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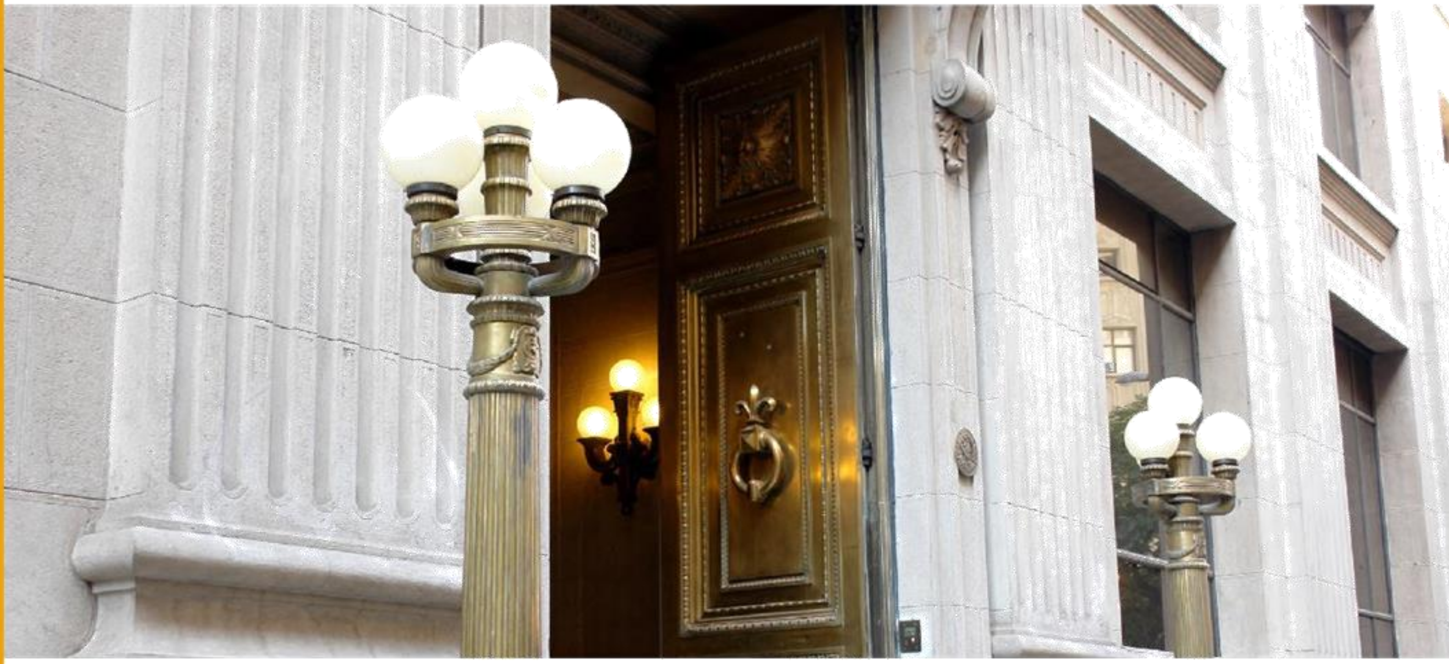

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Overborrowing and Systemic Externalities in the Business Cycle Under Imperfect Information*

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Abstract

We study the interaction between imperfect information and financial frictions and its role in driving financial crises in small open economies. We use a model where households observe income growth but do not perceive whether the underlying shocks are permanent or transitory, and borrowing is subject to a collateral constraint. The optimal macroprudential policy helps stabilize the economy by actively taxing debt. We show that the combination of imperfect information and a borrowing constraint is a significant source of economic instability. The optimal tax under these conditions is six times larger than the tax in the perfect information limit.

Resumen

Estudiamos la interacción entre información imperfecta y fricciones financieras y su rol en la formación de crisis financieras en economías pequeñas y abiertas. Proponemos un modelo donde los hogares enfrentan una restricción de endeudamiento que se suma a la imposibilidad de distinguir si las variaciones en el ingreso son transitorias o permanentes. Mostramos que la combinación entre la restricción de endeudamiento e información imperfecta es una fuente importante de inestabilidad económica y financiera. Nuestros resultados muestran que en este escenario, una política macroprudencial activa resulta óptima para reducir la vulnerabilidad de la economía. En particular, mostramos que el impuesto óptimo a la deuda externa bajo estas condiciones es seis veces mayor que el impuesto bajo información perfecta.

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1 Introduction

Three empirical regularities distinguish business cycles in emerging economies: consumption volatility is higher than income volatility, the current account exhibits a strong counter-cyclical pattern, and the economy experiences recurring macro-financial crises (often called Sudden Stops). These crises carry significant macroeconomic implications. They entail sharp reversals of capital inflows, corrections in asset prices, lower economic growth, and, in some cases, exclusion from international credit markets (Calvo, 1998; Mendoza, 2010).[1]

The literature has put forth two main mechanisms to explain these phenomena. One mechanism suggests that more stringent financial constraints characterize emerging economies and that adverse shocks may create debt-deflation episodes that are amplified by a decline in relative prices (see Mendoza (2002), Bianchi (2011), and Mendoza (2010)). The other mechanism proposes that the stochastic nature of shocks in emerging economies is different, and economic agents might not perfectly observe the persistence of the shocks they face. This uncertainty about the fundamentals leads to a more volatile cycle and makes the economy more vulnerable to sudden changes in economic conditions (see Aguiar and Gopinath (2007), Boz et al. (2011), and Blanchard et al. (2013)).

This paper focuses on the macroeconomic implications of the interplay between these two mechanisms. We study the role of imperfect information about the economy's fundamentals in generating Sudden Stops in a model where agents are subject to a borrowing limit that depends on the tradable value of domestic income.

We contribute to the existing literature in two ways. First, we study the macroeconomic impact of imperfect information about the fundamental components of income on a small open economy model with occasionally binding collateral constraints. Second, we investigate the optimal macroprudential policy for economies where endogenous collateral constraints interact with imperfect information.

[1] For the simulations presented in this paper, we define a Sudden Stop as an episode in which the current account improves (i.e., it becomes less negative or even positive) by more than one-standard-deviation above its long-term average, and the collateral constraint becomes binding. From this point onward, we will use the terms *Sudden Stop* and *financial crises* interchangeably.

Our main result shows that standard models of endogenous collateral constraints, when assuming perfect information, underestimate the extent of the welfare loss stemming from the externality that emerges when households pledge collateral goods or assets at market prices (Mendoza, 2002; Bianchi, 2011). Notably, the assumption of perfect information also leads to underestimating the optimal tax policy required to mitigate the effects of this pecuniary externality.

In order to incorporate imperfect information into a standard small open economy model with an occasionally binding collateral constraint, our approach draws upon the contributions of Bianchi (2011) and Seoane and Yurdagul (2019). In our economy, households receive stochastic income endowments from both the tradable and nontradable sectors, with each endowment being driven by a sector-specific transitory component and a common-trend component (representing the cumulative effect of current and past growth shocks) to both sectors. Due to imperfect information, households cannot directly observe the underlying components of each endowment; instead, they form beliefs about the fundamentals using the Kalman filter to solve a signal extraction problem. When new information becomes available, households optimally adjust their consumption decisions based on their updated beliefs about the unobservable components of income while also considering potential past mistakes.

Our general framework operates under the assumption of incomplete credit markets, where households only have access to a one-period, non-state-contingent bond denominated in units of tradable goods. A collateral requirement restricts the household's borrowing to a fraction of their total income, defined as the sum of their tradable income and the tradable value of their domestic income. Since collateral is valued at market prices, a pecuniary externality emerges due to private households failing to internalize how their decisions impact the equilibrium price of nontradable goods and their borrowing capacity.[2] The presence of the pecuniary externality leads private households to

[2] In good times–when consumption is high–the price of nontradable goods relative to tradable goods rises, leading to a relaxation of the collateral constraint. A higher debt limit encourages households to increase borrowing and consumption, strengthening the upswing in demand. During bad times, a Fisherian debt-deflation mechanism can trigger sharp and sudden adjustments in foreign financing access. Lower demand exerts downward pressure on the relative price of nontradable goods, causing a decline in the value of collateral. With credit conditions tightening, households must deleverage and

choose inefficient consumption and borrowing allocations relative to the choices made by a Social Planner capable of internalizing market prices into its decision-making. More importantly, this market failure motivates the implementation of macroprudential policy to restore market efficiency.

Introducing imperfect information adds a significant source of uncertainty to the model. Since we assume agents use the Kalman filter to solve the signal extraction problem, they will find it optimal to formulate beliefs that involve a non-zero probability that a specific shock of income is explained by changes in the transitory and the permanent components. Stated differently, this implies the economy will have permanent-like responses to purely transitory shocks and vice-versa.

We find that under imperfect information, the decentralized economy and the Social Planner increase their mean debt-to-GDP ratio by about two percentage points relative to their perfectly informed counterparts. More importantly, under both perfect and imperfect information, the pecuniary externality causes private households to overborrow about one percentage point of GDP more than the constrained Planner.

The interaction between the information friction and the pecuniary externality, while not causing a significant change in the level of overborrowing, does yield substantial macroeconomic consequences. We find that while debt does not increase dramatically under imperfect information, financial crises become more frequent. In particular, the decentralized economy experiences a 32 percent increase in the frequency of Sudden Stops compared to the same economy under perfect information. Notably, the uninformed constrained Planner experiences about 12 percent fewer financial crises than a perfectly informed Planner. This result highlights the importance of studying the nonlinearity involved in the interaction between imperfect information and the pecuniary externality.

Next, we delve into the welfare implications of overborrowing under imperfect information. While the information friction does not alter the degree of overborrowing resulting from the pecuniary externality, it notably amplifies the associated welfare costs. Our research findings show that the welfare losses attributed to the pecuniary externality

curtail consumption, prompting additional credit contraction and intensifying the economic downturn.

more than double under imperfect information. This result stems from the asymmetric impact of the information friction over how the Social Planner values wealth and future consumption. Private households and the Social Planner know that higher uncertainty raises the likelihood of facing a binding collateral constraint, and both agents increase their precautionary savings in response to this risk. However, the constraint Planner can adjust its valuation of wealth and future consumption to reflect that uncertainty leads to increased volatility in the collateral's value. This ultimately results in a stronger precautionary motive for the Social Planner.

One way to quantitatively observe this result is by comparing the average consumption decline during Sudden Stops across both information setups. Under imperfect information, consumption in the decentralized economy drops roughly 17 percent more than during the typical crises experienced by a constrained Planner. In contrast, as the perfectly informed economy carries less debt on average, consumption in the decentralized economy decreases about 2 percent more than it does for the Planner during financial crises.

Our findings show that considering the interaction between information and financial frictions has important implications for the role of macro-prudential policies in helping prevent and mitigate the risk of financial crises. Implementing the optimal capital control policy helps reduce the frequency and severity of financial crises experienced by the uninformed economy. In particular, we show that, under imperfect information, the optimal tax needed to restore the constrained-efficient allocation is roughly six times higher. Moreover, the optimal tax in the uninformed economy is active ($\tau_t > 0$) above ninety percent of the time. In comparison, the informed economy sees a positive tax only around thirty percent of the time.

Concerning the cyclicality of optimal tax policy, our findings reveal that under imperfect information, the constrained Planner increases taxes during bad times and lowers them during booms. This counter-cyclical behavior aligns with the findings of Schmitt-Grohé and Uribe (2017), who observe that the Planner addresses the trade-off created by highly impatient households and the need to avoid financial crises by increasing taxes on foreign debt when Sudden Stops are more likely (i.e. when income is low). Interestingly, in our benchmark model with perfect information, capital control taxes are procyclical, i.e., taxes on debt are higher when GDP increases and lower when it decreases.

The sign-switch in the cyclicality of optimal taxes can be explained by the differential effect of introducing trend shocks to the economy under conditions of perfect and imperfect information. According to Flemming et al. (2019), perfectly observable trend shocks to income contribute to aligning private and social incentives, particularly during unfavorable economic periods. When negative trend shocks impact the economy, private households tend to increase their savings because they anticipate a lower future income. Therefore, a constrained Planner observing these trend shocks raises taxes in periods with high-income growth and lowers them during economic downturns.

However, we find that this intuition only holds under perfect information. If agents cannot observe the underlying components of income, a purely negative trend shock to income will have a transitory-like response. Private households will want to save less during economic downturns than under perfect information. Since the shock might be transitory, households would rather increase borrowing to ensure a smoother consumption pattern. In our calibration, this translates into the planner wanting to increase taxes when GDP is low but Sudden Stops are more likely. This discrepancy in the cyclicality of the optimal tax policy underscores the intricate interplay between information availability and the pecuniary externality created by the collateral constraint.

We also study the implementation and practicality of the optimal macroprudential policy under imperfect information. As we mentioned, the uninformed constrained Planner chooses a highly nonlinear optimal policy and adjusts debt taxes more frequently than the informed planner. However, data indicates that policymakers generally prefer "sticky" policy rules. For instance, studying 21 emerging countries, Acosta et al. (2020) finds that authorities infrequently adjust capital controls; once an optimal tax is applied, it remains unchanged for an extended period. To contribute to this ongoing debate, we assess whether a simplified implementation of our predicted optimal tax policy effectively offsets the welfare costs arising from the pecuniary externality. Following the approach of Hernandez and Mendoza (2017), we analyze the welfare benefits of enacting a debt tax equivalent to the unconditional average of the optimal tax. However, our findings indicate that such a rule is ineffective and does not contribute significantly to restoring constrained-efficient allocations.

1.1 Related Literature.

This paper contributes to various dimensions of the literature that explores small open economy macroeconomics by examining the interaction between information and financial frictions.

First, we contribute to the literature studying the cyclical properties of emerging economies. The ongoing debate primarily revolves around determining the key factor driving the business cycle—whether it is trend (or growth) shocks, as argued by Aguiar and Gopinath (2007), or if permanent shocks play a secondary role due to the presence of financial frictions, as proposed by Neumeyer and Perri (2005) and Garcia-Cicco et al. (2010). According to the latter strand of the literature, properly calibrated models incorporating transitory and trend shocks require either financial frictions or interest rate shocks to replicate fundamental features of the business cycle in emerging countries. However, Boz et al. (2011) and Blanchard et al. (2013) validate the significance of trend shocks by considering the impact of imperfect information on the cycle. In particular, they show that by incorporating a learning process related to the nature of shocks, models where income depends on permanent and transitory components, can effectively reproduce the volatility of consumption and vulnerability to crises typical of emerging economies. We contribute to this body of literature by showing that a model featuring information and financial frictions can also replicate the empirical regularities found in the business cycles in emerging economies.

Second, our work is related to a growing literature studying the macroeconomic implications of financial frictions in emerging economies. Our work stems from the seminal contribution of Mendoza (2002) and Mendoza (2010), who introduced a theoretical dynamic general equilibrium model with an endogenous collateral constraint capable of generating sudden stops within regular business cycles. Using a quantitative framework, Bianchi (2011) demonstrated that partially utilizing external debt against domestic income introduces a pecuniary externality in the credit market, thereby quantifying the welfare improvements of implementing macroprudential policy. Under parameter calibrations typically used for emerging economies, most studies in this literature find the decentralized economy overborrows relative to the constrained planner.[3] However, Schmitt-Grohé and Uribe (2020) proved the existence of multiple equilibria in the standard model used by the literature (i.e., Bianchi (2011)). More importantly, the authors show that for plausible deviations from the standard calibration, there exists an equilibrium exhibiting underborrowing. We contribute to this discussion by studying whether the interaction between the information structure and the pecuniary externality is critical to observing overborrowing and whether it affects the frequency and severity of sudden stops.

Third, this paper contributes to the literature examining the desirability and implementation of macroprudential policy. Standard models in this literature analyze optimal tax policy in economies impacted by standard transitory shocks (e.g., productivity, terms-of-trade, or interest rate shocks) under the assumption of perfect information (Bianchi, 2011; Benigno et al., 2013, 2016; Korinek, 2011, 2018; Schmitt-Grohé and Uribe, 2017), research has shown that alternative sources of financial volatility, such as news shocks, trend shocks, or the relaxation of the perfect information assumption, have important implications for formulating capital control policy.

Within this literature strand, our paper is closely related to Bianchi et al. (2012), Bianchi et al. (2016), Flemming et al. (2019), and Seoane and Yurdagul (2019). For instance, in a model centered on the interplay between financial innovation, credit frictions, and imperfect information within the financial transmission mechanism, Bianchi et al. (2012) study a scenario where Bayesian learning and information crucially shape macroprudential policy. Like our approach, they depart from the standard assumption of perfect information about the stochastic process driving fluctuations in credit conditions.

[3]See, among others, Akinci and Chahrour (2018), Benigno et al. (2016) Bianchi et al. (2016), Flemming et al. (2019), Jeanne and Korinek (2019), Seoane and Yurdagul (2019), Ottonello (2021), and Schmitt-Grohé and Uribe (2017).

Differing from our work, the information friction in their model centers around optimistic (pessimistic) beliefs regarding financial innovation.

Bianchi et al. (2016) studies an economy characterized by regime changes in world interest rates and news shocks about future fundamental realizations. They show that as the precision of news shocks increases, the efficacy of implementing capital controls lowers. Furthermore, consistent with our findings, they establish that the optimal tax policy is highly nonlinear and requires significant variation across capital-market regimes and news shocks.

Finally, our research is strongly connected to the works of Flemming et al. (2019) and Seoane and Yurdagul (2019). These studies extend the standard model with endogenous collateral constraints to include permanent income (trend) but abstract from imperfect information. With some minor differences, our benchmark model under perfect information collapses to the model in Flemming et al. (2019), where the economy is affected by both permanent and transitory shocks but agents can perfectly observe them.

Plan for the paper. The remainder of the paper is organized as follows. Section 2 provides the model and explains the household problem, the endowment properties, and the information structure. Section 3 describes the equilibrium and presents the optimality conditions for the competitive and constrained-efficient Planner. Section 4 presents our quantitative results, and Section 5 concludes.

2 Theoretical Framework

For our modeling framework, we modify the model of a small open economy and endogenous collateral constrained proposed by Bianchi (2011). This is an interesting starting point because it is the framework typically used in the related quantitative literature. Similar to Seoane and Yurdagul (2019), we modify the endowment structure of Bianchi's model to include trend (permanent) and transitory shocks. These endowments are the only source of uncertainty in the model and provide the structure through which we relax the perfect information in the model. The following sections explain in detail each part of the model.

2.1 Households

The household's intertemporal preferences are given by a standard constant relative risk aversion (CRRA) function:

$$\mathbb{E}_0^j \left[\sum_{t=0}^{\infty} \beta^t \left(\frac{C_t^{1-\sigma}}{1-\sigma} \right) \right] , \quad \sigma > 0 \tag{1}$$

where β is the discount factor, and σ denotes the inverse of the intertemporal elasticity of substitution. Expectations are taken over the information set j, where $j \in \{ii, uu\}$. In this set, uu denotes an economy experiencing information frictions (i.e., households are uninformed), and ii denotes an economy populated by perfectly informed households.

Total consumption (C_t) is a bundle of tradable (C_t^T) and non-tradable (C_t^N) goods given by a CES aggregator with $\epsilon > -1$ as the elasticity of substitution within tradable and nontradable goods. The aggregator function is defined by:

$$C_t = \left[\omega \left(C_t^T \right)^{\frac{\epsilon-1}{\epsilon}} + (1-\omega) \left(C_t^N \right)^{\frac{\epsilon-1}{\epsilon}} \right]^{\frac{\epsilon}{\epsilon-1}}$$

where $1-\omega$ is the weight given to nontradable goods, and $0 \leq \omega \leq 1$. At the beginning of period t, households receive their endowments, repay their debt, and choose their consumption and borrowing. The budget constraint is given by:

$$B_{t+1} = (1 + r)B_t + Y_t^T + p_t Y_t^N - C_t^T - p_t C_t^N \tag{2}$$

Y_t^s is the income endowment from sector s where $s \in \{T, N\}$ denotes the tradable and nontradable sectors. Borrowing occurs through choosing the amount of foreign bonds (B_{t+1}) to be repaid next period at the international interest rate r. Bonds are non-state-contingent and denominated in units of tradable goods (i.e., foreign currency). From equation (2), it is clear that p_t is the relative price of nontradable goods in terms of tradable goods.

Beyond the non-availability of a state-contingent bond, credit markets are also imperfect due to a borrowing constraint that limits the amount of debt (measured as a negative nominal value of bonds) a household can hold. In particular, borrowing is required to be less than a given fraction κ of total current income (measured in tradable units):

$$B_{t+1} \geq -\kappa \left(Y_t^T + p_t Y_t^N \right) \tag{3}$$

Equation (3) has two characteristics that are worth noting. First, the constraint is consistent with empirical evidence showing that income is one of the key determinants of access to credit markets (Jappelli, 1990). Second, international creditors require short-term external debt (denominated in units of tradable goods) to be partially leveraged by the endowment of the nontradable sector, a common observation in emerging countries.

The relationship between the relative price of tradable goods, p_t, and the value of the collateral implied by the borrowing constraint introduces a debt-deflation mechanism like the one proposed by Fisher (1933) into the model. In good times, when income is high, the value of the collateral increases, incentivizing borrowing and consumption. As a result, the price of nontradable goods also increases, relaxing the collateral constraint even further and reinforcing the initial response of borrowing. In bad times, lower income reduces consumption and borrowing. In response, the price of nontradable goods will fall, as will the value of the collateral. As the constraint tightens, the household must further reduce its consumption, reducing the value of its collateral again and forcing even more deleverage. This downward spiral can move the collateral constraint to the point where it binds, shutting off access to credit markets and triggering a sudden stop.

Since households take prices as exogenously given, they fail to internalize how their choices affect the relative price of nontradable goods in general equilibrium. As pointed out by Bianchi (2011), the household's equilibrium decisions on consumption and borrowing will be inefficient compared to those made by a constrained Planner who internalizes the mutual feedback between prices and the value of collateral constraint.

As we will show in the following sections, introducing imperfect information significantly amplifies the implications of this type of pecuniary externality.

2.2 Endowment Properties

Each period, households receive two endowments from the tradable and nontradable sectors. Each endowment is composed of a sector-specific transitory component and a common permanent (or trend) component.[4] To implement the information friction, we assume that households cannot directly observe the underlying components of income, only its aggregate value.

In particular, we assume that each endowment is given by:

$$Y_t^s = \Gamma_t e^{z_t^s}, \ \ \forall\, s \in \{T,\, N\} \tag{4}$$

where z_t^s denotes the transitory component of the endowment coming from sector s. The trend component is given by Γ_t which we assume to be the cumulative product of current and previous realizations of growth shocks to the economy. In particular, the trend component is:

$$\Gamma_t = \Gamma_{t-1} e^{g_t} = \prod_{j=0}^{t} e^{g_j} \tag{5}$$

where g_t is the stochastic growth rate of the permanent component and follows an AR(1)

[4]See Aguiar and Gopinath (2007), Gertler et al. (2007), and Boz et al. (2011) for a discussion on the relevance of permanent shocks to explain unconditional business cycle moments in emerging economies.

process given by:

$$g_t = (1 - \rho_g)\mu_g + \rho_g g_{t-1} + \epsilon_t^g \tag{6}$$

The long-run mean growth rate of the permanent component of income is denoted by μ_g and $|\rho_g|< 1$. The stochastic term ϵ_t^g is an independent and identically distributed random variable that follows a normal distribution with mean zero and variance σ_g^2.

Equations (4) and (5) imply that both sectors share the same trend component but are exposed to different transitory shocks. Moreover, we are implicitly assuming independence between g_t and z_t^s. In particular, z_t^T and z_t^N are determined by the vector autoregression:

$$z_t = \begin{bmatrix} z_t^T \\ z_t^N \end{bmatrix} = \begin{bmatrix} \rho_{z^T,z^T} & \rho_{z^T,z^N} \\ \rho_{z^N,z^T} & \rho_{z^N,z^N} \end{bmatrix} \begin{bmatrix} z_{t-1}^T \\ z_{t-1}^N \end{bmatrix} + \begin{bmatrix} \epsilon_t^T \\ \epsilon_t^N \end{bmatrix} \tag{7}$$

$$= \mathbf{A} z_{t-1} + \varepsilon_t^z \tag{8}$$

where ε_t^s follows a bivariate normal distribution with mean zero and a variance-covariance matrix Σ.

2.2.1 Information Friction and Learning Problem

As explained above, households in our economy are not able to directly observe the underlying permanent and transitory components of income. Instead, in each period households must form beliefs about the unobserved components by using the information available in the economy.

To model this belief-formation process, we make two fundamental assumptions. First, at any given time t, households in our economy know the complete history of endowment realizations and the main properties of the stochastic processes that generate them. Second, because the endowments are informative about the underlying components, linear in differences, and with Gaussian innovations, we assume households use the Kalman filter to form their beliefs. Moreover, as the Kalman filter chooses the decomposition that minimizes the mean square error between the observed and predicted signals, we implicitly assume that households use all of the available information to produce optimal beliefs about the unobservable components of income.

The Kalman Filter

To implement the Kalman filter, first, we need to formally define the set of information that is available to the household at any given time t. Let $\mathbb{I}_t$ denote this set, and be defined as:

$$\mathbb{I}_t \equiv \left\{ \left\{ Y^i_{t-s} \right\}_{s=0}^{\infty}, \, f\left(\epsilon^T_t, \, \epsilon^N_t \right), \, f\left(\epsilon^g_t \right) \right\}, \quad \forall i \in [T, \, N] \tag{9}$$

where $\left\{ y^i_{t-s} \right\}_{s=0}^{\infty}$ is the full stream of current, and past realizations of income, $f(\epsilon^T_t, \, \epsilon^N_t)$ and $f(\epsilon^g_t)$ are the underlying probabilistic distributions of z^T, z^N, and Γ, respectively.

Second, we need to find a relationship between observable signals (i.e., elements in $\mathbb{I}_t$) and the underlying exogenous states. Let the growth rate of the tradable income (g^T_t) and the growth rate of the nontradable component relative to tradable income (g^N_t) be given by:

$$\Delta^T_t = \ln\left(\frac{Y^T_t}{Y^T_{t-1}} \right) = \ln\left(\frac{\Gamma_{t-1} e^{g_t} e^{z^T_t}}{\Gamma_{t-1} e^{z^T_{t-1}}} \right) = z^T_t - z^T_{t-1} + g_t \tag{10}$$

$$\Delta^N_t = \ln\left(\frac{Y^N_t}{Y^T_{t-1}} \right) = \ln\left(\frac{\Gamma_{t-1} e^{g_t} e^{z^N_t}}{\Gamma_{t-1} e^{z^T_{t-1}}} \right) = z^N_t - z^T_{t-1} + g_t \tag{11}$$

By observing the growth rates Δ^T_t and Δ^N_t the households also perceive a linear combination of the unobservable exogenous states $\left\{ z^T_t, \, z^N_t, \, g_t \right\}$. By rewriting the learning problem into its state-space form, we reduce it to a set of two fundamental equations. The first one is obtained by writing (10) and (11) as a system of equations:

$$s_t = \begin{bmatrix} \Delta^T_t \\ \Delta^N_t \end{bmatrix} = \mathbf{Z}\alpha_t = \begin{bmatrix} 1 & 0 & 1 & -1 \\ 0 & 1 & 1 & -1 \end{bmatrix} \begin{bmatrix} z^T_t \\ z^N_t \\ g_t \\ z^T_{t-1} \end{bmatrix} \tag{12}$$

where s_t denotes a vector of observable signals, and α_t is the vector of exogenous states.

Equation (12) is known as the observation (or measurement) equation, and it relates the observable signals to the underlying unobservable states.

The second fundamental equation of the state-space specifies how the underlying variables evolve over time. This equation is called the transition equation and is given by:

$$\begin{bmatrix} z_t^T \\ z_t^N \\ g_t \\ z_{t-1}^T \end{bmatrix} = \begin{bmatrix} \rho_{z^T,z^T} & \rho_{z^T,z^N} & 0 & 0 \\ \rho_{z^N,z^T} & \rho_{z^N,z^N} & 0 & 0 \\ 0 & 0 & \rho_g & 0 \\ 1 & 0 & 0 & 0 \end{bmatrix} \begin{bmatrix} z_{t-1}^T \\ z_{t-1}^N \\ g_{t-1} \\ z_{t-2}^T \end{bmatrix} + \begin{bmatrix} 0 \\ 0 \\ (1-\rho_g)\mu_g \\ 0 \end{bmatrix} + \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \\ 0 & 0 & 0 \end{bmatrix} \begin{bmatrix} \epsilon_t^T \\ \epsilon_t^N \\ \epsilon_t^g \end{bmatrix} \tag{13}$$

The equation, in compact form, is:

$$\alpha_t = \mathbf{c} + \mathbf{A}\alpha_{t-1} + \mathbf{R}\eta_t, \quad \text{with} \quad \eta_t \sim N(0, \mathbf{Q}), \;\; \mathbf{Q} \; = \begin{pmatrix} \sigma^2_{z^T,z^T} & \sigma_{z^T,z^N} & 0 \\ \sigma_{z^N,z^T} & \sigma^2_{z^N,z^N} & 0 \\ 0 & 0 & \sigma_g^2 \end{pmatrix} \tag{14}$$

where $\mathbf{c}$ denotes a vector containing the mean of each variable, $\mathbf{A}$ is the matrix containing the autocorrelation parameters and, $\mathbf{R}\eta$ is the error term. Errors come from a normal distribution with mean zero and variance-covariance $\mathbf{Q}$.

Let $\mathbf{a}_t$ be the optimal estimator of α_t. Therefore, the expectation of the underlying exogenous state variables conditional on current and past information sets is given by $\mathbf{a}_t = \mathbb{E}[\alpha_t|\mathbb{I}_t]$ and $\mathbf{a}_{t|t-1} = \mathbb{E}[\alpha_t|\mathbb{I}_{t-1}]$. The Kalman filter states that the posterior beliefs $\mathbf{a}_t$ will be a convex combination of the prior $\mathbf{a}_{t-1}$ and the new information added by the vector of signals s_t. The system given by the filter is:

$$\mathbf{a}_{t|t-1} = \mathbf{c} + \mathbf{A}\mathbf{a}_{t-1} \tag{15}$$

$$\mathbf{a}_t = k_1\mathbf{a}_{t|t-1} + k_2 s_t \tag{16}$$

where k_1 and k_2 in equation (16) are the Kalman gains and are defined as:

$$k_1 = \mathbf{I} - \mathbf{PZ}(\mathbf{ZPZ})^{-1}\mathbf{Z}$$
$$k_2 = \mathbf{PZ}'(\mathbf{ZPZ}')^{-1}$$

and where $\mathbf{P}$ is the variance-covariance matrix that solves the Riccati equation:

$$\mathbf{P} = \mathbf{APA}' - \mathbf{APZ}'(\mathbf{ZPZ}')^{-1}\mathbf{ZPA}' + \mathbf{RQR}' \tag{17}$$

In summary, the forecast $\mathbf{a}_t$ will be determined by the weight k_1 given to the forecast of $\mathbf{a}_{t|t-1}$ based only on information available at time $t-1$, and the weight k_2 attached to the new information about α_t contained in the current signals.

3 Equilibrium

The household's decisions about consumption and borrowing and its beliefs about the permanent and transitory components of income determine the household's intertemporal flow of utility. Therefore, the household's problem at time t consists of choosing the optimal sequence of consumption and borrowing subject to the budget and borrowing constraints and a given set of information $\mathbb{I}_t$. The recursive maximization problem is:

$$V(B, \mathbf{a}, \mathbf{y}) = \max_{C^T, C^N, B'} U\left(C(C^T, C^N)\right) + \beta \mathbb{E}\left[V\left(B', \mathbf{a}', \mathbf{y}'\right)\right] \tag{18}$$

subject to

$$B' = (1+r)B + Y^T + pY^N - C^T - pC^N \tag{19}$$
$$B' \geq -\kappa\left(Y^T + pY^N\right) \tag{20}$$

where variables without a subscript correspond to the current period, and variables with a prime superscript correspond to the next period. Moreover, $\mathbf{a}$ is a vector that contains the household's beliefs about the transitory and permanent components of the endowments, and $\mathbf{y} = \{Y^T, Y^N\}$. Then, a competitive equilibrium is a set of allocations $\{C^T, C^N, B'\}$, a set of beliefs $\mathbf{a}_t = \mathbb{E}[\alpha_t|\mathbb{I}_t]$, and the pair of prices $\{r, p\}$, such that households maximize their intertemporal flow of consumption, all of the constraints are satisfied, and the market for bonds and goods both clear.

3.1 Decentralized Economy

To develop more intuition about the role of the borrowing constraint in a competitive economy, we focus our attention on the solution of the sequential version of (18). We denote Λ_t and μ_t, the Lagrange multipliers correspond to the budget and borrowing constraints. Since tradable and nontradable income are permanently growing, we need to transform the dynamic system described by our economy to make it stationary. In general, the literature normalizes by Γ_{t-1}; however, because in our environment, households do not observe Γ_{t-1}, we will use the endowment of tradable income in the previous period, Y_{t-1}^T. Let $\lambda_t = \Lambda_t \left(Y_{t-1}^T\right)^{\sigma}$, and $\hat{x}_t = X_t/Y_{t-1}^T$ for each variable X_t. The normalized optimality conditions are:

$$\lambda_t = \omega \hat{c}_t^{-\sigma+\frac{1}{\epsilon}} (\hat{c}_t^T)^{-\frac{1}{\epsilon}} \tag{21}$$

$$p_t = \frac{(1-\omega)}{\omega} (\frac{\hat{c}_t^N}{\hat{c}_t^T})^{-\frac{1}{\epsilon}} \tag{22}$$

$$\lambda_t [1-\mu_t] = (1+r)\beta e^{(-\sigma g_t^T)} \mathbb{E}_t \lambda_{t+1} \tag{23}$$

$$e^{g_t^T} \hat{b}_{t+1} = \hat{b}_t(1+r) + e^{g_t^T} - \hat{c}_t^T \tag{24}$$

$$\hat{b}_{t+1} \geq -\kappa \left(1 + p_t \frac{e^{g_t^N}}{e^{g_t^T}}\right) \tag{25}$$

$$\mu_t \geq 0; \ \mu_t \left[\hat{b}_{t+1} + \kappa \left(1 + p_t \frac{e^{g_t^N}}{e^{g_t^T}}\right)\right] = 0 \tag{26}$$

Equation (23) represents the Euler equation for bonds. When the borrowing constraint is not binding (i.e., $\mu_t = 0$), the solution to the problem is to equalize the marginal benefit of increasing one unit of consumption today to the discounted cost of sacrificing one unit of future consumption. Whenever the constraint binds, the marginal utility of current consumption is adjusted by the shadow value of relaxing the collateral constraint μ_t.

The market clearing condition of this economy implies the nontradable endowment is fully spent on nontradable goods $Y_t^N = C_t^N$, therefore, the equilibrium price of nontradable goods relative to tradable goods is given by:

$$p_t = \frac{1-\omega}{\omega} \left(\frac{Y_t^N}{C_t^T} \right)^{-\frac{1}{\epsilon}} \tag{27}$$

Equation 27 explains intuitively the nature of the pecuniary externality. In equilibrium, changes in C_t^T will affect p_t proportionately and, more importantly, the collateral constraint's value. Households know but fail to internalize it into their intertemporal choices.

3.2 The Social Planner's Problem

In contrast to private households, a Social Planner can internalize the market clearing condition and does not take prices as given. In particular, the Planner will make borrowing and consumption decisions by solving the following problem:

$$V^{SP}(B, \mathbf{a}, \mathbf{y}) = \underset{C^T, B'}{max} U\left(C(C^T, Y^N)\right) + \beta \mathbb{E}\left[V\left(B', \mathbf{a}', \mathbf{y}'\right)\right] \tag{28}$$

subject to

$$B' = (1+r)B + Y^T - C^T$$

$$B' \geq -\kappa \left(Y^T + \left(\frac{1-\omega}{\omega} \left(\frac{Y^N}{C^T} \right)^{-\frac{1}{\epsilon}} \right) Y^N \right)$$

where, as before, $\mathbf{a}$ is a vector that contains the planner's beliefs about the transitory and permanent components of the endowments, and $\mathbf{y} = \left\{Y^T, Y^N\right\}$. Let Λ_t^{SP} and μ_t^{SP}, the Lagrange multipliers of the social planner corresponding to the budget and the borrowing constraint in the sequential version of the optimization problem described by (28). As before, we need to transform the model to make it stationary. The transformed first order conditions for the Planner's problem are:

$$\lambda_t^{SP}\left[1-\mu_t^{SP}\hat{\Phi}_t\right] = \omega \hat{c}_t^{-\sigma+\frac{1}{\epsilon}}(\hat{c}_t^T)^{-\frac{1}{\epsilon}} \tag{29}$$

$$\lambda_t^{SP}\left[1-\mu_t^{SP}\right] = \beta(1+r)e^{-\sigma g_t^T}\mathbb{E}_t^j \lambda_{t+1}^{SP} \tag{30}$$

$$e^{g_t^T}\hat{b}_{t+1} = \hat{b}_t(1+r) + e^{g_t^T} - \hat{c}_t^T \tag{31}$$

$$\hat{b}_{t+1} \geq -\kappa\left(1+\frac{1-\omega}{\omega}\left(\frac{\hat{c}_t^T}{e^{g_t^N}}\right)^{-(\frac{1}{\epsilon})}\frac{e^{g_t^N}}{e^{g_t^T}}\right) \tag{32}$$

$$\mu_t^{SP} \geq 0; \qquad \mu_t^{SP}\left(\hat{b}_{t+1}+\kappa\left(1+\frac{1-\omega}{\omega}\left(\frac{\hat{c}_t^T}{e^{g_t^N}}\right)^{-\frac{1}{\epsilon}}\frac{e^{g_t^N}}{e^{g_t^T}}\right)\right) = 0 \tag{33}$$

Note that the first order condition (29) changes relative to that from the decentralized equilibrium described by (21). In particular, the constrained planner would like to equate the marginal utility of tradable consumption (RHS of equation (29)), to the marginal utility of wealth, adjusted for the marginal change in the value of the collateral when consumption of tradable goods changes $\left(\Phi_t = \frac{\partial \tilde{BC}_t}{\partial C_t^T} = \kappa\frac{1-\omega}{\omega}\frac{1}{\epsilon}\left(\frac{\hat{c}_t^T}{e^{g_t^N}}\right)^{\frac{1}{\epsilon}-1}\right)$.

The differences between the planner's and the household's marginal utility of consumption are due to the pecuniary externality and explain why the competitive equilibrium undervalues wealth and chooses different allocations than the planner. When the planner's consumption increases by one unit, the marginal utility of consumption is affected by the marginal utility of transferring one unit of wealth to the future increases. Under the standard parametrization of these models, the combined effect means the constrained Planner will increase his precautionary savings and reduce external borrowing.[5]

More importantly, equation (29) shows that contrary to private households, when imperfect information is added into the mix, the constrained Planner adjusts its marginal utility of wealth to reflect that the increased uncertainty affects its valuation of how the value of collateral changes with consumption.

[5] See Schmitt-Grohé and Uribe (2020) for a thorough discussion on how different parametrizations can yield overborrowing/underborrowing.

4 Quantitative Analysis

In this section, we describe the calibration of the model and present the quantitative results. We solve the model using global solution methods. Further details on the calibration and the solution method are available in appendix A and B.

4.1 Calibration

To calibrate our model, we divide our empirical strategy into two parts. First, we use the Kalman filter and its statistical properties to estimate the hidden states of the shocks and the parameters governing the processes for the unobservable components of income. Second, we follow Bianchi (2011) to set the parameters of the model that do not affect the income processes.

Since the innovations, $\left\{\varepsilon_t^T, \varepsilon_t^N, \varepsilon_t^g\right\}$ affecting the transitory and permanent components of income are Gaussian, the Kalman filter's distribution of forecasts errors is also Gaussian (Hamilton, 1994). Therefore, we can write a log-likelihood function $\mathcal{L}(\Theta, s_t)$ that depends on the observable signals (s_t) and a vector (θ) containing the structural parameters conforming the state transition matrix $\mathbf{A}$ and the noise covariance matrix $\mathbf{Q}$. Our strategy is to get maximum likelihood estimates for the parameters in θ.[6]

We use annual data from Argentina from 1903 to 2018 from Ferreres (2020). We compute *tradable output* (Y_t^T) as the sum of the GDP in agriculture, forestry, fishing, mining, and manufacturing. *Non-tradable output* (Y_t^N) includes the residual between total and tradable GDP.[7] Following equations (10) and (11), we define the observable signals Δ_t^T and Δ_t^N as $\ln \frac{Y_t^T}{Y_{t-1}^T}$ and $\ln \frac{Y_t^N}{Y_{t-1}^T}$, respectively. The observable signals have a standard deviation equal to $\sigma_\Delta^T = 0.065$ and $\sigma_\Delta^N = 0.118$, and the correlation between the two series is 0.336. Thus, both signals are positively correlated, and the signal coming from the non-tradable sector is approximately twice as volatile as that from the tradable sector.

[6]See appendix A for more details.

[7]The GDP of the tradable sector includes the following categories: Farming, livestock, hunting, and forestry; Fisheries; Mine exploitation and quarries; and manufacturing. The GDP of the non-tradable sector is the sum of the sectoral GDP of Construction, Electricity, gas, and water; Transport, storage, and communications; financial intermediation; real estate activities; and other services.

Table 1 presents the maximum likelihood estimates for the parameters of **A** and **Q**. Our findings show that the relationship between transitory and trend shocks to income is contingent upon the sector. Specifically, transitory shocks exhibit greater persistence than trend shocks for tradable income, whereas trend shocks are less persistent than transitory shocks for the non-tradable sector. In terms of volatility, our analysis reveals that transitory shocks to tradable income are 1.5 times more volatile than trend shocks. However, the relationship is reversed for non-tradable income, where transitory shocks are about half as volatile as trend shocks. Unconditionally, the z_t^T, z_t^T, and g_t are highly volatile, with standard deviations of 10.0 percent, 4.1 percent, and 6.6 percent per year. Finally, following Garcia-Cicco et al. (2010), we set μ_g equal to 1.31 percent to match Argentina's average GDP per capita growth rate between 1900 and 2018.

Table 1: Estimated Parameters for Stochastic Income Processes.

Parameter	Estimate	Std. Deviation
ρ_{z^T,z^T}	0.7347	0.0867
ρ_{z^T,z^N}	-0.2553	0.0535
ρ_{z^N,z^T}	0.0337	0.1464
ρ_{z^N,z^N}	0.4170	0.0383
ρ_g	0.4968	0.1368
$\sigma_{z^T z^T}$	0.0680	0.1220
$\sigma_{z^N z^T}$	0.0004	0.1086
$\sigma_{z^N z^N}$	0.0370	0.0955
σ_g	0.0572	0.0517

Note: The table reports the estimated values for the parameters that dictate the behavior of the exogenous processes in the model. The second column shows the standard errors of the estimated parameters. Please refer to the main body of the paper for the notation of the parameters.

Appendix C discusses our results when varying the persistence and volatility of the income processes. This sensitivity analysis shows that the main results presented in the paper hold for plausible deviations from the estimated parameters used to model the stochastic income processes.

We follow Bianchi (2011) for the remaining structural parameters of the model. We set the international risk-free annual interest rate, r, to 4 percent. The inverse of the intertemporal elasticity of substitution, σ, is set to 2. The elasticity of substitution between tradable and non-tradable goods, ϵ, is set to 0.83. The share of tradable goods in the consumption aggregator, ω, is set to 0.31. The discount factor, β, and the parameter controlling the borrowing constraint's tightness, κ, are free parameters that we choose. We set them such that the competitive equilibrium with imperfect information matches Argentina's net foreign assets to GDP ratio equal to -29 percent of GDP and a frequency of financial crises equal to 5.5%. Table 2 summarizes the chosen parameters.

We discretize the estimated income processes using the simulation approach proposed by Schmitt-Grohé and Uribe (2009). Under perfect information, we assume that the agent directly observes the underlying states. We use three equally spaced grids of 19 points for each of the underlying components of income: z_t^T, z_t^N, and g_t. The resulting transition matrix summarizes the probability of transitioning from one of the known 6,859 (19^3) possible realizations to another.

Under imperfect information, the agent understands the stochastic structure of income shocks but cannot directly observe the underlying components. Instead, the agent can only observe the realizations of the two signals. To create the transition matrix, we first simulate a time series of 1,000,000 periods for the unobservable states. Next, we compute the value of the signals using the system of equations (12). Then, we apply the Kalman filter to the time series of Δ_t^T and Δ_t^N to compute forecasts for the underlying values of z_t^T, z_t^N, and g_t. Using distance minimization, we approximate each forecast and the realization of the observable signals to the values of five equally spaced grids of 19 points. Finally, to compute the transition matrix, we use the resulting discrete-valued time series to estimate the probability of transitioning from one realization of z_t^T, z_t^N, g_t, Δ_t^T and Δ_t^N to another. Notice that under imperfect information, the dimensionality of our exogenous state-space increased from 19^3 to 19^5 possible realizations.

Due to the nonlinearity introduced by the occasionally binding borrowing constraint, we solve the model using global solution methods. We use value function iteration to find the solution for the Social Planner's problem. In the case of competitive equilibrium, we

Table 2: Parameter values

Parameter	Meaning	Value	Source/Target
r	Interest Rate	4.00%	Bianchi (2011)
σ	Inverse of intertemporal elasticity of substitution	2.00	Bianchi (2011)
ϵ	Elasticity of substitution between Tradable and Nontradable goods	0.83	Bianchi (2011)
ω	Weight of C_t^T in C_t	0.31	Bianchi (2011)
β	Discount factor β	0.83	Average NFA-GDP: -29%
κ	Borrowing constraint	0.335	Frequency of crises: 5.5%
μ_g	Avg growth rate of g_t	1.31%	Argentina's average per capita GDP growth rate

Note: The parameters β and κ are calibrated to match data moments from Argentina. Appendix C discusses the results when assuming different calibrations of β and κ.

use time iteration. In both cases, the grid for bond holdings includes 501 equally spaced points.[8]

4.2 The Interaction Between the Information Friction and the Collateral Constraint.

We divide the analysis of our results into two parts. First, we study quantitatively how information frictions affect the business cycle. Second, we study the interaction between the information friction and the pecuniary externality in the collateral constraint. The first part can be interpreted as an extension of Boz, Daude, and Durdu (2011) to a setup involving a small open economy featuring occasionally-binding constraints.

4.2.1 How Does the Information Friction Affect the Business Cycle?

Introducing imperfect information adds a significant source of uncertainty to the standard model of endogenous collateral constraints. Since we assume agents use the Kalman filter to solve the signal extraction problem, they will find it optimal to formulate beliefs that involve a non-zero probability that a specific shock of income is explained by changes in the transitory and the permanent components. Stated differently, this implies the economy will have permanent-like responses to purely transitory shocks and vice-versa.

[8]For more details on the numerical method, see appendix B.

Similar to Boz et al. (2011), the uninformed economy will experience a business cycle with more persistence and amplification than an informed economy. More importantly, the economy will have transitory-like responses to purely permanent shocks and vice versa. To understand this result, refer back to equations (10) and (11). In our model, agents are aware that each period's tradable and nontradable endowments convey information about the current transitory and permanent underlying components (Z_t^T, Z_t^N, g_t), as well as the previous realization of the transitory component of tradable income (Z_{t-1}^T). This is a critical feature of our model because it means that the household adjusts its beliefs every period based on what is happening now and what was happening with Z^T.

For instance, when a negative shock to the permanent component income occurs, the agent observes negative growth rates Δ_t^T and Δ_t^N. According to the measurement equation given by (10), a negative value of Δ_t^T could be explained by each of the following scenarios:

1. A negative transitory shock $\left(Z_t^T \downarrow\right)$.

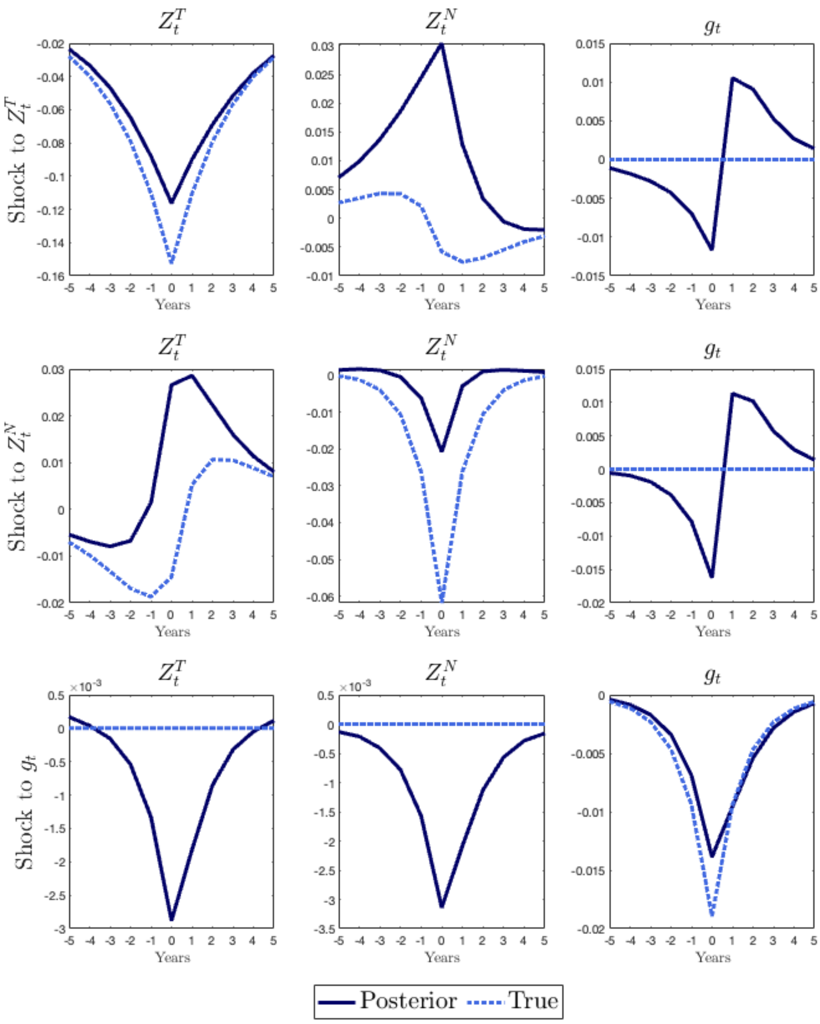
2. A positive transitory shock in $t-1$ that went unnoticed $(Z_{t-1}^T \uparrow)$.

3. A negative shock to the permanent component $(g_t \downarrow)$.

The optimal forecast produced by the Kalman filter implies that agents will form beliefs $\tilde{z}_t^T$, $\tilde{z}_{t-1}^T$, and $\tilde{g}_t$ consistent with each of the three scenarios having a positive probability to have occurred. In other words, the agent's beliefs will satisfy $\tilde{z}_t^T - \tilde{z}_{t-1}^T < 0$. Suppose the economy starts at equilibrium (i.e., $z_t^s = z_{t-1}^s = 0, \forall\, s \in \{T, N\}$), then the actual growth rate observed today is determined only by the movement in the permanent component g_t. According to (10), $g_t = \Delta_t^T < \Delta_t^T - (\tilde{z}_t^T - \tilde{z}_{t-1}^T) = \tilde{g}_t < 0$. Therefore, agents believe that the shock to the permanent component is less negative than it actually is. Moreover, consistent with scenarios 1 and 2 being likely, the household will believe z_t^T, z_{t-1}^T, and z_t^N are moving.[9] Consistent with this set of beliefs, the uninformed economy's response to permanent shocks is more muted than in an informed economy.

[9]According to equation (11), a negative shock to z_{t-1}^T that went unnoticed translates into a positive Δ_t^N. From the agent's perspective, this also can be explained by a positive shock to the transitory component of nontradable income z_t^N, which explains why, in the first row of figure 1, the household believes that $\tilde{z}_t^N$ increases at impact.

Figure 1: Response of Beliefs Under Different Observable Scenarios



Note: This figure shows how the posterior beliefs of the household change in response to shocks to the unobserved exogenous states. For each case, the fundamentals are subject to a negative one-standard-deviation shock. The horizontal axis spans five years before and after the shock occurrence.

Figure 1 compares the agents' posterior beliefs to the actual realization of the shocks. Each row shows a pure shock to an underlying component of income. For each case, it is possible to build a similar rationale to the one we presented above. As with the shock to g_t, agents assume that shocks to the transitory components of income are less severe than they actually are. Interestingly, starting in $t+1$, any shock to z_t^T or z_t^N will fade out as $z_{t+1}^j = \rho_{z^T,z^T} z_t^j$ where $j \in T, N$. The initial period of negative income growth is followed by several periods of positive but decreasing growth as $\Delta_{t+1}^j = (\rho_z - 1) z_t^j > 0$. This explains why in the first two rows of figure 1, g_{t+1} turns positive after impact.

How does this fit into our analysis? First, the permanent-like responses to purely transitory shocks imply that the uninformed economy is more likely to observe additional consumption volatility. Second, frequently adjusting consumption due to uncertainty means the uninformed economy will face a higher likelihood of financial crises. Finally, since the Social Planner can internalize that increased uncertainty affects its valuation of how the value of collateral changes with consumption (see equation (29)), the added volatility of consumption will amplify the welfare effects of the pecuniary externality embedded in the collateral constraint.

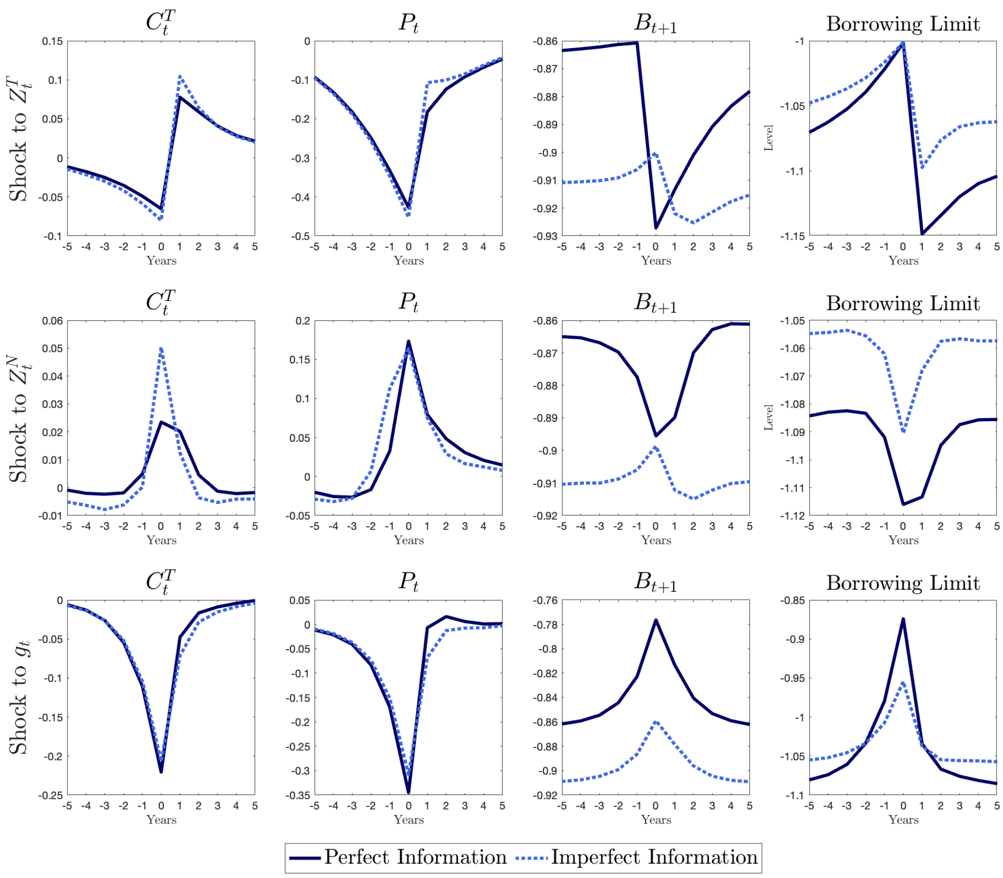
4.2.2 Borrowing and Consumption Under Imperfect Information

As we noted, the household under imperfect information will form beliefs about the unobserved components of income that contain errors. For instance, the household will interpret a purely transitory shock as partially permanent. Similarly, a strictly permanent shock will be understood as partially transitory.

Figure 2 shows the response of consumption, the relative price, bond holdings, and the borrowing limit to pure shocks to Z_t^T, Z_t^N, and g_t. The first row shows a pure one-standard-deviation negative shock to the transitory component of tradable income (Z_t^T). Under perfect and imperfect information, tradable consumption and prices fall, and the borrowing limit tightens in response to lower income. However, external borrowing responds differently across models. Consistent with the permanent consumption hypothesis, a transitory shock implies an increase in external borrowing to smooth consumption.

In contrast, the uninformed household reduces borrowing as it assumes the shock is partially permanent. The second row shows a shock to the transitory component of nontradable income (Z_t^N). Under perfect information, as consumption of nontradable goods falls, according to equation (27), the relative price p_t increases. This relaxes the collateral constraint and allows for an increase in tradable consumption financed with higher borrowing. Once again, as the imperfectly informed economy assumes it is partially permanent, the response of C_t^T and P_t^T is more muted. More importantly, as the shock is assumed to be partially permanent, the household reduces external borrowing.

Figure 2: Endogenous Responses to Shocks to the Underlying Components of Income



Note: Each row displays the response of consumption of tradable goods, the relative price of nontradables, debt holdings, and the borrowing limit to a negative one-standard-deviation shock to one of the fundamental income components. The value of the borrowing limit is given by $\kappa\left(Y_t^T + p_t Y_t^N\right)$.

Finally, the third row shows the effect of a negative shock on the permanent component of income. As in the previous scenarios, the response of C_t^T and p_t is in the expected direction. Both economies decrease borrowing, but the reduction is much lower under imperfect information.

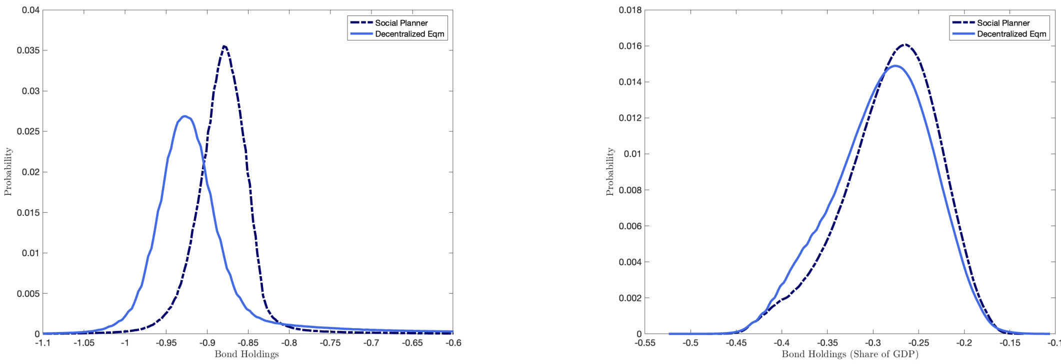
4.2.3 The Interaction Between the Information Friction and the Collateral Constraint

This section analyzes how the information friction interacts with the pecuniary externality. We study the degree of overborrowing, the frequency and severity of financial crises, the welfare costs created by market inefficiency, and the characteristics of the optimal macroprudential policy that restores constrained efficiency. Table 4 summarizes the key insights of this section.

Figure 3: Ergodic Distribution of Assets Under Imperfect Information

(a) Bond Holdings

(b) Debt-to-GDP Ratio



Note: This figure shows the ergodic distribution of asset holdings for the constrained planner and the competitive equilibrium under imperfect information. Debt increases to the left. The distribution is computed by repeatedly drawing from the policy functions of each model.

Figure 3 shows the ergodic distribution of external borrowing under perfect and imperfect information. The first thing to note is that, as expected, the information friction does not change the qualitative observation that the pecuniary externality induces overborrowing.[10] Both in absolute terms and as a percentage of GDP, the Social Planner chooses less debt than the decentralized economy.

Table 3: Debt to Output Ratios

	Perfect Information	Imperfect Information	Information Effect
Constrained Planner	26.16%	28.06 %	1.90 p.p
Competitive Equilibrium	27.15%	29.02 %	1.88 p.p
Externality Effect	0.99 p.p	0.97 p.p	-

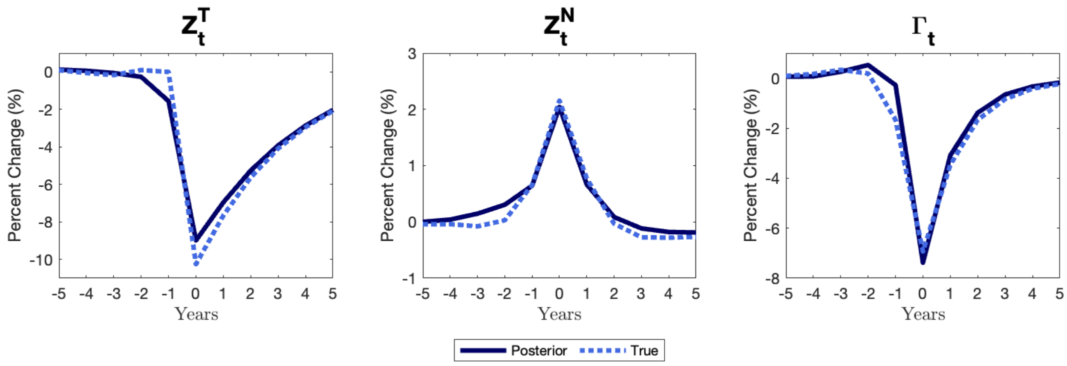
Note: This table presents the average debt-to-output ratios for the four benchmark allocations we have considered. The information effect is computed as the difference between the second and first columns. The Externality effect is the difference between the second and first rows.

Table 3 presents average debt-to-output ratios for each equilibrium analyzed. The third row shows the difference between the planner and competitive allocations holding the information set constant, i.e., the effect of the pecuniary externality. In our

[10] Schmitt-Grohé and Uribe (2020) showed that models with endogenous collateral constraints are prone to exhibit multiple equilibria. Models like Bianchi (2011) can display underborrowing for plausible calibrations. However, since our benchmark calibration is identical to Bianchi (2011), we implicitly discard the parameter scenarios that could yield underborrowing under imperfect information. This could be an interesting avenue for future research.

benchmark calibration, the total amount of overborrowing changes very little between the informed and uninformed economies. Also, as shown in the third column of table 3, adding imperfect information increases the amount of debt-to-GDP by about 1.9 percent for both the decentralized economy and the constrained Planner.

Figure 4: Shocks to the Underlying Component of Income Driving Financial Crises

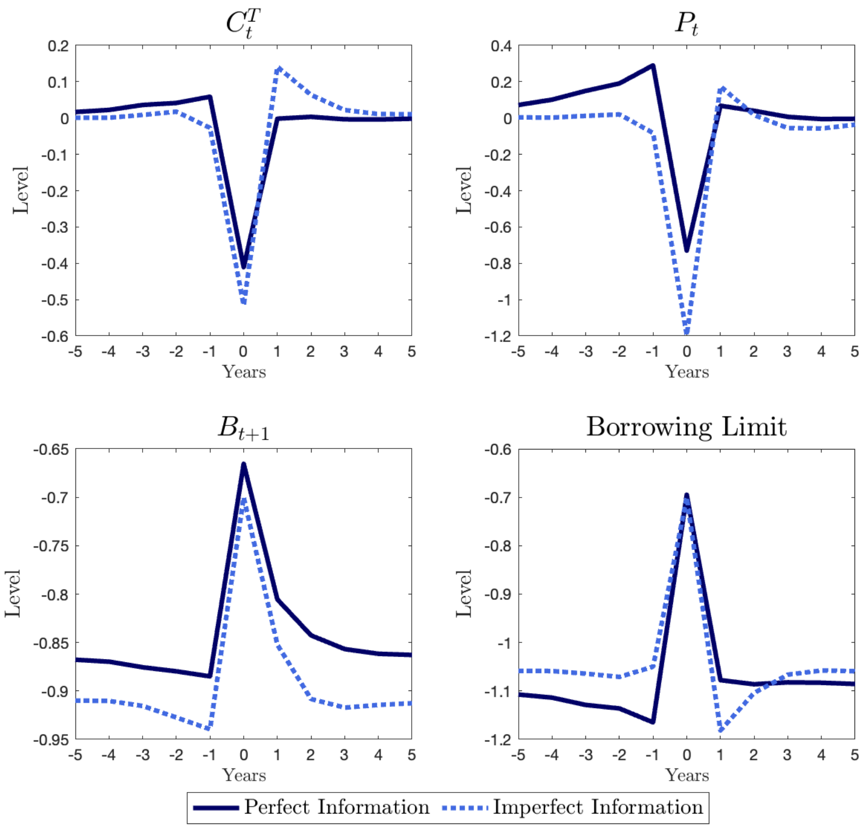


The higher exposure to debt has a more noticeable impact on the conditional moments rather than on unconditional averages. This finding makes intuitive sense, as having a binding constraint is rare; unconditional averages might mask the full effect of these unusual but painful episodes. In fact, table 4 shows that while debt does not increase dramatically under imperfect information, financial crises become more frequent. In particular, the decentralized economy experiences a 32 percent increase in the frequency of Sudden Stops compared to the same economy under perfect information. Notably, the uninformed constrained Planner experiences about 12 percent fewer financial crises than a perfectly informed Planner. This result gives quantitative support to our initial intuition that the Social Planner can internalize that increased uncertainty due to imperfect information affects its valuation of how the value of collateral changes with consumption.

On average, financial crises are triggered by a sequence of simultaneous adverse shocks to the transitory component of tradable income (Z_t^T) and the permanent component (g_t). Figure 4 illustrates that in the years preceding the crisis, the uninformed economy experiences a series of negative permanent income shocks, which agents perceive as transitory. The crisis emerges when simultaneous shocks to Z_t^T and g_T impact the economy at $t = 0$.

The informed decentralized economy experiences fewer Sudden Stops than the econ-

Figure 5: Endogenous Response to Financial Crises



omy under imperfect information. However, as depicted in figure 5, these Sudden Stops tend to be more severe on average, as indicated by the larger drop in consumption during financial crises. Nevertheless, table 4 reveals that under imperfect information, the consumption decline in the decentralized economy is approximately 17 percent greater than the decline observed during the typical crisis faced by a constrained Planner. In contrast, consumption in the informed decentralized economy decreases only about 2 percent more during a crisis than it does for the informed Planner.

However, table 4 shows that under imperfect information, consumption in the decentralized economy drops roughly 17 percent more than during the typical crises experienced by a constrained Planner. In contrast, as the perfectly informed economy carries less debt on average, consumption in the informed decentralized economy decreases about 2 percent more than it does for the informed Planner during financial crises. These outcomes offer a glimpse into the welfare costs linked to the pecuniary externality under imperfect information.

Table 4: Key Moments from Different Models Under Perfect and Imperfect Information

	Baseline Model				*Recalibrated Model*	
	Perfect Information		*Imperfect Information*		*Perfect Information*	
	D.E	*S.P*	*D.E*	*S.P*	*D.E*	*S.P*
Avg. Debt-to-GDP Ratio (%)	-27.15	-26.16	-29.02	-28.06	-28.95	-28.60
Frequency of Financial Crises (%)	4.15	1.98	5.53	1.73	5.50	4.16
Consumption Drop During Financial Crises (%)	-25.06	-24.55	-24.71	-21.06	-30.53	-29.14
$\sigma(C_t/Y_t)$ (%)	3.72	3.42	3.97	3.42	4.21	3.91
$\rho(CA_t, Y_t)$	-0.60	-0.53	-0.40	-0.01	-0.73	-0.67
$\sigma(CA_t/Y_t)$ (%)	4.64	3.07	4.24	1.46	7.67	5.77
Welfare cost (%)	0.11	-	0.24	-	0.15	-
Avg. Tax on Foreign Debt (τ, %)	-	2.30	-	14.32	-	13.24
$\rho(\tau_t, Y_t)$	-	0.22	-	-0.38	-	0.31

Note: Under the baseline model, the parameters β and κ were adjusted in order to calibrate the uninformed decentralized economy to match an average Debt-to-GDP of 29% and a frequency of crises equal to 5.5%. For the recalibrated model, we changed these parameters in order to get the decentralized equilibrium under perfect information to match the moments in the data. The welfare costs presented in the table were calculated relative to the constrained-Planner sharing the same information set.

4.3 Welfare Costs and Optimal Macroprudential Policy

In this subsection, we compare the welfare loss caused by the pecuniary externality under perfect and imperfect information. Let the value function for the constrained planner be given by

$$v^{SP}(x_t, b_t) = \mathbb{E}_t \sum_{s=0}^{\infty} \beta^s \frac{c_{t+s}^{CE}\left(1 + \frac{\Lambda(x_t, b_t)}{100}\right)}{1-\sigma} \tag{34}$$

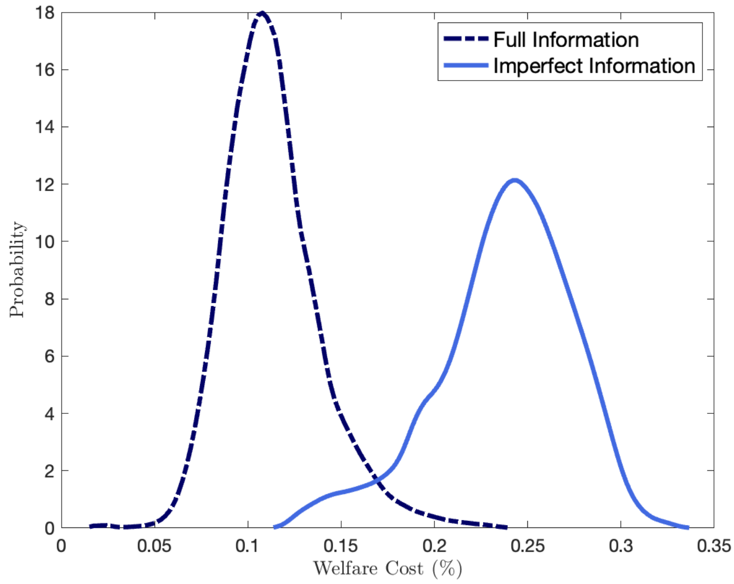
where c_{t+s}^{CE} is the value of consumption achieved by the competitive equilibrium and $\Lambda(x_t, b_t)$ represents how much equivalent consumption the household in a competitive economy is losing with respect to the constrained planner due to the pecuniary externality. Solving (34), the welfare loss is given by:

$$\Lambda(x_t, b_t) = 100\left(\left[\frac{v^{SP}(x_t, b_t)}{v^{CE}(x_t, b_t)}\right]^{\left(\frac{1}{1-\sigma}\right)} - 1\right) \tag{35}$$

where x_t is the vector containing the exogenous states.

Under imperfect information, the average welfare loss due to the pecuniary externality is approximately 0.24 percent of lifetime consumption, more than double the average loss observed under full information. Figure 6 shows the ergodic distribution for the welfare costs under perfect and imperfect information. Notably, these distributions have not only significantly different means but also different standard deviations.

Figure 6: Welfare Costs of the Pecunary Externality Under Different Information Sets



Note: This figure shows the ergodic distribution of the welfare costs generated by the pecuniary externality under perfect and imperfect information. The distribution is computed by simulating the model for one million periods. The standard deviation for the welfare cost under perfect information is 0.026 percent. The standard deviation for the welfare cost under perfect information is 0.04 percent.

These results stem from the asymmetric impact of the information friction over how the Social Planner values wealth and future consumption. Private households and the Social Planner know that higher uncertainty raises the likelihood of facing a binding collateral constraint, and both agents increase their precautionary savings in response to this risk. However, the constraint Planner can adjust its valuation of wealth and future consumption to reflect that uncertainty leads to increased volatility in the collateral's value. This ultimately results in a stronger precautionary motive for the Social Planner.

Besides computing the welfare costs of the interaction between the information friction and the collateral constraint, we have also computed the welfare cost of the information friction. To do so, we compared the welfare costs of a household moving from a perfectly informed decentralized economy to an uninformed decentralized economy. Similarly, we did the same computation for a Social Planner.[11]

[11] To compute these costs, we modified equation (35) to keep the economic equilibrium constant but

Table 5: Welfare Costs (Gains) From Moving Across Regimes

	Perfect Information		Imperfect Information	
	Constrained Planner	Decentralized Economy	Constrained Planner	Decentralized Economy
Informed Constrained Planner	-	0.11	0.94	1.18
Informed Decentralized Economy			-2.08	1.06
Uninformed Constrained Planner				0.24

Note: This table presents the welfare costs (gains) of moving across different regimes. The table should be read as the welfare cost implied by moving from a regime in the rows to a regime in the columns. A negative value implies a welfare gain. All values are in percent units of lifetime consumption. For instance, the welfare cost of moving from the informed constrained Planner to the informed decentralized economy is equal to 0.11 percent of lifetime consumption.

Table 5 presents the results. It shows that under our baseline calibration, the welfare costs of the information friction in the decentralized economy are 1.06 percent of lifetime consumption. Similarly, a planner operating in an economy with imperfect information is willing to pay 0.94 percent of her lifetime consumption to operate in an economy with perfect information. These results show that the welfare costs of the information friction are significantly higher than those of the pecuniary externality.

4.3.1 Optimal Macroprudential Policy

The existence of the pecuniary externality justifies the introduction of policies looking toward restoring credit market efficiency. In this section, we analyze the tax on foreign debt that a Social Planner would like to implement over the decentralized equilibrium.

As we explained in subsection 3.2, the pecuniary externality translates into different Euler equations for both the competitive equilibrium and the Social Planner. The optimal tax on foreign debt, is defined as the tax a planner would impose on the decentralized equilibrium in order to equalize their Euler equations Bianchi (2011). When the constraint binds $\mu_t = 0$, we set the optimal tax τ_t to zero as both the planner and the household in the competitive equilibrium have the same marginal utility of consumption, therefore, the same allocations for borrowing and consumption. If the constraint is not binding,

switched across information structures.

but it is expected to bind in the future (i.e., $\mu_t = 0$ and $\mathbb{E}_t[\mu_{t+1}] > 0$), the optimal tax on foreign borrowing is given by:

$$\tau_t^* = \frac{\mathbb{E}\left[\mu_{t+1}^{SP}\Phi_{t+1}\right]}{\mathbb{E}\left[U_T(t+1)\right]}$$

where Φ_{t+1} is the marginal change in the value of the collateral due to changes in consumption of tradable goods (as defined in section 3.2), and U_T is the marginal utility of tradable consumption. Note the planner implements a tax equal to the expected value of the uninternalized marginal cost of borrowing discounted by the expected value of the marginal utility of tradable consumption.

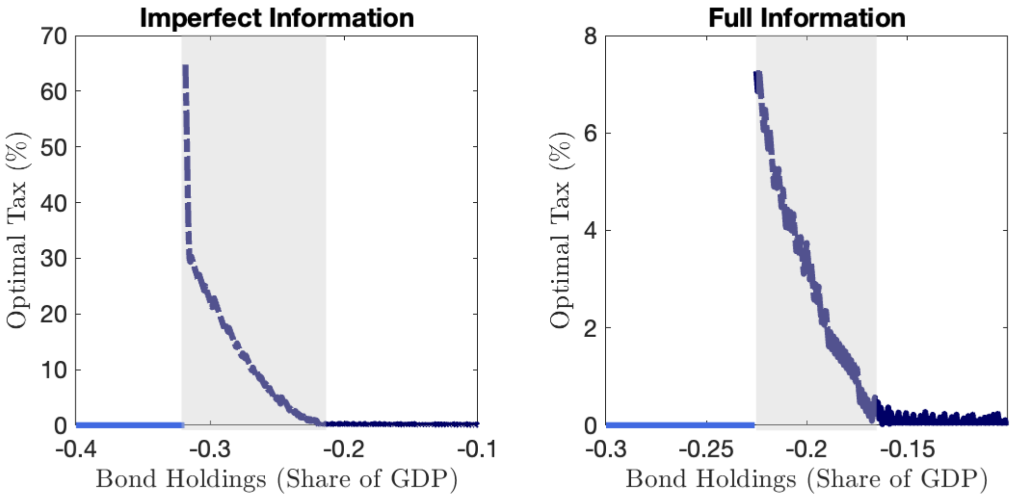


Figure 7: Optimal Tax Functions

Note: This figure shows the optimal tax rates as a function of the bond holdings for a particular realization of the underlying components of income.

The increased welfare costs of the pecuniary externality due to the information friction incentivize the Social Planner to implement a higher tax foreign borrowing relative to the optimal tax under perfect information. Figure 7 shows the optimal tax policy functions for both the informed and uninformed equilibria. In both cases, the optimal function displays three identifiable areas. First, as explained before, a section in which the constraint is binding and, therefore, the tax is equal to zero. Second, the optimal tax increases with the bond holdings. Third, if the planner considers the economy is sufficiently insured against observing a binding collateral constraint, then it chooses to deactivate the tax.

Figure 8 shows that considering the interaction between information and financial

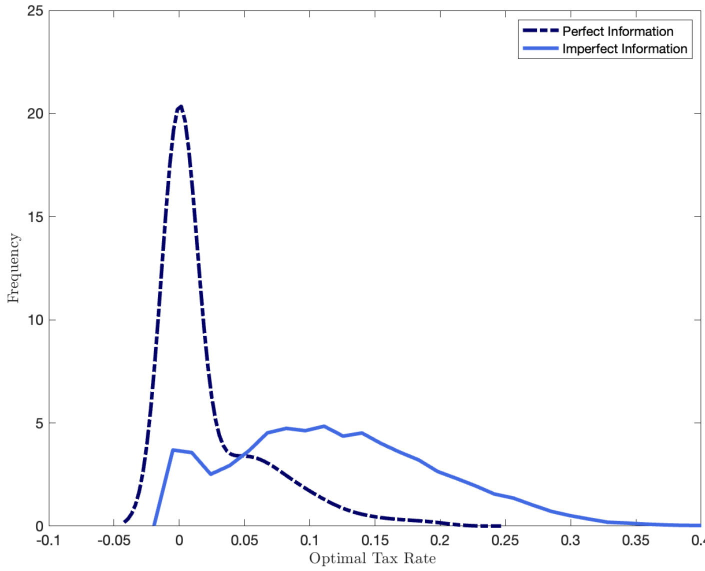


Figure 8: Optimal Tax: Ergodic Distribution

Note: This figure shows the ergodic distribution of the optimal tax under both imperfect and perfect information.

frictions has important implications for the role of macro-prudential policies in helping prevent and mitigate the risk of financial crises. Implementing the optimal capital control policy helps reduce the frequency and severity of financial crises experienced by the uninformed economy. Under imperfect information, the optimal tax needed to restore the constrained-efficient allocation is roughly six times higher.[12] Moreover, the optimal tax in the uninformed economy is active ($\tau_t > 0$) above ninety percent of the time. In comparison, the informed economy sees a positive tax only around thirty percent of the time.

Concerning the cyclicality of optimal tax policy, table 4 shows that under imperfect information, the constrained Planner increases taxes during bad times and lowers them during booms. This counter-cyclical behavior aligns with the findings of Schmitt-Grohé and Uribe (2017), who observe that the Planner addresses the trade-off created by highly impatient households and the need to avoid financial crises by increasing taxes on foreign debt when Sudden Stops are more likely (i.e. when income is low). Interestingly, in the model with perfect information, capital control taxes are procyclical, i.e., taxes on

[12] Figure 7 ilustrates this point for a given realization of the fundamental.

debt are higher when GDP increases and lower when it decreases. We also study the implementation and practicality of the optimal macroprudential policy under imperfect information. As we mentioned, the uninformed constrained Planner chooses a highly non-linear optimal policy and adjusts debt taxes more frequently than the informed planner. However, data indicates that policymakers generally prefer "sticky" policy rules (Acosta et al., 2020). Following the approach of Hernandez and Mendoza (2017), we analyze the welfare benefits of enacting a debt tax equivalent to the unconditional average of the optimal tax for the uninformed economy.

Under the simple rule, the uninformed economy displays underborrowing. The debt-to-GDP ratio in the decentralized equilibrium with the simple tax is equal to 24.45%, about 3.6% of GDP less than the level selected by the uninformed Planner. The significant reduction in debt holdings impacts the frequency of financial crises. Under the flat tax rate, the economy experiences only 0.68 crises per century, significantly lower than the frequency of crises observed under constrained efficiency (1.73%) and that of the decentralized economy with no taxes (5.5%).

In line with the results of Hernandez and Mendoza (2017), the welfare costs of the pecuniary externality under the flat rate tax (0.2 % of lifetime consumption) are almost as high as the welfare costs generated in the laissez-faire economy (0.24% of lifetime consumption). Having said this, a household living in a decentralized economy with no capital controls would increase their lifetime consumption by about 0.03 percent by moving to a regulated economy with a flat rate tax.

Related to the implementation of the optimal policy, from the perspective of a central banker, the relevant question might be whether calibrating a model under perfect information leads him to a policy rule that is very different from the "true" optimal policy. To evaluate this issue, we compare the optimal policies enacted by Planners in economies calibrated economies, i.e., when both the informed and uninformed economies are calibrated to match the same level of debt-to-GDP and frequency of crises.

Table 4 shows summarize our findings. Under this scenario, the informed planner in the recalibrated economy chooses a mean tax similar to the average macroprudential

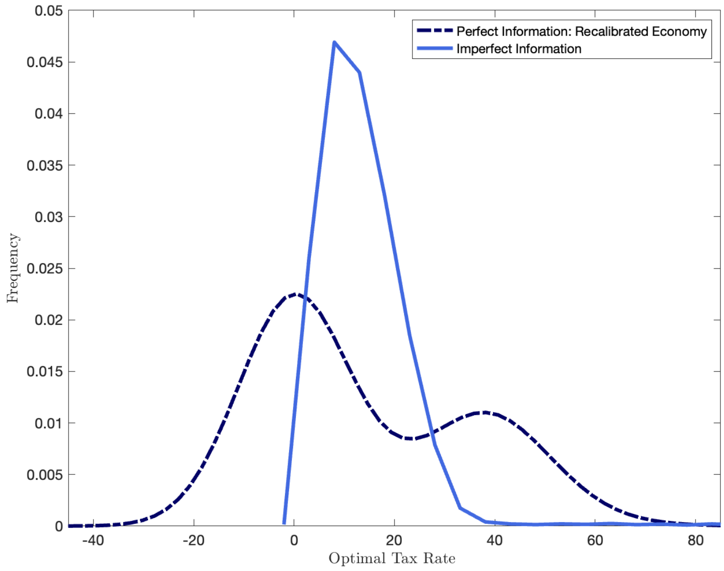


Figure 9: Optimal Tax Distribution: Recalibrated Economy

Note: This figure shows the ergodic distribution of the optimal tax under both imperfect and perfect information.

tax implemented by the uninformed planner. However, as depicted in figure 9, the distributions of the optimal policy are entirely different, with the optimal policy for the recalibrated informed economy having a higher standard deviation.

These differences stem from one crucial caveat in the recalibration. Given our estimated stochastic processes, the degree of impatience required to match the average debt-to-GDP ratio and the frequency of financial crises observed in the data is very high. In particular, we need an annual discount factor (β) of 0.53, which is quite low for the standard values used in this literature. This result is somewhat implicit in our original benchmark as the β used to calibrate the imperfectly informed economy is already low. The high level of impatience implied by our model contrasts with the calibrations used by Bianchi (2011), Flemming et al. (2019), and Seoane and Yurdagul (2019). However, as we choose all the model parameters as in Bianchi (2011), the difference in the level of impatience highlights the relevance of relaxing the assumption of imperfect information.[13]

[13]The model comparisons presented in Table 4 prompt us to consider the comparability of the calibrations employed for each scenario. In Appendix C, we address this concern by investigating an array of exercises replicating our results using plausible deviations from our primary calibration. Overall, our findings indicate that although there are quantitative variations, our qualitative results remain consistent across each case.

5 Concluding Remarks

This paper studies the role of imperfect information about the economy's fundamentals in generating Sudden Stops in a model where agents are subject to a borrowing limit that depends on the tradable value of domestic income. Our findings emphasize that accounting for the interplay between information and financial frictions carries significant implications for the efficacy of macro-prudential policies in averting and mitigating the risks of financial crises. Policymakers aiming to enhance resilience against sudden stops should consider the presence of imperfect information. More crucially, policymakers should recognize how this interaction amplifies the necessity for higher macroprudential taxes on external borrowing and more frequent utilization of such capital controls.

A Calibration Details

As mentioned in the paper, we use the Kalman filter and its statistical properties to estimate the structural parameters governing the income processes included in our model.

In particular, since we assume the innovations, $\left\{\varepsilon_t^T,\, \varepsilon_t^N,\, \varepsilon_t^g\right\}$ are Gaussian, we can derive a likelihood function $\mathcal{L}(\Theta,\, s_t)$, where s_t is a two-column matrix that contains the observable signals Δ_t^T and Δ_t^N; and (θ) is a vector containing the structural parameters of the model (Hamilton, 1994). The log-likelihood function is given by

$$
\begin{aligned}
l(\Theta,\, s_t) = -\frac{Tn}{2}\ln\left(2\pi\right) - \frac{T}{2}\ln\left(\det\left(\mathbf{ZPZ}'\right)\right) + \\
\frac{1}{2}\sum_{t=1}^{T}\left((\mathbf{s^{\cdot}t} - \mathbf{Za}_{t|t-1})'(\mathbf{ZPZ}')^{-1}(\mathbf{s^{\cdot}t} - \mathbf{Za}_{t|t-1})\right)
\end{aligned}
\tag{36}
$$

which can be maximized with respect to Θ to find the maximum likelihood estimates of the parameters that form the state transition matrix $\mathbf{A}$ and the noise covariance matrix $\mathbf{Q}$. As shown by equations 12 and 13, the output of this process is a vector $\Theta^* = \left(\rho_{z^T,z^T},\, \rho_{z^T,z^N},\, \rho_{z^N z^T},\, \rho_{z^N,z^N},\, \rho_g,\, \sigma_{z^T z^T},\, \sigma_{z^N z^T},\, \sigma_{z^N,z^N}, \sigma_g\right)$ plus the corresponding forecasts for the unobservable components of income Z_t^T, Z_t^N and g_t.

Following Garcia-Cicco et al. (2010), estimating trend shocks in the data requires long samples. We use annual data from Argentina from 1903 to 2018 from Ferreres (2020). We compute *tradable output* (Y_t^T) as the sum of the GDP of the following categories: Farming, livestock, hunting, and forestry; Fisheries; Mine exploitation and quarries; and manufacturing. *Non-tradable* GDP is the sum of the sectoral output of construction, electricity, gas, and water; Transport, storage, and communications; financial intermediation; real estate activities; and other services. Non-tradable output equals total GDP minus tradable output.

Following equations (10) and (11), we define the observable signals Δ_t^T and Δ_t^N as $\ln\frac{Y_t^T}{Y_{t-1}^T}$ and $\ln\frac{Y_t^N}{Y_{t-1}^T}$, respectively. We detrend these series using a quadratic trend. We find the maximum likelihood estimates using the following computational algorithm:

1. Set an initial value Θ_0.

2. Set matrices **A** and **Q** to form the state-space described in (13).

3. Using the Kalman Filter, compute $\mathbf{a}_{t|t-1}$ and P following (15),(16), and (17) .

4. Compute the log-likelihood function value using 36.

5. Iterate over values for Θ until a local maximum, denoted as $\hat{\Theta}$, is found.[14]

6. Use $\hat{\Theta}$ as the initial value to start a global maximization search process. [15]

7. Iterate over values for Θ until you find a global maximum Θ^*.

8. Define the information matrix as the negative hessian of $l(\Theta^*, s_t)$ divided by the length of Δ_t^T and Δ_t^N.

9. Compute the standard errors of Θ^* as the squared root of the diagonal elements of the inverted information matrix.

The Matlab code required to implement this routine is available at https://bit.ly/458eSSm.

B Solution Method

In this appendix, we explain in detail the methods used to solve for the equilibria under perfect and imperfect information. Regarding perfect information, we follow the algorithm proposed by Bianchi (2011) to find the solutions for both the decentralized equilibrium and the Social Planner's problem. However, to account for the presence of growth shocks, we need to expand the solution method to include a different state space for shocks.

Under imperfect information, the state space changes as the agent only observes the signals and not the fundamental components of income. In this sense, the state space under imperfect information is larger as it includes not only the exogenous processes for Z_t^T, Z_t^N, and g_t but also the processes for the signals Δ_t^T, and Δ_t^N. Moreover, the

[14]For this step, we use Matlab's *fmincon* minimization routine. The bounds are set to prevent negative numbers from appearing in the diagonal elements of matrix **Q**.

[15]For this step, we use Matlab's *patternsearch* command.

discretization of the exogenous processes and the corresponding transition matrix should summarize the information friction. To do so, we use the following algorithm:

1. Simulate a time series of 1,000,000 periods for the unobservable states Z_t^T, Z_t^N, and g_t.

2. Compute the value of the signals Δ_t^T and Δ_t^N using the system of equations (12).

3. Apply the Kalman filter to Δ_t^T and Δ_t^N to compute forecasts for the underlying values of $\tilde{z}_t^T$, $\tilde{z}_t^N$, and $\tilde{z}_t$.

4. Using distance minimization, approximate each forecast and the realization of the observable signals to the values of five equally spaced grids of 19 points.

5. With the resulting discrete-valued time series, estimate the probability of transitioning from a given quintet $\{z_t^T, z_t^N, g_t, \Delta_t^T, \Delta_t^N\}$ to another.

With the calculated transition matrix and corresponding grids, we can proceed to solve for the equilibrium in each of the proposed models. Under perfect and imperfect information, we use standard value function iteration to solve the Social Planner's problem. For the competitive equilibrium, we use time iteration. The process includes an equally spaced grid for the endogenous state B_{t+1} with 501 points. The algorithm is as follows:

1. For a conjecture of B_{t+1}, and given the endowment, solve for the price of relative price p, and tradable consumption c_t^T.

2. Compute the marginal utility of consumption: this will give you a mapping $z^T \times z^N \times z \times g^T \times g^N \times B$ into $\mathbb{R}$.

3. Compute the Euler equation for each point of the mapping.

4. Get the optimal value of the Lagrange multiplier associated to the occasionally binding borrowing constraint $\mu^*(b_{t+1})$ as the $\underset{b_{t+1} \in B}{arg\,min} |\mu\,(b_{t+1})\,|$

5. Update your initial conjecture of the marginal utility of consumption.

6. Iterate until you reach a fixed point.

All the Matlab code is available at https://bit.ly/458eSSm.

C Sensitivity analysis

We conducted a series of exercises to evaluate alternative parameter values, exploring their impact on the outcomes. This comprehensive analysis allowed us to assess the sensitivity of the results and gain deeper insights into the model's behavior. We divided our sensitivity analysis into three sets. Table 6 summarizes the results for the whole set of calibrations we tested.

First, we tested the parameters affecting the stochastic processes for the underlying components of income. In particular, we considered alternative values for the persistence and volatility affecting the permanent and transitory components. We studied deviations above and below 15 percent from the estimated parameters for each case. We conclude that while quantitatively different, our qualitative results hold. In particular, the welfare costs of overborrowing under imperfect information are roughly twice, and the mean tax is roughly six times larger than the respective values in the perfectly informed economy. The level of overborrowing is roughly one percentage point, and the difference between the frequency of financial crises is similar.

Second, we solved the model for different values of β in order to show that the differences between these economies are not due to the impatience of the household. Although our baseline model requires a relatively impatient household to match the data on debt-to-GDP and the frequency of crises. Our results hold qualitatively for a model solved using a higher β.

Finally, we switch our benchmark to a perfectly informed decentralized economy calibrated to match the same moments as in our baseline model. The primary outcome of this exercise is that the informed planner in the recalibrated economy chooses a mean tax similar to the average macroprudential tax implemented by the uninformed planner. However, as you see in figure 9, the distributions of the optimal policy are entirely different, with the optimal policy for the recalibrated informed economy having a higher standard deviation.

These differences stem from one crucial caveat in the recalibration. Given our estimated stochastic processes, the degree of impatience required to match the average debt-to-GDP ratio and the frequency of financial crises observed in the data is very high. In particular, we need an annual discount factor (β) of 0.53, which is quite low for the standard values used in this literature. This result is somewhat implicit in our original benchmark as the β used to calibrate the imperfectly informed economy is already low.

The high level of impatience implied by our model contrasts with the calibrations used by Bianchi (2011), Flemming et al. (2019), and Seoane and Yurdagul (2019). However, it is worth noting that, as in those papers, except for β and κ, we chose all the model parameters as in Bianchi (2011). Therefore, the high degree of impatience implied by our model highlights the relevance of relaxing the assumption of perfect information.

Table 6: Sensitivity Analysis

	Welfare Costs		Tax on Debt		Debt-to-Output Ratio				Probability of Crises				Severity of Financial Crises: Consumption				Severity of Financial Crises: RER				Severity of Financial Crises: Current Account			
					Perf. Info		*Imp. Info*		*Perf. Info*		*Imp. Info*		*Perf. Info*		*Imp. Info*		*Perf. Info*		*Imp. Info*		*Perf. Info*		*Imp. Info*	
	Perf. Info	*Imp. Info*	*Perf. Info*	*Imp. Info*	*D.E*	*S.P*	*D.E*	*S.P*	*D.E*	*S.P*	*D.E*	*S.P*	*D.E*	*S.P*	*D.E*	*S.P*	*D.E*	*S.P*	*D.E*	*S.P*	*D.E*	*S.P*	*D.E*	*S.P*
Baseline ($\beta = 0.83,\ \kappa = 0.335$)	0.11	0.24	2.30	14.32	-27.15	-26.16	-29.02	-28.06	4.15	1.98	5.53	1.73	-25.06	-24.55	-24.71	-21.08	66.57	62.18	70.90	59.15	17.41	14.20	15.48	8.28
$\beta = 0.90,\ \kappa = 0.335$	0.06	0.11	1.02	7.47	-25.92	-24.85	-28.12	-27.17	2.42	1.02	2.95	0.78	-22.94	-22.65	-22.15	-18.86	65.17	62.92	68.75	61.52	15.14	12.52	12.59	7.26
Recalibrated F.I Economy ($\beta = 0.53,\ \kappa = 0.3525$)	0.15	0.24	13.24	14.32	-28.95	-28.60	-29.02	-28.06	5.50	4.16	5.53	1.73	-30.53	-29.14	-24.71	-21.08	86.25	76.89	70.90	59.15	25.89	21.88	15.48	8.28
Autocorrelation ρ_g *(15 % less)*	0.12	0.25	2.28	14.84	-27.17	-26.15	-29.05	-28.06	4.25	2.01	5.54	1.75	-24.98	-24.34	-24.70	-21.10	65.93	61.00	71.35	58.77	17.32	13.91	15.59	8.08
Autocorrelation ρ_g *(15 % more)*	0.11	0.22	2.32	13.66	-27.11	-26.15	-28.99	-28.04	4.03	1.95	5.40	1.76	-25.08	-24.69	-24.51	-21.18	67.44	63.67	70.94	59.29	17.55	14.54	15.52	8.46
Volatility σ_g *(15 % less)*	0.12	0.25	2.44	14.93	-27.49	-26.49	-29.15	-28.19	4.40	2.03	5.80	1.81	-24.12	-23.40	-23.85	-20.15	65.80	61.19	69.85	58.18	17.45	14.07	15.37	8.11
Volatility σ_g *(15 % more)*	0.10	0.23	2.05	13.69	-26.82	-25.85	-28.90	-27.93	3.93	1.92	5.23	1.68	-25.98	-25.66	-25.51	-21.98	67.42	63.53	72.42	-24.53	17.38	14.37	15.68	8.40

References

Acosta, M., L. Alfaro, and A. Fernández (2020, April). Sticky capital controls. Working Paper 26997, National Bureau of Economic Research.

Aguiar, M. and G. Gopinath (2007). Emerging market business cycles: The cycle is the trend. *Journal of Political Economy 115*, 69–102.

Akinci, O. and R. Chahrour (2018). Good news is bad news: Leverage cycles and sudden stops. *Journal of International Economics 114*, 362 – 375.

Benigno, G., H. Chen, C. Otrok, A. Rebucci, and E. R. Young (2013). Financial crises and macroprudential policies. *Journal of International Economics 89*(2), 453 – 470.

Benigno, G., H. Chen, C. Otrok, A. Rebucci, and E. R. Young (2016). Optimal capital controls and real exchange rate policies: A pecuniary externality perspective. *Journal of Monetary Economics 84*(C), 147–165.

Bianchi, J. (2011). Overborrowing and systemic externalities in the business cycle. *American Economic Review 101*(7), 3400–3426.

Bianchi, J., E. Boz, and E. G. Mendoza (2012). Macroprudential policy in a fisherian model of financial innovation. *IMF Economic Review 60*(2), 223–269.

Bianchi, J., C. Liu, and E. G. Mendoza (2016). Fundamentals news, global liquidity and macroprudential policy. *Journal of International Economics 99*(S1), 2–15.

Blanchard, O. J., J.-P. L'Huillier, and G. Lorenzoni (2013). News, noise, and fluctuations: An empirical exploration. *American Economic Review 103*(7), 3045–3070.

Boz, E., C. Daude, and C. B. Durdu (2011). Emerging market business cycles: Learning about the trend. *Journal of Monetary Economics 58*(6), 616–631.

Calvo, G. A. (1998). Capital flows and capital-market crises: The simple economics of sudden stops. *Journal of Applied Economics 1*, 35–54.

Ferreres, O. (2020). *Dos Siglos de Economía Argentina: 1810 - 2018*. Fundación Norte y Sur.

Fisher, I. (1933). The debt-deflation theory of great depressions. *Econometrica 1*(4), 337–357.

Flemming, J., J.-P. L'Huillier, and F. Piguillem (2019). Macro-prudential taxation in good times. *Journal of International Economics 121*, 103251.

Garcia-Cicco, J., R. Pancrazi, and M. Uribe (2010). Real Business Cycles in Emerging Countries? *American Economic Review 100*(5), 2510–2531.

Gertler, M., S. Gilchrist, and F. Natalucci (2007). External constraints on monetary policy and the financial accelerator. *Journal of Money, Credit and Banking 39*(2-3), 295–330.

Hamilton, J. D. (1994). *Time Series Analysis*. Princeton University Press.

Hernandez, J. M. and E. G. Mendoza (2017). Optimal v. simple financial policy rules in a production economy with "liability dollarization". *Ensayos sobre Política Económica 35*(82), 25–39.

Jappelli, T. (1990). Who is Credit Constrained in the U. S. Economy? *The Quarterly Journal of Economics 105*(1), 219–234.

Jeanne, O. and A. Korinek (2019). Managing credit booms and busts: A pigouvian taxation approach. *Journal of Monetary Economics 107*, 2–17.

Korinek, A. (2011). Excessive dollar borrowing in emerging markets: Balance sheet effects and macroeconomic externalities. University of Maryland.

Korinek, A. (2018). Regulating capital flows to emerging markets: An externality view. *Journal of International Economics 111*, 61 – 80.

Mendoza, E. G. (2002). Credit, prices, and crashes: Business cycles with a sudden stop. In *Preventing Currency Crises in Emerging Markets*, NBER Chapters, pp. 335–392. National Bureau of Economic Research, Inc.

Mendoza, E. G. (2010). Sudden stops, financial crises, and leverage. *American Economic Review 100*(5), 1941–1966.

Neumeyer, P. A. and F. Perri (2005). Business cycles in emerging economies: the role of interest rates. *Journal of Monetary Economics 52*(2), 345–380.

Ottonello, P. (2021). Optimal exchange-rate policy under collateral constraints and wage rigidity. *Journal of International Economics 131*, 103478.

Schmitt-Grohé, S. and M. Uribe (2017). Is optimal capital control policy countercyclical in open economy models with collateral constraints? *IMF Economic Review 65*(3), 498–527.

Schmitt-Grohé, S. and M. Uribe (2020, 05). Multiple Equilibria in Open Economies with Collateral Constraints. *The Review of Economic Studies 88*(2), 969–1001.

Schmitt-Grohé, S. and M. Uribe (2009). Finite-state approximation of var processes: A simulation approach.

Seoane, H. D. and E. Yurdagul (2019). Trend shocks and sudden stops. *Journal of International Economics 121*, 103252.

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