DOCUMENTOS DE TRABAJO

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Òscar Jordà
Fernanda Nechio

N° 850 Octubre 2019

BANCO CENTRAL DE CHILE

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Documentos de Trabajo del Banco Central de Chile
Working Papers of the Central Bank of Chile
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Teléfono: (56-2) 3882475; Fax: (56-2) 3882231

Documento de Trabajo
N° 850

Working Paper
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Inflation Globally*

Òscar Jordà
FRB San Francisco
and UC Davis

Fernanda Nechio
FRB San Francisco

Abstract

The Phillips curve remains central to stabilization policy. Increasing financial linkages, international supply chains, and managed exchange rate policy have given core currencies an outsized influence on the domestic affairs of world economies. We exploit such influence as a source of exogenous variation to examine the effects of the recent financial crisis on the Phillips curve mechanism. Using a difference-in-differences approach, and comparing countries before and after the 2008 financial crisis sorted by whether they endured or escaped the crisis, we are able to assess the evolution of the Phillips curve globally.

Resumen

La curva de Phillips sigue siendo fundamental en la política de estabilización. El aumento de los vínculos financieros, las cadenas internacionales de oferta y los tipos de cambio manejados han otorgado a las monedas principales una influencia desmesurada en los asuntos internos de las economías del mundo. Examinamos esta influencia como fuente de variación exógena para analizar los efectos de la reciente crisis financiera en el mecanismo de la curva de Phillips. Utilizando un enfoque de diferencias en diferencias, y comparando los países antes y después de la crisis financiera del 2008, clasificados según si sufrieron la crisis o se libraron, podemos evaluar la evolución de la curva de Phillips a nivel mundial.

* We are thankful to our discussant, Luca Gambetti, and conference participants who provided very helpful advice on how to improve the paper. We thank Chitra Marti, Ben Shapiro, and Eric Tallman for excellent research assistance. The views expressed in this paper are the sole responsibility of the authors and to not necessarily reflect the views of the Federal Reserve Bank of San Francisco or the Federal Reserve System. Jorda: oscar.jorda@sf.frb.org and ojorda@ucdavis.edu. Nechio: fernanda.nechio@sf.frb.org.

1. Introduction

The fortunes of the Phillips curve have ebbed and flowed ever since it was proposed by Phillips (1958). Although its origins are primarily as an empirical regularity, there is now a vast literature that provides more formal justification (see, *e.g.* Galí, 2008; Woodford, 2010, for a textbook review of the literature). In recent times, the Great Moderation and the modern era of central banking brought about the apparent empirical demise of this core relationship. As central banks gained credibility and inflation targeting became wide-spread, inflation expectations became better anchored, although the debate is far from settled (see, *e.g.*, Orphanides and Williams, 2005, Gürkaynak, Sack, and Swanson, 2005, and Gürkaynak, Levin, and Swanson, 2010). Starting in the mid-1980s, several advanced economies have generally experienced the business cycle with barely a ripple in inflation. Paradoxically, a credible, inflation-targeting central bank that cares about the tradeoff spelled by the Phillips curve and sets policy to offset fluctuations in aggregate demand will make empirical estimates of the Phillips curve appear flatter than they really are. The Phillips curve is fundamental for a central bank to evaluate counterfactual policy outcomes. It is not intended to be a forecasting tool.

From the beginning, the standing of the Phillips curve in the macroeconomics literature has been fraught (see Shimer, 2017, for a review). Its role in the standard New Keynesian model sat uneasily with ardent proponents of a more microfounded approach to macroeconomics coming from the Real Business Cycle tradition. Yet even today, New Keynesian monetary models featuring Phillips curve mechanisms remain mainstream in central bank circles (once again, two textbook references are Galí, 2008, and Woodford, 2010).

The Global Financial Crisis broke mold. Inflation surprised on the downside almost everywhere around the planet, even in economies that were seemingly unaffected by the crisis. The conversation quickly switched to a discussion of what policy measures should central banks implement to avoid outright deflation. With the crisis ten years behind us, it is only now that inflation appears to be returning to more normal levels, albeit slowly, once again defying well worn tenets.

Of course, to a student of economic history, the behavior of inflation following the crisis was not entirely surprising. Jordà, Schularick, and Taylor (2013) document that inflation usually runs low after financial crises, especially if they are preceded by a credit boom, as this one was. Even a simple average of inflation across advanced economies following a financial crisis, such as that displayed in Figure 1, is sufficient to clearly illustrate this point. A credit boom gone bust depresses inflation because aggregate demand flags for an extended period of time.

Against this background, we set out to investigate the Phillips curve globally. More than evaluating its empirical merits (which we also do), we use the Phillips curve as a yardstick with which to think about inflation dynamics globally. The Phillips yardstick then is a useful way to assess and contrast the recent history of advanced and developing economies, and specially between those economies that experienced the crisis (most of the advanced world), versus those that seemingly escaped unscathed.

We think that understanding what happened before and after the crisis across advanced and developing economies, and across economies that suffered and escaped the Global Financial crisis sheds light on important questions about the dynamics of inflation that have generated a great deal of debate. The literature on the nexus between inflation and credit is not large, in part because up to recently, credit has been a silent bystander in many macroeconomic models. A useful exception is Gilchrist, Schoenle, Sim, and Zakrajšek (2017). They argue that financially constrained firms have an incentive to raise prices in response to adverse financial or demand shocks in order to preserve internal liquidity. Such behavior would be consistent with an asymmetric Phillips curve that is flatter when credit is constrained since inflation would appear to be less responsive to fluctuations in demand.

Relating inflation and economic slack is, however, difficult. Aggregate demand factors will tend to push inflation and economic activity in the same direction, whereas supply cost-push factors operate in the opposite direction. Identification of the Phillips mechanism thus requires a source of exogenous variation. Our paper departs from the literature in this respect and builds, on one hand, on work by Galí and Gertler (1999), and Galí, Gertler, and López-Salido (2005), and on the other hand, on the work of di Giovanni, McCrary, and von Wachter (2009), and Jordà, Schularick, and Taylor (2017). Whereas the first investigate the Phillips curve using alternative measures of slack in a general setting, the latter suggest that monetary policy from large economies can bleed through into smaller economies that manage their exchange rates tightly and thus have unintended effects on domestic policy. Such a mechanism will be useful to complement some of the potential instrumental variables used in Galí and Gertler (1999), and Galí et al. (2005).

More specifically, the well known *trilemma* of international finance (see, *e.g.*, Obstfeld and Taylor, 1998, Obstfeld and Taylor, 2003; Obstfeld, Shambaugh, and Taylor, 2004; Obstfeld, Shambaugh, and Taylor, 2005; and Shambaugh, 2004) explains how such bleed through can occur. Investors trying to arbitrage returns across similar assets tend to equalize their returns. If exchange rate risk is removed (as it largely is when economies peg), such equalization neutralizes domestic monetary policy to a large degree. Large economies set monetary policy domestically, but through the trilemma mechanism, can have effects beyond their borders. Such occurrences are the type of exogenous variation that will permit a cleaner read of the Phillips curve mechanism.

Using an instrumental variable for economic slack sets our analysis apart from most of the literature. However, we take matters one step further. Our interest in examining the effects of the financial crisis on the Phillips curve requires that we recognize that during this period there have potentially been other forces at work. Such forces include development of global value chains (Auer, Borio, and Filardo, 2017), the role of China on global inflation (Eickmeier and Kühnlenz, 2018), international spillovers from commodity prices (Fernández, Schmitt-Grohé, and Uribe, 2017), and so on. A finding that the slope of the Phillips curve shifted from 2008 onwards could be explained by any of these factors and not by the quick deceleration of credit that followed the crisis.

We avoid such confounding with a difference-in-differences strategy. In addition to comparing Phillips curve estimates before and after the crisis using instrumental variables, we also compare estimates for crisis-hit versus crisis-missed countries. That is, we ask first whether there was a measurable shift in the slope and persistence of the Phillips curve, and whether this shift was comparable across subpopulations. Such an empirical strategy is not novel in the applied microeconomic literature, but it is somewhat uncommon in international macroeconomics.

The bird's eye view of inflation globally is surprising. By most accounts, the Global Financial Crisis was an Advanced Economies Crisis. Many of the developing economies of Asia and Latin America, with less developed financial systems, did not experience similar credit booms to those experienced in the developed world, nor did they experience the rapid loss in employment that followed. Yet their inflation appears to have taken a hit during the crisis that is reminiscent of what happened in the developed world. More interestingly and with a few glaring exceptions, inflation globally continued to decline toward levels more consistent with what advanced economies have experienced in the past 20 years. That raises some interesting links to a nascent literature on the neutral rate of interest, and secular stagnation. This apparent widespread decline in inflation takes place despite record low levels of nominal interest rates, and increasing evidence of a decline in the natural rate of interest (*e.g.*, Summers, 2014, Carvalho, Ferrero, and Nechio, 2016, and Eggertsson, Mehrotra, and Robbins, 2017).

Our findings provide insights on some of the main hypotheses entertained in the literature. To a casual observer, the relative stability of inflation early on as economies were experiencing turmoil might have seemed consistent with the Gilchrist et al. (2017) argument that credit constrains forced firms to pass-through price increases when demand was flailing. However, we show that the evidence in support of this hypothesis is mixed. Instead, we document that there was a gradual movement in the Phillips curve toward a larger role for inflation expectations and a diminished role for backward looking terms, at the same time that the Phillips curve became somewhat flatter. Such a trend is visible in both countries hit and missed by the crisis.

Had we only analyzed crisis hit economies, we might have concluded that such changes were due to the financial crisis. Hence, pairing our difference-in-differences identification strategy with the trilemma instrument appears to have paid off in avoiding confounding from underlying trends in global inflation consistent with central banks gaining greater credibility globally.

It would likely be miscalculation to interpret the flattening of the Phillips curve as a license to stimulate the economy. With the crisis came severe distortions in labor markets that forced many individuals out of the labor force. As the economy recovered and the unemployment rate declined to more normal levels, some voices have pushed for maintaining accommodative monetary policy for a while longer to try and reclaim workers back into the labor force. Such a view rests on the observation that inflation has remained relatively quiescent as the labor market quickly improved, consistent with the Phillips curve being flat. But of course, the stability of inflation relies on the central bank adjusting the degree of accommodation as the economy improves. To deviate from that norm, may have greater effects on inflation than is widely understood by casual observation.

2. International evidence: inflation before and after the Global Financial Crisis

Financial crises tend to depress inflation long after the crisis has past. This pattern was repeated in the aftermath of the Global Financial Crisis and arguably represents a sort of natural experiment. That is, we can evaluate the effects of the crisis (and of a credit boom gone bust) on the dynamics of inflation (and hence its effects on the Phillips curve) by comparing crisis-hit countries against those that avoided it. Of course, this will require that we account for possible unrelated pre-existing trends and for spillovers or contagion effects. These are some of the issues that we discuss in more detail when we introduce the methods that we employ in our analysis.

Importantly, the recent financial crisis is the first to affect a large number of advanced economies in the era of modern central banking—a time where we tend to think that inflation expectations had been well-anchored in many economies—and where the consensus is that central banks largely responded to the crisis in the right direction, even if the question of whether they did with sufficient force remains open.

A simple way to begin our journey and to illustrate the main ideas is to use historical data. Financial crises are relatively rare events (at least in advanced economies) so it helps to have a long sample. Using historical data for 17 advanced economies available from the database described in Jordà, Schularick, and Taylor (2016), Figure 1 shows the average path of inflation and real GDP per capita across 17 advanced economies following past financial crises set against the average path of inflation after a non-financial crisis recession.[1,2] In addition, we show the path of inflation for economies hit by the 2008 financial crisis.

More specifically, Figure 1 panel (a) displays the path of headline CPI inflation for the crisis-hit countries since the Great Recession set against the average rate of inflation observed in normal recessions and past financial crises using data across the 17 advanced economies, observed from 1870 to 2015. The data are normalized to the rate of the average CPI inflation in 2017 across crisis-hit economies to facilitate the comparison. The panel shows that, on average, prices tend to remain subdued for several years after a financial crisis (blue, dot-dash line). Interestingly, up to 2013, the behavior of average inflation (solid black line) resembled that of a typical recession, not a financial crisis (red, short-dash line). Since 2013, however, prices have been slower to recover, more in line with financial crises.

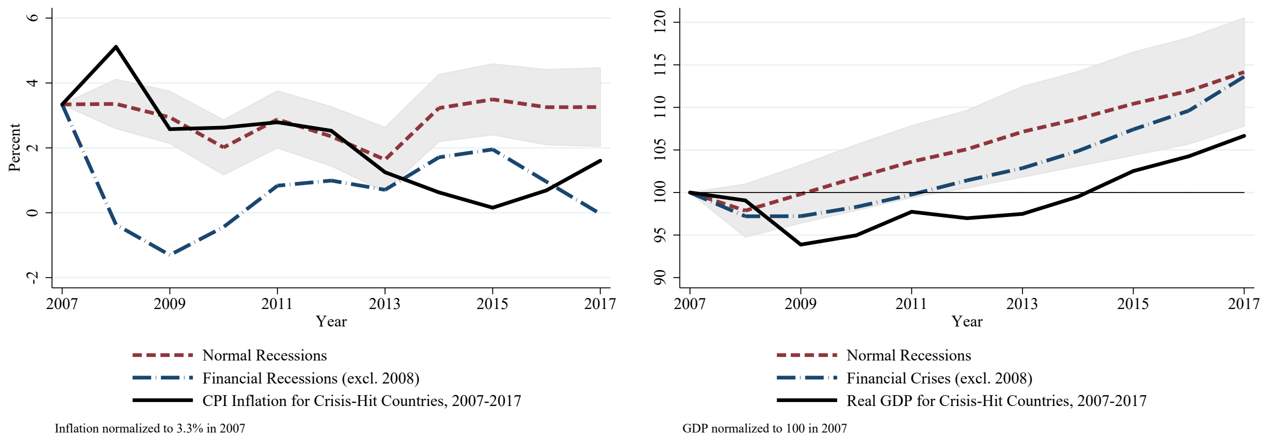
Panel (b) shows the average path of real GDP per capita following typical recessions, past financial crises, and the actual experience for the crisis-hit countries since the financial crisis. The path of real GDP per capita is normalized to 100 at the start of each of these events. It shows that real GDP per capita in crisis-hit countries have been relatively slow to recover. Moreover, whereas in previous financial crises it appears that real GDP per capita recovered after about 10 years, the latest

[1] The database is available at www.macrohistory.net/data.

[2] The set of countries include: Australia, Belgium, Canada, Switzerland, Germany, Denmark, Spain, Finland, France, Italy, Japan, Netherlands, Norway, Portugal, Sweden, the United Kingdom and the Unites States.

Figure 1: *Headline CPI inflation and real GDP per capita after financial crises and normal recessions*

(a) *Headline CPI Inflation* **(b)** *Real GDP per capita*



Notes: Headline CPI price index and real GDP per capita reported as an index normalized to 100 in 2007. 90% error bands reported for normal recessions as a gray shaded region.

financial crisis appears to have had permanent effects on the economy.[3]

These observations have to be set against the behavior of the economy. Panel (b) of Figure 1 shows that in typical recessions, real GDP per capita declines by about 2.5% in the first year of the recession, but by the second year, real GDP per capita is back to where is was at the peak, and continues to grow thereafter. This is shown with the red dashed line. In financial crises, the economic toll is heavier and longer lasting. Returning to peak levels takes four rather than two years, and only 10 years after the crisis begins does real GDP per capita catch up to the path we see for typical recessions. The world experience following the financial crisis is harrowing. The gap opened by the crisis has not only failed to narrow, it appears to have continued to widen (albeit only slightly). There appears to be a permanent loss in economic welfare that is somewhat unprecedented in economic history.

What happened in 2008 and how does it compare with the historical record? Figure 2 provides a summary using different groupings of economies by region. Panel (a) of that figure shows the experience of the U.S. and the euro area[4] (the two largest economic zones hit by the crisis) against Australia, the reference economy selected as an example of an advanced economy that was largely unaffected by the crisis (this will become clearer in Figure 3, which shows the unemployment rate for these economies). Panel (b) simply summarizes the recent history of inflation for Asian and Latin American economies compared to Advanced Economies.[5]

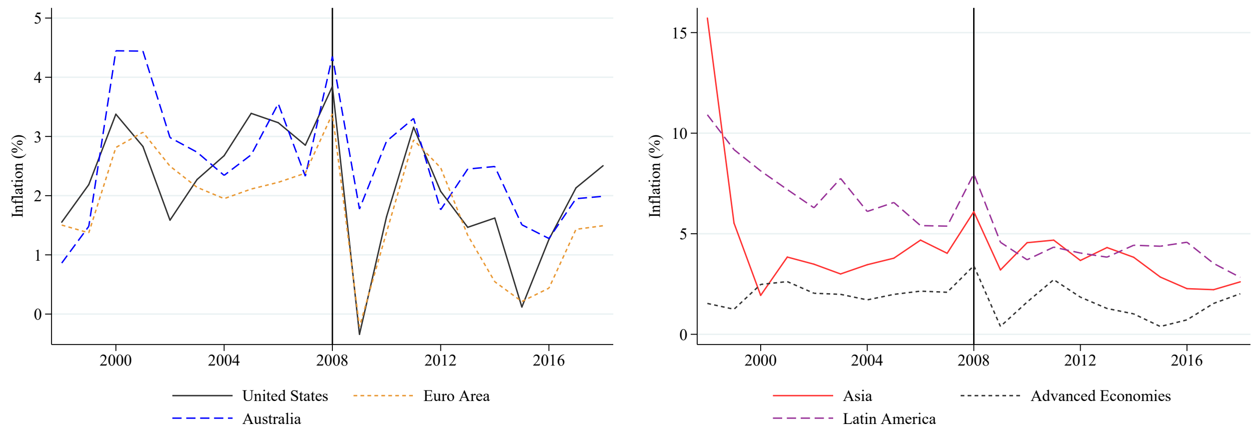
[3] Barnichon, Matthes, and Ziegenbein (2018) estimate a lifetime present-value loss of about $70,000 per person for the United States.

[4] Euro area countries exclude Estonia, Latvia and Lithuania due to lack of data.

[5] Asian economies include: China, India, Indonesia, Japan, South Korea, Malaysia, Philippines, Singapore, Thailand, and Vietnam. Latin America includes: Brazil, Chile, Colombia, Costa Rica, Mexico. Advanced

Figure 2: *CPI inflation before and after the Global Financial Crisis*

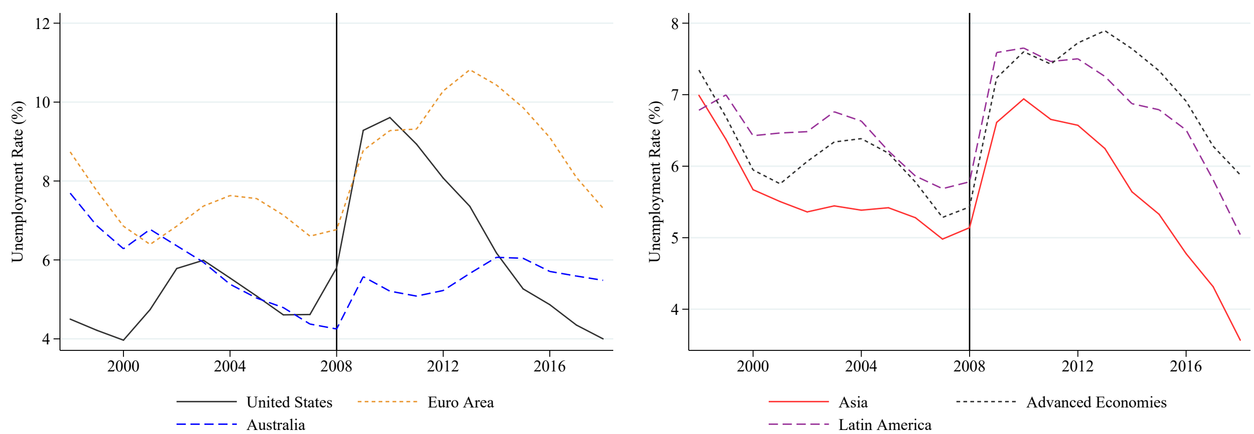
(a) *U.S., Euro Area, Australia* **(b)** *Asia, Advanced Economies, Latin America*



Notes: Sample: 1997–2017. Data for U.S., Euro Area (Austria, Belgium, Cyprus, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Malta, the Netherlands, Portugal, Slovakia, Slovenia, and Spain), Canada, and Australia.

Figure 3: *Unemployment before and after the Global Financial Crisis*

(a) *U.S., Euro Area, Australia* **(b)** *Asia, Advanced Economies, Latin America*



Notes: Sample: 1997–2017. Data for U.S., euro area (Austria, Belgium, Cyprus, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Malta, the Netherlands, Portugal, Slovakia, Slovenia, and Spain), Canada, and Australia.

Like Figure 1, Figure 2 shows that following the crisis inflation declined sharply in the year of the crisis, but has stayed subdued until very recently (in the U.S. core PCE inflation is now near its long-run target of 2%). However, this time there was less outright deflation (except for the

economies include: Australia, Austria, Belgium, Canada, Croatia, Denmark, Estonia, Finland, France, Germany, Iceland, Ireland, Italy, Japan, Luxembourg, Netherlands, New Zealand, Norway, South Korea, Spain, Sweden, Switzerland, United Kingdom, United States, and Singapore.

euro area, which experienced the initial hit of the financial crisis followed by the sovereign debt crisis). Australian inflation slowed down slightly, but it could be argued that this slowdown was part of a trend toward lower inflation that preceded the crisis. This is one of the possibilities that we investigate more carefully in our analysis below.

Panel (b) of Figure 2 also shows a general decline of inflation across the world. Even discounting some of the hyperinflation episodes early in the sample, inflation in Latin America had run consistently above 5% on average prior to the crisis, but has been running consistently below since. Inflation in Asian economies (except for some high inflation episodes affecting the average at the start of the sample) has remained fairly stable throughout the period displayed.

Much, but not all of the behavior of inflation can be explained by cyclical fluctuations here exemplified by the unemployment rate in Figure 3. This figure is organized in the same manner as Figure 2. Panel (a) shows the rapid and dramatic increases in the unemployment rate in the U.S. and in the euro area (especially following the sovereign debt crisis) in contrast to the considerable stability of the unemployment rate in Australia. Yet, Australia's inflation rate continued a mild decline similar to the economies of the U.S. and the euro area. Meanwhile, the declines in the inflation rate in Asian and Latin American economies visible in Figure 2 seem to correspond to a generalized slowdown in economic activity in these regions. The unemployment rate also went up in these regions, in part because some countries also experienced the effects of the financial crisis outright, or indirectly, through weaker global demand.

Some of the main themes to come are becoming apparent in Figure 1 and Figure 2. First, relative to the rapid increase in the unemployment rate depicted in Figure 3, the puzzle seems to be why did inflation not fall by more early in the Global Financial Crisis, as it had done in the previous 140 years? At this point it is probably good to remember that, at least in the U.S., the revival of productivity that stretched over the decade spanning 1995 to 2005, had already began to quickly taper off before the crisis, and had bottomed out during that time only to experience a very mild recovery more recently. Others have argued that the global trend to higher level of concentration across sectors provides a buffer against sharp declines in inflation although this literature is still in its infancy

Secondly, and perhaps as important for our purposes, Australia experienced a slowdown in inflation that matches the experience of crisis economies reasonably well. This pattern, however, seems to suggest little role for the traditional Phillips mechanism as Australia's unemployment rate did not move as much. Crisis countries did not see inflation dip as in previous eras, and some non-crisis countries followed a similar pattern of subdued inflation that seemed, at times, unrelated to domestic economic activity. On this evidence alone, it could be argued that, if anything, inflation expectations became increasingly well anchored throughout a very turbulent period.

3. International inflation dynamics: basic facts

As a way to summarize the dynamics of inflation globally, we pursue a straightforward strategy. Whenever we want to characterize the degree of interconnectedness of a given variable, say headline CPI internationally, we report a 5-year rolling window average of a country's correlation with another, that is:

$$\bar{r}_t = \frac{\sum_i \sum_j r_t^{i,j}}{N}; \quad N = \frac{(n-1)n}{2}, \tag{1}$$

where $r_t^{i,j}$ refers to the sample correlation coefficient between countries i and j, calculated over a 5-year rolling window that ends at time t. The number of countries in the sample is n, and hence N refers to the total number of distinct correlation pairs in a sample with n countries.

At times we will modify this statistic slightly. We will be interested, for example, on the correlation of headline CPI inflation for a given country against oil price inflation. And we want to report a summary statistic for the correlation observed across all countries. In that case we modify Equation 1 as follows:

$$\bar{r}_t = \frac{\sum_i r_t^{i,x}}{n}, \tag{2}$$

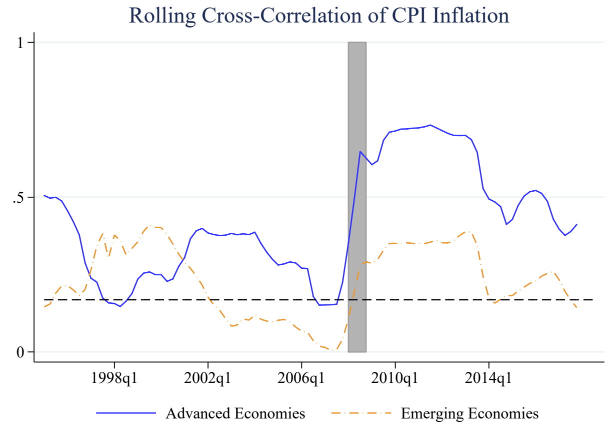
where $r_t^{i,x}$ refers to the correlation of country i against a given variable of interest x, in our example, oil price inflation. We think that these simple statistics help convey the main features of inflation globally more clearly than if we had used, for example, a factor model in which the factors would have to be "interpreted" as representing some quantity of interest.

With these preliminaries out of the way, we begin our data exploration with Figure 4. The figure reports the cross-correlation of CPI inflation across economies (see Equation 1 organized into two blocs: advanced vs. emerging economies (see the Appendix Table A1 for the list of countries under each grouping). A 95% significance band is provided as a reference in the figure. Figure 4 shows clearly that the financial crisis was an advanced economies event. Before the crisis, inflation was loosely connected in both advanced and emerging economies (borderline significant at best), but as the crisis hit and inflation became subdued in crisis-hit economies, the separation between advanced and emerging economies became more visible.

Because we are using headline CPI inflation (the most widely available measure of inflation), we have to be mindful that some of the patterns that we observed could be explained by energy and commodity prices. For this reason, Figure 5 displays the correlation of CPI inflation with oil price inflation (using West Texas Intermediate–WTI–crude oil) and commodity price inflation. These are displayed respectively in panels (a) and (b) of the figure.

Figure 5 panel (a) shows that, although the correlation of CPI inflation with oil prices has grown over time, it was marginally significant for all economies before the financial crisis, but has grown over time more noticeably for advanced economies. It is good to remember that oil prices grew

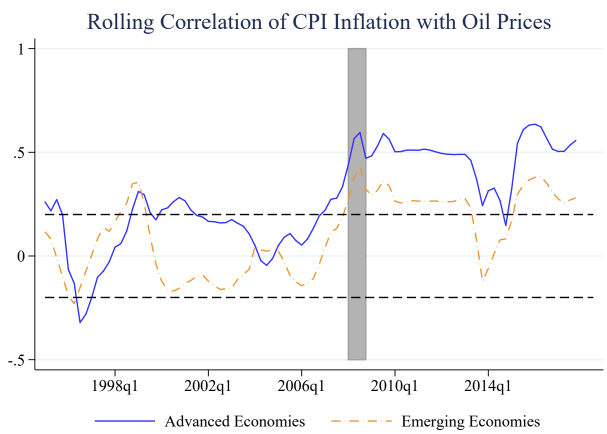
Figure 4: *Headline CPI: rolling window average cross-correlation*



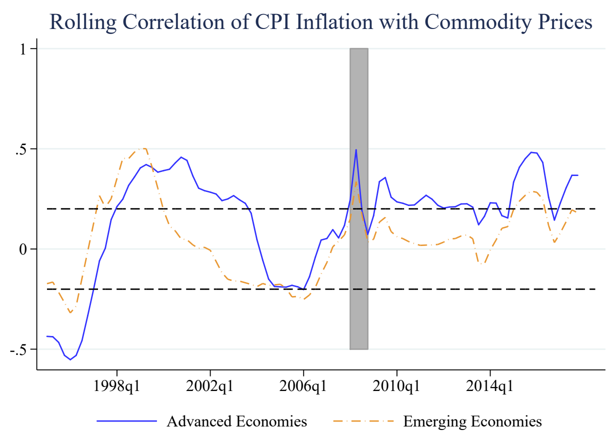
Notes: Cross correlation calculated as in expression Equation 1. Data organized into Advanced Economies and Emerging Economies according to the country grouping listed in the Appendix. Dashed line is the 95% significance critical value. Shaded gray region indicates 2008 to 2009, the year of the financial crisis for most countries. See text for additional details.

Figure 5: *Headline CPI: country cross correlation and autocorrelation*

(a) *Average correlation with oil prices*



(b) *Average correlation with commodity prices*

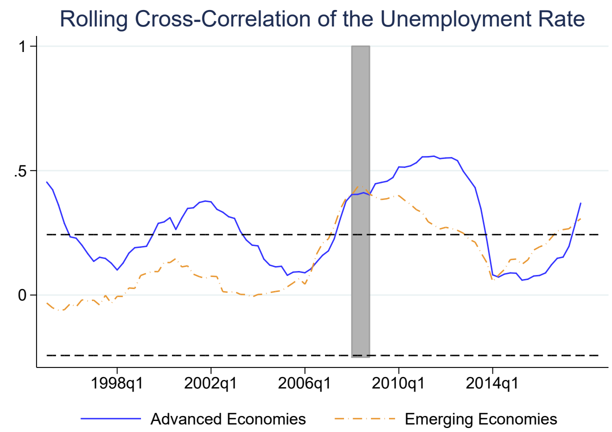


Notes: Average correlation calculated as in expression Equation 2 using a 5-year rolling window. Data organized into Advanced Economies and Emerging Economies according to the country grouping listed in the appendix. Dashed line is the 95% significance critical value. Shaded grey region indicates 2008 to 2009, the year of the financial crisis for most countries. See text.

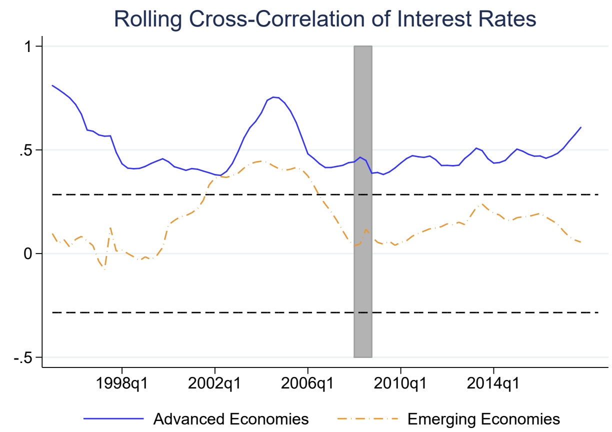
rapidly before the crisis and in the first few years thereafter, only to subsequently decline quite noticeably. Some commentators (see, *e.g.*, Cao and Shapiro, 2016, and references therein) in fact attribute the decline in inflation expectations to oil prices. Again, if inflation were well anchored, headline CPI inflation would primarily move with energy prices, and perhaps the increase over time of the correlation displayed in Figure 5 is a reflection of that. Interesting, later on we provide

Figure 6: *Headline CPI: country cross correlation and autocorrelation*

(a) *Unemployment rate average cross-correlation*



(b) *10-year bond yield average cross correlation*



Notes: Cross correlations calculated as in expression Equation 1 using a 5-year rolling window. Data organized into Advanced Economies and Emerging Economies according to the country grouping listed in the Appendix. Dashed line is the 95% significance critical value. Shaded grey region indicates 2008 to 2009, the year of the financial crisis for most countries. See text for additional details.

additional evidence pointing toward a better anchoring of inflation expectations since the crisis.

Our final set of charts are shown in Figure 6. Panel (a) shows the cross-correlation of unemployment rates and could be interpreted as measure the amount of international business cycle synchronization. Meanwhile, panel (b) shows the cross-correlation in long-term bond yields (government securities with typical duration of 10 years) in an effort to examine the oft-cited synchronization in interest rates due to the decline of the real rate of interest in advanced economies reported, for example, in Holston, Laubach, and Williams (2017).

Beginning with panel (a) of Figure 6, evidence of synchronization in business cycles is surprisingly feeble for emerging economies, with a slight tick up during the crisis, but in any case small in economic and statistical terms. Synchronization in advanced economies is somewhat more visible, especially after the crisis, as to be expected, but it has clearly died down in recent times. Meanwhile, panel (b) suggests that, while there is considerable comovement of interest rates in advanced economies (averaging about 0.5 or higher for the entire sample), the same cannot be said for emerging economies, with almost near zero correlation. We do not investigate this dichotomy further, but it strikes us as an interesting divergence that does not fit the neat experience of advanced economies, which have seen decline in long term rates over the past 30-40 years.

Summing up, we use the results of these figures in perhaps a peculiar way. To anticipate our analysis, we will rely on the different experiences advanced economies (primarily) endured during the crisis set against the experience of (mostly) emerging market economies to try to tease out the manner in which both the crisis and the subsequent credit crunch affected the dynamics of inflation embodied by the Phillips curve.

The figures in this section show that there is a fair amount of synchronicity in advanced economies, not just in terms of inflation, but also in terms of the business cycle (as shown for unemployment rates), and in terms of interest rates. They also show that oil prices seem to be a less important source of variation in headline CPI inflation for emerging markets than for advanced economies. The contrasting experiences of advanced and emerging market economies will be helpful in getting a cleaner read on the causal effects of the crisis on inflation.

4. Identification of the Phillips Curve

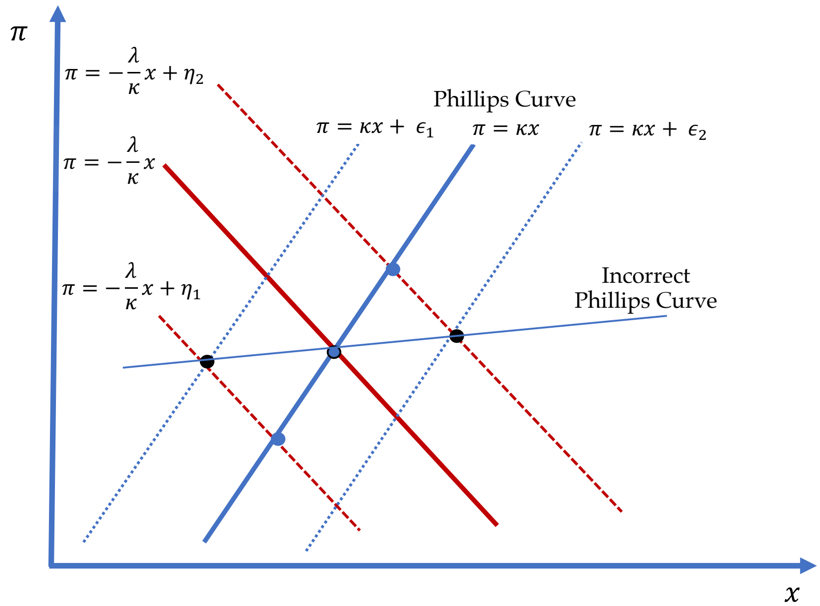
Economies that endured the Global Financial Crisis experienced rapid increases in unemployment, dramatic declines in economic activity, but remarkable stability in inflation rates. The *missing disinflation* shown earlier in Figure 1 was a widespread phenomenon. Mechanically, such an outcome will tend to eliminate the correlation between inflation and economic slack—the unemployment rate fluctuated wildly but inflation remained relatively stable. This disconnect has been widely interpreted as a flattening of the Phillips curve (see, *e.g.* Ball and Mazumder, 2011; Blanchard, Cerutti, and Summers, 2015; Coibion and Gorodnichenko, 2015; Dotsey, Fujita, and Stark, 2017; Forbes, Kirkham, and Theodoridis, 2018). More recently, the missing disinflation has turned into the *missing inflation.* With most economies now recovered from the financial crisis and several running close to, or at full employment, inflation has remained relatively subdued.

Even an earlier literature has documented the empirical challenges in estimating the contributions of economic slack to inflation. These challenges include mismeasurement concerns regarding the measures of output gap, omitted variables, misspecification, estimation concerns, and difficulty in obtaining measures of inflation expectations (Galí and Gertler, 1999; Sbordone, 2002; Mavroeidis, 2005; Stock and Watson, 2007, 2008; Coibion and Gorodnichenko, 2015; Mavroeidis, Plagborg-Møller, and Stock, 2014; Nason and Smith, 2008). In addition, more recently, McLeay and Tenreyro (2018) argue that most estimates of the Phillips curve insufficiently recognize the role of a history of "good monetary policy" in the estimation of the Phillips curve. In the context of a traditional New Keynesian framework and absent any supply-side shocks, an inflation-targeting central bank that conducts countercyclical policy to neutralize aggregate demand fluctuations will achieve constant inflation at the targeted level. As a result, the correlation between inflation and measures of economic slack will be zero.

These empirical challenges and the seemingly weak relationship between slack and inflation stands in sharp contrast to standard macroeconomic models, such as the New Keynesian ones (see, *e.g.*, Galí, 2008; Smets and Wouters, 2007).

While the empirical literature varies on their reasonings behind the weak empirical properties of Phillips curves, most papers agree that the implication of their concerns is that identification of the slope of the Phillips curve requires exogenous shifts in policy that cannot be explained by aggregate demand fluctuations. In plain English, we need a valid instrumental variable. Authors have long recognized these issues and have used instrumental variable methods, including measures of oil and commodity price inflation to soak up cost-push fluctuations in inflation (*e.g.*, Roberts, 1995;

Figure 7: *Identification of the Phillips curve through exogenous policy implementation*



Notes: Graphical representation of equations (3) and (5) for different values of the cost-push and implementation shocks. "Incorrect Phillips Curve" refers to the Phillips curve that would be inferred from observing equilibrium outcomes. See text for additional details.

Galí and Gertler, 1999; Galí et al., 2005), and tried to account for changes in productivity and other supply side factors (*e.g.* Ball and Moffitt, 2001).

Figure 7 helps illustrate the need for instrumental variables when estimating the Phillips curve. Like McLeay and Tenreyro (2018) we borrow a simple New Keynesian model from Galí (2008) to communicate the main ideas. Consider a log-linearized New Keynesian curve given by:

$$\pi_t = \beta E_t\, \pi_{t+1} + \kappa\, x_t + \epsilon_t, \tag{3}$$

where π_t is the deviation of inflation from its target, x_t measures economic slack with the output gap, and ϵ_t is a cost-push shock. Assume that $\kappa > 0$.

Assume that the policymaker can directly target economic slack, so that we can set aside having to discuss the IS curve (which only provides the nexus between monetary policy and economic slack). Under discretion (McLeay and Tenreyro (2018) shows that similar results can be obtained under commitment and under more general settings), assume the policymaker minimizes the following quadratic loss

$$L_t = \pi_t^2 + \lambda x_t^2, \tag{4}$$

where $\lambda \geq 0$ is the policymaker's preference parameter over output stabilization relative to inflation stabilization. Given Equation 3, the policymaker's optimal targeting rule equals

$$\pi_t = -\frac{\lambda}{\kappa} x_t + \eta_t, \tag{5}$$

where we have added the implementation error process η_t. This process naturally generates exogenous variation in the manner monetary policy is implemented.

The Phillips curve, Equation 3, and the target rule, Equation 5, are displayed in Figure 7 in solid blue and red, respectively. Movements along the Phillips curve show a positive relationship between the output gap and inflation. Shocks to this curve, however, result in a negative relationship between the latter two variables. If one only observes the unemployment gap and inflation equilibrium outcomes, the estimation would lead to the "Incorrect Phillips Curve." The challenge is, hence, to identify movements along the Phillips curve. To do so, the econometrician can rely on shocks to the target rule, which would trace out movements along the correct Phillips curve. In very simple terms, this is what we aim for with our empirical strategy laid out in the next section.

5. Statistical design

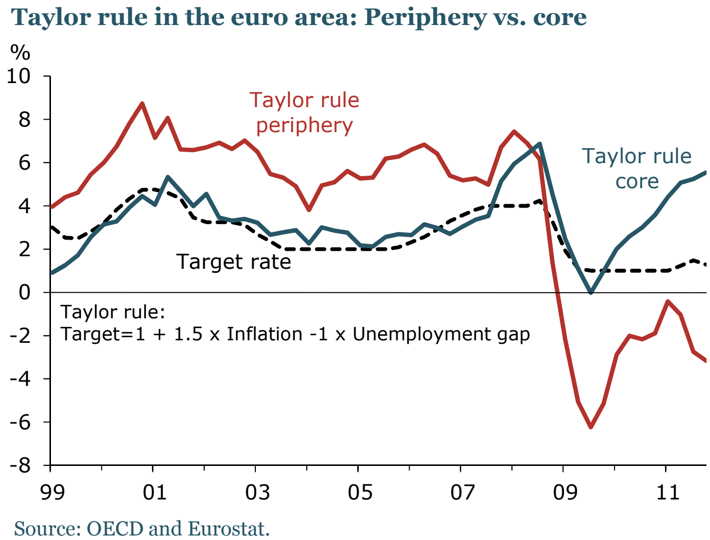
The previous section forcefully makes the case that to properly estimate the Phillips curve one requires instrumental variable methods. However, as Figure 2 makes clear, declines in the rate of inflation were already evident in many economies that did not experience the financial crisis directly. If we were to estimate the Phillips curve before and after the financial crisis, we may be tempted to conclude that in its aftermath—like many times in the past—the slope has flattened. We think conclusive evidence requires that we go one step further. In addition to proposing an instrumental variable strategy, we consider a difference-in-differences approach. We discuss our choice of instrumental variable first.

5.1. The trilemma as a source of exogenous variation

One of the difficulties in extracting conclusions about the Phillips curve from raw data on inflation, expected inflation, and a measure of the economic activity gap (such as the deviation of the unemployment rate from its natural rate) is classical simultaneity bias, as we just discussed. In other words, setting aside the role of expectations, the correlation between inflation and economic activity reflects movements along the Phillips curve as well as shifts generated by supply shocks. We need to find an instrumental variable.

To address this identification issue in a manner that can be used across a wide swath of countries, we borrow from previous work by di Giovanni et al. (2009), and Jordà, Schularick, and Taylor (2015, 2017). The core idea in these papers is to exploit the *trilemma* of international finance. Simply stated, the trilemma suggests that countries that peg their exchange rate while allowing capital to flow freely across borders, give up a great deal of monetary autonomy. The reason is that pegging the

Figure 8: *The trilemma in the euro zone: An Illustration*



Notes: This figure reproduces Figure 3 in Nechio (2011). See original citation for details.

exchange rate (or even floating, but managing the exchange rate over a narrow band) mitigates exchange rate risk considerably. Using absence of arbitrage and uncovered interest rate parity based arguments, similar assets (in risk and maturity adjusted terms) should have similar returns across borders. Countries that peg to a base economy will therefore relinquish much of their ability to affect interest rates since base country interest rates will largely determine domestic rates.

To implement the trilemma idea, we divide the sample into three subpopulations: base economies, pegs, and floats. Base economies in our sample will be the U.S. and Germany (for euro zone countries only). Pegs are economies that fixed their exchange rate to that of a base economy. For example, we interpret that euro zone economies peg to Germany, the largest economy in the bloc. Moreover, a cursory look at how policy rates are set in the euro zone suggests that this may not be a bad approximation. We illustrate this point in Figure 8.

This figure divides the euro area into core (think Germany as an example) and periphery (think Spain as an example) economies. It then calculates the prescribed policy rate based on a standard Taylor rule and compares the result with the euro zone target rate. The point that the figure makes is abundantly clear and fits with the intuition of many commentators: in the lead up to the crisis, monetary policy was too accommodative for countries like Spain (whose inflation rate doubled that of Germany during this period), but in line with what would have been optimal for Northern European economies.

We also consider in our sample countries that peg to the U.S. dollar. We rely on Ilzetzki, Reinhart, and Rogoff (2017) to sort those countries into the appropriate categories. All other economies, the floats, are assumed to allow their exchange rate to vary freely with market forces. For this reason, the pass-through of, say, U.S. monetary policy to domestic rates will be greatly attenuated if not altogether eliminated. Within this division into three subpopulations, we will also narrow our focus and further divide the data into OECD and non-OCED economies, for example. The reason is that one could argue that developing economies may be a poor control.

5.2. Difference-in-differences estimates

The second feature that we bring to the analysis is designed to tackle the following situation. If we were to estimate the Phillips curve using our panel of pegs before and after the financial crisis, we would have no guarantee that any changes in the Phillips curve reflected the aftereffects of the crisis as opposed to other forces that may have affected the dynamics of inflation over time. To account for that possibility, the strategy we pursue comes directly from the applied microeconomics literature. Basically, we will further divide the data into a treated and control groups (countries that were hit by the crisis versus those that were not). Then we will compare each group's Phillips curve before and after the crisis.

The basic specification of the hybrid Phillips curve that we are interested in estimating is that given by

$$\pi_{it} = \alpha_i + \rho_1 \pi_{i,t-1} + \rho_e \pi^e_{it} + \beta x_{it} + \boldsymbol{\gamma}\, \boldsymbol{w_t} + \epsilon_{it} \tag{6}$$

where α_i is a country-fixed effect, ρ_1 measures the accelerationist or persistent term of inflation, ρ_e measures the weight on inflation expectations, and β is the slope of the Phillips curve—x_{it} refers to the measure of slack, either the output gap or in robustness checks provided in the appendix, the unemployment rate in deviations from the natural rate, $u_{it} - u^*_{it}$. In addition, $\boldsymbol{w}_t$ will capture fluctuations in the price of oil and in commodity prices. Because these variables are common across countries, they act as a pseudo common factor for inflation. Below we describe these variables in more detail.

Next, define two indicator variables, $G_i \in \{0, 1\}$ which selects those countries in our sample that experienced the financial crisis ($G_i = 1$) versus those that did not ($G_i = 0$). The other indicator variable is $D_t \in \{0, 1\}$, which takes the value of 0 for observations preceding 2008Q1, and 1 thereafter. In other words, $D_t = I(t \geq 2008Q1)$. Using these indicator variables, we can now expand Equation 6 as follows:

$$\begin{aligned}\pi_{it} = \alpha_i &+ \{\rho^0_1 \pi_{i,t-1} + \rho^0_e \pi^e_{it} + \beta^0 x_{it}\} \quad + \\ &+ \{\rho^c_1 \pi_{i,t-1} + \rho^c_e \pi^e_{it} + \beta^c x_{it}\} G_i \quad + \\ &+ \{\rho^a_1 \pi_{i,t-1} + \rho^a_e \pi^e_{it} + \beta^a x_{it}\} D_t \quad + \\ &+ \{\rho^{ac}_1 \pi_{i,t-1} + \rho^{ac}_e \pi^e_{it} + \beta^{ac} x_{it}\} G_i\, D_t \; + \boldsymbol{\gamma}\, \boldsymbol{w_t} + \epsilon_{it}\end{aligned} \tag{7}$$

For example, focusing on the slope of the Phillips curve coefficient, $\hat{\beta}^0$ is the estimate of the baseline slope for the control group, that is, those countries that did not experience the crisis, evaluated before the crisis; $\hat{\beta}^0 + \hat{\beta}^c$ is an estimate of the slope for countries hit by the crisis and a test of the null $H_0 : \beta^c = 0$ is a test of the null that the slope of the Phillips curve between the treated group (crisis-hit economies) and the control group is the same in the period before the crisis. Next, $\hat{\beta}^0 + \hat{\beta}^a$ is an estimate of changes in the Phillips curve slope after $2008q1$ for the control group. A test of the null $H_0 : \beta^a = 0$ would indicate that non-crisis economies saw no changes in the slope of the Phillips curve.

However, the key parameter that captures the effect that we pursue is $\hat{\beta}^{ac}$ and the corresponding null hypothesis is $H_0 : \beta^{ac} = 0$. This null evaluates the effect of having being hit by the crisis and evaluates the slope in the post-2007 sample, stripping any changes in the slope of the Phillips curve that could have affected all economies even if the crisis had not occurred (the counterfactual). To save degrees of freedom, we assume that the fixed effects and the effect of oil and commodity prices remained unchanged throughout.

Our analysis differs from common applications of difference-in-differences estimators. Typical applications in applied microeconomics often take as the object of interest the introduction of a particular policy (the treatment), so that the change in policy is itself indicated with a binary variable. In our case, we are concerned about changes in two parameters that could have been affected by the financial crisis, the accelerationist term ρ_1 as well as the expectations term ρ^e, and the slope parameter β. In addition, there are often two periods involved, before and after the policy is implemented. In our application, we have two different samples rather than two points in time. The next few sections put all these methods to work.

6. Analysis

Below we take these ideas to the data using a broad cross section of economies observed at quarterly frequency over the past 20 years or more. We will gradually build the analysis as follows. First we provide a description of the data, its sources and the main transformations. Next, we start from a full sample, panel IV estimate of the Phillips curve to draw the main features. The analysis uses a coarse breakdown of economies to spot where differences may be coming from. We follow this preliminary look at the data with a more careful difference-in-difference, panel IV, analysis to examine more carefully the main hypothesis of our analysis: Did the financial crisis and subsequent credit crunch cause the Phillips curve to change? And if so, in what ways?

6.1. Data description

The sample that we examine consists of a panel that includes 45 OECD and non-OECD countries across the world. Because our focus is on a narrow window of time, we need as large a cross section of countries to improve the precision of our estimates. For many of our economies, data is only available starting sometime in the mid-1990s. In particular, we focus on the 1986Q1 to 2018Q1 period and divide the sample in 2007Q4 to mark the financial crisis starting in 2008. We recognize that not all countries experienced the same starting date for the financial crisis, although Figure 2 suggests that this characterization is not too far off the mark.

To achieve better sample sizes and consistent measures across countries, we rely on CPI as our inflation measure. Our measure of inflation expectations correspond to one-year-ahead expectations and are obtained directly from alternative sources or constructed as in Hamilton, Harris, Hatzius, and West (2016) using past inflation to generate out of sample forecasts. We measure economic slack with output gap, and provide results with unemployment gaps in the Appendix. Output gaps are either obtained directly from alternative sources or constructed as the wedge between real GDP and its 4-quarter average (we use a similar approach to obtain unemployment gaps). Oil and commodity prices are obtained from WTI oil prices and commodity prices are measured from a future price index. Finally, because our sample includes countries that experienced periods of high inflation, we exclude from the sample country-dates in which inflation readings were above 25%.

The Appendix provides extensive details on the samples of countries, data sources and methodologies applied to improve data quality.

6.2. Solving attenuation bias with instrumental variables

Using the trilemma logic, we preview the basic elements of the empirical strategy that is to follow with a simple example. Consider the hybrid specification of the Phillips curve (see, *e.g.*, Galí and Gertler, 1999; Galí, Gertler, and López-Salido, 2005):

$$\pi_{it} = \alpha_i + \rho_1 \pi_{i,t-1} + \rho_e \pi^e_{it} + \beta x_{it} + \boldsymbol{\gamma} \boldsymbol{w}_t + \epsilon_{it} \tag{8}$$

where π_{it} refers to quarterly headline CPI inflation expressed in percent annually, π^e_{it} refers to time t projected future expected inflation, and x_{it} is the output gap expressed in percent (in the Appendix, the unemployment gap is given by the difference between the unemployment rate expressed in percent with respect to its natural rate). We do not constrain the coefficients on the lagged inflation and inflation expectations to add up to one although this is an interesting reference value to compare to. When $\rho_1 = 1$ and $\rho_e = 0$ we get the accelerationist version of the Phillips curve (Phelps, 1967; Friedman, 1968). When $\rho_1 = 0$ and $\rho_e = 1$ we have a modern version of the expectations-based Phillips curve.

We estimate Equation 6 by two-stage least squares (TSLS). We instrument the output gap using interest rates from the base economy to which each country pegs. Specifically, for countries in the euro zone, we chose the German 10-year Bund rate. The reason is that this maturity never quite reached the zero lower bound so it will be a natural stand-in for the policy rate for Germany. Naturally, movements in this rate reflect movements in the premiums. However, as the sovereign debt crisis showed, these premiums are probably small enough that movements in the rate are a reasonable proxy for policy movements.

All other pegging economies fixed their exchange rate to the U.S. Following Swanson and

Williams (2014), we use the 2-year T-bond rate. Swanson and Williams (2014) show that this rate captures policy movements quite well during the period in which the funds rate hit the zero lower bound. Gertler and Karadi (2015) use a similar strategy based on the 1-year T-Bill rate instead, but the differences are minor. The 2-year T-bond rate will be our instrument for the subset of pegs to the dollar.

Table 1 provides a first look at the Phillips curve by reporting estimates of Equation 6 using full sample panels using all countries (ALL), OECD economies except Hungary, Greece, Latvia and Lithuania (OECD) and a third group containing all remaining non-OECD economies (Non-OECD). A few findings deserve comment.

First, the IV first-stage F-statistic is quite high denoting that the instruments are highly relevant. This is perhaps not too surprising since the endogenous variables are very persistent so lagged information usually provides a good prediction. Second, there are visible differences between the OLS and the IV estimates suggesting that OLS estimates are biased as our previous discussion already intimated. Third, although the persistence and expectations terms do not add up to one, they are reasonably close in economic terms and certainly in statistical terms. Fourth, the expectations term is quite important across all economies. Fifth, as many before us have documented, estimates of the slope of the Phillips curve are generally economically and statistically close to zero, although with the correct sign. The appendix provides estimates based on the unemployment gap, which tell a similar story.

Table 1: *Hybrid Phillips curve using the output gap. Full Sample (1986Q1-2018Q1)*

	All		OECD		Non-OECD	
	OLS	IV	OLS	IV	OLS	IV
Persistence (ρ_1)	0.77***	0.66***	0.69***	0.87***	0.79***	0.41***
	(0.03)	(0.04)	(0.03)	(0.04)	(0.03)	(0.12)
Inflation Expectations (ρ_e)	0.19***	0.34***	0.25***	0.06**	0.18***	0.78***
	(0.04)	(0.06)	(0.04)	(0.03)	(0.05)	(0.19)
Slack (β)	0.03***	0.03**	0.03***	0.02***	0.03*	0.00
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.04)
Observations	3224	2978	1835	1795	1389	1183
$\bar{R}^2$		0.91		0.92		0.73
K-P Stat		6.67		12.83		2.83
1^{st}-stage F-stat *p-value*		0.00		0.00		0.00

Notes: Estimates based on Equation 6 using OLS and TSLS. Sample includes all countries, OECD economies (excluding Hungary, Greece, Latvia, and Lithuania) and non-OECD economies. Panel estimates using fixed effects. Clustered robust standard errors. */**/*** indicates significant at the 90/95/99% confidence level. See text.

Table 2: *Hybrid Phillips curve using the output gap before Crisis (1986Q1-2007Q4)*

	All		OECD		Non-OECD	
	OLS	IV	OLS	IV	OLS	IV
Persistence (ρ_1)	0.76***	0.66***	0.71***	0.96***	0.77***	0.64***
	(0.03)	(0.05)	(0.04)	(0.07)	(0.04)	(0.09)
Inflation Expectations (ρ_e)	0.21***	0.34***	0.24***	-0.03	0.22***	0.45***
	(0.04)	(0.05)	(0.05)	(0.06)	(0.05)	(0.11)
Slack (β)	0.03***	0.03*	0.05***	0.02***	0.01	-0.02
	(0.01)	(0.02)	(0.01)	(0.01)	(0.02)	(0.02)
Observations	2037	1811	1261	1221	776	590
$\bar{R}^2$		0.89		0.91		0.87
K-P Stat		4.78		13.77		2.74
1^{st}-stage F-stat *p-value*		0.00		0.00		0.00

Table 3: *Hybrid Phillips curve using the output gap after Crisis (2008Q1-2018Q1)*

	All		OECD		Non-OECD	
	OLS	IV	OLS	IV	OLS	IV
Persistence (ρ_1)	0.74***	0.50***	0.62***	0.49***	0.76***	0.54***
	(0.06)	(0.09)	(0.03)	(0.09)	(0.06)	(0.11)
Inflation Expectations (ρ_e)	0.25**	0.80***	0.41***	0.74***	0.23*	0.72***
	(0.10)	(0.16)	(0.05)	(0.27)	(0.11)	(0.17)
Slack (β)	0.02**	0.03	0.01	0.01	0.03*	0.03
	(0.01)	(0.02)	(0.01)	(0.01)	(0.01)	(0.02)
Observations	1187	1167	574	574	613	593
$\bar{R}^2$		0.83		0.88		0.84
K-P Stat		6.99		8.99		4.18
1^{st}-stage F-stat *p-value*		0.00		0.00		0.00

Notes: Estimates based on Equation 6 using OLS and TSLS. Sample includes all countries, OECD economies (excluding Hungary, Greece, Latvia, and Lithuania) and non-OECD economies. Panel estimates using fixed effects. Clustered robust standard errors. */**/*** indicates significant at the 90/95/99% confidence level. See text.

Breaking down the sample before and after the financial crisis, Table 2 and Table 3 provide useful insights. Before the financial crisis, the persistence term is considerably larger and the expectations term much smaller. This is true across the board although more so in OECD economies. Consistent with this observation, estimates of the slope of the Phillips curve are bigger and almost always significant. In contrast, estimates based on the sample following the crisis (Table 3) indicate that expectations became better anchored and the persistence parameter became much smaller and the Phillips curve flatter.

Thus, this first pass of the data provides already some support to the notion that the Phillips curve might have evolved around the time of the financial crisis, in part perhaps because of the credit crunch that followed it. The next section builds on this basic setup to obtain a more careful measure of the effect of the crisis on the Phillips curve.

6.3. Difference-in-differences results

Having shown the attenuation bias from using OLS vs IV when estimating the Phillips curve, we move now toward the main hypothesis of interest. That is, how did the financial crisis affect inflation dynamics? Did the credit crunch that followed the crisis boost the role of the slack component in the Phillips curve? Or did the relative stability of inflation throughout a period of considerable turmoil boost the public's confidence in the ability of central banks to keep inflation in check? Or did the crisis have no effect on the Phillips curve?

Table 4 reports estimates of Equation 7 using the sample of all countries. The table is organized into three blocks of columns referring to estimates for each of the parameters of interest in the Phillips curve using a variety of methods. The column *ALL-OLS* uses panel fixed effect estimates using the float and the peg subpopulations (the subpopulation of floats is too small to provide reliable estimates), the column *Peg-OLS* uses panel fixed effects but using the subpopulation of pegging economies, and the column *Peg-IV* uses panel IV with fixed effects using the subpopulation of pegs. The reason for these three alternatives is to show that OLS estimates based on the entire population or the subpopulation of pegs are very similar to each other. However, the instrument only operates for the subpopulation of pegs. Hence the third column of each block is meant to display the attenuation bias of OLS v IV estimation.

Next, the table is divided into three blocks of rows. Panel (a) refers to estimates for the subpopulation of economies that did not experience the Global Financial Crisis; panel (b) refers to the subpopulation of crisis-hit economies. Within each of these two blocks, we report estimates based on a sample preceding the financial crisis and labeled *Before*, and then using a sample following the crisis, labeled *After*. The row labeled *Diff* then collects the difference in the coefficients before and after.

The difference-in-difference measure of the treatment effect is reported in the third block of rows in panel (c). It measures the difference between changes in the parameters before and after the crisis for each of the subpopulations considered (crisis-hit v. crisis-missed countries). One way to think about this measure is as a counterfactual. If the trends in non-crisis hit economies had also been present in crisis-hit economies, what would we have expected the coefficients to look like? And hence, how do they differ relative to the coefficients we actually estimated?

Table 4 nicely sets the stage. Comparing estimates of the Phillips curve parameters between

Table 4: *Difference in difference estimation. Phillips curve using output gap. All countries*

	Persistence (ρ_1)			*Inflation Expectations* (ρ_e)			*Slack* (β)		
	All-OLS	Peg-OLS	Peg-IV	All-OLS	Peg-OLS	Peg-IV	All-OLS	Peg-OLS	Peg-IV
				(a) No Crisis economies, $G_i = 0$					
Before	0.76***	0.79***	1.02***	0.22***	0.18**	-0.11	0.04	0.06***	0.09***
	(0.04)	(0.06)	(0.18)	(0.06)	(0.08)	(0.28)	(0.03)	(0.02)	(0.02)
After	0.70***	0.74***	0.60***	0.34***	0.25**	0.46***	0.04	0.07**	0.09***
	(0.06)	(0.07)	(0.04)	(0.09)	(0.12)	(0.12)	(0.03)	(0.03)	(0.01)
(i) Diff.	-0.06	-0.05	-0.42**	0.12*	0.07	0.56***	-0.00	0.01	0.01
	(0.04)	(0.03)	(0.20)	(0.06)	(0.05)	(0.21)	(0.01)	(0.01)	(0.02)
				(b) Crisis economies, $G_i = 1$					
Before	0.66***	0.63***	0.64***	0.35***	0.39***	0.40*	0.01	0.01	0.01
	(0.04)	(0.04)	(0.17)	(0.04)	(0.04)	(0.21)	(0.01)	(0.01)	(0.02)
After	0.60***	0.60***	0.53***	0.49***	0.49***	0.63***	0.01	-0.00	-0.00
	(0.02)	(0.02)	(0.05)	(0.03)	(0.05)	(0.13)	(0.01)	(0.01)	(0.02)
(ii) Diff.	-0.06	-0.03	-0.11	0.13***	0.11**	0.23**	0.00	-0.01	-0.01
	(0.04)	(0.03)	(0.12)	(0.05)	(0.05)	(0.09)	(0.02)	(0.02)	(0.02)
				(c) Treatment effect: (ii) – (i)					
D-i-D:	-0.00	0.02	0.31	0.02	0.04	-0.33	0.00	-0.02	-0.02
	(0.06)	(0.05)	(0.28)	(0.08)	(0.07)	(0.26)	(0.02)	(0.02)	(0.03)
Obs.	3464	2228	2134						
$\bar{R}^2$	0.88	0.91	0.87						

Notes: Sample includes all countries. Clustered robust standard errors. */**/*** indicates significant at the 90/95/99% confidence level. See text.

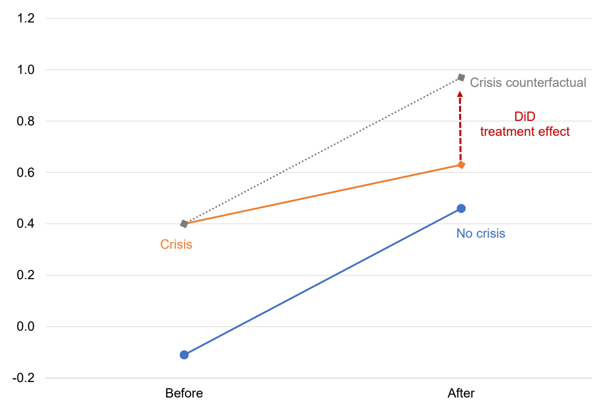
the ALL-OLS and Peg-OLS columns, it is fair to say that the differences are relatively small, in almost all the cases, well within the margin of error. It is safe to conclude that there are no major differences between the subpopulations of floats and pegs. Hence any conclusions obtained using IV estimates can probably be extrapolated to characterize the subpopulation of economies that float their exchange rate. To use the language of the treatment evaluation literature, because the instrument only works for the subpopulation of pegs, what we are doing, properly speaking, is estimating a *local* average treatment effect, or LATE. We return to this issue momentarily

For now, the table reveals, however, that not using an instrumental variable approach can result in considerable attenuation bias. Estimates for the persistence parameter for the crisis-missed economies go from 0.79 to 1.02, for example. We find similar attenuation in several other estimates,

Figure 9: *Less persistence, better anchoring. Difference-in-difference measures of the effect of the crisis. Full sample*

(a) *Persistence parameter* ρ_1

(b) *Expectations parameter* ρ_e



Notes: The charts in the figure present the same parameter estimates as Table 4. See text for additional details.

consistent with earlier results.

The more economically interesting results are hence contained in the Peg-IV columns. Note that if we had considered only the crisis-hit economies (panel (b) of the table) we would have concluded that (*i*) persistence declined from 0.64 to 0.53, a decline of 0.11 and not statistically significant; (*ii*) the role of expectations measured by estimates of the parameter ρ_e went up in similar proportion, from 0.40 to 0.63, an increase of 0.23 and significant; and that (*ii*) in both periods the Phillips curve remained mostly flat. It would thus be tempting to conclude that as a result of the crisis, expectations became better anchored. However, a similar story took place in economies that did not experience the financial crisis, as panel (a) of Table 4 shows. If anything, the decline in the accelerationist term is much larger and so is the increase in the weight that inflation expectations now receive. As we will see shortly, this difference is driven by differences between OECD and non-OECD economies.

Hence, the estimate of the difference-in-differences (local) treatment effect of the financial crisis reported in panel (c) of the Table 4 is critical. In terms of broad trends, we find no actionable statistical evidence indicating substantial changes in crisis-hit economies relative to economies that escaped the crisis. However, it is clear that both types of economies saw changes in the Phillips curve indicative of better anchoring to inflation expectations. One should be careful though. Although the D-i-D estimates are not significant statistically speaking, the magnitudes are relatively sizable: a reduction of persistence of about 0.3 that translated into a boost of similar magnitude to the coefficient on expectations. That is our best measure of the effect of the crisis on the Phillips curve based on full sample results.

To better visualize the results reported in Table 4, Figure 9 presents graphically the estimates of crisis/no crisis economies, before and after the crisis, and the counterfactual path that allows us

Table 5: *Difference in difference estimation. Phillips curve using output gap. OECD (exluding HUN, GRC, LVA, LTU)*

	Persistence (ρ_1)			*Inflation Expectations* (ρ_e)			*Slack* (β)		
	All-OLS	Peg-OLS	Peg-IV	All-OLS	Peg-OLS	Peg-IV	All-OLS	Peg-OLS	Peg-IV
				(a) No Crisis economies, $G_i = 0$					
Before	0.54***	0.49***	0.68***	0.47***	0.51***	0.25	0.04***	0.05***	0.04***
	(0.05)	(0.06)	(0.14)	(0.07)	(0.13)	(0.18)	(0.01)	(0.01)	(0.01)
After	0.56***	0.56***	0.56***	0.51***	0.48***	0.44***	0.04***	0.05***	0.05***
	(0.04)	(0.07)	(0.05)	(0.07)	(0.13)	(0.09)	(0.01)	(0.02)	(0.02)
(i) Diff.	0.02	0.07***	-0.12	0.05	-0.02***	0.18*	0.00	0.00	0.00
	(0.06)	(0.01)	(0.11)	(0.06)	(0.01)	(0.11)	(0.01)	(0.01)	(0.01)
				(b) Crisis economies, $G_i = 1$					
Before	0.70***	0.67***	0.81***	0.29***	0.32***	0.13	0.02**	0.03***	0.04***
	(0.03)	(0.05)	(0.07)	(0.03)	(0.04)	(0.09)	(0.01)	(0.01)	(0.01)
After	0.61***	0.61***	0.62***	0.46***	0.46***	0.39***	0.03**	0.01	0.03***
	(0.02)	(0.02)	(0.03)	(0.04)	(0.02)	(0.10)	(0.01)	(0.01)	(0.01)
(ii) Diff	-0.10**	-0.06*	-0.19***	0.18***	0.14***	0.27***	0.01	-0.01	-0.01
	(0.04)	(0.03)	(0.06)	(0.05)	(0.03)	(0.07)	(0.02)	(0.02)	(0.01)
				(c) Treatment effect: (ii) – (i)					
D-i-D	-0.11*	-0.13***	-0.07	0.13*	0.17***	0.08	0.00	-0.02	-0.01
	(0.07)	(0.03)	(0.11)	(0.08)	(0.03)	(0.10)	(0.02)	(0.02)	(0.02)
Obs.	1760	1146	1146						
$\bar{R}^2$	0.88	0.89	0.89						

Notes: Sample includes OECD countries except Hungary, Greece, Latvia, and Lithuania. Clustered robust standard errors. */**/*** indicates significant at the 90/95/99% confidence level. See text.

to measure the treatment effect. Panel (a) of the figure corresponds to estimates of the persistence parameter ρ_1 and panel (b) corresponds to estimates of the expectations parameter ρ_e. The blue solid line denoted "No crisis" corresponds to estimates before and after the crisis for countries that did not experience the crisis. Note the decline in the persistence parameter and the increase in the expectations parameter. The solid orange line corresponds to the subpopulations of crisis hit economies. The decline in the persistence parameter is also visible but it is more muted. Similarly, the increase in the expectations parameter is still there, but is also more muted. The grey dahsed line is the counterfactual path that crisis hit countries would have been expected to follow had they shared the same trends as the crisis-missed countries. As we remarked earlier, the effect is quite sizable economically speaking, though imprecisely estimated. The red dashed line visually represents the difference-in-difference estimates reported in panel (c) of Table 4.

In economic terms, Figure 9 neatly shows how the crisis affected the Phillips curve. Generally speaking, leading into the crisis, all countries were experiencing a boost to the expectations term and a concomitant decline in the accelerationist term consistent with a flattening of the Phillips curve. A natural explanation of all these developments is that central banks were generally becoming more credible. Crisis hit economies saw that trend slow down considerably relative to non-crisis hit economies, consistent with Gilchrist et al. (2017). The effects are economically sizable although not estimated precisely enough to provide statistically conclusive evidence.

It is well known, however, that the crisis was primarily an advanced economies event. Moreover, advanced economies—more than emerging markets—have a longer tradition of an independent central banks. These features show up clearly in the results reported in Table 5. The table is organized exactly as Table 4. Hence we can focus directly on panel (a) of Table 5, which shows that the few OECD economies not hit by the crisis (think primarily of Canada, Australia, and New Zealand), there was a small decline in the weight of the accelerationist term (from 0.68 to 0.56 for a difference of 0.12), with a similarly small boost to the weight on the expectations terms (from 0.25 to 0.44 for a difference of 0.18).

The values reported for the crisis-hit economies in panel (b) of Table 5 are very similar indeed. The weight on the persistence parameter declines from 0.81 to 0.62 or a drop of 0.19 and significant. The weight on the expectations term goes from 0.13 to 0.39 or an increase of 0.27 and significant. Interestingly, without constraining the coefficients to be so, the weight on lagged inflation and the expectations terms sum up to close to 1, as the theory prescribes. In addition, the slope of the Phillips curve appears far more stable. Both types of countries have a similar slope (in the order of 0.04) and it does not change meaningfully from one group to the other or before and after the crisis. It is no surprise that the treatment effect of the crisis in all cases is essentially zero. That is, for OECD economies the evidence suggests that the trends set in motion before the crisis explain changes in the Phillips curve and we see essentially no evidence that the crisis itself had any lasting effects on the Phillips curve.

The natural complement to Table 4 and Table 5 is provided in Table 6. The results presented in the table make clear that the experiences of OECD and non-OECD economies were quite different. Persistence generally declines after the crisis, but it declines much more for non-crisis hit economies and hence the differences-in-differences estimate is 0.27—sizable economically, although imprecisely estimated and of a similar magnitude to the effect estimated using all countries. This is almost the mirror image of what happens with the expectations term, which gains in importance after the crisis and the difference-in-differences effect at -0.30, which nearly matches, but with the opposite sign, what happened with the persistence parameter. Interestingly, although we cannot see any effects of the crisis on the difference-in-differences estimate, it is clear that non-crisis hit economies have a much steeper Phillips curve (at 0.09 and significant) versus crisis-hit economies (-0.01 and not significant).

Table 6: *Difference in difference estimation. Phillips curve using output gap. Non-OECD*

	Persistence (ρ_1)			*Inflation Expectations (ρ_e)*			*Slack (β)*		
	All-OLS	Peg-OLS	Peg-IV	All-OLS	Peg-OLS	Peg-IV	All-OLS	Peg-OLS	Peg-IV
				(a) No Crisis economies, $G_i = 0$					
Before	0.76***	0.80***	1.01***	0.22***	0.17**	-0.08	0.04	0.06**	0.09***
	(0.04)	(0.06)	(0.17)	(0.06)	(0.09)	(0.25)	(0.03)	(0.02)	(0.01)
After	0.71***	0.75***	0.64***	0.33***	0.24**	0.42***	0.04	0.07**	0.09***
	(0.06)	(0.08)	(0.06)	(0.10)	(0.12)	(0.09)	(0.04)	(0.03)	(0.02)
(i) Diff.	-0.05	-0.05	-0.36*	0.11*	0.07	0.50**	-0.00	0.01	0.00
	(0.04)	(0.03)	(0.21)	(0.07)	(0.05)	(0.23)	(0.02)	(0.01)	(0.02)
				(b) Crisis economies, $G_i = 1$					
Before	0.56***	0.57***	0.62***	0.48***	0.47***	0.42***	-0.01	-0.01	-0.01
	(0.02)	(0.02)	(0.07)	(0.02)	(0.02)	(0.08)	(0.01)	(0.01)	(0.01)
After	0.56***	0.57***	0.53***	0.58***	0.56***	0.62***	-0.01	-0.01*	-0.01
	(0.02)	(0.02)	(0.03)	(0.06)	(0.06)	(0.04)	(0.01)	(0.01)	(0.02)
(ii) Diff.	0.00	0.00	-0.09*	0.10	0.09	0.20***	0.00	-0.00	-0.01
	(0.03)	(0.03)	(0.05)	(0.07)	(0.07)	(0.07)	(0.01)	(0.01)	(0.01)
				(c) Treatment effect: (ii) – (i)					
D-i-D	0.06	0.05	0.27	-0.01	0.03	-0.30	0.00	-0.01	-0.01
	(0.05)	(0.05)	(0.23)	(0.10)	(0.08)	(0.24)	(0.02)	(0.02)	(0.03)
Obs.	1704	1082	988						
$\bar{R}^2$	0.89	0.91	0.88						

Notes: Sample excludes OECD countries. Clustered robust standard errors. */**/*** indicates significant at the 90/95/99% confidence level. See text.

The increase in the expectations term in crisis-hit economies is quite large at 0.50 even though there is no evidence that the slope of the Phillips curve became any flatter. At 0.09, the slope of the Phillips curve is reminiscent of the values observed for the U.S. in the mid-1980s and earlier. Crisis hit economies started from a much different position and perhaps this in part explains why the changes in the main coefficients are more muted. The coefficient on the expectations term was already at 0.42 before the crisis (0.62 for the persistence or accelerationist parameter, thus adding almost exactly to 1) and with a completely flat Phillips curve. After the crisis the expectations term increases from 0.42 to 0.62 (and the persistence parameter declines from 0.62 to 0.53), which reinforces the earlier message that the crisis mainly affected advanced economies, which in turn operated with a more modern Phillips curve to begin with.

7. Conclusion

The aftereffects of the Global Financial Crisis cannot be overstated. Ten years after the crisis, many economies remain far from their pre-crisis trend growth paths. The permanent losses of income are quite dramatic and stand out in comparison to similar events in the history of modern finance, as Figure 1 showed. Inflation after financial crises tends to fall sharply and remain subdued for extended periods of time. This time inflation declined far less than in previous times, but it has been difficult to arouse from its torpor. It is still early to know whether inflation is now turning a corner. Such features of the recent inflation experience have to be set against a background in which central banks were gaining increasing independence and credibility (see, e.g. den Haan, Ilzetzki, McMahon, and Reis, 2017). Our goal has been to examine, what if any, were the consequences to inflation dynamics from the unfolding collapse in credit and subsequent dip in demand, all within the global context.

The financial crisis was a global event. Even countries outside its destructive path were nevertheless buffeted by its downdraft. Economies are interconnected through a variety of channels that we discussed earlier, perhaps now to a greater extent than ever before. Inflation in advanced economies now moves in greater unison than in the past (Figure 4), and it is more sensitive to movements in oil prices (Figure 5). Such a development is consistent with modern central banking. The ability to better execute countercyclical policy to smooth shocks to aggregate demand probably makes inflation more correlated with oil prices and other transitory shocks.

Despite its international dimension, it is clear that advanced economies differ considerably from emerging markets. The business cycle, inflation, and interest rates are far more synchronized in the advanced world than in developing economies (Figure 6). That said, some of the trends advanced economies experienced in earlier decades are now becoming more clearly visible in emerging markets.

That much is clear from our analysis. Such views influenced our empirical investigation of inflation dynamics globally. Our premise was to examine in what ways, if any, had the financial crisis affected the basic Phillips mechanism. But that investigation had to be set against the background of an evolving Phillips curve and in an environment of increasing central bank independence. Central bank credibility has largely made inflation less susceptible to aggregate demand shocks. Short-run fluctuations in inflation largely come from transitory factors to which central banks rarely feel the need to respond to (see, e.g. Ball and Mazumder, 2018).

We showed the importance of being careful about identification along two fronts. First by recognizing that OLS estimates of the Phillips curve suffer from classical simultaneity bias. We addressed this bias using instrumental variable methods based on the trilemma of international finance (see, e.g. Obstfeld et al., 2005). We showed that ignoring simultaneity can result in considerable attenuation bias of the main coefficients of interest.

However, trends set in motion in the decades leading to the crisis could also obfuscate its true impact on inflation dynamics. Here again we resorted to another tool from the treatment evaluation literature: a difference-in-differences strategy. Economically speaking, a persuasive mechanism that could explain the relative firmness of inflation in the early days of the crisis has to do with how the collapse in credit affected pricing decisions, as suggested, for example, by Gilchrist et al. (2017). We find that the evidence is somewhat mixed. Statistically speaking, estimates for this mechanism are imprecise though economically sizable (Figure 9). However, one has also to contend with the observation that inflation dynamics in advanced economies were already determined, to a great degree, by an expectations mechanism. The accelerationist term had already declined considerably and the slope of the Phillips curve was basically flat, as many others had documented (see, e.g. Ball and Mazumder, 2011).

What should policymakers takeaway from our analysis? Inflation is currently subdued, often running below levels many central banks target explicitly or implicitly. It would be tempting to take advantage of this circumstance to try to stimulate the economy above its potential. However, this seems ill-advised. The decline of inflation persistence and the increasing weight of inflation expectations together with a relatively flat Phillips curve, are all consistent with central banks being generally seen as credible inflation fighters. If central banks start behaving differently than the public expects, it would be reasonable to then expect a reversal of these trends. That would make inflation misses and transitory factors more persistent, and it would make it costlier to rain in runaway inflation expectations.

Inflation globally also appears to have a stronger common component. In part this probably reflects the crisis itself. In part it probably also reflects common transitory factors (such as oil prices) that affect inflation across borders in an environment where central banks effectively implement countercyclical policy. Meanwhile, inflation has been declining almost everywhere (Figure 2). No doubt part of this decline reflects more effective policymaking. However, others have pushed forward alternative explanations based on demographic factors (e.g. Carvalho et al., 2016), secular stagnation (e.g. Summers, 2014), and so on. We leave to others to contrast these theories against one another.

References

Auer, R., C. Borio, and A. J. Filardo (2017). The globalisation of inflation: the growing importance of global value chains. Technical report, CEPR.

Ball, L. and S. Mazumder (2011). Inflation Dynamics and the Great Recession. *Brookings Papers on Economic Activity 42*(1 (Spring), 337–405.

Ball, L. and S. Mazumder (2018). A phillips curve with anchored expectations and short-term unemployment. *Journal of Money, Credit and Banking 0*(0).

Ball, L. and R. Moffitt (2001). Productivity Growth and the Phillips Curve. NBER Working Papers 8421, National Bureau of Economic Research, Inc.

Barnichon, R., C. Matthes, and A. Ziegenbein (2018). The financial crisis at 10: Will we ever recover? *FRBSF Economic Letter 2018-19*.

Blanchard, O., E. Cerutti, and L. H. Summers (2015). Inflation and Activity: Two Explorations and Their Monetary Policy Implications. Working Paper Series WP15-19, Peterson Institute for International Economics.

Cao, Y. and A. H. Shapiro (2016). Energy's Impact on Inflation Expectations. *FRBSF Economic Letter 2016-19*.

Carvalho, C., A. Ferrero, and F. Nechio (2016). Demographics and real interest rates: Inspecting the mechanism. *European Economic Review 88*(C), 208–226.

Coibion, O. and Y. Gorodnichenko (2015). Is the Phillips Curve Alive and Well after All? Inflation Expectations and the Missing Disinflation. *American Economic Journal: Macroeconomics 7*(1), 197–232.

den Haan, W., E. Ilzetzki, M. McMahon, and R. Reis (2017). Is the era of central bank independence drawing to a close? *LSE Business School Blog*, http://eprints.lse.ac.uk/79768/1/blogs.lse.ac.uk-Is%20the%20era%20of%20central%20bank%20independence%20drawing%20to%20a%20close.pdf.

di Giovanni, J., J. McCrary, and T. von Wachter (2009). Following Germany's Lead: Using International Monetary Linkages to Estimate the Effect of Monetary Policy on the Economy. *The Review of Economics and Statistics 91*(2), 315–331.

Dotsey, M., S. Fujita, and T. Stark (2017). Do Phillips Curves Conditionally Help to Forecast Inflation? Working Papers 17-26, Federal Reserve Bank of Philadelphia.

Eggertsson, G. B., N. R. Mehrotra, and J. A. Robbins (2017). A model of secular stagnation: Theory and quantitative evaluation. Working Paper 23093, National Bureau of Economic Research.

Eickmeier, S. and M. Kühnlenz (2018). China's role in global inflation dynamics. *Macroeconomic Dynamics 22*(2), 225–254.

Fernández, A., S. Schmitt-Grohé, and M. Uribe (2017). World shocks, world prices, and business cycles: An empirical investigation. *Journal of International Economics 108*(S1), S2–S14.

Forbes, K., L. Kirkham, and K. Theodoridis (2018). A Trendy Approach to UK Inflation Dynamics. CEPR Discussion Papers 12652, C.E.P.R. Discussion Papers.

Friedman, M. (1968). The role of monetary policy. *American Economic Review 58*, 1–17.

Galí, J. (2008). Introduction to monetary policy, inflation, and the business cycle: An introduction to the new keynesian framework. In *Monetary Policy, Inflation, and the Business Cycle: An Introduction to the New Keynesian Framework*. Princeton University Press.

Galí, J. and M. Gertler (1999). Inflation dynamics: A structural econometric analysis. *Journal of Monetary Economics 44*(2), 195 – 222.

Galí, J., M. Gertler, and D. J. López-Salido (2005). Robustness of the estimates of the hybrid New Keynesian Phillips curve. *Journal of Monetary Economics 52*(6), 1107–1118.

Galí, J., M. Gertler, and J. D. López-Salido (2005). Robustness of the estimates of the hybrid new keynesian phillips curve. *Journal of Monetary Economics 52*(6), 1107 – 1118. The econometrics of the New Keynesian price equation.

Gertler, M. and P. Karadi (2015). Monetary Policy Surprises, Credit Costs, and Economic Activity. *American Economic Journal: Macroeconomics 7*(1), 44–76.

Gilchrist, S., R. Schoenle, J. Sim, and E. Zakrajšek (2017). Inflation dynamics during the financial crisis. *American Economic Review 107*(3), 785–823.

Gürkaynak, R. S., A. Levin, and E. Swanson (2010). Does inflation targeting anchor long, run inflation expectations? evidence from the u.s., uk, and sweden4. *Journal of the European Economic Association 8*(6), 1208–1242.

Gürkaynak, R. S., 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*(1).

Hamilton, J. D., E. S. Harris, J. Hatzius, and K. D. West (2016). The Equilibrium Real Funds Rate: Past, Present, and Future. *IMF Economic Review 64*(4), 660–707.

Holston, K., T. Laubach, and J. C. Williams (2017). Measuring the natural rate of interest: International trends and determinants. *Journal of International Economics 108*, S59 – S75. 39th Annual NBER International Seminar on Macroeconomics.

Ilzetzki, E., C. M. Reinhart, and K. S. Rogoff (2017). The country chronologies to exchange rate arrangements into the 21st century: Will the anchor currency hold? Working Paper 23135, National Bureau of Economic Research.

Jordà, Ò., M. Schularick, and A. M. Taylor (2013). When credit bites back. *Journal of Money, Credit and Banking 45*(s2), 3–28.

Jordà, O., M. Schularick, and A. M. Taylor (2015). Betting the house. *Journal of International Economics 96*, S2 – S18. 37th Annual NBER International Seminar on Macroeconomics.

Jordà, Ò., M. Schularick, and A. M. Taylor (2016). *Macrofinancial History and the New Business Cycle Facts*, pp. 213–263. University of Chicago Press.

Jordà, O., M. Schularick, and A. M. Taylor (2017). The effects of quasi-random monetary experiments. Working Paper 23074, National Bureau of Economic Research.

Mavroeidis, S. (2005). Identification issues in forward-looking models estimated by gmm, with an application to the phillips curve. *Journal of Money, Credit and Banking*, 421–448.

Mavroeidis, S., M. Plagborg-Møller, and J. H. Stock (2014). Empirical Evidence on Inflation Expectations in the New Keynesian Phillips Curve. *Journal of Economic Literature 52*(1), 124–188.

McLeay, M. and S. Tenreyro (2018). Optimal inflation and the identification of the phillips curve. London School of Economics, mimeograph.

Nason, J. M. and G. W. Smith (2008). Identifying the new Keynesian Phillips curve. *Journal of Applied Econometrics 23*(5), 525–551.

Nechio, F. (2011). Monetary policy when one size does not fit all. Economic Letter 2011-18, Federal Reserve Bank of San Francisco.

Obstfeld, M., J. C. Shambaugh, and A. M. Taylor (2004). Monetary sovereignty, exchange rates, and capital controls: The trilemma in the interwar period. *IMF Staff Papers*, 75–108.

Obstfeld, M., J. C. Shambaugh, and A. M. Taylor (2005). The trilemma in history: Tradeoffs among exchange rates, monetary policies, and capital mobility. *The Review of Economics and Statistics 87*(3), 423–438.

Obstfeld, M. and A. Taylor (1998). The great depression as a watershed: International capital mobility over the long run. In *The Defining Moment: The Great Depression and the American Economy in the Twentieth Century*, pp. 353–402. National Bureau of Economic Research, Inc.

Obstfeld, M. and A. Taylor (2003). Globalization and capital markets. In *Globalization in Historical Perspective*. University of Chicago Press.

Orphanides, A. and J. C. Williams (2005). The decline of activist stabilization policy: Natural rate misperceptions, learning, and expectations. *Journal of Economic Dynamics and Control 29*(11), 1927 – 1950. Expectations, learning, and monetary policy.

Phelps, E. S. (1967). Phillips curves, expectations of inflation, and optimal employment over time. *Economica 63*, 675–94.

Phillips, A. W. (1958). The relation between unemployment and the rate of change of money wage rates in the united kingdom, 1861-1957. *Economica 25*(100), 283–299.

Roberts, J. M. (1995). New Keynesian Economics and the Phillips Curve. *Journal of Money, Credit and Banking 27*(4), 975–984.

Sbordone, A. M. (2002). Prices and unit labor costs: a new test of price stickiness. *Journal of Monetary Economics 49*(2), 265 – 292.

Shambaugh, J. (2004). The effect of fixed exchange rates on monetary policy. *The Quarterly Journal of Economics 119*(1), 301–352.

Shimer, R. (2017). Labor markets. *Journal of Political Economy 125*(6), 1834–1840.

Smets, F. and R. Wouters (2007). Shocks and frictions in us business cycles: A bayesian dsge approach. *The American Economic Review*, 586–606.

Stock, J. H. and M. W. Watson (2007). Why has u.s. inflation become harder to forecast? *Journal of Money, Credit and Banking 39*(s1), 3–33.

Stock, J. H. and M. W. Watson (2008). Phillips curve inflation forecasts. *Conference Series ; [Proceedings] 53*.

Summers, L. H. (2014). Reflections on the 'New Secular Stagnation Hypothesis'. In *Secular Stagnation: Facts, Causes and Cures*, Chapter 1, pp. 27–38. VoxEU.org.

Swanson, E. T. and J. C. Williams (2014). Measuring the effect of the zero lower bound on medium- and longer-term interest rates. *American Economic Review 104*(10), 3154–85.

Woodford, M. (2010). Chapter 14 - optimal monetary stabilization policy. Volume 3 of *Handbook of Monetary Economics*, pp. 723 – 828. Elsevier.

Appendix: Data Sources and Calculations

The set of countries included in the analysis are: Australia, Austria, Belgium, Brazil, Canada, Chile, China, Colombia, Costa Rica, the Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, India, Ireland, Israel, Indonesia, Italy, Japan, Korea, Lithuania, Luxembourg, Mexico, the Netherlands, Norway, New Zealand, Poland, Portugal, Russia, Saudi Arabia, Slovakia, Slovenia, South Africa, Spain, Sweden, Switzerland, Turkey, the United Kingdom, and the United States.

Inflation and Expected Inflation

We use year-over-year inflation calculated from the quarterly headline consumer price index. See Table A1 for inflation sources. We use primarily IFS and OECD data, though we use Swiss National Bank data for Switzerland and Tao Zha's compiled dataset for China.

Quarterly expected inflation is often available from the OECD as year-over-year CPI growth. We use the Society of Professional Forecasters (SPF) expected year-over-year CPI inflation, which is also quarterly, for the United States. If expected inflation is not available, we estimate it as in Hamilton et al. (2016):

First, we take annual year-over-year CPI inflation. Then, we estimate a rolling regression of current on lagged inflation with a twenty-year window separately for each country. With the rolling coefficients we then predict inflation using the coefficients from the previous twenty years of data to obtain a reasonable estimate of expected inflation for the next year. Finally, we linearly interpolate the estimated annual expected inflation to quarterly.

Unemployment and NAIRU

When available, we use seasonally adjusted harmonized unemployment rates from the OECD (BLS for the U.S.); however, for a number of countries seasonally adjusted data is not available. For those, we implement an x12 seasonal adjustment on the raw series.

Country-specific NAIRU is also typically available through the OECD (CBO for the U.S.); if not we use a four-quarter moving average of seasonally adjusted unemployment rates as a country's NAIRU. Thus unemployment gap is calculated as seasonally adjusted unemployment minus NAIRU.

NOTE: Where does Brazilian inflation data come from? Called the source "Nechio" for now.

Interest Rates

We use the two-year treasury constant maturity rate for the U.S, which comes from the Board of Governors. We use the ten-year main long-term government bond yield for Germany, which comes from the OECD. Both series are available on FRED.

We use the natural rate of interest from Holston, Laubach and Williams (2017) for the U.S., U.K., Germany, and Canada to calculate the Taylor Rule and its residual for each country.

Actual and Potential GDP

Actual GDP is nearly always provided by the OECD. The exceptions are the U.S., for which we use CBO measures; and Saudi Arabia, which comes from its own Central Department of Statistics and Inflation with exchange rates from the Saudi Arabian Monetary Authority.

Potential GDP also comes from the OECD or CBO when available; otherwise we use a four-quarter moving average.

Output gap is calculated as actual minus potential GDP, divided by potential GDP.

Oil and Commodity Inflation

We use the West Texas Intermediate crude oil dollars per barrel. The index is monthly; we calculate inflation as year-over-year growth based on the quarterly average of the index.

Commodity inflation comes from the Continuous Commodity Future Price Index in Bloomberg, which is compiled by Thomson Reuters. The series is an "equal-weighted geometric average of commodity price levels relative to the base year average price." The index is daily; we calculate inflation as year-over-year growth based on the quarterly average of the index.

Global Financial Crisis

We use Laven and Valencia (2012), which lists the start years for Systematic Banking Crises across countries, to define countries that experienced the Global Financial Crisis. We list a country as having experienced the Global Financial Crisis if it experienced a Systematic Banking Crisis startin in 2007 or 2008. The countries in our sample that experienced the Global Financial Crisis are: Austria, Belgium, Denmark, France, Germany, Greece, Hungary, Israel, Italy, Luxembourg, Latvia, the Netherlands, Portugal, Slovenia, Spain, Sweden, Switzerland, the United Kingdom, and the United States.

Table A1: *Data Sources*

Country	Inflation	Unemp. Rate	Exp. Infl.	NAIRU	GDP	Potential GDP	Interest Rate	GFC
				OECD economies				
AUS	OECD	OECD	OECD	OECD	OECD	OECD	OECD 3M	0
AUT	IFS	OECD	OECD	OECD	OECD	OECD	OECD 10Y	1
BEL	IFS	OECD	OECD	OECD	OECD	OECD	OECD 10Y	1
CAN	OECD	OECD	OECD	OECD	OECD	OECD	OECD 10Y	0
CHE	SNB	OECD	OECD	OECD	OECD	OECD	OECD 10Y	1
CZE	OECD	OECD	OECD	OECD	OECD	OECD	OECD 3M	0
DEU	IFS	OECD	OECD	OECD	OECD	OECD	OECD 10Y	1
DNK	IFS	OECD	OECD	OECD	OECD	OECD	OECD 10Y	1
ESP	IFS	OECD	OECD	OECD	OECD	OECD	OECD 10Y	1
EST	IFS	OECD	OECD	OECD	OECD	OECD	OECD 3M	0
FIN	IFS	OECD	OECD	OECD	OECD	OECD	OECD 10Y	0
FRA	OECD	OECD	OECD	OECD	OECD	OECD	OECD 10Y	1
GBR	IFS	OECD	OECD	OECD	OECD	OECD	OECD 10Y	1
GRC	IFS	OECD	OECD	OECD	OECD	OECD	OECD 10Y	1
HUN	IFS	OECD	OECD	OECD	OECD	OECD	OECD 10Y	1
IRL	IFS	OECD	OECD	OECD	OECD	OECD	OECD 10Y	1
ISL	IFS	OECD	OECD	OECD	OECD	OECD	OECD 3M	1
ISR	IFS	OECD	OECD	OECD	OECD	OECD	OECD 10Y	0
ITA	IFS	OECD	OECD	OECD	OECD	OECD	OECD 10Y	1
JPN	IFS	OECD	OECD	OECD	OECD	OECD	OECD 10Y	0
KOR	IFS	OECD	OECD	OECD	OECD	OECD	OECD 3M	0
LUX	IFS	OECD	OECD	OECD	OECD	OECD	GFD 10Y	1
LVA	IFS	OECD	OECD	OECD	OECD	OECD	GFD 10Y	1
MEX	IFS	OECD	OECD	OECD	OECD	4Q	OECD 3M	0
NLD	IFS	OECD	OECD	OECD	OECD	OECD	OECD 10Y	1
NOR	IFS	OECD	OECD	OECD	OECD	OECD	OECD 3M	0
NZL	OECD	OECD	OECD	OECD	OECD	OECD	OECD 3M	0
POL	IFS	OECD	OECD	OECD	OECD	OECD	OECD 3M	0
PRT	IFS	OECD	OECD	OECD	OECD	OECD	OECD 10Y	1
SVK	IFS	OECD	OECD	OECD	OECD	OECD	OECD 10Y	0
SVN	OECD	OECD	OECD	OECD	OECD	OECD		1
SWE	IFS	OECD	OECD	OECD	OECD	OECD	OECD 10Y	1
TUR	IFS	OECD	OECD	4Q	OECD	4Q	Bloomberg 2Y	0
USA	BLS	BLS	SPF	CBO	CBO	CBO	Bloomberg 2Y	1
				Non-OECD economies				
BRA	BCB	OECD/x12	OECD	4Q	OECD	4Q	Bloomberg 2Y	0
CHL	OECD	OECD	OECD	OECD	OECD	4Q	OECD 3M	0
CHN	ZHA	IFS/x12	OECD	4Q	OECD	4Q	OECD 3M	0
COL	IFS	IFS/x12	OECD	4Q	OECD	4Q	Bloomberg 2Y	0
CRI	IFS	IFS/x12	Rolling Reg.	4Q	OECD	4Q	OECD 3M	0
IDN	IFS	IFS/x12	OECD	4Q	OECD	4Q	OECD 3M	0
IND	IFS	Eurostat/x12	OECD	4Q	OECD	4Q	GFD 10Y	0
LTU	OECD	IFS/x12	Rolling Reg.	4Q	OECD	4Q	GFD 10Y	0
RUS	IFS	IFS/x12	OECD	4Q	OECD	4Q	OECD 3M	0
SAU	IFS	IFS/x12	Rolling Reg.	4Q	CDSI	4Q		0
ZAF	IFS	IFS/x12	OECD	4Q	OECD	4Q	OECD 3M	0

Estimates of the Phillips curve using the unemployment gap (Equation 6)

Table A2: *Full Sample (1986Q1-2018Q1) - Unemployment Gap*

	All		OECD		Non-OECD	
	OLS	IV	OLS	IV	OLS	IV
Persistence (ρ_1)	0.79***	0.66***	0.74***	0.90***	0.79***	0.41**
	(0.03)	(0.04)	(0.03)	(0.03)	(0.03)	(0.19)
Inflation Expectations (ρ_e)	0.17***	0.35***	0.20***	0.03	0.17***	0.79**
	(0.04)	(0.06)	(0.03)	(0.03)	(0.04)	(0.32)
Slack (γ)	-0.03***	-0.02	-0.03**	-0.02*	-0.03*	0.01
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.05)
Observations	3181	2977	1863	1795	1318	1182
Adjusted R^2		0.91		0.92		0.73
K-P Stat		4.99		12.63		2.99

Table A3: *Before Crisis (1986Q1-2007Q4) - Unemployment Gap*

	All		OECD		Non-OECD	
	OLS	IV	OLS	IV	OLS	IV
Persistence (ρ_1)	0.77***	0.63***	0.77***	0.99***	0.78***	0.67***
	(0.04)	(0.06)	(0.03)	(0.06)	(0.05)	(0.07)
Inflation Expectations (ρ_e)	0.19***	0.39***	0.17***	-0.06	0.20***	0.40***
	(0.04)	(0.06)	(0.04)	(0.06)	(0.05)	(0.10)
Slack (γ)	-0.04***	-0.04*	-0.05***	-0.03**	-0.02	-0.01
	(0.01)	(0.02)	(0.02)	(0.01)	(0.03)	(0.05)
Observations	2006	1811	1289	1221	717	590
Adjusted R^2		0.89		0.90		0.88
K-P Stat		4.56		14.01		2.99

Table A4: *After Crisis (2008Q1-2018Q1) - Unemployment Gap*

	All		OECD		Non-OECD	
	OLS	IV	OLS	IV	OLS	IV
Persistence (ρ_1)	0.73***	0.45***	0.63***	0.47***	0.74***	0.51***
	(0.06)	(0.10)	(0.03)	(0.10)	(0.07)	(0.11)
Inflation Expectations (ρ_e)	0.30***	0.97***	0.42***	0.83***	0.28**	0.82***
	(0.11)	(0.17)	(0.05)	(0.30)	(0.12)	(0.17)
Slack (γ)	-0.01	0.03	0.02**	0.03***	-0.03	0.01
	(0.02)	(0.03)	(0.01)	(0.01)	(0.03)	(0.04)
Observations	1175	1166	574	574	601	592
Adjusted R^2		0.78		0.87		0.82
K-P Stat		7.10		9.15		4.07

Difference-in-differences results using the unemployment gap

Table A5: *Difference in difference estimation. Phillips curve using unemployment gap. All countries*

	Persistence (ρ_1)			*Inflation Expectations* (ρ_e)			*Slack* (β)		
	All-OLS	Peg-OLS	Peg-IV	All-OLS	Peg-OLS	Peg-IV	All-OLS	Peg-OLS	Peg-IV
				(a) No Crisis economies, $G_i = 0$					
Before	0.76***	0.80***	1.04***	0.24***	0.19*	-0.10	-0.01	-0.02	-0.08
	(0.04)	(0.08)	(0.18)	(0.06)	(0.11)	(0.28)	(0.01)	(0.02)	(0.05)
After	0.68***	0.72***	0.62***	0.38***	0.30**	0.45***	-0.06***	-0.06***	-0.07***
	(0.06)	(0.08)	(0.04)	(0.09)	(0.13)	(0.13)	(0.02)	(0.02)	(0.02)
(i) Diff.	-0.08*	-0.08***	-0.42**	0.14**	0.10***	0.54**	-0.05*	-0.04	0.01
	(0.04)	(0.03)	(0.20)	(0.05)	(0.04)	(0.22)	(0.03)	(0.03)	(0.05)
				(b) Crisis economies, $G_i = 1$					
Before	0.66***	0.63***	0.71***	0.36***	0.39***	0.29**	-0.01	0.00	-0.02
	(0.04)	(0.04)	(0.10)	(0.04)	(0.04)	(0.13)	(0.01)	(0.01)	(0.02)
After	0.60***	0.61***	0.59***	0.48***	0.48***	0.51***	-0.01	-0.00	-0.00
	(0.02)	(0.02)	(0.05)	(0.04)	(0.05)	(0.12)	(0.01)	(0.01)	(0.02)
(ii) Diff.	-0.05	-0.02	-0.13**	0.12**	0.09*	0.21***	-0.00	-0.00	0.02
	(0.04)	(0.03)	(0.06)	(0.05)	(0.05)	(0.06)	(0.02)	(0.02)	(0.02)
				(c) Treatment effect: (ii) – (i)					
D-i-D	0.03	0.06	0.30	-0.01	-0.01	-0.33	0.05	0.03	0.01
	(0.06)	(0.04)	(0.23)	(0.07)	(0.06)	(0.23)	(0.03)	(0.03)	(0.06)
Obs.	3376	2162	2134						
$\bar{R}^2$	0.88	0.90	0.87						

Notes: Sample includes all countries. Clustered robust standard errors. */**/*** indicates significant at the 90/95/99% confidence level. See text.

Table A6: *Difference in difference estimation. Phillips curve using unemployment gap. OECD (except Hungary, Greece, Latvia, and Lithuania)*

	Persistence (ρ_1)			*Inflation Expectations (ρ_e)*			*Slack (β)*		
	All-OLS	Peg-OLS	Peg-IV	All-OLS	Peg-OLS	Peg-IV	All-OLS	Peg-OLS	Peg-IV
				(a) No Crisis economies, $G_i = 0$					
Before	0.54***	0.50***	0.71***	0.50***	0.58***	0.29*	-0.01	-0.01	-0.09
	(0.05)	(0.06)	(0.13)	(0.08)	(0.12)	(0.15)	(0.05)	(0.09)	(0.09)
After	0.58***	0.60***	0.59***	0.51***	0.51***	0.46***	-0.03	0.06	-0.00
	(0.04)	(0.08)	(0.06)	(0.07)	(0.15)	(0.10)	(0.04)	(0.04)	(0.03)
(i) Diff.	0.04	0.09***	-0.12	0.02	-0.07**	0.16*	-0.02	0.07	0.08
	(0.06)	(0.02)	(0.09)	(0.06)	(0.03)	(0.08)	(0.04)	(0.05)	(0.09)
				(b) Crisis economies, $G_i = 1$					
Before	0.71***	0.68***	0.77***	0.30***	0.33***	0.20*	-0.01	-0.00	-0.02
	(0.03)	(0.05)	(0.08)	(0.03)	(0.05)	(0.11)	(0.01)	(0.01)	(0.02)
After	0.61***	0.62***	0.64***	0.46***	0.46***	0.37***	-0.01	0.00	-0.01
	(0.03)	(0.02)	(0.04)	(0.04)	(0.03)	(0.12)	(0.01)	(0.01)	(0.01)
(ii) Diff.	-0.10**	-0.06	-0.12*	0.16***	0.13***	0.18**	-0.01	0.01	0.02
	(0.05)	(0.04)	(0.07)	(0.05)	(0.04)	(0.08)	(0.01)	(0.01)	(0.02)
				(c) Treatment effect: (ii) – (i)					
D-i-D	-0.14*	-0.15***	-0.01	0.14*	0.20***	0.01	0.01	-0.06	-0.07
	(0.07)	(0.04)	(0.09)	(0.08)	(0.05)	(0.08)	(0.05)	(0.05)	(0.09)
Obs.	1760	1146	1146						
$\bar{R}^2$	0.88	0.89	0.89						

Notes: Sample includes OECD countries except Hungary, Greece, Latvia, and Lithuania. Clustered robust standard errors. */**/*** indicates significant at the 90/95/99% confidence level. See text.

Table A7: *Difference in difference estimation. Phillips curve using unemployment gap. Non-OECD (except Hungary, Greece, Latvia, and Lithuania)*

	Persistence (ρ_1)			*Inflation Expectations* (ρ_e)			*Slack* (β)		
	All-OLS	Peg-OLS	Peg-IV	All-OLS	Peg-OLS	Peg-IV	All-OLS	Peg-OLS	Peg-IV
				(a) No Crisis economies, $G_i = 0$					
Before	0.76***	0.81***	1.04***	0.24***	0.19*	-0.10	-0.01	-0.02	-0.07
	(0.05)	(0.08)	(0.18)	(0.06)	(0.11)	(0.27)	(0.02)	(0.02)	(0.05)
After	0.69***	0.73***	0.67***	0.37***	0.28**	0.39***	-0.06***	-0.06***	-0.07***
	(0.06)	(0.09)	(0.05)	(0.10)	(0.13)	(0.11)	(0.02)	(0.02)	(0.02)
(i) Diff.	-0.07	-0.07**	-0.37*	0.13**	0.10**	0.49**	-0.06*	-0.04	-0.00
	(0.04)	(0.03)	(0.21)	(0.06)	(0.04)	(0.24)	(0.03)	(0.03)	(0.06)
				(b) Crisis economies, $G_i = 1$					
Before	0.58***	0.59***	0.75***	0.46***	0.43***	0.24***	0.02	0.02**	-0.04
	(0.04)	(0.04)	(0.05)	(0.03)	(0.04)	(0.05)	(0.01)	(0.01)	(0.03)
After	0.57***	0.58***	0.58***	0.56***	0.53***	0.49***	0.00	0.00	-0.01
	(0.02)	(0.02)	(0.02)	(0.05)	(0.06)	(0.06)	(0.02)	(0.03)	(0.03)
(ii) Diff.	-0.01	-0.01	-0.17***	0.10	0.09	0.25***	-0.02	-0.02	0.03
	(0.04)	(0.03)	(0.04)	(0.08)	(0.07)	(0.07)	(0.03)	(0.03)	(0.02)
				(c) Treatment effect: (ii) – (i)					
D-i-D	0.06	0.06	0.21	-0.03	-0.00	-0.24	0.04	0.02	0.04
	(0.06)	(0.05)	(0.22)	(0.09)	(0.08)	(0.24)	(0.04)	(0.04)	(0.06)
Obs.	1616	1016	988						
$\bar{R}^2$	0.88	0.91	0.87						

Notes: Sample excludes OECD countries. Clustered robust standard errors. */**/*** indicates significant at the 90/95/99% confidence level. See text.

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