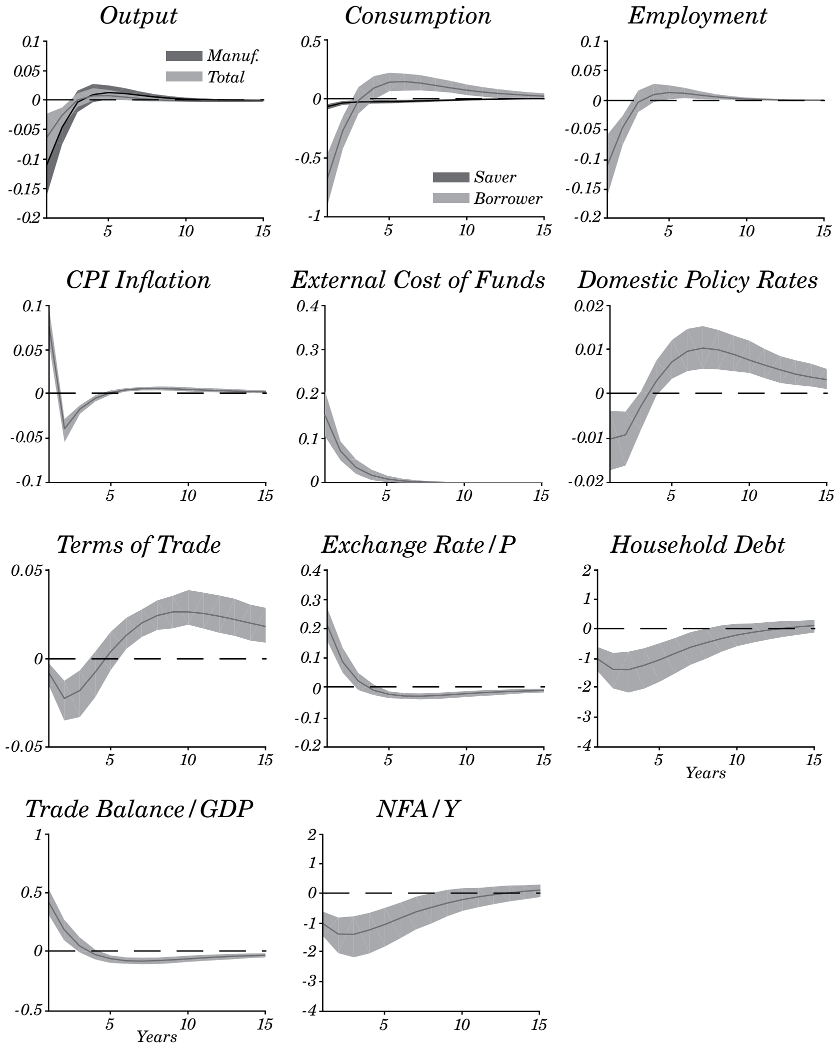


Figure 9. Bayesian IRF: Copper Shock

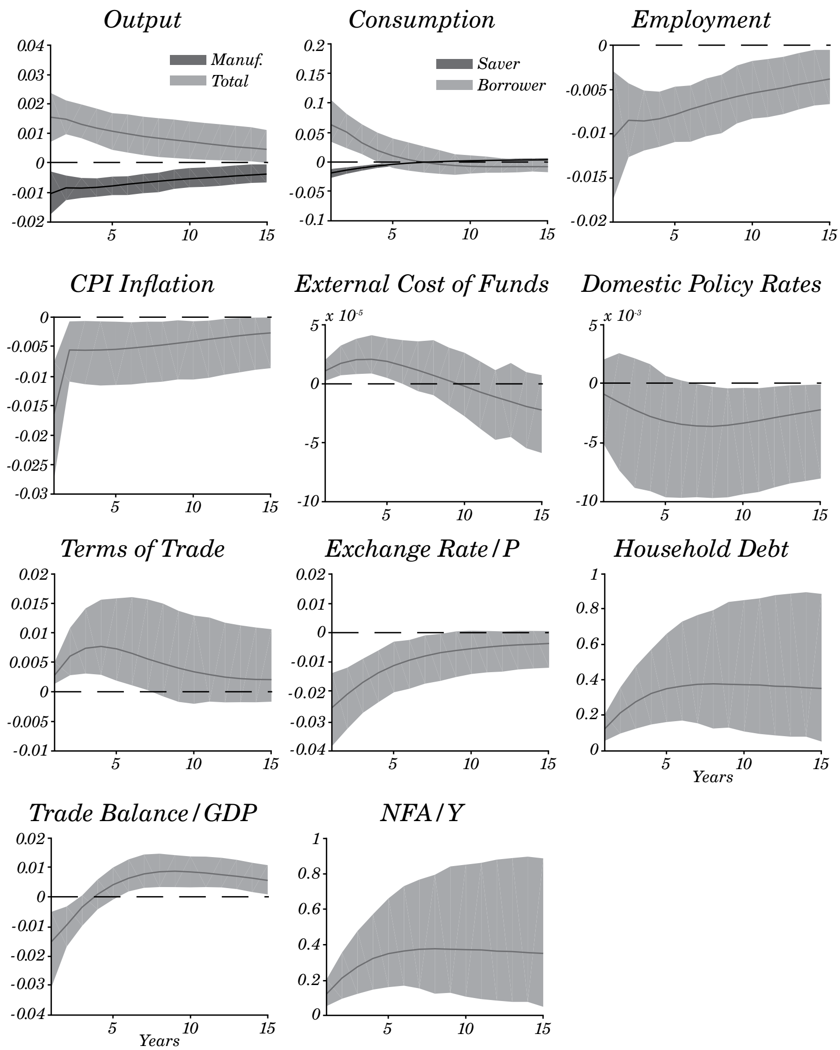


Figure 10. Estimated vs. Predicted Variables

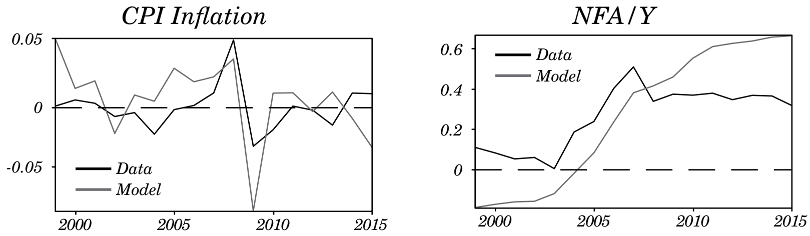
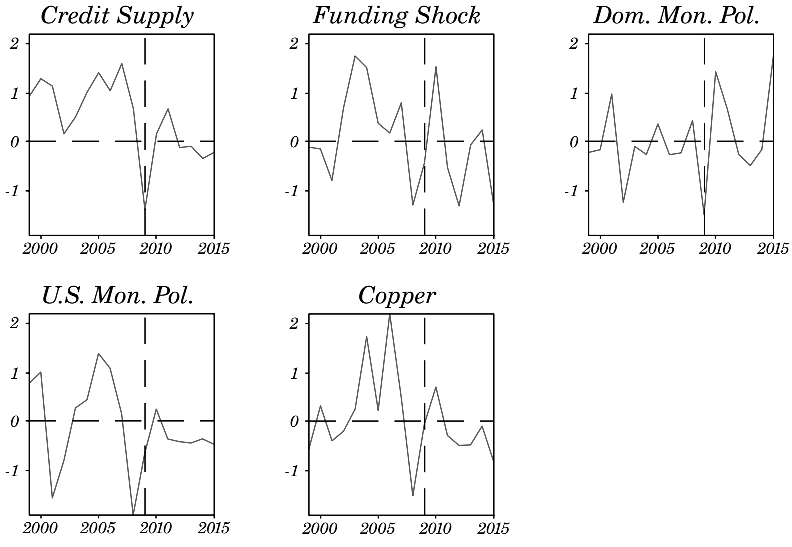


Figure 10 compares the model and predicted evolutions for Chile's CPI inflation (filtered) and the ratio of its net foreign asset to its output.

These two variables do not enter into the estimation procedure, so they provide a window on the ability of the estimated model to capture Chile's outcomes. Overall, the model does a reasonable good job for both variables. As in the data, CPI inflation increases between 2002 and 2008. It collapses in 2009 as economic activity slows down sharply. Inflation in the model rebounds more rapidly than in the data, but remains below the target inflation. The predicted NFA position of Chile improves rapidly as copper revenues surge in the early 2000s. In fact, the model predicts that it continues to rise after 2008 towards 60% of GDP, above the 40% of GDP observed in the data.

To illuminate further how the estimated model accounts for Chile's recent macroeconomic history, figure 11 reports the posterior shocks, estimated from the smoother of the Kalman Filter. The figure reveals that a major negative shock to dollar copper revenues occurs in 2008, followed by a sharp contraction in credit supply and a risk premium shock in 2011, while both U.S. and Chilean monetary policies turned very expansionary in 2009 and 2010.

Figure 11. Smoothed Posterior Shocks



4. Conclusion

How are U.S. and domestic monetary policies transmitted to a small open emerging-market economy? In the terminology of Secretary of Defense Donald Rumsfeld, this is a “known unknown”: despite the practical importance of this question for policymakers around the world, we know that we know very little about it.

This paper argues that the answer to this question depends on the strength of financial spillovers. In a world with limited financial spillovers, the transmission is broadly in line with the standard analysis of Mundell and Fleming: U.S. monetary policy tightenings are expansionary abroad, and it is optimal to let the nominal exchange fluctuate so as to absorb the brunt of the adjustment. As financial spillovers increase, this conclusion is not necessarily warranted any longer. First, for intermediate levels of spillovers, U.S. monetary policy is transmitted positively: a tightening in the center is contractionary abroad. These effects can be further amplified by the global financial cycle. With intermediate financial spillovers, a depreciation of the domestic currency is contractionary, as it tightens domestic financial constraints and reduces domestic net worth.

This validates the concern of emerging-market policymakers who worry that monetary policy in the U.S. may generate volatility in their own economy. But the case of intermediate spillovers indicate that domestic monetary policy still operate in a "normal" way, so that the best response to a U.S. tightening is to reduce domestic policy rates, and to let the currency depreciate further. This is so, despite the negative effect of the currency depreciation on domestic activity. Therefore, the presence of financial spillovers does not, per se, invalidate a key result of the "trilemma": exchange rate flexibility is even more important, despite the more limited effectiveness of domestic monetary policy.

Second, if financial spillovers become really strong, the transmission of domestic monetary policy itself is altered: a tightening of the policy rate, because of its impact on the value of the currency, would become expansionary, not contractionary. Our analysis shows that it is only in the case of such "perverse" transmission of monetary policy that exchange rate flexibility becomes less effective.

While some policymakers have argued that indeed higher policy rates are expansionary and not contractionary, the issue is mostly an empirical one. The paper estimates a small scale DSGE model to the Chilean economy, a leading example of a small open emerging economy. The resulting estimates indicate, at least for that country and for the recent period, that financial spillovers are intermediate. It follows from our analysis that exchange rate flexibility is even more important than in the Mundell-Fleming case.

How can we reconcile our analysis with the common view that exchange rate flexibility looses its effectiveness when depreciations are contractionary? We offer two possible explanations. First, the distributional effects of exchange rate changes are more complex in presence of financial spillovers. In addition to the usual distinction between exporters who gain and consumers who lose (the former benefitting from a depreciation, the latter suffering because of the adverse terms of trade effect), financial spillovers imply that borrowers and financial intermediaries may suffer from a depreciation of the local currency. The political economy may be adversely affected. Second, because monetary policy loses some of its effectiveness when financial spillovers are intermediate, and larger movements in policy rates may be needed to stabilize the economy. This also increases the within-country distributional consequences of monetary policy. Further, it makes it more likely that monetary policy will be constrained at the effective lower bound.

References

An, S. and F. Schorfheide (2007). ""Bayesian Analysis of DSGE Models." *Econometric Reviews* 26(2-4): 113–72.

Aoki, K., G. Benigno, and N. Kiyotaki (2015). "Monetary and Financial Policies in Emerging Markets." Mimeo, Princeton University.

Başçı, E., Ö. Özel, and Ç. Sarıkaya (2008). "The Monetary Transmission Mechanism in Turkey: New Developments." BIS Papers No. 35, Bank for International Settlements.

Bernanke, B.S. (2017). "Federal Reserve Policy in an International Context." *IMF Economic Review* 65(1): 5–36.

Blanchard, O. (2016). "Currency Wars, Coordination, and Capital Controls." NBER Working Paper 22388.

Borio, C. and H. Zhu (2012). "Capital Regulation, Risk-taking and Monetary Policy: A Missing Link in the Transmission Mechanism?" *Journal of Financial Stability* 8(4): 236–51.

Bruno, V. and H.S. Shin (2014). "Cross-border Banking and Global Liquidity." *Review of Economic Studies* 82(2): 535–64.

———. (2015). "Capital Flows and the Risk-taking Channel of Monetary Policy." *Journal of Monetary Economics* 71: 119–32.

Casas, C., F.J. Díez, G. Gopinath, and P-O. Gourinchas (2016). "Dominant Currency Paradigm." NBER Working Paper 22943.

Chen, Y.-C., K.S. Rogoff, and B. Rossi (2010). "Can Exchange Rates Forecast Commodity Prices?" *Quarterly Journal of Economics* 125(3): 1145–94.

Coibion, O. and Y. Gorodnichenko (2011). "Monetary Policy, Trend Inflation, and the Great Moderation: An Alternative Interpretation." *American Economic Review* 101(1): 341–70.

Devereux, M.B., K. Shi, and J. Xu (2007). "Global Monetary Policy under a Dollar Standard." *Journal of International Economics* 71(1): 113–32.

Devereux, M. B., E.R. Young, and C. Yu (2015). "A New Dilemma: Capital Controls and Monetary Policy in Sudden Stop Economies." NBER Working Paper 21791.

Eggertsson, G. and P. Krugman (2012). "Debt, Deleveraging, and the Liquidity Trap: A Fisher-Minskykoo Approach." *Quarterly Journal of Economics* 127(3): 1469–513.

Farhi, E. and I. Werning (2014). "Dilemma Not Trilemma? Capital Controls and Exchange Rates with Volatile Capital Flows." *IMF Economic Review* 62(4): 569–605.

Galí, J. (2008). *Monetary Policy, Inflation and the Business Cycle: An Introduction to the New Keynesian Framework*. Princeton, NJ: Princeton University Press.

Galí, J. and Monacelli, T. (2005). "Monetary Policy and Exchange Rate Volatility in a Small Open Economy." *Review of Economic Studies* 72(3): 707–34.

Gopinath, G. (2015). *The International Price System*. In Jackson Hole Symposium, vol. 27, Federal Reserve Bank of Kansas City.

Gopinath, G. and O. Itskhoki (2010). "In Search of Real Rigidities." In *NBER Macroeconomics Annual*, vol. 25, edited by D. Acemoglu and M. Woodford. Chicago, Ill: University of Chicago Press.

Gourinchas, P.-O., T. Philippon, and D. Vayanos (2016). "The Analytics of the Greek Crisis." In *NBER Macroeconomics Annual*, vol. 31. Chicago, Ill: University of Chicago Press.

Gudmundsson, M. (2017). "Global Financial Integration and Central Bank Policies in Small, Open Economies." *The Singapore Economic Review* 62(1): 1740006.

Iacoviello, M. (2015). "Financial Business Cycles." *Review of Economic Dynamics* 18(1): 140–63.

Kimball, M. (1995). "The Quantitative Analytics of the Basic Neomonetarist Model." *Journal of Money, Credit and Banking* 27(4): 1241–77.

Klenow, P.J. and J.L Willis (2006). "Real Rigidities and Nominal Price Changes." Mimeo, Stanford University.

Krugman, P. (2014). "Currency Regimes, Capital Flows, and Crises." *IMF Economic Review* 62(4): 470–93.

Lane, P.R. and G.M. Milesi-Ferretti (2007). "The External Wealth of Nations Mark II: Revised and Extended Estimates of Foreign Assets and Liabilities, 1970-2004." *Journal of International Economics* 73(2): 223–50.

Mendoza, E.G. (2010). "Sudden Stops, Financial Crises, and Leverage." *American Economic Review* 100: 1941–66.

Rey, H. (2013). "Dilemma Not Trilemma: The Global Cycle and Monetary Policy Independence." In *Proceedings-Economic Policy Symposium-Jackson Hole*, pages 1–2. Federal Reserve Bank of Kansas City.

———. (2016). "International Channels of Transmission of Monetary Policy and the Mundellian Trilemma." *IMF Economic Review* 64(1): 6–35.

Rudebusch, G. and L.E. Svensson (1999). "Policy Rules for Inflation Targeting." In *Monetary Policy Rules*. Chicago, Ill: University of Chicago Press.

Schmitt-Grohe, S. and M. Uribe (2003). "Closing Small Open Economy Models." *Journal of International Economics* 61(1): 163–85.

Taylor, A. and M. Obstfeld (2017). "International Monetary and Financial Relations in the 21st century." Forthcoming in *Journal of Economc Perspectives*.

APPENDIX

A.1 Data Sources

All data are annual.

- U.S. policy rate: Effective Federal Funds Rate. Source: FRED. Code: FEDFUNDS.
- Chile's policy rate: After 1995, Central Bank policy rate. Source: International Financial Statistics (IFS). Code: FPOLM_PA. Before 1995: Chile Central Bank Minimum Interest Rate. Source: Global Financial Database (GFD). Code: IDCHLD.
- Chile's output gap: Real Gross Domestic Product. Source: IFS. Code: NGDP_R_IX. The output gap is constructed as the deviation of (log) real output from a linear trend.
- Chile's private credit to GDP: Other Deposit Corporations Survey, Claims on Other Sectors, Claims on Private Sector, National Currency. Source: IFS. Code: FOSAOP_XDC
- Chile's Gross Domestic Product: Nominal, National Currency. Source: IFS. Code NGDP_XDC
- Chile's Trade Balance: Exports minus imports, divided by nominal output. Exports: External Sector, Exports of Goods and Services, Nominal, National Currency. Source: IFS. Code: NX_ XDC. Imports: External Sector, Imports of Goods and Services, Nominal, National Currency. Source: IFS. Code: NM_XDC.
- Copper Exports: Copper exports FOB, millions of U.S. dollars. Source: Central Bank of Chile.
- Dollar Nominal exchange rate: Source: OECD Financial Indicators.
- Manufacturing Terms of Trade: Ratio of export deflator to import deflator. Source: Central Bank of Chile (internal source).
- Chile's Net Foreign Asset Position: Before 2011 from Lane and Milesi-Ferretti (2007)'s External Wealth of Nations database (Mark II), millions of current USD. After 2011: Source: IMF Balance of Payment. Code: 228IFR_BP6_USD.A.
- Chile's CPI inflation: Consumer Price Index, All items, Percent Change. Source: IFS. Code: PCPI_PC_CP_A_PT.
- Chile dollar real exchange rate: constructed as $\varepsilon P^*/P$ where ε is the dollar peso nominal exchange rate, P^* is the U.S. CPI. Source: OECD Main Economic Indicators (via FRED). Code: CPALTT01USA661S and P is the Chilean CPI. Source OECD Main Economic Indicators (via FRED). Code: CHLCPIALLAINMEI.

A.2 Filtering

For the estimation of the model, variables are filtered as follows:

- The U.S. and Chilean policy rates are centered on $1/\beta - 1$.
- Chile's output gap is computed as the (log) deviation from a linear trend estimated over the 1999-2015 period.
- (log) private credit to GDP is computed as the deviation of log private credit to GDP from a linear trend estimated over the 1990-2015 period. It is then centered on the average credit to GDP in the data (0.68).
- Chile's manufacturing terms of trade: The (log) manufacturing ToT are measured in deviation from a linear trend for the 1999-2015 period and centered on the model-implied steady-state manufacturing terms of trade.
- Chile's CPI inflation are de-meaned, since the model implies zero steady-state inflation.

A.3 Calibration

Table 1 contains 20 parameters calibrated from the literature and existing data. The discount factor for patient households is set at 0.97, a common value in the literature. The fraction of impatient households is set to 0.65, as in Gourinchas and others (2016). The openness coefficient is set to 0.3. The inverse Frisch elasticity and the coefficient of relative risk aversion are set to 1. The steady-state elasticity of substitution between varieties of goods and of labor is set to 6. We assume a superelasticity of demand, $\varepsilon = 1$ so that the steady-state elasticity of the markup to prices is $\Gamma = \varepsilon/(\sigma - 1) = 1/5$, a relatively low value. The Calvo pricing parameters are set to 0.65, for both wages and prices. The *NFA* adjustment cost is set to a small positive number, to ensure stationarity while leaving the system's dynamics largely unchanged. The coefficients of the Taylor rule in H and U are consistent with parameters often employed in the literature. We set the inertial coefficients ρ_{iH} and ρ_{iU} to 0.66, which corresponds to a first order autoregressive coefficient of 0.9 on quarterly data (see Coibion and Gorodnichenko (2011) for some estimates for the U.S.) We set the coefficients on inflation and the output gap in Chile to 1.5 and 0.5, respectively. Finally, we set the coefficient on global output in the U.S. Taylor rule to 0.1, which corresponds to a coefficient of

0.5 on U.S. output and takes into account the fact that U.S. output represents about 1/5 of world output. Next, we measure a quarterly serial correlation of world output of 0.89, which translates to $\rho_{yU} = 0.6$ at an annual frequency. We borrow the coefficient ϕ_{iU} of the impact of lagged U.S. policy rates on world output from Rudebusch and Svensson (1999). These authors estimate a semi-elasticity of lagged U.S. interest rates on world output of –0.1. Assuming that U.S. output represents 1/5 of world output, this coefficient is equal to $-5(1-\rho_{yU})\phi_{iU}$, from which we infer that $\phi_{iU} = 0.05$. Lastly, the coefficients θ_{ij}^{U} are obtained from the Central Bank of Chile as the share of exports and imports invoiced in U.S. dollars.

Table 1. Calibrated Parameters

Parameter	*Description*	*Value*
β	discount factor	0.97
χ	fraction of impatient consumers	0.65
γ	openness coefficient	0.7
φ	inverse Frisch elasticity	1
σ_c	CRRA	1
σ	steady-state elasticity of substitution between goods	2
ε	superelasticity of demand	1
ϑ	elasticity of substitution between labor varieties	2
δ_p	price stickiness	0.65
δ_w	wage stickiness	0.65
Ψ_b	NFA adjustment cost	0.001
ρ_{iH}	inertia in *H*'s Taylor rule	0.66
ϕ_{pH}	Taylor rule inflation coefficient	1.5
ϕ_{yH}	Taylor rule output gap coefficient	0.5
ρ_{iU}	inertia in *U*'s Taylor rule	0.66
ϕ_{yU}	Taylor rule output coefficient for U.S.	0.1
ρ_{yU}	serial correlation in global output	0.6
ϕ_{iU}	impact of lagged U.S. rate on world output	0.05
θ_{UH}^{U}	share of *H*'s imports in U.S. dollars	0.8627
θ_{UH}^{U}	share of *H*'s exports in U.S. dollars	0.9434

A.4 Estimation

We estimate 17 parameters. We set priors in the [0,1] interval, except for Ψ_{be}, for which we assume a Gamma prior. Table 2 reports the prior and posterior mean of the estimated coefficients.

Table 2. Priors and Posteriors

			Prior		*Posterior*		
	Parameter Description	*Dist.*	*Mean*	*S.D*	*Mean*	*90% Interval*	
ρ^{rp}	funding shock	beta	0.85	0.10	0.48	0.35	0.62
σ^{rp}		beta	0.20	0.10	0.15	0.10	0.20
ρ^{mH}	home monetary shock	beta	0.5	0.1	0.36	0.23	0.50
σ^{mH}		beta	0.70	0.20	0.02	0.01	0.02
ρ^{mU}	U.S. monetary shock	beta	0.5	0.1	0.50	0.37	0.65
σ^{mU}		beta	0.70	0.20	0.02	0.01	0.02
ρ^{b}	borrowing limit	beta	0.25	0.1	0.36	0.17	0.53
σ^{b}		beta	0.70	0.20	0.20	0.10	0.27
ρ^{a}	productivity	beta	0.85	0.10	0.89	0.81	0.99
σ^{a}		beta	0.20	0.10	0.10	0.04	0.16
ρ^{co}	copper	beta	0.85	0.10	0.90	0.83	0.99
σ^{co}		beta	0.70	0.20	0.20	0.13	0.26
ρ^{yU}	global output	beta	0.85	0.10	0.77	0.63	0.90
σ^{yU}		beta	0.20	0.10	0.06	0.03	0.09
Ψ_{be}	financial spillover	gamma	2.00	1.00	4.96	3.29	6.54
χ_{wc}	working capital	beta	0.80	0.10	0.76	0.61	0.90
ρ_{b}	persistence borrowing limit	beta	0.85	0.10	0.93	0.87	0.98

The table presents Bayesian estimates of model parameters. It specifies the distribution for the prior, its mean, standard deviation, as well as posterior mean and 90% confidence interval.

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