KU LEUVEN

DEPARTMENT OF ECONOMICS

DISCUSSION PAPER SERIES
DPS16.04

APRIL 2016

Sovereign debt and asymmetric market information

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February 2016

Abstract

I extend the recent quantitative models of sovereign default by allowing asymmetry in information between the government and foreign lenders. As a result, the model can account for the empirical fact that less transparent governments have higher levels of debt. Introducing information asymmetry emphasizes several mechanisms. First, a more informed government demands less precautionary savings. Second, less informed lenders offer a relatively better price when the probability of a bad outcome is higher. The effects of these channels are amplified when government is financially constrained, and any small change in price may trigger a default and bring the average debt level down considerably. Additionally, introducing asymmetric information allows assessing the consequences of the misalignment of market sentiments and generate business cycle moments closer to the one observed in the data.

JEL classification: F34, F41, D82.

Key words: sovereign debt, endogenous default, asymmetric information, transparency.

*Acknowledgements: I would like to thank Pedro Gomes, Davide Debortoli, Hernan Seoane, Stefan Niemann, Juan Jose Dolado, Matthias Kredler, and Sandra Lizarazo. I am also grateful to the seminar participants of the following events for their comments and feedback: the UC3M workshops, European Macroeconomic Workshop, London; University of Minnesota student workshop; KU Leuven seminar; ENTER Jamboree; Belgian Macroeconomic Workshop. The research leading to these results has received funding from the European Community's Seventh Framework Programme (FP7/2007-2013) under grant agreement Integrated Macro-Financial Modeling for Robust Policy Design (MACFINROBODS, grant no. 612796). All the remaining errors are mine.

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1 Introduction

It is a well known fact that emerging market economies are prone to poor institutions, additional layers of uncertainty and lack of transparency. The 2008-2009 debt crisis had shown that, eventually, no country is shielded from high interest rate spreads, unsustainable debt and lack of transparency. Even developed countries like Spain[1] and Greece have been undermined by revealed hidden debts, economic uncertainty and respectively unaffordable borrowing costs.

One would think that less transparent governments would be readily punished by credit markets by being charged higher interest rates and therefore would find it harder to borrow more. However, the data shows that it is the less transparent countries that have higher levels of debt. Figure 1 points out that governments with lower transparency register higher amounts of debt, not only among the same income group but also within it

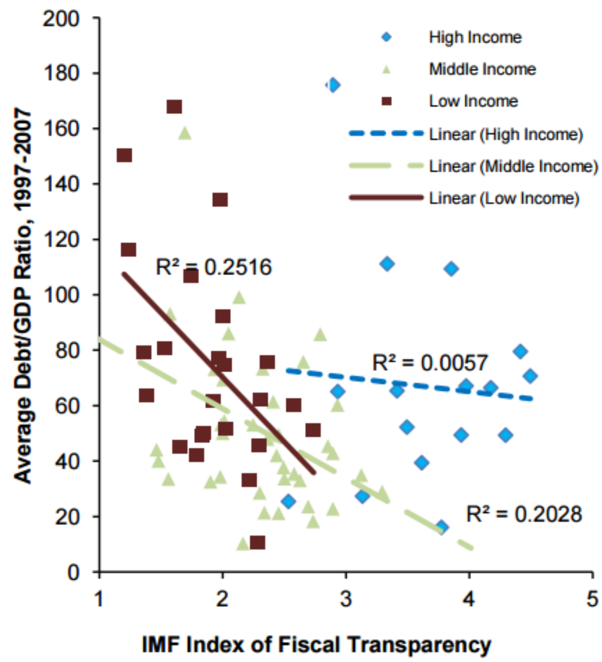
There is a growing body of empirical literature that documents this correspondence, but finds it hard to establish the causal relationship between transparency and fiscal outcomes due to endogeneity of fiscal transparency.[2] This paper develops a theoretical model that offers an explanation as to why even among countries with the same level of economic development less transparent governments borrow more.

In order to rationalize the above facts, I build a model of a small open economy with endogenous sovereign default and allow government and lenders to receive signals about future fundamentals with different accuracy. The main intuition of the model is that less transparent governments are able to borrow more since they can raise money when they need it most. If a government is not financially constrained, the change in price due to lenders' expectations will affect the average level of debt slightly. On the other hand, when government is heavily indebted, any accurate bad information may freeze the debt market and force it to default. Hence, on average a government will borrow more if lenders observe

[1]In March 2011 Spanish local governments revealed the accumulated debts that had not been shown previously.

[2]see Hameed (2005), Alt and Lassen (2006)

Figure 1: Debt and Transparency



Source: Cottarelli (2012)

less accurate information.

When government observes more accurate information in comparison to lenders, there are two mechanisms at play. First, once the government is more aware of the future output, it demands less precautionary savings and therefore borrows more. Second, less informed lenders, due to the higher uncertainty they face, offer a relatively better price when the probability of bad realizations of output is higher. Even though less informed lenders charge a relatively higher cost during good times, a more informed government, that expects higher output tomorrow and is guided by consumption smoothing behavior, will only marginally reduce the level of debt. Therefore, due to lenders' lack of information, the amount of debt the government borrows when expecting bad times is higher than the amount of debt that government foregoes when it expects to be in good times. The effect is especially strong when government is overindebted, and any marginal change in price may trigger a default. The analysis shows that when a government's signal becomes more informative relative to the lenders' one, the level of contracted debt triples in comparison to the no-signal economy.

The model additionally gives some complementary results. By introducing asymmetric information the model can explain another empirical fact documented by Grauwe and Ji (2013). The authors find that significant change in sovereign spreads for the Euro zone periphery were driven by non-economic fundamentals. I show that in less transparent countries, the case of the Euro periphery comes about, where the share of market sentiments in variation of spreads is higher and probability of default due to unaligned market expectations and fundamentals increases.

The model's business cycle moments, for the case when lenders observe worse qualitative information than government about latter's fundamentals, are also closer to the values observed in the data for emerging markets. The variation in consumption is higher, the correlation between output and consumption is lower and the correlation between output and spreads is significantly negative. Hence, the asymmetry of information between lenders and governments may play an important role in explaining the patterns observed in the data.

The model is an extension of literature on sovereign default, started by Eaton and Gersovitz (1981). Aguiar and Gopinath (2006) and Arellano (2008) extended the general equilibrium model with endogenous sovereign default to study business cycles in emerging economies. There is vast literature that builds upon these models in order to account for the facts left unexplained, especially for the relatively low level of debt and lack of defaults occurring during good times. Hatchondo, Martinez, and Sapriza (2009) show that by introducing political uncertainty the model can generate defaults not only during bad times. Hatchondo and Martinez (2009) and Chatterjee and Eyigungor (2012) introduce bonds of longer duration to improve quantitative properties of the models. The present paper adds to this literature and offers additional channels that can generate higher levels of debt as well as defaults that are not linked to fundamentals.

I extend the set-up described in Durdu, Nunes, and Sapriza (2013) by allowing agents to receive signals that are not common knowledge information. The model allows to examine the additional effects that difference in the amount of information has on the outcomes of an economy and helps reconcile the model with the patterns present in the data. Regardless of this, by introducing the asymmetric information the model is able to generate some business cycle statistics that are much closer to the ones observed in the data for emerging markets, in particular less consumption smoothing and a more pronounced negative correlation between output and interest rate spreads.

In allowing for asymmetric information between government and lenders, our model connects to several studies that find the lack of common knowledge to be a key determinant in fluctuations of sovereign spreads. Most of these studies consider the case where investors learn from the agents' actions, update their beliefs about future types of borrowers and reprice the assets along the way. This is done at the expense of not having features that are of interest for this study. Ranciere, Fostel, and Catao (2011) have studied a three-period model to explain the decouplings in cross-country bond yields after prolonged periods of convergence. The studies by Alfaro and Kanczuk (2005), in a model of sovereign default, and Chatterjee, Corbae, Nakajima, and Rios-Rull (2007), in a model of unsecured consumer debt, both assume an exogenous fixed level of debt upon which creditors make the decision to default. I will abstract from the signal extraction problem as it considerably complicates the set-up and limits the study of variables of interest. The assumption is not completely unreasonable, as Calvo and Mendoza (2000) show that in a global economy, information gathering is costly and investors would rather follow the market than waste their time and resources in making their own assessments. The paper adds to this strand of literature by assessing the effect of the precision of future fundamentals on contracted level of debt and the consequences of misalignment of market sentiments.

The structure of the paper is as follows. Section 1.1 brings up evidence about the relationship between transparency and sovereign debt. Sections 2 and 3 describe the theoretical model, show the equilibrium outcome and explain the main mechanism of the model. Sections 4 and 5 discuss the main results of the paper.

1.1 Motivating Evidence

Before proceeding to the theoretical set-up, I provide some evidence on how the difference in uncertainty regarding future fundamentals is related to different levels of debt. There are two reasons why I use uncertainty rather than government transparency to show the pattern that debt exhibits when there is asymmetric information among market participants. Firstly, lower transparency is often associated with a higher uncertainty surrounding the policies and therefore outcomes for which government provides information. Some notable examples where governments increase transparency by reducing uncertainty around policies are introduction of fiscal rules or inflation targeting used in monetary policy. Secondly, in the theoretical model that I describe later, asymmetry of information appears in the knowledge about future endowment. Therefore, uncertainty of future output growth serves a better indicator of the point I would like to make.

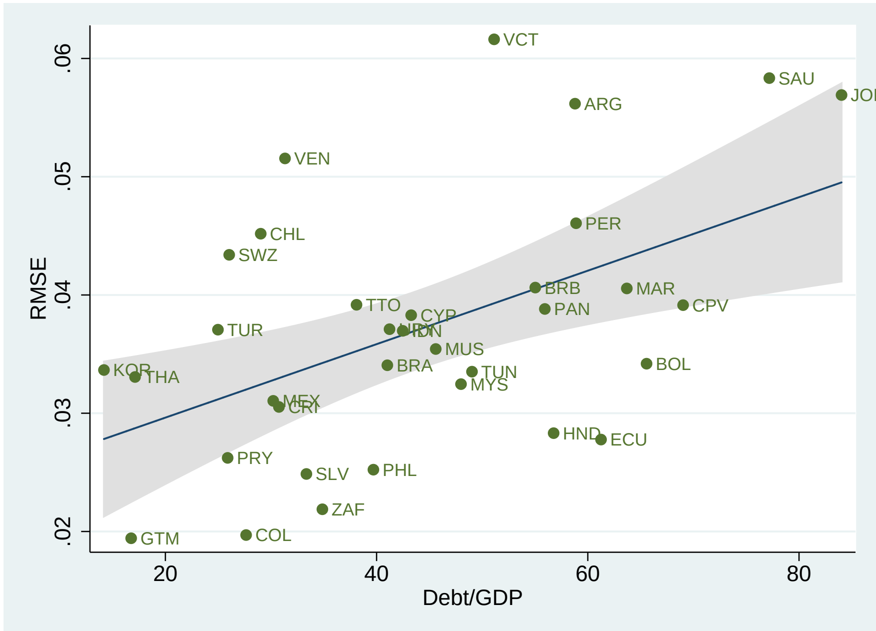
For this purpose, I compute the standard deviations of the forecast errors of GDP per capita growth and compute the correlation between root mean square error (RMSE) and level of debt for a group of emerging countries. Let's define the forecast of GDP per capita growth at time $t+1$ as $\hat{y}_{t+1|t}$, then the forecast error is given by:

$$\varepsilon_{t+1|t} = y_{t+1} - \hat{y}_{t+1|t}$$

Forecast errors are estimated by means of ARIMA model using real GDP per capita data for 131 countries over 26 years, from 1980 till 2005. The summary of standard deviations of the difference between predicted and observed values is given in appendix B. Higher RMSE denotes a higher uncertainty of the forecast of the variable for a given country.

In order to show the plausibility of the fitted model and received results, I plot the relationship between RMSE and GDP per capita. Figure 10 in the appendix displays a negative relationship, indicating that more developed countries show a lower uncertainty in the economic forecasts. The simple ARIMA estimation yields a standard deviation of forecast

Figure 2: RMSE and Debt/GDP ratio for middle income countries



errors 98% higher for Latin American countries in comparison to high income countries. Timmermann (2007) documents that the average standard deviations of forecast errors of GDP growth for advanced economies is 1.35 while for developing Asia and the Western hemisphere these are 2.22 and 2.41 respectively. Hence, the results are consistent with the World Economic Forecast reported by IMF.

Also, figure 9 in the appendix shows that RMSE is negatively correlated with the Fiscal Transparency Index as defined by Wang, Irwin, and Murara (2015). As was mentioned earlier, higher uncertainty is often associated with lower fiscal transparency (lower values of the index). Hence, RMSE is a good proxy for government transparency and is used for futher analysis.

Figure 2 presents the evidence for a positive relationship between uncertainty about future fundamentals, namely RMSE of GDP per capita growth, and the debt to gdp ratio. Herein, I plot the RMSE and debt to GDP ratios for middle income economies. A similar pattern can be observed for the other two - low and high income countries, which can be seen in figure 11 in the appendix. Groups are differentiated by gross national income per capita as it is specified by the World Bank[3]. Since I relate the uncertainty with the degree of transparency of a country it is important to note that results are consistent with the case where the IMF Index of Fiscal Transparency is used instead. Figure 1 mentioned in the introduction shows that more transparent countries (with a higher index of fiscal transparency) register lower levels of debt. And, as in the case of RMSE, the pattern holds for all other income groups.

The causality relationship between these two variables can go in either direction. It can be the case that a higher level of debt brings higher uncertainty along with it as the country's position maybe more vulnerable when it is overindebted. It also may be the case that governments are able to rollover higher amounts of debt as a result of lower transparency. A less transparent country can more easily hide the expected bad output tomorrow and therefore take advantage of a relatively better price debt. As a result, it is able to accumulate and sustain a higher amount of debt. Empirical work on fiscal transparency finds it hard to determine the causality of this existing relationship due to lack of appropriate instruments for transparency.[4] In what follows, I will develop a model that is able to generate higher levels of debt for the cases where foreign lenders have less accurate information regarding a country's future fundamentals and will explain the mechanisms behind the results.

2 The model

Consider the environment of a small open economy with a representative household, government and foreign lenders. Time is discrete and the economy lasts indefinitely, $t = 0, 1, \ldots$. The household is maximizing the stream of consumption that is composed of a stochastic endowment and a government transfer. The government smooths the household's consumption by trading one period non-contingent bonds in a credit market. The gains/losses are passed to the household in the form of a lump sum transfer. The government trades with a large number of identical risk-neutral foreign creditors which will lend any amount as long

[3] http://data.worldbank.org/news/2015-country-classifications

[4] Alt and Lassen (2006) suggest political competition; see Hameed (2005) for other references.

as they expect a value equal to the one received by trading in a risk-free market. The price of each bond reflects the lenders' assessment of the likelihood of a default event.

The government and lenders are assumed to receive different quality of information about future government's endowment. This assumption tries to capture the fact that governments, especially in developing countries, can hold a certain degree of private information regarding the state of economy. One possible explanation is that governments know more about their willingness to implement structural reforms or deal with corruption, and therefore can better asses future economic output. A similar argument has been used by Tsyrennikov (2013) and Sandleris (2008).[5] Another possibility is a world where the government deliberately hides some information about the state of economy. Reinhart and Rogoff (2011) document that official data often has little reliability and the government hides the weaknesses in financial systems.

2.1 Information structure

At the beginning of each period, the government and lenders each receive their own signal about said government's future endowment.

Assumption about government. Government observes its own signal and infers lenders' signal when it participates in the credit market.

Assumption about lenders. Lenders receive their own signal and cannot observe that of the government. Additionally, they cannot update their signal after observing the debt contracted by the government. Given the available information about the state of the economy (the current endowment and their own signal about the future endowment), lenders design a bond price schedule to which they commit. Hence, government can borrow any amount of debt at a price offered by the lenders that is consistent with this schedule. If lenders could back out of the government's signal, the model would collapse to a symmetric information

[5] Tsyrennikov (2013) assumes that due to corruption and other similar factors, the world may not be able to observe the quality or the productivity of the investment. Sandleris (2008) assumes that this causes limited information about current fundamentals which may affect economic agents' decisions.

case.

Calvo and Mendoza (2000) argue that globalization may promote contagion by weakening incentives for gathering costly information on each country's fundamentals. Therefore investors would rather follow the "market" than take the time and expenses to make their own assessments. Following this argument I find it plausible to assume that lenders receive an external signal regarding future fundamentals which may be more or less precise, mimicking their herding behavior.

Time-line. At the beginning of every period t,

1. government (g) inherits a debt level b_t, observes output y_t and receives a private signal regarding future endowment s_t^g;
2. foreign lenders (ℓ) observe a signal regarding government's future output, s_t^ℓ, the current endowment and the inherited debt. Given this information, they form the asset price schedule.
3. Government decides whether to default or not.
4. If the government defaults, it is not allowed to participate in the credit market and incurs a cost in the form of foregone endowment by consuming y^{def}. It re-enters the credit market with a probability ω.
5. If the government does not default, it observes lenders' signal through the offered price and decides upon the level of debt b_{t+1}.

In what follows, I describe the signal shocks and the joint dynamics of the endowment and the signals.

2.2 Signal specification

As in Arellano (2008), endowment follows an AR(1) log normal process with $\varepsilon_t \sim N(0, \sigma_\varepsilon^2)$

$$\log(y_t) = \rho \log(y_{t-1}) + \varepsilon_t, \quad |\rho| < 1 \tag{1}$$

The process is approximated by Markov chain with probabilities $\Pr(y_{t+1} = m | y_t = j)\ \forall m, j \in \mathcal{Y}$. Every period the government and the lenders receive a signal, s^i, $\forall i = \{g, \ell\}$, regarding the next period's endowment. Signal's set $\mathcal{S}^i$ for both parties has the same size and we consider that $|\mathcal{Y}| = |\mathcal{S}^g| = |\mathcal{S}^\ell|$. The superscripts g and ℓ stand for the government's and foreign lenders' signal set. It is important to underline that signals which government and lenders receive are not necessarily the same and they are independently distributed.

Precision stands for the ability of the received signal to predict the future output. Or, put in a more formal way, it is the probability of receiving a signal regarding a particular endowment conditional on receiving it in the next period. If the received signal is inaccurate (i.e. signal is not precise) the probability of receiving the latter is similar to the case of economies without any informational system. If the signal is more precise the probability of receiving this particular output increases. Given the available informational set, we can specify the joint process of the signals and endowment shocks. The forecast conditional on current information is given by Bayes theorem.

$$\Pr(y_{t+1} = k | y_t = n, s_t^g = m) = \frac{\Pr(s_t^g = m | y_{t+1} = k) \Pr(y_{t+1} = k | y_t = n)}{\sum_j \Pr(s_t^g = m | y_{t+1} = j) \Pr(y_{t+1} = j | y_t = n)}; \tag{2}$$

Joint distribution of the signals and endowment used in the simulation is given by $\Pi(y', s^{g\prime}, s^{\ell\prime} | y, s^g)$. The derivation and the explicit formula is given in the appendix.

For simplicity we assume a symmetric signal precision that is given by:

$$\Pr(s_t^g = i | y_{t+1} = j) = \begin{cases} \psi^g, & i = j, \\ \frac{1-\psi^g}{|\mathcal{S}^g|-1}, & otw. \end{cases}$$

If the precision of the signal is high, i.e. $\psi^g \to 1$, then the signal perfectly predicts the output realization tomorrow, i.e. $\Pr(y_{t+1} = j | s_t^g = i) \to 1$, for $i = j$. If the precision is low, the signal gives no additional information and $\Pr(y_{t+1} = j | s_t^g = i) = \Pr(y_{t+1} = j)$.

A similar symmetric structure is assumed for the lenders' signal.

2.3 Environment

Preferences. Household's preferences are given by the utility function:

$$E_0 \sum_{t=0}^{\infty} \beta^t u(c_t),$$

where c_t is the current consumption and β is the discount factor. Utility function is strictly increasing, concave and continuously differentiable. The household does not participate in the credit market, but instead receives a lump sum transfer from the government.

Government's objective is to maximize household's present value of consumption. It smooths the consumption by borrowing in the foreign credit market at a price $q(b_{t+1}, y_t, s_t^\ell)$ and transfers all the proceeds to consumers. Financial markets are incomplete and government trades only one period, non contingent bond b. Sovereign debt is not enforceable, and at the beginning of each period government decides whether to default or not. The default decision has a cost in the form of a lower endowment and temporary exclusion from the credit market.

Government's problem can be written in a recursive way. Given the state variables, the value function is given by:

$$V_0(b, y, s^g, s^\ell) = \max\{V^{ND}(b, y, s^g, s^\ell), V^D(y, s^g)\},$$

where $V^{ND}(b, y, s^g, s^\ell)$ is the value if government continues the repayment and $V^D(y, s^g)$ is the value if government defaults.

When government decides to default, it temporarily exits the international credit market.

Being in autarky, government can regain the possibility to lend/borrow in the credit market with probability ω. Government re-enters the credit market with zero debt.

The value function in case of default is given by:

$$V^D(y, s^g) = u(y^{def}) + \beta \sum_{y', s^{g\prime}, s^{\ell\prime}} \left[(1-\omega)V^D(y', s^{g\prime}) + \omega V_0(0, y', s^{g\prime}, s^{\ell\prime})\right] \Pi(y', s^{g\prime}, s^{\ell\prime}|y, s^g).$$

Besides the temporal autarky, default imposes additional cost in the form of output loss. The specification follows Arellano (2008):

$$y^{def} = \min\Big\{y, \phi E(y)\Big\}, \tag{3}$$

where $\phi < 1$. Mendoza and Yue (2012) develop a theoretical model that explains the rising cost of default with higher output. Furceri and Zdzienicka (2011) also document that the cost of default is an increasing function of endowment.

If government decides to repay the debt, its value function is:

$$V^{ND}(b, y, s^g, s^\ell) = \max_{b'} \left\{ u\Big(y + b - q(b', y, s^\ell)b'\Big) + \beta \sum_{y', s^{g\prime}, s^{\ell\prime}} V_0(b', y', s^{g\prime}, s^{\ell\prime}) \Pi(y', s^{g\prime}, s^{\ell\prime}|y, s^g) \right\}. \tag{4}$$

The government maximizes the utility by choosing an optimal level of debt, b'. The resource constraint is given by the sum of endowment and net borrowing. The debt is bounded below, $b \geq -Z$ to prevent Ponzi schemes, but does not bind in equilibrium.

For a given level of debt, the default set of the government includes the collection of possible endowments, as well as lenders' and government's signals for which the value of default is greater than the value of repayment. Precisely, the default set is given by:

$$\mathcal{D}(b) = \{(y, s^g, s^\ell) \in \mathcal{Y} \times \mathcal{S}^g \times \mathcal{S}^\ell : V^{ND}(b, y, s^g, s^\ell) < V^D(y, s^g)\}. \tag{5}$$

The expected probability of default for a given level of debt is then the weighted sum of default events:

$$\delta(b', y, s^g, s^\ell) = \sum_{y', s^{g\prime}, s^{\ell\prime} \in \mathcal{D}(b')} \Pi(y', s^{g\prime}, s^{\ell\prime} | y, s^g).$$

Lenders receive their own signal and do not observe the signal received by the government. Lenders are risk neutral, act competitively and maximize their profits. They buy the bond today at a price q and expect to receive its face value tomorrow with the probability δ_t^ℓ that government does not default.

$$\pi = -q_t b_{t+1} + \frac{\delta_t^\ell(b_{t+1}, s_t^\ell, y_t)}{1+r} 0 + \frac{(1 - \delta_t^\ell(b_{t+1}, s_t^\ell, y_t))}{1+r} b_{t+1},$$

where $\delta_t^\ell(b_{t+1}, s_t^\ell, y_t)$ is the probability of sovereign default as perceived by the lender. Since lenders do not observe the government's signal and cannot extract information from government's choices, the expected probability of default for a given level of debt perceived by them can differ from that expected by the government.

Lenders' perceived probability of government default, given its signal, is given by:

$$\delta_t^\ell(b_{t+1}, s_t^\ell, y_t) = E\left[\mathbf{1}\left\{(V^{ND}(b, y, s^g, s^\ell) < V^D(y, s^g) \middle| s^\ell)\right\}\right]. \quad (6)$$

Since the market is competitive and the lenders satisfy the zero profit condition, the price function is given by:

$$q(b_{t+1}, s_t^\ell, y_t) = \frac{(1 - \delta_t^\ell(b_{t+1}, s_t^\ell, y_t))}{1+r}.$$

3 Quantitative analysis

The model is solved numerically. This section describes the parametrization and solution method. Then it discusses the main mechanism of the model. It analyzes the behavior of asset policy functions and explains the implications of introducing asymmetric information. To emphasize the distinction between different types of information (uninformative, symmetric and asymmetric) I will add different types of signals step by step and show the contribution of each of them.

3.1 Parametrization

The benchmark model is calibrated for the case of Argentina, so that the results of the model can be compared across several papers (Arellano (2008), Durdu, Nunes, and Sapriza (2013)). I will specifically follow the parametrization used by Arellano (2008) which is equivalent to the extreme case when both government and lenders receive a noisy signal (i.e. $\psi^g = \psi^\ell = 1/\mathcal{S}$).

Each period in the model refers to a quarter. The risk aversion parameter is set to $\sigma = 2$, the value extensively used in the literature. Default penalty, $\phi = 0.969$, is set to generate output loss in Argentina as estimated in Arellano (2008). Discount factor, $\beta = 0.953$, is set to receive 3% probability of default, equal to 3 historical defaults in the last 100 years. Risk-free interest rate, $r = 1.7\%$, is estimated from the US series of 5-year quarterly yield of treasury bonds. The probability of re-entering the credit market after being in autarky is set according to the estimates in Gelos, Sahay and Sandleris (2004).

Table 1: Calibration

Parameter	Notation	Value
Discount factor	β	0.953
Risk free interest rate	r	0.017
Stochastic structure, AR(1) coef.	ρ	0.945
Risk aversion	σ	2
Cost of output during default	ϕ	0.969
Reentry in the credit market	ω	0.282
Signal precision	ψ^g, ψ^ℓ	$\left[\frac{1}{\lvert S \rvert}, 0.9\right]$

The utility function takes the CRRA form:

$$u(c) = \frac{c^{(1-\sigma)}}{1-\sigma}.$$

Table 2: Business Cycle Statistics[6]

	Data	No info	Informed government
$\sigma(c)/\sigma(y)$	1.32	1.10	1.28
$\rho(y,c)$	0.77	0.97	0.89
$\rho(y,nx/y)$	-0.46	-0.25	-0.24
$\rho(y,spread)$	-0.25	-0.21	-0.49

Notes: Data computes the averages across countries for a sample of emerging economies.
Source: Durdu, Nunes, and Sapriza (2013)

For the simulation exercise, I use the discrete state space method. The asset space is discretized in 100 equidistant points. The stochastic process of output is assumed to be the log-normal AR(1) process described in section 2.2. The autocorrelation and standard deviation of output are set to match the moments of Argentina's GDP estimated in Arellano (2008), $\rho = 0.945$ and $\sigma_\varepsilon = 0.025$. The output shock is discretized in 21-state Markov chain points. Since the set of signals and the set of output shocks have the same size, signal sets are also discretized in 21 points for each party. The simulated series are logged and filtered with a linear trend.

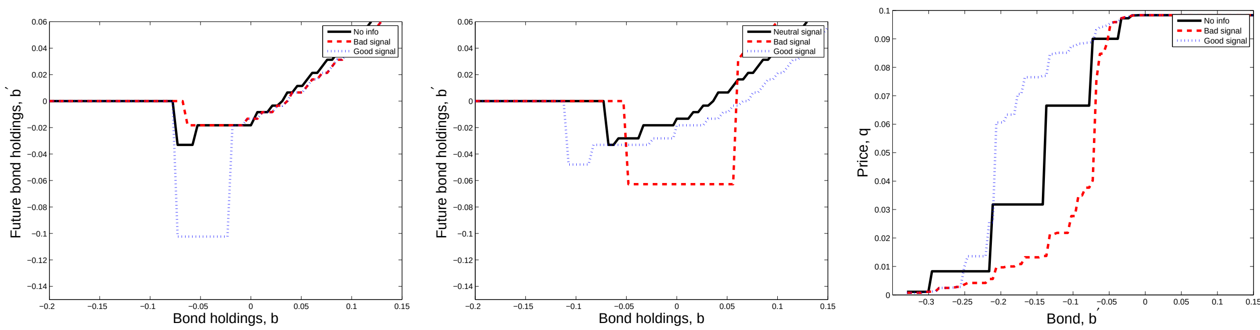
3.2 Results

I start by analyzing the behavior of the benchmark model when adding signal accuracy and information asymmetry, explaining the intuition of the model's mechanism and the expected results.

In the benchmark model, where the signals are uninformative, the asset price depends on the level of new borrowing and current endowment. The government is likelier to default when in higher debt and during bad states. As a result, during recession, debt is expensive and consumption is close to output. This leads to a countercyclical interest rate and trade

[6]The statistics reported in the table are averages of 200 samples of 74 observations before default (the number of periods between defaults in Argentina (Q3.1983-Q4.2001)). The simulated series are logged and filtered with a linear trend.

Figure 3: Price and bond policy functions



(a) Change in lenders' signals (b) Change in government's signals (c) Change in lenders' signals

Notes: Government and lenders receive signals with precision, $\psi^g = 0.7$ and $\psi^l = 0.3$. Good/bad signals indicate that endowment tomorrow will increase/decrease by 2.3%.

balance. Output cost during autarky, exclusion cost and discount factor generate a relatively small level of debt to gdp, 5.95%.

Additional information on the future fundamentals, as in Durdu, Nunes, and Sapriza (2013), can help account for the differences between developed and emerging economies. Symmetric good news about future fundamentals may allow the government to contract a higher level of debt despite lower current endowment. In a similar way, common bad news can trigger default events during good times. As the precision of the signal increases, equivalent to the case of developed countries, trade and interest rates become less countercyclical and the variability of consumption relative to output decreases.

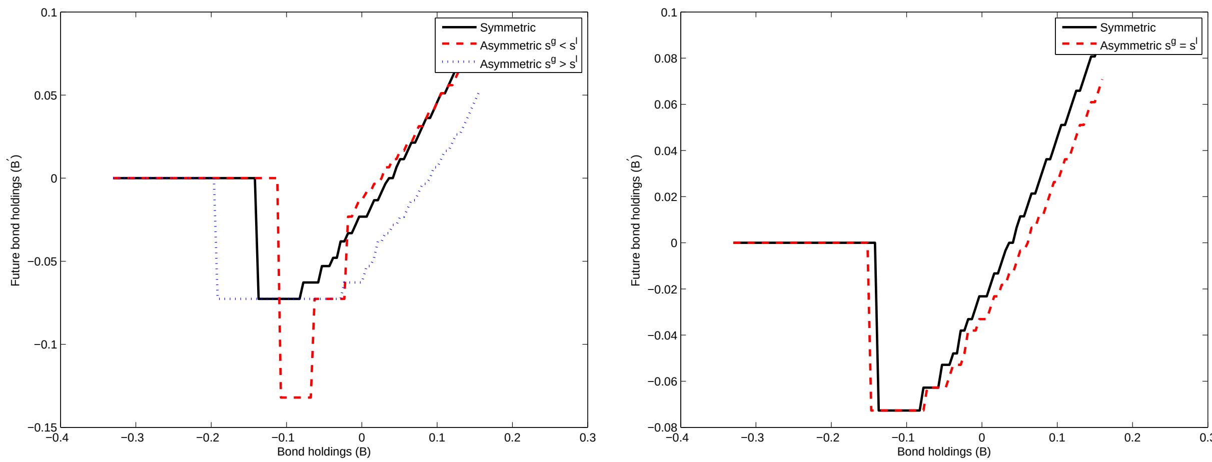
Including the asymmetric information allows the analysis of a new dimension of the model. The model succeeds in matching the empirical finding that less transparent government borrows more. Regardless, lower transparency, as a characteristic of less developed countries, increases the variability of consumption and interest rate spreads, shown in table 2. Furthermore, it generates a higher amount of debt and permits analysis of the frequency of debt crises induced by the market sentiments.

Figure 3 describes the main intuition behind the asymmetric information case. It compares the bond policy functions when agents receive different informative signals with the benchmark model. The black solid line shows the optimal response when information is irrelevant and the debt and default decisions depend solely on the fundamentals. The first panel depicts the optimal government's response to change in lender signal. When lenders receive a signal that tomorrow's endowment will be high, the expected perceived probability of government default decreases. As a result, lenders offer a higher price for the same amount of assets (dotted blue line in figure 3c). A lower cost of borrowing leads to higher optimal debt. A symmetric opposite reaction happens when lenders receive a bad signal. The graph also shows that government tends to save less when it has more precise information. Since the future uncertainty is lower, the precautionary saving motive becomes less dominant. Therefore, government demands less assets compared to the no information case depicted by the solid black line in figure 3a.

Figure 3b compares the bond policy functions when government receives different informative signals. The lenders in this case offer the same price schedule, and the only thing that changes is the government's expectations about the future state. When government receives a good signal, it expects an improvement in output. Governed by the consumption smoothing behavior, it will increase the demand for debt for all current debt holdings. If government receives a bad signal, it defaults for relatively lower current debt holdings but borrows more when it is less constrained. If tomorrow it expects a lower output, government will find it optimal to renege on repaying high amounts of debt. Therefore, today it will also prefer to default and enjoy higher consumption. Once the present wealth increases and government becomes less constrained, it ends up borrowing more in comparison to the neutral signal case. This is due to the consumption smoothing behavior and relatively better price offered by less-informed lenders.

Figure 4 shows that government will borrow more than in the symmetric case even if both agents receive the signals with the same precision. It is important to note that similar precision does not guarantee observing the same signals. Figure 4a compares the bond policy functions when government and lenders receive different signals with similar accuracy. The

Figure 4: Bond policy function under asymmetric and symmetric information



(a) Different signals (b) Same signal

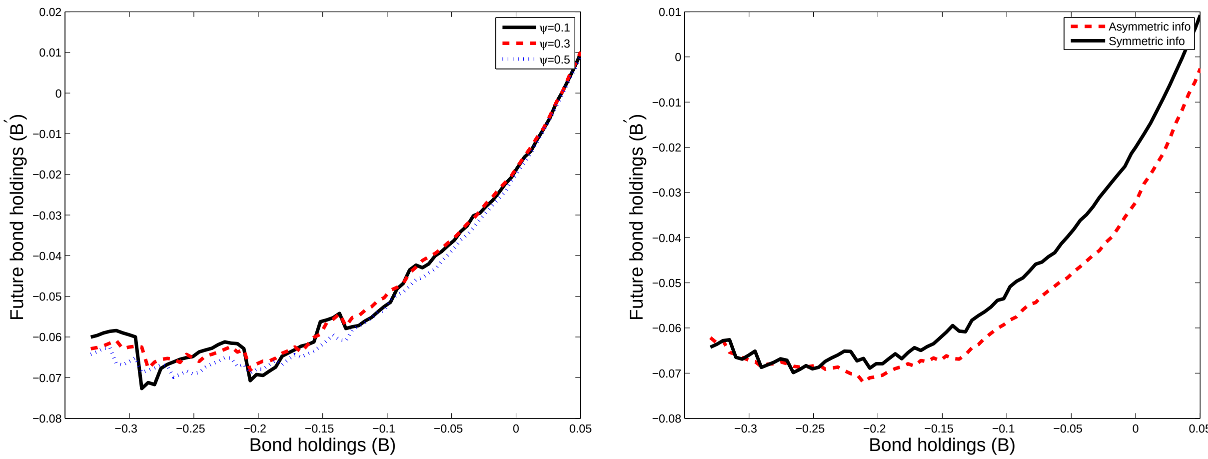
Notes: Government and lenders receive signals with the same precision, $\psi^g = \psi^l = 0.7$. In the left figure, (4a), government under asymmetric information receives a different signal from lenders, while in the right figure, (4b), they receive the same signal.

red dashed line plots the optimal bond holdings when government observes a worse signal than lenders and the blue dotted line plots the results when they receive a better signal than lenders. Since agents observe the signals with the same accuracy, the price schedules offered by lenders in the symmetric and asymmetric information cases coincide. Therefore the pattern is similar to the one observed in figure 3b where government's signal deviates around asymmetric neutral signal.

Figure 4b shows that the optimal level of debt increases even if the observed signal is the same. In the asymmetric information case encountering a similar signal today does not guarantee receiving the same signal tomorrow. As was discussed before, government is, on average, able to sustain a higher level of debt when it has asymmetric information. Therefore, tomorrow government would expect to default on a relatively higher level of debt. Since the value function is increasing in debt it will also borrow more today.

Figure 5 plots the unconditional bond holdings for the cases described above. The future period asset holdings are weighted by the long run probabilities of the output and signal shocks, which causes the non-monotonicity of the policy function. The left panel shows the

Figure 5: Bond policy function and signal precision under asymmetric and symmetric information



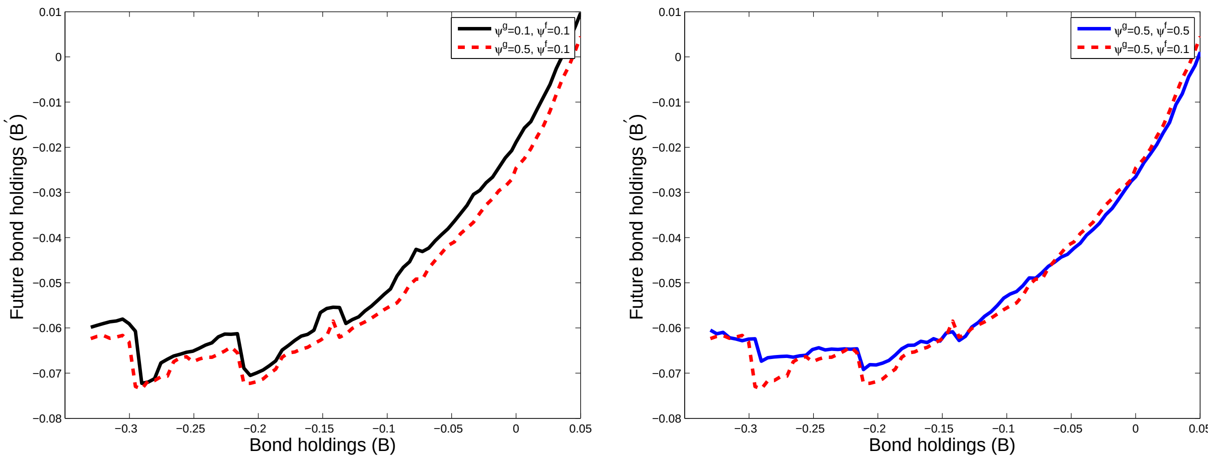
(a) Symmetric information

(b) Symmetric vs Asymmetric

Notes: The figure plots the level of future bond holdings given the current debt/savings for different levels of signals' precision when information is symmetric (left), for the same signals' precision but asymmetric information (center), and for different precision levels under asymmetric information (right). The debt is weighted by the long run probabilities of signal and output shocks.

bond policy functions for various signal precisions when information is symmetric. As it is shown in Durdu, Nunes, and Sapriza (2013), the unconditional average bond holdings increase with information precision. Figure 5b compares the two cases of symmetric and asymmetric information. The black solid line shows the optimal bond holdings when information is symmetric and is commonly known to both government and lenders. The red dashed line plots the case when they receive different signals, although their precision is similar. As was explained above, government ends up borrowing more when it receives a distinct signal from lenders. Given that the chances of observing different signals tomorrow is higher, so is the sustainable level of debt. Therefore government finds it optimal to increase the demand for bonds even when the signals observed today are the same. As a result, under asymmetric information, government's optimal debt holdings are higher than under symmetric information.

Figure 6: Bond policy function and signal accuracy



(a) ψ^g increases

(b) ψ^l increases

Notes: Figure plots the bond policy function when government's signal accuracy increases (left panel) and lenders' signal accuracy catches up (right). The debt is weighted by the long run probabilities of output shocks.

4 Transparency and debt level

The previous section discussed the changes that occur in optimal bond policy functions once government and lenders receive asymmetric information about government's future endowment. This section attempts to answer the question as to how the difference in agents' signal precision, which is equivalent to government's transparency, affect the level of debt and probability of default.

Figure 6 plots the optimal level of asset holdings as a function of current debt (savings) for different levels of signal accuracy. Figure 6a shows the asset policy functions for two values of government signal precision, while lenders are observing a relatively noisy signal. When government has more information than lenders about future endowment, it contracts on average a higher amount of debt. Government is less uncertain about the future output and therefore demands less precautionary savings, shifting the debt policy function downwards.

Figure 6b shows the changes in the asset policy function when the difference in signal accuracy between agents decreases and lenders catch up to the government's signal precision. Diminishing the difference in signals precision shifts the asset policy function up, and government borrows less for the same amount of current debt. As was discussed previously, government demands on average more debt when it observes a different signal from lenders. Given that the probability of receiving a signal similar to government's rises when lenders' signal accuracy increases, optimal debt level diminishes.

However, the changes in government's demand for borrowing are relatively smaller for a lower level of current debt in comparison to the case when it is highly indebted. When government is less constrained, it needs to rollover smaller amounts of debt, and changes in price affect the amount of bonds less. On the other hand, when the government is highly indebted and requires a higher quantity of debt, it reacts much stronger to smaller price changes. The reason is that whenever government observes a different signal from lenders, the former takes advantage of less-informed lenders and borrows more where it needs it the most, or in the risky zones. Therefore, the relative change in the optimal amount of debt when lenders receive a more accurate signal differs for lower and higher amounts of government's current asset holdings.

In the case when government has a high level of debt and both government and lenders better understand the future state, government cannot take advantage of uninformed lenders and defaults more often in comparison to the case when lenders are uninformed. When the latter are less certain about the future outcome they offer a better price in bad times than better-informed ones. Therefore government can sustain a higher level of debt and default less often, which on average drives the borrowing level up.

Table 3 displays the probability of default and the average level of debt as a percentage of output for different levels of government's and lenders' signal precision. As government's information becomes more precise, its level of debt to output ratio increases by more than twice. This is accompanied with substantial rise in default rates. However, as soon as the difference in signal precision between government and lenders shrinks, the level of debt to output ratio also goes down.

Table 3: Debt and Probability of Default Statistics

	$\psi^f = 0.1$	$\psi^f = 0.1$	$\psi^f = 0.1$	$\psi^f = 0.5$
	$\psi^g = 0.1$	$\psi^g = 0.5$	$\psi^g = 0.7$	$\psi^g = 0.7$
Mean debt (% of output)	5.7	12.5	16.7	12.7
Probability of default (%)	3.4	23.1	28.1	23.5

Figure 7 plots the relationship between transparency and the level of debt. I define transparency as the distance between agents' signals precision. When transparency equals one, government and lenders observe the signals with the same accuracy. Lower numbers of transparency show that lenders receive less accurate information about future fundamentals than government. Following this notation, higher numbers mean higher government transparency. Additionally, in this setup another dimension exists - the case where government itself can receive a more accurate signal. In line with the findings in Durdu, Nunes, and Sapriza (2013), I will speak of a government that observes more precise information about future output to be part of the developed economies. It is important to note that, given the same transparency level (i.e agents observe the signals with the same accuracy), there is higher probability that lenders will receive a similar signal if government observes more accurate information. Less developed economies are likelier to hold a larger share in the black economy; therefore official statistics may not always reflect the true state of the economy. As a result, foreign lenders may appeal to their own sources of information and hence, receive a different forecast of a country's economy despite its government being relatively transparent. This is less characteristic for developed economies. Therefore the notion of transparency reflects the difference between signal accuracy rather than non-similarity in observed signals.

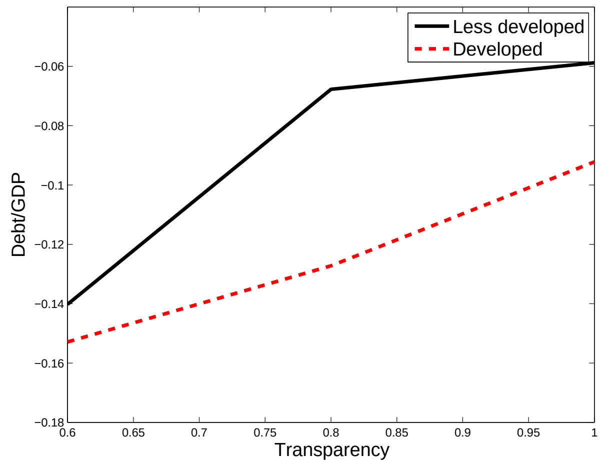
Figure 7 shows that government that is less transparent will contract a higher amount of debt. Once the transparency increases, the average debt drops. This relationship holds for both emerging economies (solid black line) and developed ones (dashed red line). This pattern is in line with the empirical evidence described in section 1.1. When government is less transparent there are several effects taking place. First, more informed government demands less precautionary savings. Second, it can take advantage of a relatively better price and hence borrow more. Signal accuracy plays an especially important role when government has a high level of debt. If government has little borrowings, the changes in asset prices do not alter the average level of debt. It can contract a lower level of debt, but it will not default as the cost of reneging on its obligations is higher. However, when government is on the edge of defaulting the price considerably affects the average level of debt. If lenders receive a good signal, government will be able to borrow more. But, if lenders receive a bad signal, the cost of borrowing becomes too high to continue repaying, driving the average level of debt down considerably. Since the price offered by less-informed lenders observing a bad signal is better than the one offered by the informed ones, government contracts a higher amount of debt when it is less transparent.

Figure 7 also shows that given the same level of transparency, when government observes more accurate information it also contracts higher amount of debt. Figure 1 in the introduction shows that indeed more developed countries are having a higher amount of debt on average for the same transparency index. Countries with better information systems are able to more effectively manage the debt and as a result sustain higher amounts of debt.

5 Market sentiments and debt crises

The dynamics of the economic crises of the last few decades in Mexico, Asia, and Europe have been the focus of the growing literature that is trying to explain the provenience and conditions that generate speculative attacks and economic turmoil. Although they are different in nature, they share several similarities, one being the fact that lack of transparency and contagion gave rise to panic behavior, soaring interest rates, and liquidity problems. This subsection discusses the extent to which information asymmetry gives room for default

Figure 7: Transparency and level of debt



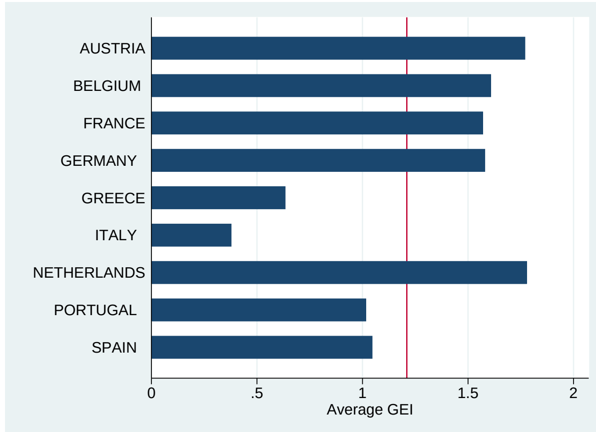
Notes: The figure plots the level of future bond holdings given the current debt/savings for a different level of signal precision when information is symmetric (left), for the same signals precision but asymmetric information (center), and for different precision levels under asymmetric information (right). The debt is weighted by the long run probabilities of output shocks.

events due to bad expectations of lenders despite good fundamentals and positive government forecast.

Several papers show that significant change in sovereign spreads for the Euro zone periphery was disconnected from economic fundamentals. Grauwe and Ji (2013) estimate that although most of the surge in bond spreads (more than 60%) for Greece was due to fundamentals, most of the total variation in spreads for other southern countries was a result of market disbelief. Hence, the share of market sentiments in the variation of spreads was more than one half for Portugal and Ireland and almost equal to one for Spain.

At the same time, the peripheral Euro zone countries registered shortcomings in financial reporting of the public sector and a lack of government transparency. Figure 8 shows that periphery countries register a lower level for the government effectiveness index, which reflects the quality of policy formulation and implementation, as well as the credibility of governmental commitment to such policies, compared to the average across Euro zone economies. In this section I highlight a potential relationship between two and calculate how much government transparency can affect the bond spreads and probability of default, which is caused

Figure 8: Government Effectiveness Index in Euro zone



Notes: The figure plots the average government effectiveness index for Euro zone countries before crisis. Red line is the average across countries. *Source: World Bank*

by factors other than fundamentals.

Following Grauwe and Ji (2013) I estimate the price equation and analyze the quantitative importance of the fundamental variables, which are debt and current output. In order to explain the variation in asset price I compute the average semi-partial correlation for each dependent variable for the sample that has been simulated in section 3.2. The change in price can be explained by fundamentals, government and lenders' signals, and residuals. The relative importance of fundamentals in the variation of spreads explained by the model for different levels of precision is shown in Table 4.

The results indicate that when lenders are less informed the change in spreads due to fundamentals decreases. Hence, when the transparency is lowered more, price will react to factors other than its current output and amount of debt to be repaid. It is important to mention that the share of semipartial correlation of non-fundamental variables in R-squared is close to zero. This rationalizes the fact that countries that register lower government effectiveness could also more often be prone to adverse market sentiments.

Table 4 also shows that less transparent governments are exposed much more often to defaults that are linked to bad market expectations. When lenders receive an erroneous bad

Table 4: Market sentiments

	$\psi^f = 0.1$	$\psi^f = 0.1$	$\psi^f = 0.7$
	$\psi^g = 0.1$	$\psi^g = 0.7$	$\psi^g = 0.7$
Proportion of default due to lenders bad expectations	0.33	0.50	0.28
Variation of spreads due to fundamentals	0.28	0.22	0.49

signal despite current and future output being higher than the trend, government reneges on its debt half of the time.

This suggests that in less transparent economies, lenders are more likely to misprice risk and induce countries in relatively better shape to default, such as Spain or Italy. This increases the risk for markets to push them into a bad equilibrium, which could be avoided by implementing policies aiming to reduce government inefficiency and increase public and private sector transparency.

Conclusion

Lower transparency and higher levels of debt go hand in hand for all the income group economies despite the belief that less transparent countries should be readily punished by credit markets by being charged higher borrowing costs and not being able to borrow as much. In this paper I develop a model demonstrating why governments with information superiority over lenders borrow more on average. For this purpose, I build a model of endogenous sovereign default where government and lenders receive a different quality of information about future fundamentals. The information is relevant for decision making, due to its effect on the asset prices and, ultimately, the level of contracted debt.

The quantitative results show that when government holds more precise information regarding future fundamentals than lenders, it retains higher levels of debt on average. The main reason for this is that less transparent governments borrow more since they have the ability to raise money when they need it the most. When government is less constrained financially, it does not react considerably to changes in price level due to better information. However, if information on bad realizations tomorrow becomes accurate when lenders are overindebted, even the slightest movement in price can trigger a default. Therefore, government will borrow more on average if lenders have less accurate information.

Additionally, the model shows that less transparent economies are also more prone to suffer from mispriced risk, which can lead to default despite good current and future fundamentals. A less transparent government will default twice as much in comparison to transparent one.

The model is also able to generate business cycle moments closer to the values observed in the data for emerging markets, particularly related to less consumption smoothing and higher correlation between output and spreads.

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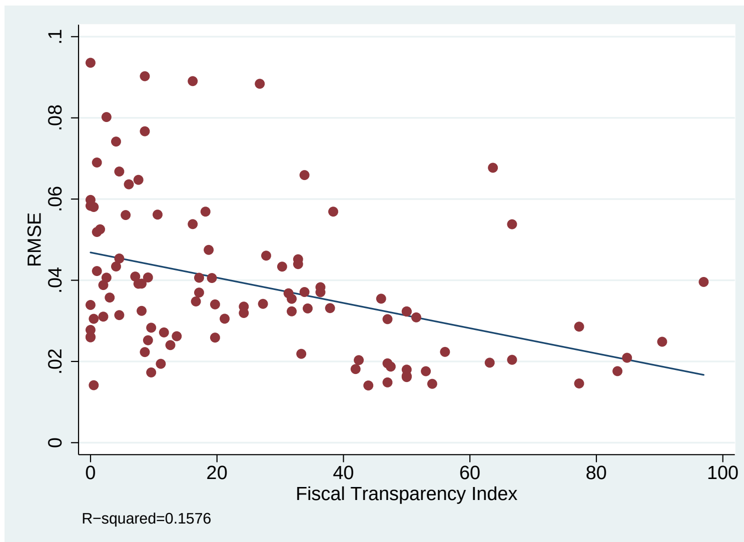
Appendices

A

Figure 9: RMSE of GDP per capita growth rate and Fiscal Transparency Index



Source: Fiscal Transparency Index is taken from Wang, Irwin, and Murara (2015)

Figure 10: RMSE of GDP per capita growth rate and GDP per capita (logs)

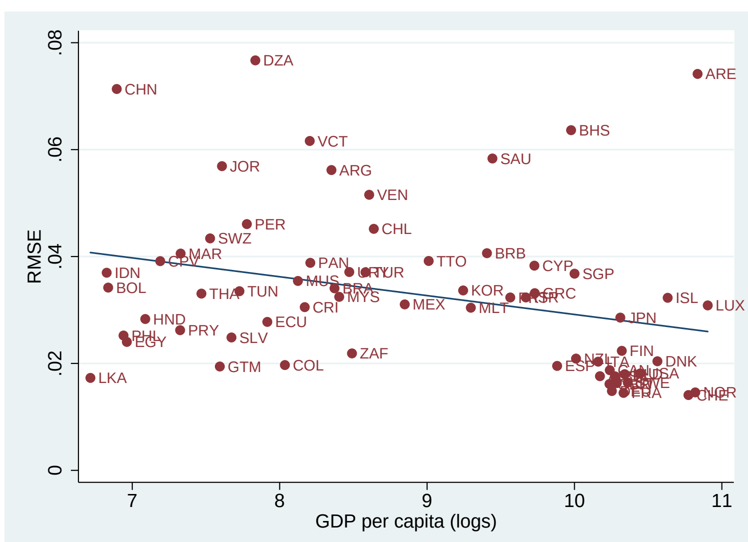
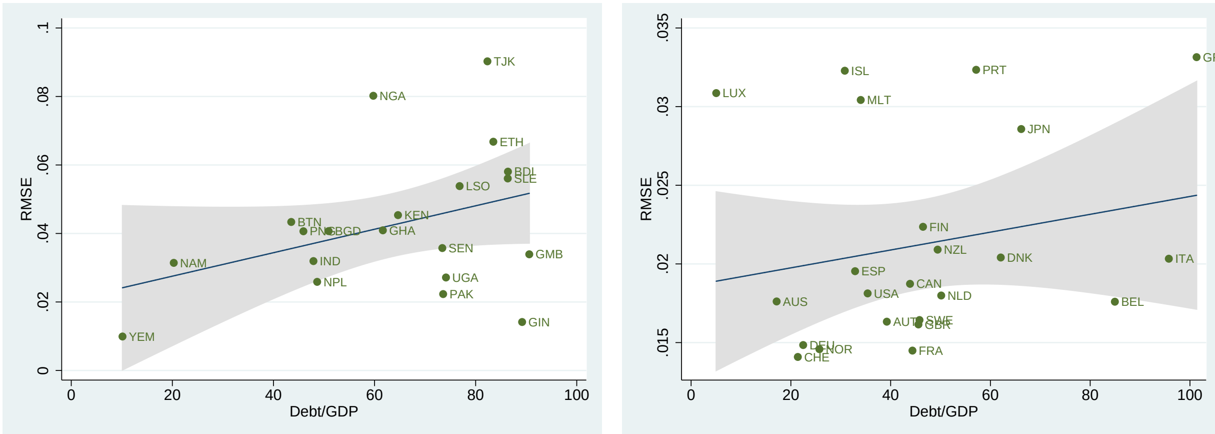


Figure 11: RMSE and Debt/GDP



(a) Low income countries

(b) High income countries

B RMSE data

Table 5: Summary of RMSE for different groups of countries by income

income group	**Mean RMSE**	**Stdev RMSE**
Low	0.050	0.022
Middle	0.046	0.023
High	0.021	0.006

C Joint distribution of endowment and signal shocks

Below I provide the expression for the Markov chain for the joint evolution of the endowment shock and the signals. The government's information set at time t is $\Omega = \{y_1, s_1^g, s_1^f, y_2, ..., s_t^f\}$. The probability of receiving signals s_{t+1}^g and s_{t+1}^f are conditionally independent given the information at time t, $\Pr(s^g_{t+1}|\Omega_t) \perp \Pr(s^f_{t+1}|\Omega_t)$.

$$p(s^g_{t+1} = i, s^\ell_{t+1} = j, y_{t+1} = k | s^g_t = m, y_t = n) = \frac{p(s^g_{t+1} = i, s^\ell_{t+1} = j, y_{t+1} = k, s^g_t = m, y_t = n)}{p(s^g_t = m, y_t = n)} =$$

$$= \frac{p(s^g_{t+1} = i, s^\ell_{t+1} = j | y_{t+1} = k, y_t = n, s^g_t = m) p(y_{t+1} = k | y_t = n, s^g_t = m) p(y_t = n, s^g_t = m)}{p(y_t = n, s^g_t = m)} =$$

$$= p(s^g_{t+1} = i, s^\ell_{t+1} = j | y_{t+1} = k, y_t = n, s^g_t = m) p(y_{t+1} = k | y_t = n, s^g_t = m);$$

$$p(s^g_{t+1} = i, s^\ell_{t+1} = j | y_{t+1} = k, y_t = n, s^g_t = m) =$$

$$= p(s^g_{t+1} = i | y_{t+1} = k, y_t = n, s^g_t = m) p(s^\ell_{t+1} = j | y_{t+1} = k, y_t = n, s^g_t = m) =$$

$$= p(s^g_{t+1} = i | y_{t+1} = k) p(s^\ell_{t+1} = j | y_{t+1} = k);$$

$$p(y_{t+1} = k | y_t = n, s^g_t = m) = \frac{p(y_{t+1} = k, y_t = n, s^g_t = m)}{p(y_t = n, s^g_t = m)} =$$

$$= \frac{p(s^g_t = m | y_{t+1} = k, y_t = n) p(y_{t+1} = k | y_t = n) p(y_t = n)}{p(s^g_t = m | y_t = n) p(y_t = n)} =$$

$$= \frac{p(s^g_t = m | y_{t+1} = k) p(y_{t+1} = k | y_t = n)}{\sum_f p(s^g_t = m | y_{t+1} = f) p(y_{t+1} = f | y_t = n)};$$

$$p(s^g_{t+1} = i, s^\ell_{t+1} = j, y_{t+1} = k | s^g_t = m, y_t = n) =$$

$$= \sum_f p(s^g_{t+1} = i | y_{t+2} = f) p(y_{t+2} = f | y_{t+1} = k) \sum_r p(s^\ell_{t+1} = j | y_{t+2} = r) p(y_{t+2} = r | y_{t+1} = k) \times$$

$$\times\, p(y_{t+1} = k | y_t = n, s^g_t = m).$$

$i, m \in \mathcal{S}^{\mathcal{G}}$, $j \in \mathcal{S}^\ell$ and $k, n, f, r \in \mathcal{Y}$