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 their role in financial crises in small open economies. We use a model where households observe income growth but cannot distinguish whether the underlying income shocks are permanent or transitory, and borrowing is subject to a collateral constraint. We show that the combination of imperfect information and a borrowing constraint is a significant source of economic instability. Optimal macroprudential policy helps stabilize the economy by actively taxing debt. Furthermore, the interaction between the collateral constraint and the information friction reshapes the correlation between the optimal tax and the underlying components of income.

Keywords: overborrowing; macroprudential policy; information frictions
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1 Introduction

Three empirical regularities distinguish business cycles in emerging economies: high relative consumption volatility, countercyclical current accounts, and the recurring presence of macro-financial crises (often called Sudden Stops). These crises entail sharp reversals of capital flows, 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 amplified by a decline in relative prices (Mendoza, 2010; Bianchi, 2011). Another 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 (Aguiar and Gopinath, 2007; Boz et al., 2011; Blanchard et al., 2013).

We contribute to the existing literature by examining the macroeconomic implications of imperfect information regarding an economy's fundamentals and its interplay with borrowing constraints. Specifically, we explore how imperfect information can trigger Sudden Stops in a small open economy model characterized by financial frictions. Additionally, we analyze how the interaction between financial and informational frictions influences the dynamics of the optimal macroprudential policy aimed at reducing the frequency and severity of financial crises.

Our main results highlight the importance of accounting for the interaction between information frictions and financial constraints in the design of macroprudential policies. First, we show that in standard open-economy models with collateral constraints, assuming perfect information results in smaller welfare gains from the optimal policy aimed at

[1] 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 a financial constraint, which in this paper takes the form of a collateral constraint, is binding. From this point onward, we will use the terms *Sudden Stop* and *financial crisis* interchangeably.

addressing the externality created when households pledge collateral goods or assets at market prices (Bianchi, 2011). Second, economies with perfect information require, on average, lower tax rates to mitigate the effects of this externality. Finally, we find that incorporating imperfect information can alter the cyclicality of the optimal macroprudential policy in response to non-tradable income shocks.

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 model economy, households receive stochastic income endowments from tradable and nontradable sectors. These endowments are subject to sector-specific transitory shocks and a common-trend shifter 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. Similar to Boz et al. (2011), in this Bayesian framework, households will formulate beliefs that assign a positive probability to the income shift being explained by changes in both transitory and permanent components.

We assume an incomplete credit market environment where households 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 in units of tradable goods. Since the value of collateral is a function of the relative price of non-tradable goods, a pecuniary externality emerges due to private households failing to internalize how their decisions, once properly aggregated, impact the relative price of nontradable goods and their borrowing capacity. This leads them to choose inefficient levels of consumption and debt. This effect, referred to in the literature as a Fisherian debt-deflation, has been studied as a potential cause of large reversals in credit during times of financial distress and as a motivation for the implementation of macroprudential policies aimed at restoring efficiency in credit markets.

Under imperfect information, both the decentralized economy and the Social Planner increase their debt-to-GDP ratios by two percentage points compared to perfect information, with private households overborrowing by a similar margin—approximately one percentage point more than the constrained Planner. Nonetheless, the interaction between the information friction and the pecuniary externality produces significant macroeconomic effects, raising the frequency of crises by 1.4 percentage points in the decentralized economy while reducing Sudden Stops for the Planner by 0.25 percentage points.

Crucially, the information friction more than doubles the welfare gains of implementing the optimal policy that addresses the externality, even though it produces a level of overborrowing similar to that in a perfectly informed economy. These results arise from how information frictions affect the Social Planner's valuation of wealth and future consumption relative to individual agents. Both recognize that uncertainty heightens the risk of a binding collateral constraint, leading to increased precautionary savings. However, the constrained Planner adjusts its marginal utility of wealth to account for collateral value shifts under uncertainty, adopting a cautious approach that becomes particularly significant as debt approaches the collateral limit, amplifying its effects during financial distress.

The interaction between information and financial frictions has important implications for the design and effectiveness of macroprudential policy. First, the optimal average tax on foreign borrowing is 11.4 percent, 1.7 percentage points above the level under perfect information. Second, implementing this policy reduces the frequency of financial crises from 5.5% to 1.7% and mitigates the average consumption decline during Sudden Stops from 25% to 21% of pre-crisis levels. Finally, the optimal tax is active over 90% of the time and changes very frequently. We also find that a fixed tax on debt delivers welfare gains that are lower compared to the optimal policy, yet still substantial, while reducing both the frequency and severity of financial crises.

Regarding the cyclicality of the optimal tax, we find that the long-term correlation between *total income* and the optimal tax is negative, indicating that the Planner raises taxes on foreign debt when *total income* is low. This result is consistent with related literature examining shocks to the tradable endowment under perfect information, such as Schmitt-Grohé and Uribe (2017).[2] When the correlation is measured conditional on financial crises, the cyclicality of the tax reflects the strong non-linearity induced by the collateral constraint.

More specifically, during financial crises, when *total income* is very low and the borrowing constraint binds, the tax rate is set to zero.[3] Similar to Bianchi et al. (2016), the policy function shows that as income recovers, the optimal tax takes on positive values, causing income and taxes to move in tandem in the immediate aftermath of the crisis, resulting in a positive conditional correlation relative to total income. Although these episodes have significant consequences for the economy, the unconditional, long-term correlation remains negative, as it largely reflects periods outside financial fragility. Both the negative long-term and the positive conditional correlation during Sudden Stops hold under perfect and imperfect information.

Examining the cyclical behavior of the optimal tax relative to specific components of income, rather than total income, reveals significant contrasts. We find that imperfect information plays a crucial role in shaping the optimal tax response depending on the nature of the income shock. When a transitory shock affects the non-tradable component of income, introducing imperfect information shifts the optimal tax from being procyclical to being countercyclical—that is, the uninformed Planner reduces taxes as non-tradable income decreases. Conversely, if a transitory shock affects the tradable component, the tax remains procyclical under both information sets, with the planner raising taxes as tradable income declines.

For a permanent shock to income, the correlation under perfect information is negative but close to zero, highlighting a relatively muted response of the tax to these types of shocks. In contrast, under imperfect information, the correlation remains negative but increases in absolute value, signaling a more proactive policy. The changes in the

[2] We define the cyclicality of the optimal tax as in Schmitt-Grohé and Uribe (2017). For example, a *countercyclical tax* is a capital control policy that increases during booms and decreases during recessions, exhibiting a positive correlation with income.

[3] Section 4.3.1 provides further the details on how the optimal policy is determined.

correlations with respect to each of the underlying components of income hold both unconditionally and within boom-bust cycles, which are defined as episodes where a specific component of income initially rises by one standard deviation and subsequently falls by one standard deviation.

1.1 Related Literature.

This paper contributes to various dimensions of the literature that explore 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, and the relative importance of trend (or growth) shocks (Aguiar and Gopinath, 2007), and financial frictions (Neumeyer and Perri, 2005; Garcia-Cicco et al., 2010), oftentimes generating Sudden Stops via the presence of collateral constraints (Mendoza, 2002, 2010). Previous work (Boz et al., 2011; Blanchard et al., 2013), has studied the effect of imperfect information in economies with trend shocks. 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 relates to a growing body of literature that explores the macroeconomic implications of financial frictions and macroprudential policy in emerging economies. Using a quantitative framework, Bianchi (2011) showed that partially leveraging external debt against domestic income creates a pecuniary externality in the credit market, thereby quantifying the welfare gains of implementing macroprudential policy. Building on this line of research, several studies have analyzed optimal capital control policies in economies affected by common transitory shocks (e.g., tradable income, productivity, or interest rate shocks) under the assumption of perfect information.[4]

As emphasized by Schmitt-Grohé and Uribe (2017), the standard framework under transitory shocks and perfect information suggests that optimal macroprudential taxes should be reduced during booms and increased during busts. Our work extends this

[4]See, among others, Arce et al. (2023); Akinci and Chahrour (2018); Benigno et al. (2016); Jeanne and Korinek (2019); Korinek (2011, 2018); Ottonello (2021); Schmitt-Grohé and Uribe (2017, 2020).

literature by examining the desirability and implementation of macroprudential policy in a setting with both financial and information frictions, focusing on whether the interaction between a collateral constraint and imperfect information alters the cyclicality of the optimal policy relative to both total income and each underlying component of income.

In this context, our work relates to the strand of literature that emphasizes the significance of financial factors and the statistical properties of income in formulating optimal macroprudential policy. This line of research includes contributions from Bianchi et al. (2012), who develop a model that explores the interaction between financial innovation, credit frictions, and imperfect information, particularly through the lens of Bayesian learning, which shapes agents' beliefs and subsequent policy responses. Like our study, their work departs from the assumption of perfect information regarding credit fluctuations, but specifically focuses on the role of optimism and pessimism around financial innovation.

Bianchi et al. (2016) further explore how regime shifts in global interest rates and news shocks impact capital controls, finding that greater precision in news shocks weakens the effectiveness of macruprudential policy. Their analysis highlights the complexity of the optimal policy required across capital-market regimes and news shocks, a finding that resonates with the highly nonlinear policy rules observed in our framework. Bennett et al. (2023) introduce the concept of "fear of model misspecification" into the canonical framework of Bianchi (2011), showing that macroprudential policies can remain welfare-enhancing even when regulators operate based on incorrect assumptions.

Within this line of research, our paper is strongly connected to the works of Flemming et al. (2019) and Seoane and Yurdagul (2019). These studies extend the canonical model to incorporate permanent income (trend) shocks while maintaining the perfect information assumption. Except for minor differences, our benchmark model in the perfect information limit converges to that used in these studies, where the economy is subject to both permanent and transitory shocks, fully observable by agents. Our main contribution to this literature is studying how the interaction between collateral constraints and imperfect information affects borrowing decisions and reshapes the optimal policy needed to restore market efficiency. In particular, we highlight how this interaction prescribes a countercyclical optimal tax in response to transitory shocks to nontradable income.

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 optimal conditions for the decentralized economy and the constrained Planner. Section 4 presents our quantitative results, and Section 5 concludes.

2 Theoretical Framework

For our modeling framework, we adopt the standard model of a small open economy with occasionally binding collateral constraints proposed by Bianchi (2011) and widely 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, then we relax the full information assumption. 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 each block of the model in detail.

2.1 Households

Household 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 an aggregate bundle of the consumption of tradable (C_t^T)

and non-tradable (C_t^N) goods given by a CES aggregator with ϵ as the elasticity of substitution between tradable and non-tradable 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 non-tradable 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 non-tradable 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. p_t is the relative price of non-tradable goods in terms of tradable goods, and the price for tradable goods is the numeraire.

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 (defined as a negative nominal value of bonds) a household can hold. In particular, borrowing must 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; Lian and Ma, 2021). Second, international creditors require short-term external debt (denominated in units of tradable goods) to be partially leveraged by the endowment of the non-tradable 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 non-tradable 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 non-tradable 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 given, they do not internalize how their choices affect the relative price of non-tradable 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 feedback between prices and the collateral value.

2.2 Endowment Properties

Each period, households receive two endowments from the tradable and non-tradable sectors. Each endowment is composed of a sector-specific transitory component and a common permanent (or trend) component.[5] We assume that households cannot directly observe the underlying drivers of income, only its realized value. In particular, each endowment is given by:

$$Y_t^s = \Gamma_t \exp(z_t^s), \quad \forall\, s \in \{T,\, N\}, \tag{4}$$

where z_t^s denotes the transitory component of the endowment coming from sector s. The trend component is given by Γ_t, defined as the cumulative product of current and previous

[5]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.

realizations of economic growth shocks. Formally

$$\Gamma_t = \Gamma_{t-1} \exp(g_t) = \prod_{j=0}^{t} \exp(g_j), \tag{5}$$

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

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

The long-run mean growth rate of the permanent component of income is denoted by μ_g, and the autocorrelation of g satisfies the constraint $|\rho_g|< 1$. 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 assume 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 assumptions. First, at any given time t, households in our economy know the complete history of endowment realizations and the 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 define the information set that is available to the household at any given time t. Let $\mathbb{I}_t$ denote this set, and be defined as:

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

where $\left\{ Y^i_{t-s} \right\}_{s=0}^{\infty}$ is the full stream of current, and past realizations of income, $f(\varepsilon_t^T,\, \varepsilon_t^N)$ and $f(\varepsilon_t^g)$ 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 non-tradable component relative to tradable income (g_t^N) be given by:

$$\Delta_t^T = \ln\left(\frac{Y_t^T}{Y_{t-1}^T}\right) = \ln\left(\frac{\Gamma_{t-1}\exp(g_t)\exp(z_t^T)}{\Gamma_{t-1}\exp(z_{t-1}^T)}\right) = z_t^T - z_{t-1}^T + g_t, \tag{10}$$

$$\Delta_t^N = \ln\left(\frac{Y_t^N}{Y_{t-1}^T}\right) = \ln\left(\frac{\Gamma_{t-1}\exp(g_t)\exp(z_t^N)}{\Gamma_{t-1}\exp(z_{t-1}^T)}\right) = z_t^N - z_{t-1}^T + g_t. \tag{11}$$

By observing the growth rates Δ_t^T and Δ_t^N the households also perceive a linear combination of the unobservable exogenous states $\left\{z_t^T,\, z_t^N,\, g_t\right\}$. 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 equations 10 and 11 as a system of equations:

$$s_t = \begin{bmatrix} \Delta_t^T \\ \Delta_t^N \end{bmatrix} = \mathbf{Z}\alpha_t = \begin{bmatrix} 1 & 0 & 1 & -1 \\ 0 & 1 & 1 & -1 \end{bmatrix} \begin{bmatrix} z_t^T \\ z_t^N \\ g_t \\ z_{t-1}^T \end{bmatrix}, \tag{12}$$

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:

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

The equation, in compact form, is:

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

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 $k_1 = \mathbf{I} - \mathbf{PZ}(\mathbf{ZPZ})^{-1}\mathbf{Z}$ and $k_2 = \mathbf{PZ}'(\mathbf{ZPZ}')^{-1}$ are the Kalman gains. $\mathbf{P}$ 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 $\mathbf{y} = \left\{Y^T, Y^N\right\}$. Then, a competitive equilibrium is a set of allocations $\left\{C^T, C^N, B'\right\}$, 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 the maximization problem described by equation 18. We denote Λ_t and μ_t, the Lagrange multipliers correspond to the budget and borrowing constraints. Since tradable and non-tradable 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_{t-1}. Let $\lambda_t = \Lambda_t \left(Y^T_{t-1}\right)^{\sigma}$, and $\hat{x}_t = X_t/Y^T_{t-1}$ for each variable X_t. The normalized optimality conditions are:

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

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

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

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

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

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

Equation 23 represents the Euler equation for bond holdings. 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 non-tradable endowment is fully spent on non-tradable goods $Y_t^N = C_t^N$. Therefore, the equilibrium price of non-tradable 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 this general equilibrium effect into their intertemporal choices.

3.2 The Social Planner's Problem

In contrast to private households, a Social Planner internalizes 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 equation 28. The problem above makes explicit that the Planner chooses borrowing directly and that the consumption for the non-tradable good satisfies market clearing in this market ($C^N = Y^N$).

As before, we need to transform the model to make it stationary. The transformed first-order conditions for the Planner's problem are:

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

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

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

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

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

Note that the first order condition 29 changes relative to that from the decentralized equilibrium described by equation 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 $\left(\Phi_t = \frac{\partial \tilde{BC}_t}{\partial C_t^T} = \kappa\frac{1-\omega}{\omega}\frac{1}{\epsilon}\left(\frac{\hat{c}_t^T}{\exp(\Delta_t^N)}\right)^{\frac{1}{\epsilon}-1}\right)$, where BC stands for borrowing constraint.

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 parameterization of these models, the combined effect means the constrained Planner will increase his precautionary savings and reduce external borrowing.[6]

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.

[6]See Schmitt-Grohé and Uribe (2020) for a thorough discussion on how different parameterizations can yield overborrowing/underborrowing relative to the Planner. See Arce et al. (2023) for a discussion on why macroprudential policy is still desirable regardless of whether the decentralized equilibrium faces more or less borrowing than the constrained Planner.

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. A detailed description of the calibration and the solution method is available in online appendix A.1 and A.2.

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.

We use annual data from Argentina, spanning from 1903 to 2018, as provided by Ferreres (2020). *Tradable output* (Y_t^T) is calculated as the sum of the GDP, measured at constant prices, from agriculture, forestry, fishing, mining, and manufacturing. *Non-tradable output* (Y_t^N) is computed as the sum of the GDP from all other sectors not included in the tradable component.[7]

Following equations 10 and 11, we define the observable signals Δ_t^T and Δ_t^N as $\ln\left(Y_t^T/Y_{t-1}^T\right)$ and $\ln\left(Y_t^N/Y_{t-1}^T\right)$, 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

[7]Tradable sector GDP includes the following categories: Farming, livestock, hunting, and forestry; fisheries; mining and quarrying; and manufacturing. Non-tradable sector GDP comprises the sectoral GDP of construction; electricity, gas, and water; transport, storage, and communications; financial intermediation; real estate activities; and other services (including public administration and defense).

Table 1: Estimated Parameters for Stochastic Income Processes.

Parameter	Estimate	Std. Deviation	Description
ρ_{z^T,z^T}	0.7347	0.0327	Autocorrelation of Z^T
ρ_{z^T,z^N}	-0.2553	0.0284	Cross-correlation between Z^T and Z^N
ρ_{z^N,z^T}	0.0337	0.0792	Cross-correlation between Z^N and Z^T
ρ_{z^N,z^N}	0.4170	0.0331	Autocorrelation of Z^N
ρ_g	0.4968	0.1910	Autocorrelation of growth shocks
$\sigma_{z^T z^T}$	0.0680	0.1091	Standard deviation of Z^T shocks
$\sigma_{z^N z^T}$	0.0004	0.0781	Covariance Z^T and Z^N shocks
$\sigma_{z^N z^N}$	0.0370	0.0424	Standard deviation of Z^N shocks
σ_g	0.0572	0.0546	Standard deviation of growth shocks

Note: The table reports the estimated values for the parameters that dictate the behavior of the exogenous processes in the model. The third column lists the standard errors of the estimated parameters, while the fourth column provides a brief description of each parameter.

non-tradable sector is approximately twice as volatile as that from the tradable sector.

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.[8]

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

[8]Online appendix A.3 demonstrates that our main conclusions hold for plausible deviations from the estimated parameters modeling the stochastic income processes, particularly when varying their persistence and volatility.

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 non-tradable 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 A.3 discusses the results when assuming different calibrations of β and κ.

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

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. After a shifter to the unobservable permanent component of income, the economy will respond as if there was a shifter to both the permanent and transitory components of income. The converse is also true, after a shock to a transitory component of income, the economy will respond as if the economy received changes in both components.

Similar to Boz et al. (2011), the uninformed economy will experience a business cycle with more persistence and amplification than an informed economy. To understand this result, refer back to equations 10 and 11. In our model, agents are aware that each period's tradable and non-tradable 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 current realizations of observable variables and on whether these realizations are consistent with beliefs about past unobservables.

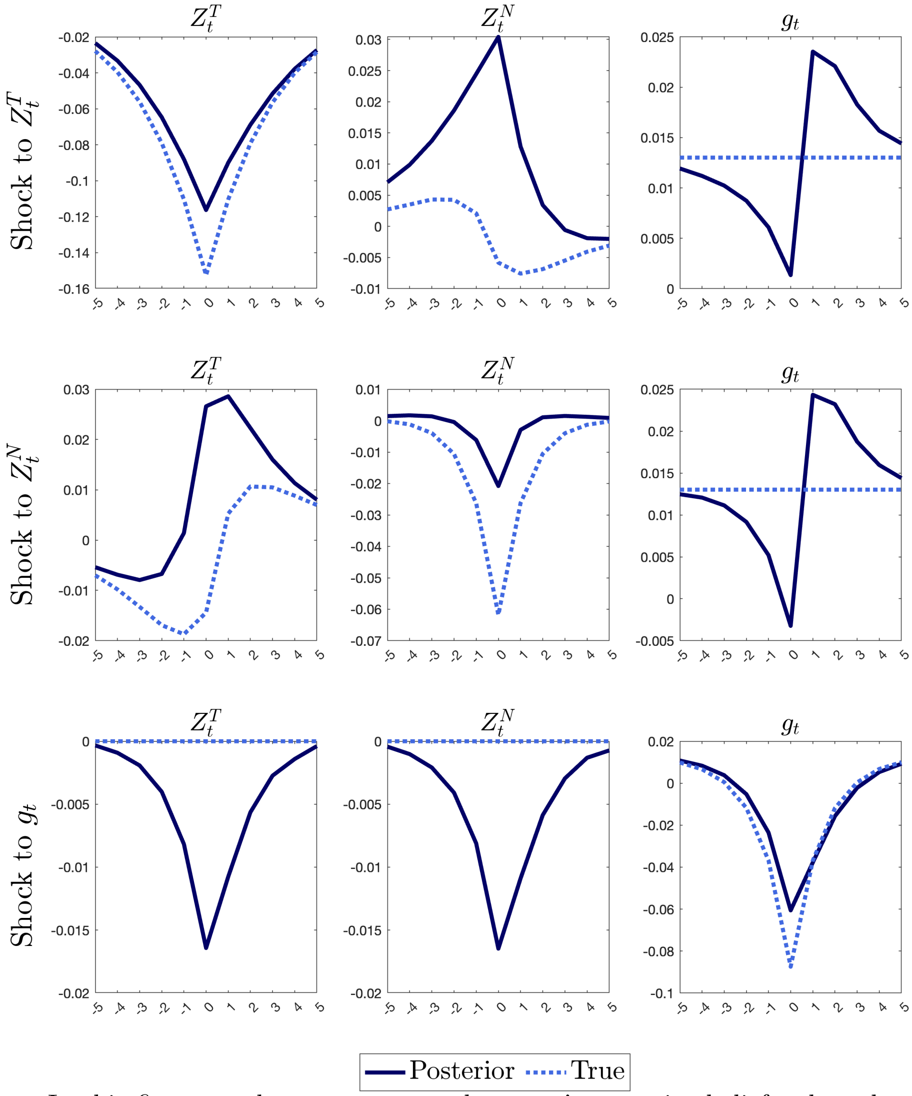
When a negative shock to the permanent component of income occurs, the agent observes negative growth rates Δ_t^T and Δ_t^N. According to the measurement equation (10), a negative Δ_t^T could arise from three possible scenarios: (1) a negative transitory shock $\left(Z_t^T \downarrow\right)$, (2) a positive transitory shock in $t-1$ that went unnoticed $\left(Z_{t-1}^T \uparrow\right)$, or (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 $\tilde{g}t$ that assign positive probabilities to each of the three possible scenarios. In other words, the agent's beliefs will satisfy $\tilde{z}_t^T - \tilde{z}_{t-1}^T < 0$. Suppose the economy begins in equilibrium (i.e., $z_t^s = z_{t-1}^s = 0, , \forall, s \in \{T, , N\}$). In this case, the observed growth rate today is determined solely by movements in the permanent component g_t. According to equation (10), $g_t = \Delta_t^T < \Delta_t^T - (\tilde{z}_t^T - \tilde{z}_{t-1}^T) = \tilde{g}_t < 0$. This means agents perceive the shock to the permanent component as being less negative than it actually is. Furthermore, consistent with scenarios 1 and 2, agents believe that z_t^T, z_{t-1}^T, and z_t^N are changing.[9] As a result of these beliefs, the response of the uninformed economy to permanent shocks is more muted than that of an informed economy.

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 are. Interestingly, starting in $t+1$, any shock to z_t^T or z_t^N will fade out

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

Figure 1: Response of Beliefs Under Different Observable Scenarios

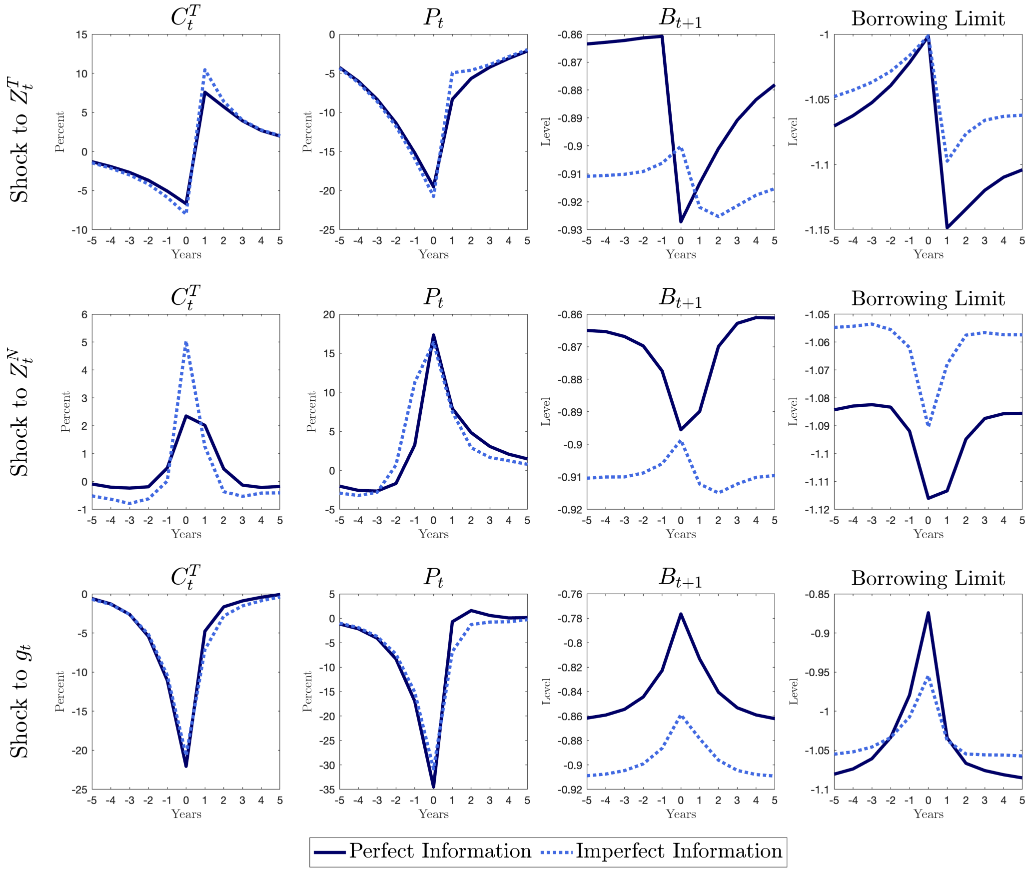


Note: In this figure, each row compares the agent's posterior beliefs when the unobserved exogenous states are subject to a negative one-standard deviation. The variable being shocked is indicated in the left axis of each row. The horizontal axis spans five years before and after the shock occurrence.

as $z^j_{t+1} = \rho_{z^T,z^T} z^j_t$ where $j \in \{T, N\}$. The initial period of negative income growth is followed by several periods of positive but decreasing growth as $\Delta^j_{t+1} = (\rho_{z^j} - 1)z^j_t > 0$. 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

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



Note: In this figure, each row compares the dynamics of the main aggregate variables under perfect and imperfect information when the economy is hit by a one-standard-deviation negative shock to the *selected* unobserved exogenous state (indicated in the left-axis of each row). The horizontal axis covers five years before and after the shock occurrence. Responses to a positive shock are shown in appendix A.4.

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

Figure 2 illustrates the responses of key variables—consumption, relative prices, bond holdings, and the borrowing limit—to negative shocks in income components (Z_t^T, Z_t^N, and g_t). For a negative transitory shock to tradable income (Z_t^T), both perfect and imperfect information models exhibit declines in tradable consumption and prices, tightening the borrowing limit. However, while perfectly informed households increase borrowing to smooth consumption, uninformed households reduce borrowing, perceiving the shock as

Table 3: 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
C_t drop during financial crises (%)	-25.06	-24.55	-24.71	-21.08	-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	-0.41	-0.01	-0.73	-0.67
$\sigma(CA_t/Y_t)$ (%)	4.64	3.07	4.24	1.46	7.67	5.77
Welfare gain (%)	-	0.11	-	0.24	-	0.15
Avg. tax on foreign debt (%)	-	9.75	-	11.40	-	37.27

Note: In the baseline model, the parameters β and κ were adjusted to calibrate the decentralized economy with imperfect information to match an average Debt-to-GDP ratio of 29% and a frequency of crises equal to 5.5%. The recalibrated model's parameters were set so that the perfectly informed decentralized equilibrium matches the aforementioned targets. The welfare gains presented in the table were calculated relative to a descentralized solution with no tax policy sharing the same information set.

partially permanent.

In response to a negative transitory shock to non-tradable income (Z_t^N), the perfect information economy displays an increase in relative prices and borrowing due to a relaxed collateral constraint, while the imperfectly informed economy responds more cautiously with muted changes in tradable consumption and prices. In contrast, negative permanent income shocks (g_t) cause reductions in borrowing across both information models, though the decline is less pronounced under imperfect information as agents partially attribute the shock to transitory factors.

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 benefits of optimal policy, and the characteristics of the optimal macroprudential policy that restores constrained efficiency. Table 3 summarizes the key insights of this section.

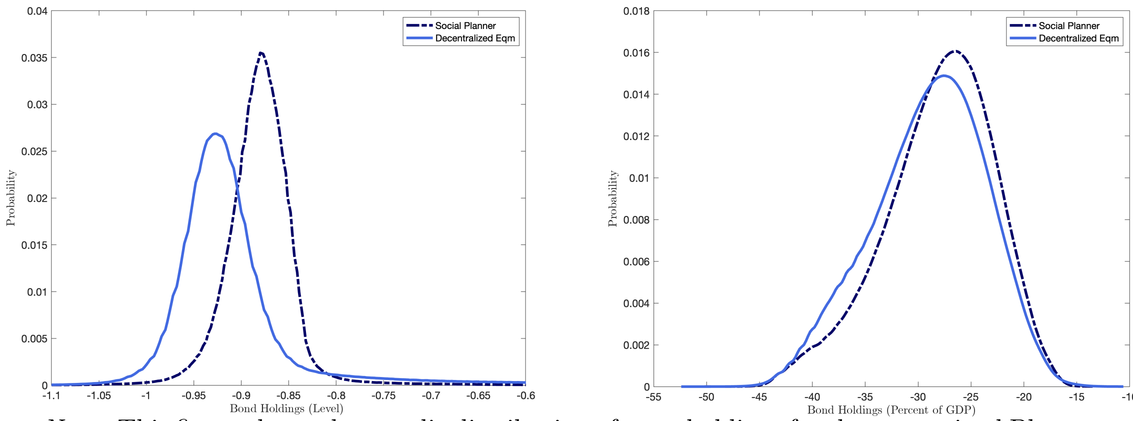
Figure 3 shows the ergodic distribution of external borrowing under perfect and imperfect information. The first thing to note is that, as expected, the information friction does not change the qualitative observation that the pecuniary externality induces overborrowing. Both in absolute terms and as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

Considering imperfect information increases the debt-to-GDP ratio by approximately two percentage points for both the Social Planner and the decentralized economy. However, as shown in Table 3, the total amount of overborrowing remains roughly the same between informed and uninformed economies under our benchmark calibration.

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 experiencing a binding constraint is rare; unconditional averages might obscure the full effect of these uncommon yet painful episodes. Table 3 shows that for the decentralized economy, financial crises become more frequent while debt does not increase dramatically under imperfect information. In contrast, the uninformed-constrained Planner experiences less financial crises than its perfectly informed counterpart.

Figure 3: Ergodic Distribution of Assets Under Imperfect Information

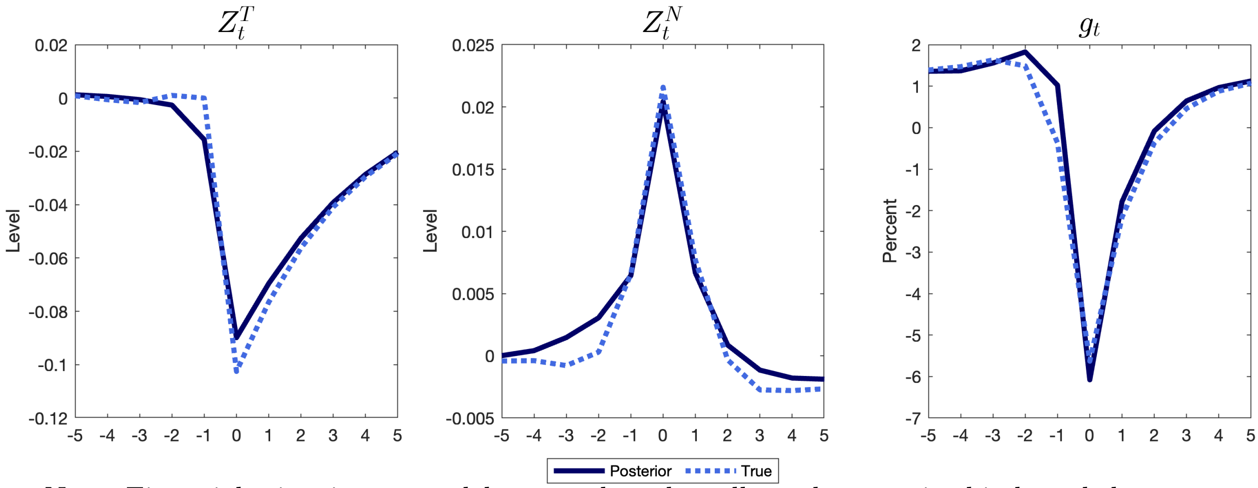
(a) Bond Holdings (b) Debt-to-GDP Ratio



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.

Furthermore, in the decentralized economy, the interaction between the information friction and the financial constraint amplifies consumption volatility while reducing current account variability. In contrast, the Planner experiences identical consumption

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



Note: Financial crises in our model occur when the collateral constraint binds and the economy experiences a sudden reversal in capital flows. In this figure, each plot illustrates the discrepancy between the agent's beliefs about the unobservable components of income and their true realizations. The horizontal axis covers five years before and after the crisis.

volatility under both information sets but reduces the current account volatility from 3.1 percent of GDP to 1.46 percent. These results give quantitative support for the intuition that the Social Planner internalizes how the increased uncertainty from imperfect information affects how the value of collateral changes with consumption.

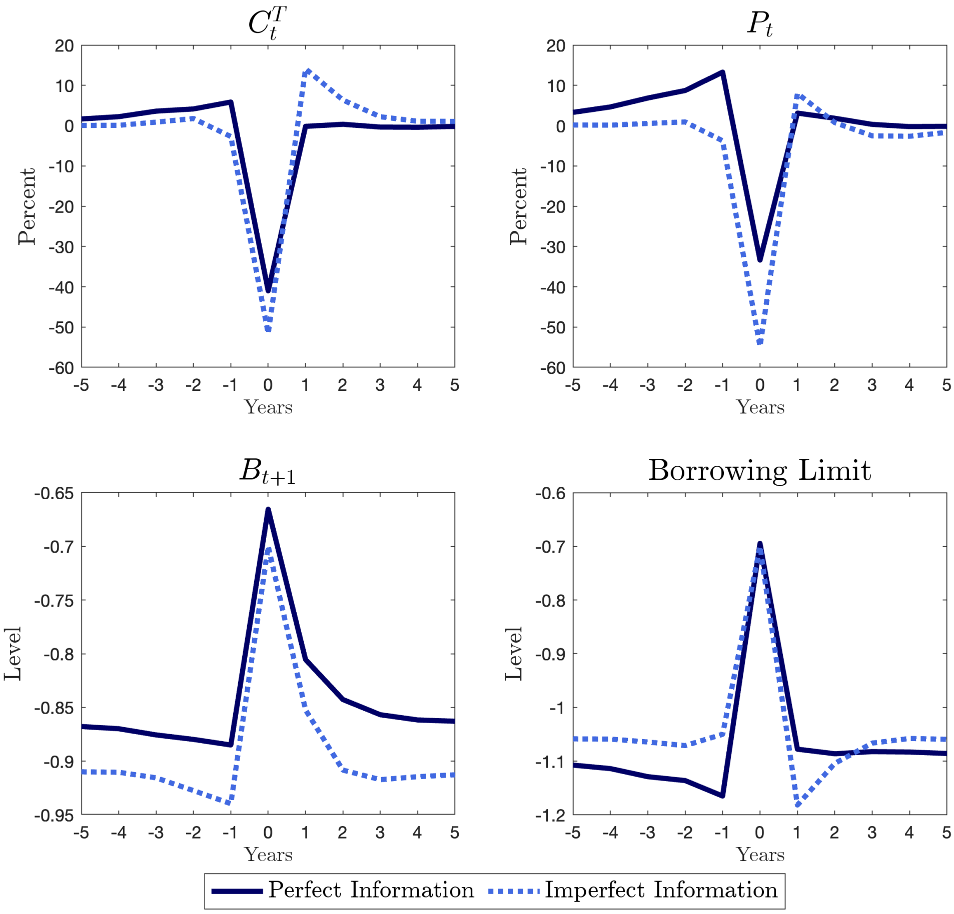
Figure 4 highlights the driving forces behind Sudden Stops in the uninformed economy. In the years leading up to the crisis, the economy is hit by a series of negative permanent income shocks, which agents misinterpret as transitory and as being partially offset by positive shocks to the nontradable endowment (Z_t^N). As shown in Figure 5, households respond by increasing their borrowing to stabilize consumption. This behavior weakens their balance sheets, leaving the economy vulnerable just before the crisis, which is triggered by simultaneous shocks to Z_t^T and g_t at $t = 0$.

4.3 Welfare Gains and Optimal Macroprudential Policy

To compute the welfare gains of the constrained planner allocation under perfect and imperfect information, we write the Planner's value function as:

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

Figure 5: Endogenous Response to Financial Crises



Note: In this figure, each plot compares the dynamics of the main aggregate variables under perfect and imperfect information during a financial crisis. The horizontal axis covers five years before and after the crisis.

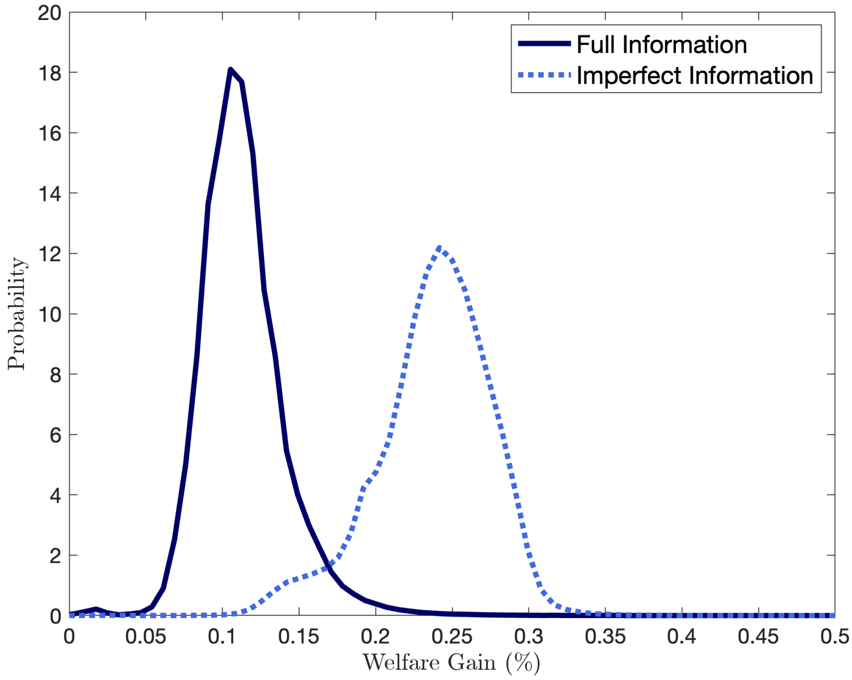
where c_{t+s}^{CE} is the consumption level in the competitive equilibrium, x_t is a vector containing the exogenous states, and $\Lambda(x_t, b_t)$ represents how much equivalent consumption the household in a competitive economy would gain in the constrained planner allocation. Solving Λ from equation 34, the welfare gain is given by:

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

For the economy under imperfect information, the average welfare gains are 0.24 percent of lifetime consumption, roughly twice the equivalent magnitude under full information. Figure 6 depicts the ergodic distribution of welfare gains under both perfect and imperfect information.

Next, we quantify the welfare gains associated with transitioning to full information. When a private household moves from imperfect to perfect information, it experiences

Figure 6: Welfare Gains of the Planner's allocation Under Different Information Sets



Note: This figure illustrates the ergodic distribution of welfare gains of the planner's allocation under perfect and imperfect information. The distribution is computed by simulating the model for one million periods. The standard deviation for the welfare gains under perfect information is 0.027 percent and 0.037 percent under imperfect information.

a gain of 1.06 percent in lifetime consumption. Similarly, when a Planner transitions from an economy with imperfect information to one with perfect information, the gain is 0.94 percent of lifetime consumption. These findings highlight that the welfare improvements from eliminating the information friction exceed those achieved by eliminating the pecuniary externality created by the presence of the collateral constraint.

4.3.1 Optimal Macroprudential Policy

The existence of the pecuniary externality justifies the introduction of policies to restore 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.

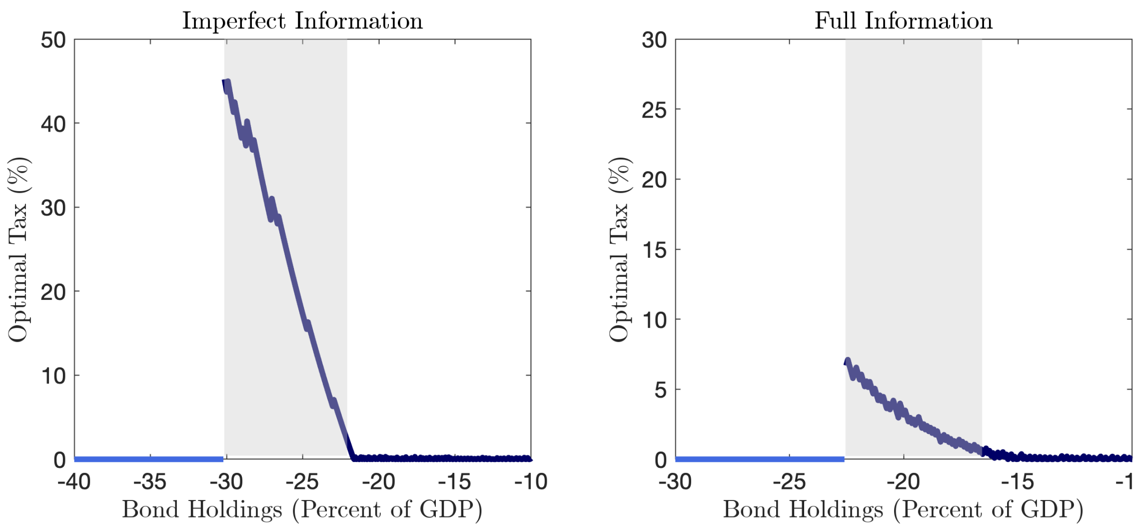
As explained in section 3.2, private agents have a different valuation of wealth than the Social Planner due to the pecuniary externality. The optimal policy is defined as the tax on foreign debt a Planner would impose on the decentralized equilibrium to equalize their marginal utilities of wealth (Bianchi, 2011). If the constraint is not binding, 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. In particular, 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

When the constraint binds ($\mu_t > 0$), the level of debt is determined by the credit constraint, with both the Planner and private agents aiming to borrow up to the maximum feasible level. In this context, a range of tax rates could implement the constrained-efficient allocation; however, following Bianchi (2011), we set $\tau_t = 0$, as this specific tax rate achieves the Social Planner's optimal allocations for borrowing and consumption. Note that if the probability of the collateral constraint binding in the next period is zero, the tax is likewise set to zero.

Figure 7: Optimal Tax Functions



Note: Debt increases to the left. The policy functions correspond to the case where a one-standard-deviation shock hits the permanent income growth component.

Figure 7 illustrates the optimal tax policy functions for the informed and uninformed equilibria when a one-standard-deviation negative shock hits the permanent income component. In both cases, the optimal function displays three identifiable areas. The first is a section where the constraint is binding; therefore, as explained above, the optimal tax is equal to zero. Second, a region in which the likelihood of observing a binding constraint is high, and the optimal tax increases rapidly with bond holdings. Third, a region where the decentralized allocations are close to the Planner's solution and the likelihood of facing a financial crisis is low. Figure 7 also shows that similar debt allocations entail higher taxes in the uninformed economy for this specific realization of the exogenous driving forces. We can generalize this result using simulated data.

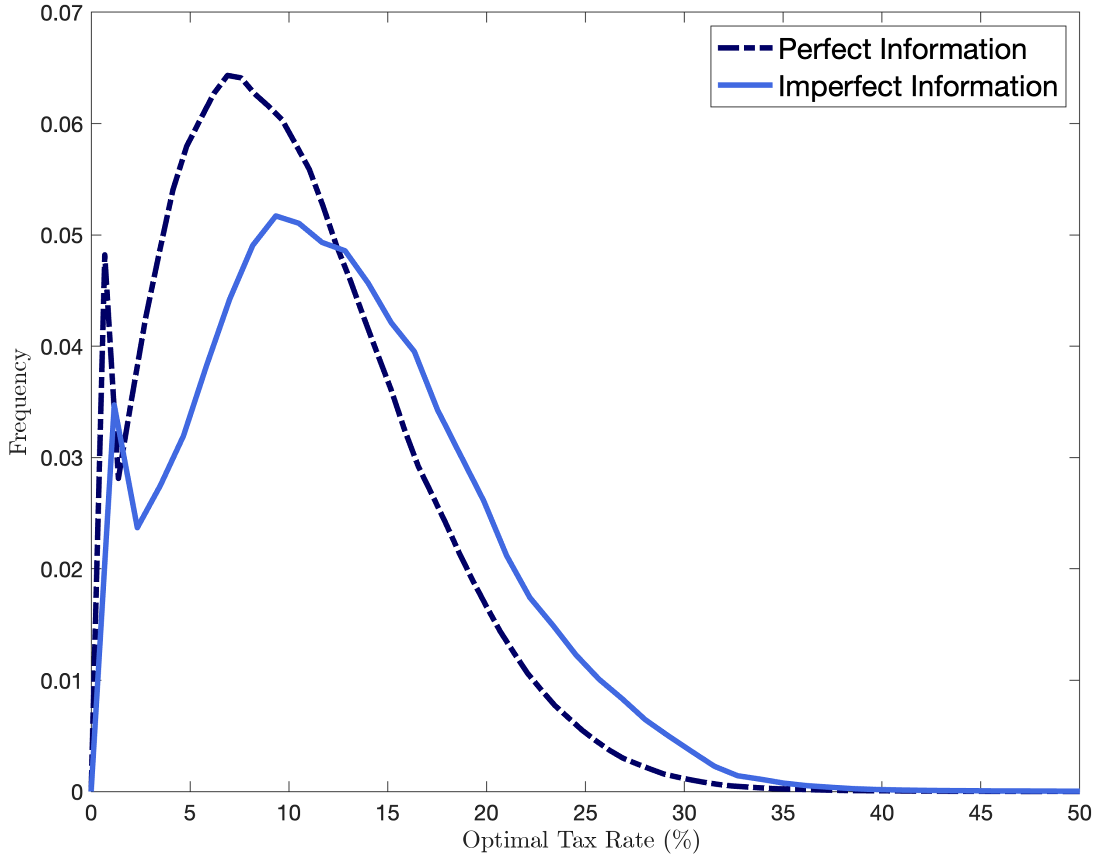
Figure 8 shows the ergodic distribution of the optimal tax for both equilibria. Due to the increased welfare gains associated with the optimal policy with information frictions, the Social Planner implements an average tax on foreign borrowing equal to 11.4 percent, about 1.7 percentage points higher than the average optimal tax under perfect information. The standard deviation of the tax distribution under imperfect information is 7.7 percent, about 1.4 percentage points higher than in a perfectly informed economy.

As before, conditional moments reveal the more noticeable differences between the tax policies of informed and uninformed economies. Figure 9 illustrates the dynamics of the optimal tax in the years preceding a Sudden Stop.[10] Specifically, it depicts a relatively constant gap between the tax rates during tranquil times. However, a wider gap emerges in the year preceding the crisis. Negative shocks to both permanent and transitory components prompt households to increase their debt for consumption smoothing (refer to Figure 4). Uninformed agents inaccurately predict the shocks to be more transitory than they are, leading to a greater surge in debt holdings (as shown in Figure 5). Consequently, the uninformed Planner increases its tax rate by 4.1 percentage points (from 12.6 percent to 16.7 percent), while the informed Planner does so by 1.3 percentage points (from 11.6 to 12.9 percent).

The Planner's optimal tax policy under information and financial frictions has important implications for the role of macroprudential policies in preventing and mitigating the risk of financial crises. Implementing the optimal capital control policy decreases the frequency of financial crises -from 5.5 crises to 1.7 every 100 years- and mitigates their

[10] Online appendix A.5 shows the dynamics of the optimal tax in the years preceding and following a Sudden Stop.

Figure 8: Optimal Tax: Ergodic Distribution



Note: This figure shows the ergodic distribution of the optimal tax under both imperfect and perfect information. The average tax under perfect information is 9.75% with a standard deviation equal to 6.3%. The average tax under imperfect information is 11.40% with a standard deviation of 7.7%.

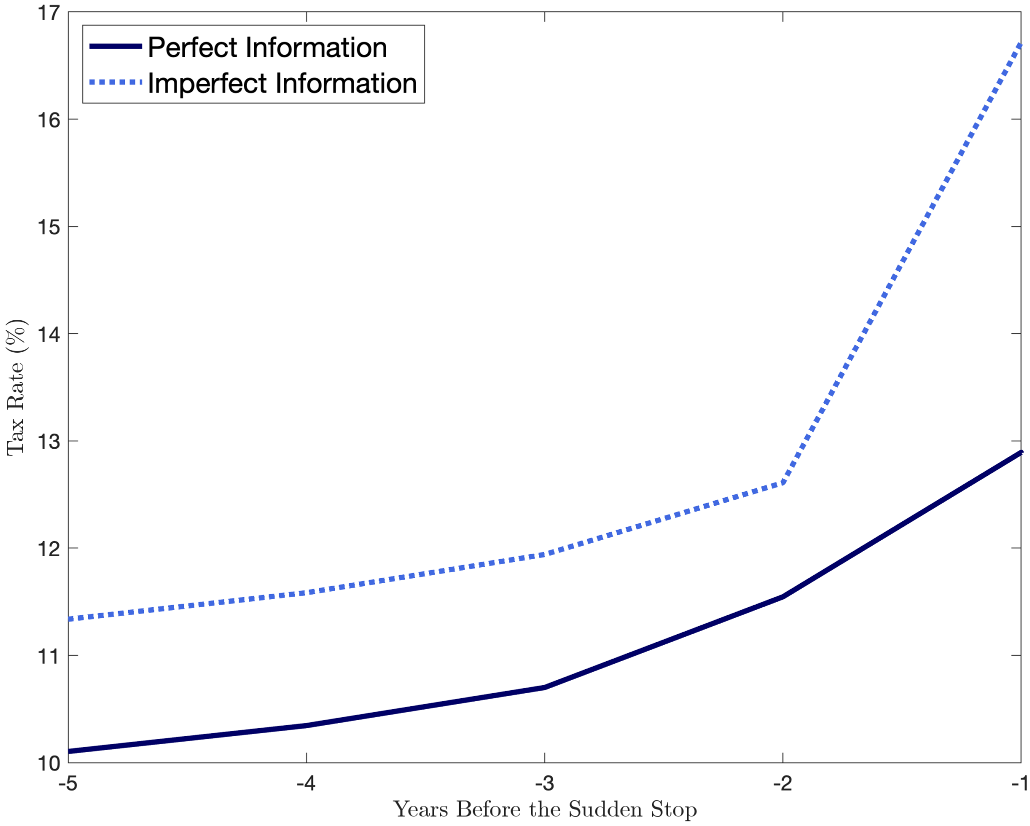
severity in the uninformed economy. In particular, the average drop in consumption during a Sudden Stop decreases from 25 to 21 percent due to the optimal tax policy. In contrast, the informed Planner implements a tax policy that reduces the drop in total consumption from 25 to 24.5 percent.

4.3.2 Cyclicality of the Optimal Tax

In this section, we examine the cyclicality of optimal macroprudential taxes under perfect and imperfect information, focusing on both unconditional and conditional correlations across distinct economic conditions. Specifically, we analyze correlations with respect to total income and its underlying components.

Our conditional analysis considers boom-bust cycles—defined as one-standard-deviation increases in income followed by one-standard-deviation drops—and Sudden Stops, charac-

Figure 9: Optimal Tax Policy in the Years Preceding a Sudden Stop.



Note: In this figure, we compare the dynamics of the optimal tax policy under perfect and imperfect information in the years leading up to a Sudden Stop. The horizontal axis covers the five years before the crisis. The Sudden Stop occurs in period 0, at which point the optimal tax rate takes a value of zero.

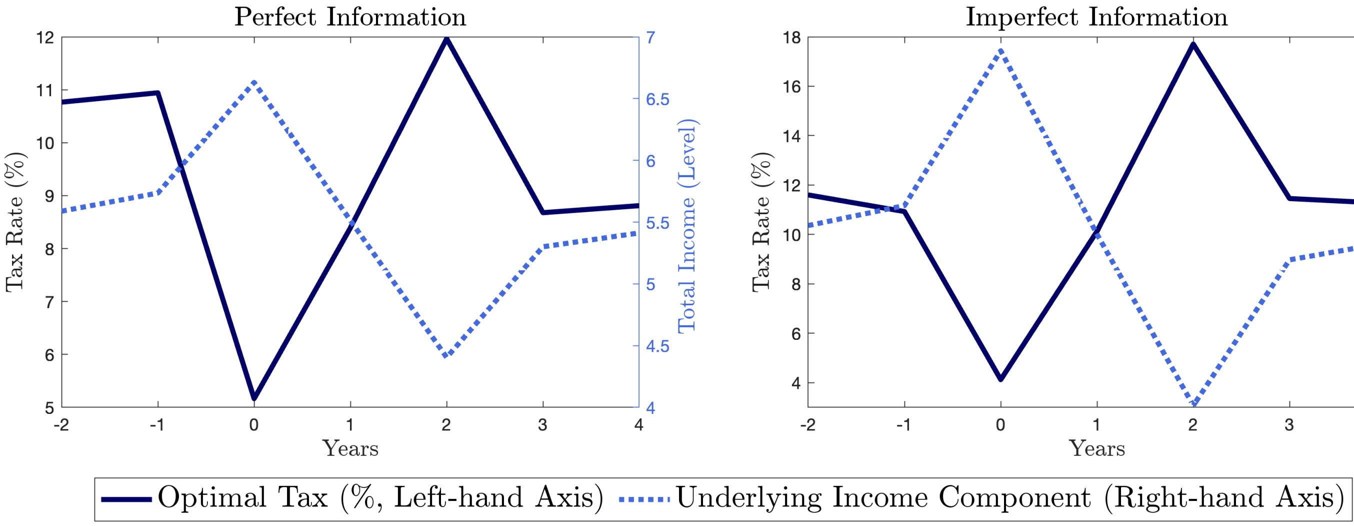
Table 4: Cyclicality of the Optimal Tax

	Total Output $\rho(\tau_t, Y_t)$		Permanent Shock $\rho(\tau_t, g_t)$		Transitory Shock Y_t^T $\rho(\tau_t, Z_t^T)$		Transitory Shock Y_t^N $\rho(\tau_t, Z_t^N)$	
	Perf. Info	*Imp. Info*	*Perf. Info*	*Imp. Info*	*Perf. Info*	*Imp. Info*	*Perf. Info*	*Imp. Info*
Baseline Model	-0.38	-0.52	-0.03	-0.16	-0.66	-0.53	-0.19	0.19
Sensitivity Analysis								
Elasticity of Subst. T and NT (ϵ = 0.5)	-0.31	-0.58	-0.08	-0.18	-0.36	-0.52	-0.04	0.17
Autocorrelation ρ_g (15 % less)	-0.44	-0.57	-0.12	-0.24	-0.65	-0.53	-0.19	0.16
Autocorrelation ρ_g (15 % more)	-0.29	-0.42	0.09	-0.04	-0.65	-0.53	-0.18	0.22
Volatility σ_g (15 % less)	-0.34	-0.53	-0.03	-0.17	-0.57	-0.53	-0.16	0.18
Volatility σ_g (15 % more)	-0.27	-0.50	-0.03	-0.15	-0.47	-0.54	-0.13	0.20

Note: This table presents the correlations between the optimal tax rate and the different components of income for both perfect and imperfect information. Each rows displays sensitivity variations from the baseline model. As in Schmitt-Grohé and Uribe (2017), we define a counter-cyclical optimal tax as a capital control policy that increases during booms and decreases during economic recessions (positive correlation).

terized by periods when the collateral constraint binds and the current account improves by more than one standard deviation. By distinguishing between these contexts, we aim to provide a comprehensive understanding of how the Planner's tax policy responds to transitory and permanent shocks to income, with and without information frictions.

Figure 10: Optimal Tax Policy During Boom-Bust Cycles in Total GDP



Note: This figure illustrates the dynamics of the optimal tax rate during a boom-bust cycle in total GDP. A boom-bust cycle is defined as an episode where total GDP growth exceeds one standard deviation above the mean at period 0 and subsequently drops to one standard deviation below the mean two years later. The figure includes data from two years prior to the boom and two years following the bust.

Table 4 presents the unconditional long-term correlations between the optimal tax and total income, as well as each of its components, and includes a sensitivity analysis of the findings. Column 1 and 2 of the table show that, under both perfect and imperfect information, the constrained Planner raises taxes during periods of low GDP and lowers them during periods of high GDP. As highlighted by Schmitt-Grohé and Uribe (2017), this behavior reflects a Planner addressing the trade-off between impatient households and the need to prevent financial crises by increasing taxes on foreign debt when total income is low and observing a binding collateral constraint becomes more likely. Figure 10 further illustrates that the conditional correlation between the optimal tax and total GDP during boom-bust cycles is also negative.

To analyze the cyclicality of the optimal tax with respect to the underlying components of income, we first examine the tax dynamics in response to movements in the permanent component of income (g_t). As shown in Table 4, the perfectly informed economy (Column 3) exhibits a negative, albeit relatively acyclical, long-term correlation between g_t and the optimal tax policy ($\rho\left(\tau_t, g_t\right) = -0.03$). By contrast, under imperfect information (Column 4), the correlation becomes larger in absolute value and equal to

-0.16.

Under perfect information, our findings are consistent with the results of Flemming et al. (2019), who found that in an economy affected by trend shocks, the optimal policy is less responsive to non-stationary shocks to income. In a perfectly informed economy, permanent shocks convey information about the economy's future performance. Following a positive (or negative) shock, agents predict a continued improvement (or deterioration) in economic conditions, leading them to reallocate resources from (or towards) the future.

Consequently, the Planner levies taxes to counteract the increase in borrowing driven by households perceiving themselves as permanently wealthier during good times. This result depends on the persistence of the permanent shock, as greater persistence leads households to increase borrowing more significantly, prompting the Planner to respond more strongly to mitigate potential risks.[11]

As discussed in section 4.2.1, uninformed agents perceive permanent shocks to income as being partially explained by transitory shocks. Consequently, in response to a positive (negative) shock to g_t, consumption and borrowing increase (decrease) by less than in the perfectly informed economy. When income rises, uninformed agents recognize the risk that the shock might be transitory and save part of the windfall. The uninformed Planner can reduce taxes during good times because, even if borrowing increases, the rise remains moderate and consistent with an economy that is permanently wealthier. Conversely, during bad times, the uninformed Planner will raise taxes because agents are likely to increase their borrowing at a time when the economy is at risk of being permanently poorer.

Next, we focus on the cyclicality of the optimal tax with respect to the transitory component of tradable income, Z_t^T. As shown in Table 4, the correlation between the tax and Z_t^T is negative under both perfect and imperfect information (Columns 5 and 6). Under imperfect information, the correlation changes from -0.66 to -0.53. Although

[11] As shown by Flemming et al. (2019), the persistence of the permanent shock ρ_g is key to this result. The more persistent the shock, the more countercyclical the policy response will be. Table 4 displays the cyclicality of the optimal tax under our baseline calibration and compares it with several sensitivity scenarios. In particular, under perfect information, increasing the persistence of the growth shock (ρ_g) by 15% increases the correlation of the optimal policy with the permanent component of income to 0.09 (from -0.03). Conversely, reducing ρ_g by 15% causes the correlation to decrease to -0.12.

this difference is numerically small, it offers intuition into how the information friction reshapes the policy response.

Under imperfect information, agents react to shocks to Z_t^T by forecasting movements in both the transitory and permanent components of income. As illustrated by Figure 2, uninformed households adjust their consumption more than fully informed households. When the shock is positive, the uninformed Planner reduces taxes, but not as much as in the perfectly informed economy. This is because, if the shock turns out to be fully permanent, encouraging borrowing during good times could excessively increase the economy's vulnerability to large negative shocks. On the other hand, if the shock is negative, the uninformed Planner increases taxes by less than under perfect information, as inducing deleverage—in the event of a permanent shock—might lead to a binding borrowing constraint and trigger a Sudden Stop.

Finally, we analyze the cyclicality of the optimal tax in response to transitory shocks to nontradable income, Z_t^N. As shown in Columns 7 and 8 of Table 4, the correlation shifts from negative to positive when introducing the information friction. Under perfect information, the correlation between Z_t^N and the optimal tax policy is -0.18, whereas under imperfect information, it becomes positive and equal to 0.19.

In the perfectly informed economy, a negative shock to Z_t^N causes tradable goods to become relatively cheaper than nontradable goods, leading households to shift their consumption toward tradable goods ($C_t^T \uparrow$). Equations 3 and 27 show that this response reinforces real appreciation, relaxes the borrowing limit, and incentivizes households to overborrow, thereby increasing the likelihood of a Sudden Stop.[12] To counteract this effect, the Planner adopts a procyclical policy, raising the tax during periods of low income and lowering it during periods of high income.

In contrast, the uninformed Planner finds it optimal to reduce taxes when negative

[12]The magnitude of the price adjustment will be directly linked to the elasticity of substitution between tradable and nontradable goods (ϵ). A higher ϵ amplifies the sensitivity of the relative price to changes in the ratio $\frac{C_t^T}{C_t^N}$. In our baseline calibration, we follow Bianchi (2011) and set $\epsilon = 0.83$. Table 4 displays the correlations for a lower degree of substitutability between tradable and non-tradable goods ($\epsilon = 0.5$). As the elasticity decreases, the response of the optimal tax under perfect information becomes more muted to transitory shocks to non-tradable income ($\rho(\tau, Z_t^N) = -0.04$). In contrast, in the imperfectly informed economy, the correlation becomes positive and larger in absolute value ($\rho(\tau, Z_t^N) = -0.17$). Online appendix A.3 discusses the model's results for $\epsilon = 0.5$.

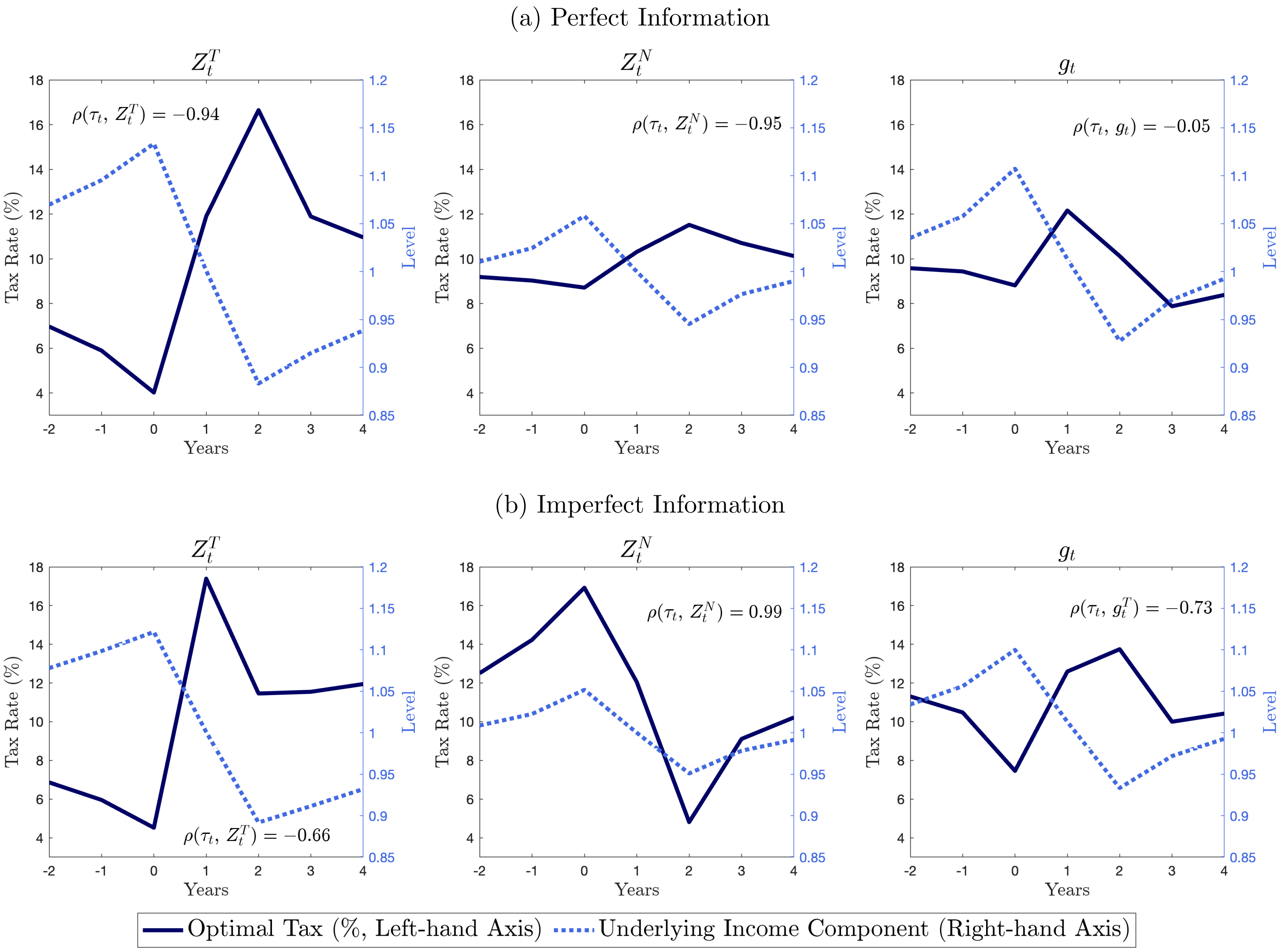
transitory shocks to nontradable income hit the economy. As shown in section 4.2.1, when the household observes a negative growth rate in nontradable income, her beliefs about the fundamentals will be consistent with a negative shock to Z_t^N, a positive shock to Z_{t-1}^T that went unnoticed, or a negative shock to the permanent component g_t, and each scenario will be optimally weighted.

As a result, when a negative shock to Z_t^N hits the uninformed economy, households substitute away from the nontradable sector as nontradable goods become relatively more expensive. Higher C_t^T reinforces the increase in the relative price and relaxes the borrowing limit. However, despite facing a loosened collateral constraint, households choose to decrease borrowing since they believe the economy might be facing a permanent negative shock. The combination of lower debt and a more relaxed financial constraint leads the Planner to adopt a countercyclical macroprudential tax policy.

The analysis of conditional correlations extends the insights gained from the unconditional analysis, demonstrating how the Planner's tax response varies during boom-bust cycles. As illustrated in Figure 11, the patterns observed in the unconditional analysis generally hold when focusing on these specific episodes, but the magnitude of the correlations reflect the heightened role of financial and information frictions during such conditions. In particular, during boom-bust cycles, the Planner's tax policy becomes more sensitive to income shocks (the absolute value of the correlations increase relative to the unconditional value), emphasizing the need to stabilize borrowing dynamics.

Since Sudden Stops are infrequent, unconditional correlations predominantly reflect periods outside financial fragility, even though these episodes have significant consequences for the economy. Due to the strong non-linearity present in the collateral constraint, the cyclicality of taxes may differ substantially during these extreme times. Figure 12 illustrates the dynamics of the optimal policy and total income during Sudden Stops. As explained in section 4.3.1, when the collateral constraint binds, the optimal tax is set to zero. Regardless of the presence of information frictions, once the economy recovers, income increases, and the Planner raises the optimal tax, resulting in a positive correlation between income and taxes during periods of acute financial distress.

Figure 11: Optimal Tax Policy Under Different Boom-Bust Scenarios

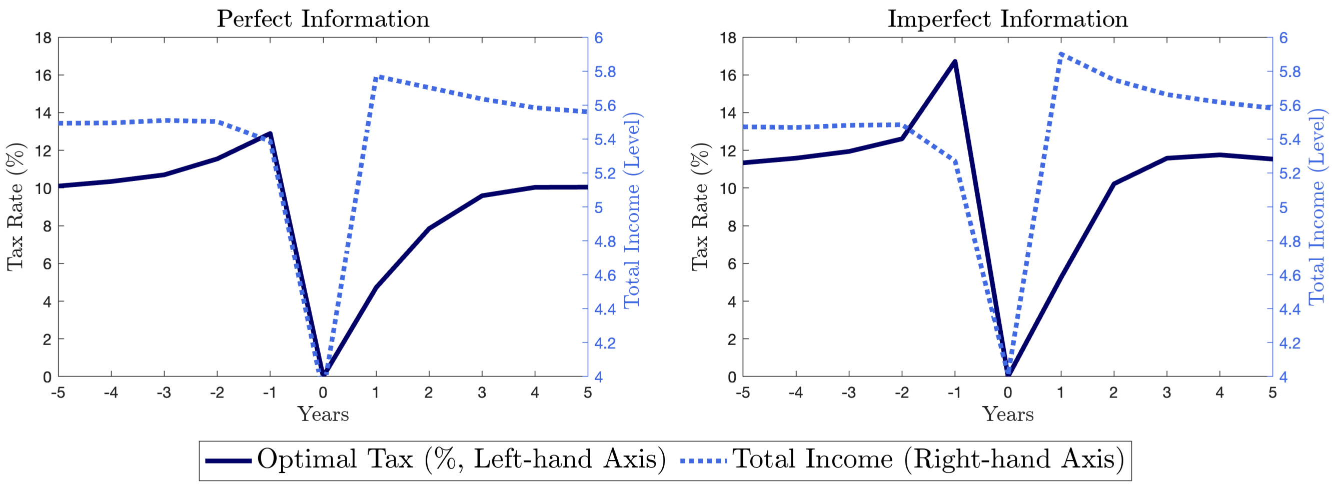


Note: This figure illustrates the boom-bust dynamics of the optimal tax rate. Each panel includes two years preceding the boom and two years following the bust. Panel 11a shows the dynamics for the informed economy, while Panel 11b presents the results for the economy under imperfect information. The annotation in each plot indicates the conditional correlation between the optimal tax and the income component.

4.3.3 Policy Implementation

Our results show that, both under perfect and imperfect information, the constrained Planner chooses highly nonlinear policy rules, which imply frequent adjustments of the optimal tax. From a policymaker's perspective, the implementation of a state-contingent tax might not be feasible due to its complexity (Hernandez and Mendoza, 2017; Bianchi and Mendoza, 2018). Furthermore, data suggests that state-contingent rules are rarely

Figure 12: Optimal Tax Policy During Sudden Stops



Note: This figure illustrates the dynamics of the optimal tax rate during a Sudden Stop. A Sudden Stop is defined by a binding collateral constraint and a sharp improvement in the current account exceeding one standard deviation. The figure includes data from five years prior to the event and five years after.

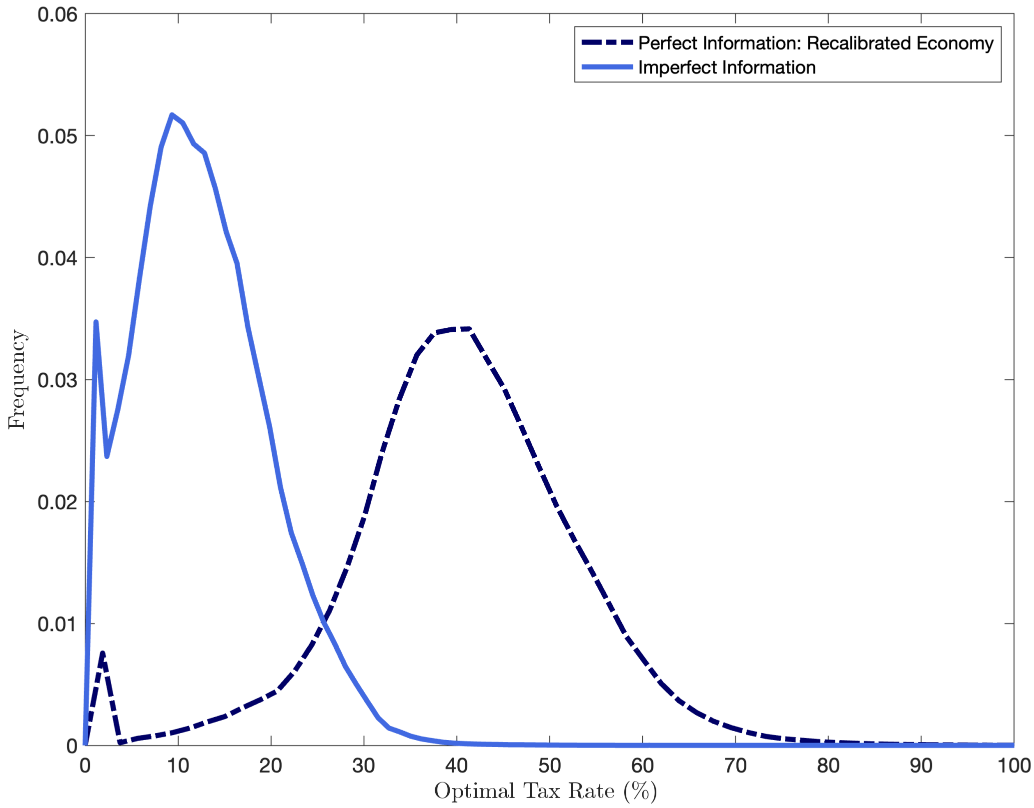
used and policymakers generally choose "sticky" capital controls (Acosta et al., 2020).

Based on these considerations, we explore whether a fixed (time- and state-invariant) tax rate can deliver significant welfare gains relative to the uninformed unregulated economy, and how those gains compare to those achieved by the optimal tax. To address this question, we follow Bianchi (2011) and consider a Planner who, at time 0, chooses the fixed tax rate that brings him closer to the second-best solution. We find that a fixed tax rate of 10 percent (approximately 88% of the ergodic mean from the optimal tax distribution) achieves 75 percent of the welfare gains associated with implementing the constrained-efficient allocations. Under this optimal fixed tax regime, the likelihood of crises decreases from 5.5 percent to 2.4 percent, and the economy borrows about 0.4 percentage points of GDP more than under the optimal tax policy.

These results broadly align with previous findings under perfect information, which indicate that, while simple fixed-tax policies can reduce the frequency of Sudden Stops, they are generally less effective than state-contingent taxes (Bianchi, 2011; Bianchi et al., 2016; Bianchi and Mendoza, 2020; Hernandez and Mendoza, 2017). Furthermore, Bianchi and Mendoza (2018) caution that poorly designed fixed taxes under a stock collateral constraint may result in welfare losses.[13]

[13]For a more detailed discussion of the normative implications of models with occasionally binding

Figure 13: Optimal Tax Distribution: Recalibrated Economy



Note: This figure depicts the ergodic distribution of the optimal tax under imperfect information using the benchmark calibration. It also shows the distribution for the optimal tax in the recalibrated, fully-informed decentralized economy.

Another relevant issue for a policymaker is whether assuming a model under perfect information significantly departs from the optimal tax policy. To address this concern, we study the optimal policy enacted by a Planner in a perfectly informed economy calibrated to match the long-term debt-to-GDP ratio and frequency of crises in the data. Columns 5 and 6 of Table 3 summarize our findings.

In the recalibrated economy, the welfare gains from implementing the optimal policy yield about 0.15 of lifetime consumption. This result is aligned with Bennett et al. (2023), who showed that even when regulators operate under incorrect assumptions, macroprudential policy remains desirable. In the recalibrated perfect information economy, the Planner chooses a tax policy with an average tax about three times larger (37.27 %) than the mean tax implemented by the uninformed Planner (11.40 %). As illustrated by Figure 13, the Planner in the recalibrated economy mostly chooses taxes between 20 and

collateral constraints, see Bianchi and Mendoza (2020).

60 percent of external debt.

The observed differences are driven by a key aspect of the recalibration process. To achieve the targeted moments under perfect information, economic agents must be much more impatient. Specifically, the recalibrated economy with full information requires an annual discount factor (β) of 0.53, significantly lower than the standard values commonly used in the literature.[14] In the recalibrated economy, the heightened impatience leads households to borrow more and face more frequent Sudden Stops, prompting the Planner to impose higher taxes than in the benchmark models.[15]

The difference in the level of impatience between the recalibration and our benchmark underscores the importance of relaxing the assumption of imperfect information to match the levels of debt observed in the data under reasonable parameterization in the presence of transitory and permanent shocks to income.

5 Concluding Remarks

This paper explores how imperfect information drives Sudden Stops in a model where borrowing constraints depend on the tradable value of domestic income. The interaction between information and financial frictions fundamentally shapes agents' consumption, borrowing, and policy responses compared to a perfect information setting. This interaction also doubles the welfare gains from implementing optimal macroprudential policies and can shift the correlation between the optimal tax and specific income components. These results highlight the critical role of accounting for information frictions when designing macroprudential policies for small open economies.

[14] For comparison, Bianchi (2011) sets β to 0.91 in a model with transitory shocks and perfect information. In our benchmark model, which incorporates both imperfect information and transitory and permanent shocks, we set $\beta = 0.83$ to match an average NFA-to-GDP ratio of 29 percent. Flemming et al. (2019) and Seoane and Yurdagul (2019) adopt the same calibration as Bianchi (2011).

[15] See Appendix A.6 for additional details on the optimal policy functions.

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