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Sovereign Default and Asymmetric Market Information

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T Í T U L O D E L A T E S I S

Sovereign Default and Asymmetric Market Information

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Sovereign Default and Asymmetric Information

Olga Croitorov

мамишке и папишке

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Foreword

It is not a novelty that emerging market economies are prone to poor institutions, additional layers of uncertainty and lack of transparency. There is quite a significant body of literature that shows the negative effects due to lack of transparency. Among others, Gelos and Wei (2005) provide evidence that less transparent countries receive less investment and that during crisis they are more likely to experience high capital outflows.[1] Marques, Gelos, and Melgar (2013) document that more opaque countries suffer more from financial globalization.

Several economic crises have been partially worsened by lack of transparency. For instance, in the recent Asian crisis, Thai government has been accused of allowing an extremely opaque financial sector to flourish. It is considered to be one of the key elements that triggered the financial turmoil in 1997. The 2008-2009 debt crisis has shown that, eventually, no country is shielded from high interest rate spreads, unsustainable debt and lack of transparency. Even developed countries like Spain and Greece have been undermined by revealed hidden debts, economic uncertainty and respectively unaffordable borrowing costs.[2] The lack of transparency practiced by a range of countries is puzzling.

In present work, I study the implications of information asymmetry, that appears between government and lenders, on economic outcomes and analyze the conditions when governments prefer to be less transparent about their states of economy. In particular, the thesis focuses on the joint dynamics of asymmetric information between market participants

[1] See Gande and Parsley (2014), Bernoth and Wolff (2008), Gavazza and Lizzeri (2009), Alt, Lassen, and Rose (2006), etc, for different aspects of economy that can be affected by lack of transparency.

[2] In March 2011 Spanish local governments revealed the accumulated debts which haven't been shown previously.

and sovereign debt and default.

In part I, “Sovereign Debt and asymmetric market information", I show that in an environment when government is less uncertain about the future state of the economy than lenders are, the former ends up borrowing higher amount of debt and defaults more often. I start with bringing some evidence that shows a positive correlation between the debt to GDP level and future economic uncertainty (proxied by root mean square of GDP growth forecast errors) for different countries. Then, I extend the recent quantitative models of sovereign default by allowing asymmetry in information between the government and foreign lenders. The key ingredients are the information about future endowment and its accuracy which are received by market participants. The obtained results can be explained by the fact that in an environment when lenders observe more accurate information, the gains for the government when lenders observe good news are less than costs that are coming from lenders observing bad news. Therefore, on average, government ends up borrowing more when lenders are less informed about future endowment and offer a relatively better price. Chapter 1 focuses on the mechanism of the model and explains how the information precision affects the level of demanded debt. In chapter 2, I simulate a small open economy and compare the results to the existing literature of endogenous sovereign default.

In part II, “Optimal Transparency", I study the economic conditions when government prefers to be less transparent about its state of economy. For this purpose, I develop a dynamic model of endogenous sovereign default with private information where both government and lenders act strategically and can update their beliefs upon observing government's actions. I find that a government prefers to be opaque when it is overindebted, expects a more severe crisis, but with a lower probability. The first two results are intuitive. A government that has high current debt or expects that recession is going to be more pronounced depends more on the external resources to finance its consumption. Therefore, a government that is experiencing a boom prefers to bear the cost of lower asset price so that it can enjoy a higher consumption if, eventually, a crisis comes.

Additionally, I show that government prefers to be less transparent when it is more likely to have better times; and commits to disclose fully its state when it expects more likely to have bad times. If the probability of an upcoming crisis is very high, uninformed lenders increase the costs of borrowing. As a result, the optimal amount of debt under null transparency is close to the level that government in a crisis can borrow even if it reveals its state. Hence, government prefers to be fully transparent and enjoy higher consumption if it ends up in a good state during high probability of a crisis. If a recession is less likely, the price offered by lenders increases, the amount of debt that a non-transparent government can borrow is higher and as a result, benefits from being opaque also rise.

Chapter 4 suggest some potential areas for future research.

Part I

Sovereign debt and asymmetric market information

Introduction

Reinhart and Rogoff (2009) wrote in their book *This time is different* that *"..., one would think a strong case could be made for less profligate governments to open up their books more readily and be rewarded for doing so by lower interest rates. This transparency, in turn, would put pressure on weak borrowers. Yet today even United States runs an extraordinarily opaque accounting system..."*. The lack of transparency exhibited by so many governments is puzzling.

In the first two chapters, I show that difference in quality of information that market participants have, can lead to higher amount of borrowing and, consequently, higher probability of default. For this purpose, I build a model of small open economy with endogenous sovereign default and allow agents to receive signals about future fundamentals with different accuracy. The information regarding macroeconomic fundamentals available to public is relevant for decision making. It acts through expectations of future economic outcomes, affects the interest rates and, ultimately, the level of contracted debt and decision to default.

It is a standard paradigm that, during good times, government wants to reveal all the information to take advantage of better offers and vice-versa when it expects bad times. In this part, I abstract, however, from government making any choice regarding the amount of information to reveal and concentrate only on the explaining the mechanism of the model when government is more informed than lenders. I extend this model by allowing government to choose the level of optimal transparency in chapter 3.

I first bring some evidence of behavior of debt and uncertainty regarding the future fundamentals. I document a positive relationship between root mean square (RMSE) of GDP growth forecasting errors and the debt to GDP level for different countries. RMSE may be thought as an indicator of future economic uncertainty, which is characteristic to countries that lack transparency. Thus, the countries that register a lower transparency on average borrow more.

When government observes better information in comparison to lenders, there are two mechanisms at play. Firstly, once government knows better the future output, it demands less precautionary savings and therefore borrows more. Secondly, less informed lenders, due to higher uncertainty they face, offer a relatively better price when government expects bad output.

The same time, less informed lenders offer a relatively lower price in good times, decreasing the demand for debt. However, since government is better informed about its future state and expects good times to be more likely, due to consumption smoothing it will be willing to borrow more. Therefore, due to lenders lack of information, the amount of debt it expects to borrow when it is in bad times is higher than the amount of debt that government foregoes when it expects to be in good times. Especially, the effect is stronger when government is overindebted.

Government that expects higher output will respond less to an increase in the price when lenders observe more accurate information. Conducted by consumption smoothing behaviour, government was borrowing an already high level of debt. But, will drop significantly the borrowing level, or even default when lenders observe an accurate bad signal and offer a slightly high credit cost. So, the gains from observing good signals increase less than the costs that are coming from lenders observing bad signals.

The model is an extension of vast 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. Several other papers came with different assumption to account for relatively low level of debt generated by the model and other facts left unexplained. Lizarazo (2011) relaxed the assumption of neutral lenders receiving a combination of higher level of debt in equilibrium and higher and more volatile spreads. Mendoza and Yue (2012) construct a general equilibrium model with endogenous output cost along with endogenous default rate. Our paper extends this literature by introducing private information and looks at its implication on the behaviour of sovereign debt and default rates of a country.

Durdu, Nunes, and Sapriza (2013) build a similar set-up to account for the fact that sovereign default happens not only in bad times, a fact empirically found by Tomz and Wright (2007). In contrast to their model I assume that economy receives signals that are not publicly available to all the agents.

In addition, by introducing the asymmetric information, the model is able to generate some business cycle statistics that are more closer to the one observed in the data for emerging markets, in particular less consumption smoothing and more pronounced negative correlation between output and interest rate spreads.

In allowing for the fact of lack of full information between government and lenders, the model connects to several studies that find the former to be a key determinant in fluctuations of sovereign spreads. Catao, Fostel, and Ranciere (2012) introduce the “fiscal discoveries" in a three-period model to explain the decouplings in cross-country bond yields after prolonged periods of convergence. Alfaro and Kanczuk (2005) focuses on the lenders inability to distinguish between borrowers characteristics and preferences to match the fact that countries with histories of default are charged higher interest rates than countries with no repayment difficulties. In these papers investors learn from the country’s action, updating their beliefs about future types of borrowers and re-pricing of sovereign bonds along the way. In order to match the empirical facts they exploit the use of additional assumption as higher costs of default, and very low discount factors, etc. I abstract from the signal extraction problem as it is beyond the scope of this model. The present work adds to this strand of literature by assessing the effect of precision of future fundamentals on contracted level of debt and probability of default.

Calvo and Mendoza (2000) argue that globalization may promote contagion by weakening incentives for gathering costly information about 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 assume that investors receive an external signal regarding future fundamentals which may be more or less precise, mimicking the investors herding behaviour.

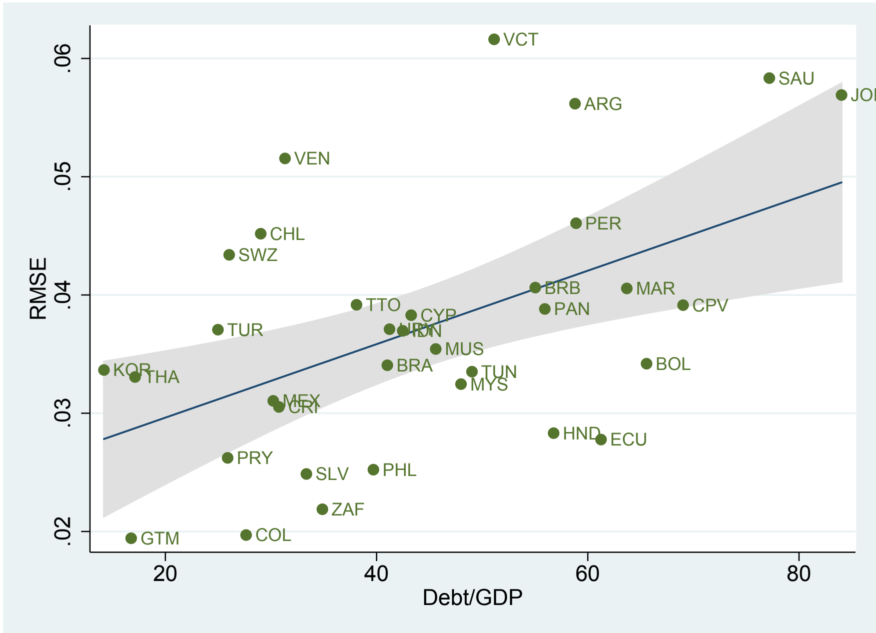
I calibrate the model of Arellano (2008), that is a particular case of the model, when parties have no information regarding future output. Then, I consider cases where government and lenders receive signals about future output with different levels of precision. I find that when government's signal becomes more informative relative to the lenders' one, the level of contracted debt almost triples in comparison to the no-signal economy. In addition, the business cycle moments for the case when lenders observe worse quality information than government about latter's fundamentals, are much closer to the values observed in the data for emerging markets. The variation of the consumption is higher (1.23) and the correlation between output and interest rate spread is negative (-0.39). Hence, transparency and asymmetry of information between lenders and governments may play an important role in explaining the differences between emerging and developed countries.

0.1 Motivating Evidence

Further, I provide some evidence as to whether difference in uncertainty regarding future fundamentals is related to different levels of debt. For this purpose, I compute the standard deviations of the forecast errors of GDP per capita growth and compute the correlation between 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

Figure 1: RMSE and Deb/GDP ratio for middle income countries



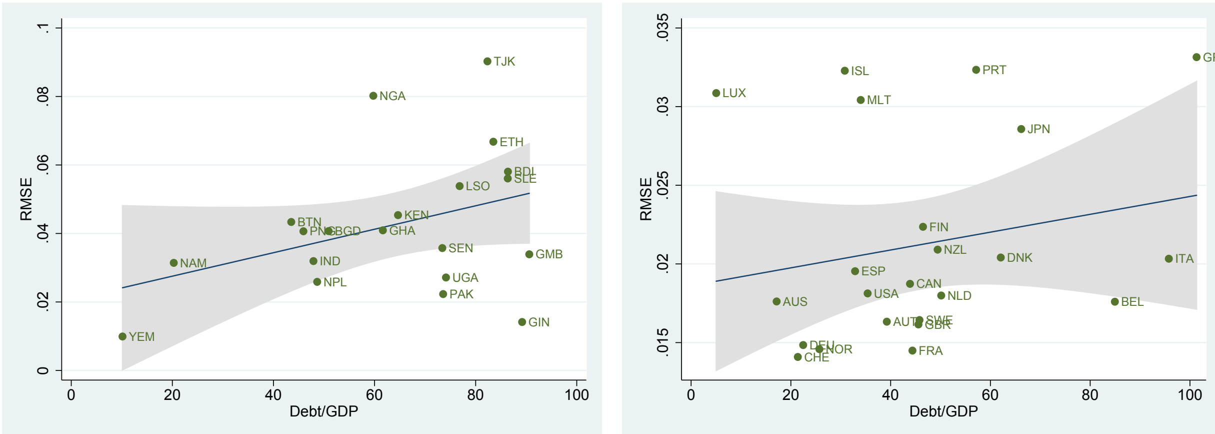
error is given by:

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

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 the appendix A3. Higher root mean square error (RMSE) shows a higher uncertainty regarding forecast 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 4, shown in the appendix, displays a negative relationship which says that more developed countries show a lower uncertainty in the economic forecasts. The simple ARIMA estimation yields a standard deviation of forecast errors 98% higher for Latin American countries in comparison to high income countries. This is consistent with the findings in Timmermann (2007) regarding the World Economic Forecast reported by IMF. He documents that the average standard deviations of forecast errors of GDP growth for advanced economies is 1.35 while for developing Asia and for

Figure 2: RMSE and Debt/GDP



(a) Low income countries

(b) High income countries

Western hemisphere are 2.22 and 2.41 respectively. One of the reasons of having higher uncertainty is the lower transparency characteristic for emerging and developing countries.

Next, I present the evidence regarding the relationship that exists between uncertainty about future fundamentals, namely, RMSE of gdp per capita growth and the debt to gdp ratio. In figure 1, I plot the RMSE and debt to GDP ratios for middle income economies as defined by the World Bank[3]. There is a clear evidence that, whenever countries have higher RMSE of GDP per capita growth forecast, they also register higher levels of debt. This graph does not have the final aim at figuring out the causality relationship, but rather to show the correlation that exists between these 2 variables. It can be the case that higher level of debt brings with it higher uncertainty as the country's position maybe more vulnerable when it is overindebted. However, it also maybe the case that governments are able to rollover higher amounts of debt as a result of lower transparency that can be one of the reasons of registering higher uncertainty. The intuition behind is the following. Less transparent country can more easily hide the expected bad stand tomorrow and therefore take advantage of relatively better price debt. As a result, it is able to accumulate and sustain higher amount of debt.

A similar pattern can be observed for the other two income groups, low and high income

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

countries. Groups are differentiated by gross national income per capita as it is specified by World Bank. In figure 2 can be seen the positive relationship between forecast error standard deviation and the level of debt for high and low income groups.

In what follows, I will develop a model that is able to generate higher levels of debt for the cases when foreign lenders have less accurate information regarding future country's fundamentals.

The structure of the rest of the part I is the following. In chapter 1, I set up a two period building block model to explain the main mechanism. In chapter 2, I extend it to an infinite horizon model by describing the environment and its key elements. In section 2.2, I simulate a small open economy and discuss the main results of the paper.

Chapter 1

Sovereign debt and asymmetric market information: Mechanism

1.1 Two-period building block model

This chapter lies down a two-period model with endogenous sovereign default. Consider an environment where the time is discrete, $t = 1, 2$. There is a small open economy with a representative household, government and foreign lenders. Household is maximising the stream of consumption over two periods which is composed from a stochastic endowment and a government transfer. The government smooths household's consumption by trading one-period non contingent bonds in a credit market. The gains/losses are passed to the household in form of the lump sum transfers. There is a large number of identical risk neutral foreign creditors which will lend any amount needed for a given price function.

Economy receives an initial endowment, $y^l < y_0 < y^h$; and $y \in (y^h, y^l)$ in the second period, drawn by nature with probability $\Pr(y^l) = \lambda$. In addition, in the first period, foreign lenders (f) and domestic government (g) receive each a signal $s^i \in \{s^{i,h}, s^{i,l}\}$, $\forall i \in \{g, f\}$ regarding the realization of the next period endowment. The signals received by the agents may not coincide. The probability of receiving a particular endowment given the signal is specified below.

By comparing the net benefits of the two options, the government chooses whether to repay or default. If it defaults it is not allowed to participate in the credit market further on. In case it decides to repay, it chooses the amount of optimal debt to contract for a given price schedule. Then, the consumption takes place and the next period follows. The price schedule depends on the level of debt and the probability of the government not repaying it in the next period, as perceived by the foreign lenders. Once the government participates in the credit market, it observes the signal received by the lenders through the offered price. In this set-up I abstract from any learning and updating of the lenders' beliefs after observing the contracted debt.[1] Hence, while government is able to learn the lenders' signal from the price schedule they offer, the latter are rationally bounded and are unable to extract any information from government's actions. This assumption is supported by the findings in Romer and Romer (2000) and Reinhart and Rogoff (2011) that argue that even more developed countries have better information due to among other reasons their desire of hiding the weaknesses in financial systems, vast resources they devote to forecasting and are not available to general public, etc.

At the beginning of the second period, nature draws the endowment. There is no credit market in this period, i.e the government does not contract any new debt. However it has to decide whether to repay the debt contracted in the previous period. In order to make government's repayment decision viable, I assume an exogenous continuation value that is higher in the repayment state. Given that this is the final period of the economy and there is no credit market, I assume that the signals regarding future states are irrelevant. I relax this assumption and increase the state space in the next chapter, where I set up an infinite horizon model. In order to keep things simple I abstract from it in this chapter.

[1] I will develop a model that relaxes this assumption in chapter 3.

1.1.1 Household

Household's preferences are given by the utility function:

$$U = u(c_1) + \beta E_t u(c_2),$$

where c_t is the current consumption and $\beta \in (0, 1]$ is the discount factor. Utility function is strictly increasing, weakly concave and twice differentiable.

The household does not participate in the credit market, instead receives an amount of transfers from the government in a lump-sum fashion. For numerical part I assume a log utility function $u(c) = log(c)$.

1.1.2 Government

Government's objective is to maximize households' utility function. It smooths the consumption by borrowing in the foreign credit market at a price $q(b_{t+1}, s^f)$. It transfers all the proceeds to consumers. Financial markets are incomplete since the government trades only one period, non contingent bonds, b. Sovereign debt is not enforceable, therefore at the beginning of each period government decides whether to default or not. The decision comes from comparing the benefits from the two states. The default decision has a cost in the form of a lower endowment and a lower future value function. This mimics the fact that, during default episodes, a country might be excluded from financial market that causes disruption in the private sector's access to credit and therefore, reduces output. Mendoza and Yue (2012) provide a theoretical model that explains such a loss in output during default. In addition, if the government abstains from repaying the outstanding debt it can no longer trade in the credit market.

Emerging economy's resource constraint when the government decides to continue the repayment is:

$$c_t = y_t - b_t + q(b_{t+1}, s^f)b_{t+1},$$

and when it decides to default:

$$c_t = y^{def},$$

where $y^{def} < \min\{y, E(y)\}$. The government optimization problem can be written in a recursive dynamic form. Given the state variables (y, s^g, s^f, b), the value function when government has access to international market is $V(y, s^g, s^f, b)$. Every period it decides whether to default or not by comparing the two options:

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

where V^D and V^{ND} are the values if the government defaults and, respectively does not. The value functions are defined below. I solve the problem using backward induction.

Backward induction: period $t = 2$

In period 2, the government observes the endowment and decides whether to default and consume the current endowment, or to continue the repayment and consume the leftover after clearing the debt. I abstract from any signal in period two, therefore, the only state variables are the endowment, y and debt, b if the government repays. Government's *continuation values* in each of the states are denoted by V^D_{fut} and V^{ND}_{fut}.

If the government defaults it consumes the output less the penalty cost, y^{def}, and the value of defaulting is given by:

$$V^D_2(y_2) = \log y^{def} + \beta V^D_{fut},$$

If the government does not default, the value of not defaulting is the sum between the utility from consuming the endowment less the debt and the discounted continuation value of repayment:

$$V_2^{ND}(y_2, b_2) = \log(y_2 - b_2) + \beta V_{fut}^{ND}.$$

The optimal default decision of the government is characterized by the comparison of the two values. The functional form of government's default decision is given by:

$$D(b_2) = \begin{cases} 1, & V_2^D(y_2) > V_2^{ND}(y_2, b_2), \\ 0, & otw. \end{cases}$$

After some manipulation I can formulate the probability of default, $\delta(b_2)$, on a given level of debt b_2:

$$\delta(b_2) = \begin{cases} 1, & b_2 > \frac{y^h\Delta - y^{def}}{\Delta}, \\ 0, & b_2 \leq \frac{y^l\Delta - y^{def}}{\Delta}, \\ \Pr(y_2 = y^l) = \lambda, & \frac{y^l\Delta - y^{def}}{\Delta} < b_2 \leq \frac{y^h\Delta - y^{def}}{\Delta} \end{cases} \tag{1.1}$$

where Δ is the discounted cost of government being deprived of participating in the credit market, $\log(\Delta) = \beta(V_{fut}^{ND} - V_{fut}^{D})$.

In the setting of a two period model with two states of the economy, the government has the option to choose between three levels of debt. If it chooses to borrow an amount smaller than the maximum one that it is able to repay in bad times, $b^L = \frac{y^l\Delta - y^{def}}{\Delta}$, it defaults with probability $\Pr = 0$. If it chooses an amount of debt higher than the maximum it can repay in good times, $b^H = \frac{y^h\Delta - y^{def}}{\Delta}$, it defaults with probability $\Pr = 1$. If it chooses any amount between these two values it defaults with probability of receiving a low endowment. Clearly, choosing a level of debt higher than it can repay in good times will never be an equilibrium.

Period $t = 1$

At the beginning of period t=1, government observes the current endowment and the signal regarding future state. Given the initial amount of debt it decides whether to default and consume the output, y^{def} in both periods or repay and keep having the access to the available resources in the credit market.

When the government chooses to repay, it forms the expectations about the future realization of endowment conditional on the signal it receives and decides upon the level of debt subject to resource constraint. The signal has a predictive character. Higher is the probability that the government receives today a signal about the true realization tomorrow, more informative is the received signal.

For simplicity I assume that the set of states has the same length as the set of signals. High signal precision means that probability of receiving a low signal given that nature draws a low realization of the output tomorrow, $\Pr(s_1^l|y_2^l)$, is close to one. For simplicity, I assume that the probability of signal's precision is symmetric, $\Pr(s_1^h|y_2^h) = \Pr(s_1^l|y_2^l) = \psi$. Respectively, $\Pr(s_1^h|y_2^l) = \Pr(s_1^l|y_2^h) = 1 - \psi$.

Probability of receiving a particular endowment given a signal is given by the Bayesian formula. Equation 1.2 shows the probability of receiving high output tomorrow conditional on receiving high signal today.

$$\Pr(y_2 = y_2^h|s^{g,h}) = \frac{\psi^g(1-\lambda)}{\psi^g(1-\lambda) + (1-\psi^g)\lambda}, \tag{1.2}$$

Given the states y_1, b_1, s^g, and the asset price function, $q_1(b_2, s^f)$, government maximizes the problem (1.3) in the first period.

$$V_1(y_1, s^g, s^f, b_1) \quad = \max\{V_1^{ND}(y_1, s^g, s^f, b_1,), V_1^D(y_1, s^g)\}, \tag{1.3}$$

where the value of not defaulting is:

$$\begin{aligned} V_1^{ND}(y_1, s^g, s^f, b_1) = \quad & \max_{b_2} \quad \log c_1 + \beta[\Pr(y_2^l|s_1^g)V_2(y_2^l, b_2) + (1 - \Pr(y_2^l|s_1^g))V_2(y_2^h, b_2)], \\ & \text{s.t.} \quad c_1 = y_1 - b_1 + q_1(b_2, s^f)b_2. \end{aligned}$$

The value of government deciding to renege on its obligations is given by:

$$V_1^D(y_1) = \log y^{def} + \beta V_2^D. \tag{1.4}$$

The optimal level of debt is a function of the signals received by the agents, s^f and s^g. Hence, the signals received today affect the expected probability of default and, therefore, the asset price. The asset price function, $q_1(b_2, s^f)$ will be discussed below.

1.1.3 Foreign lenders

Lenders are risk neutral and will lend any amount needed at a risk free rate. Lenders are operating in a competitive market, therefore their profit satisfy zero profit condition:

$$0 = -qb_2 + \frac{\delta^f(b_2, s^f)}{1+r}0 + \frac{(1-\delta^f(b_2, s^f))}{1+r}b_2, \tag{1.5}$$

δ^f is the probability of the government not honouring its debt as perceived by lenders. The signal received by lenders may differ from the government's one, since lenders are assumed to not being able to update the information set from government's choice of debt. Therefore government's probability of default, as perceived by lenders, depends only on their own signal about future government's state. This assumption is based on the fact that often official data is little reliable and government hides the weaknesses in financial systems as it is documented by Reinhart and Rogoff (2011). Another explanation, provided by Romer and Romer (2000), is that government may posses information about the state of the economy that is not known to the large public due to the vast resources that the former devotes to forecasting.

The first term shows that the lenders buy the discount bond issued by the government at a price q. Next period, the foreign lenders receive the face value of the bond with probability of repayment, $1 - \delta^f(b_2, s^f)$.

Probability of receiving high endowment conditional on the observed signal is given by

Bayesian formula that has exactly the same form as eq (1.2). The bond price functions is then equal to:

$$q(b_2, s^f) = \frac{1 - \delta^f(b_2, s^f)}{1 + r} \tag{1.6}$$

1.1.4 Qualitative analysis

This section aims to explain the intuition of the model's mechanism and expected results. As a benchmark model I take the one where the signal is symmetric and non-informative. This is the simplified version of the model described in Arellano (2008). Step-by-step, I will be adding signal accuracy and information asymmetry to show the contribution of each ingredient to the model's behaviour.

For this purpose, I solve the model numerically. The exercise is done in order to show the qualitative behaviour of the model, therefore the economy have not been parametrized for any particular country. The parameters of the model used for the analysis are displayed in Table 2.1. The endowment in good state is normalized to 1. The endowment in bad state is set to 0.4 and the output in the first period is the mean of endowments received in good and bad states. The discount factor is $\beta = 0.96$ and the risk free rate is set to be equal to $1/\beta = 1 + r$. Cost of default, y^{def} and δ are 0.5 and 2.5. Output in autarky is chosen so that it is lower than average expected endowment, but higher than the endowment in bad state. Alternative values for default cost will change the result quantitatively, but will not alter the mechanism. Higher value of default cost will shift the level of initial debt for which government will default, but will not affect considerably the general shape of debt policy function. To complete the parametrization, I assume that probability of receiving low endowment is equal to $\lambda = 0.3$. Later I provide results for a different parametrization of λ to check for the robustness of the results.

Figure 1.1 plots the equilibrium asset holdings given the initial level of debt in the case when signals are not informative for both parties, $\psi = 0.5$. Given the state variables,

Parameter	Notation	Value
Discount factor	β	0.96
Risk free interest rate	r	0.04
High level of endowment	y^h	1
Low level of endowment	y^l	0.4
Initial output	y_1	0.7
Output in autarky	y^{def}	0.5
Default penalty	δ	2.5
Prob of low state	λ	0.3

Table 1.1: Calibration

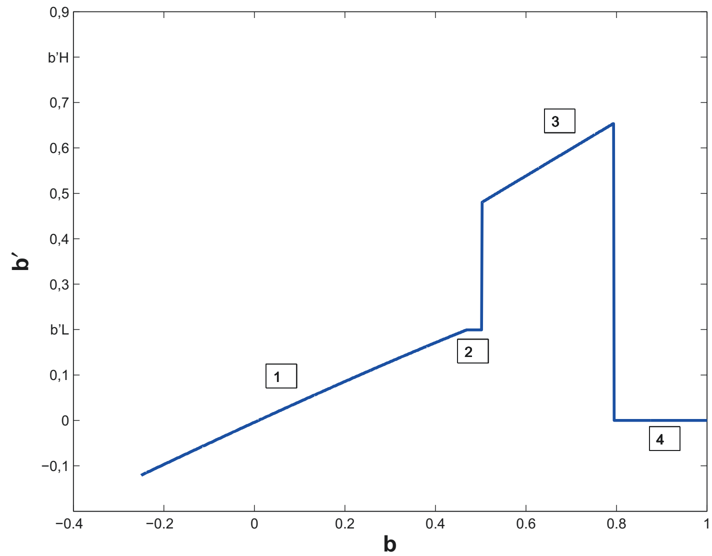
government can end up choosing the level of debt in one of the 4 regions.

The first region depicts the behaviour of an unconstrained country that has a small level of debt and still has plenty of room to sell the sovereign bonds at a risk free rate. The second region is characteristic to the countries that have reached the maximum level of debt, b^L that guarantees the zero risk. The third region describes the behaviour of the countries that already encounter some risk of paying back the debt, but have not over-borrowed yet. In this case the government will repay its obligations when it has a good state, but will default if the nature draws a bad state. The last region shows the countries that are not able to roll over the outstanding debt any more and default.

For a different parametrization of the model, it may exist another region that could be placed between the third and forth regions. In this case, the government keeps the maximum level of debt that can be repaid by the government in the good state, b^H. Any additional borrowed penny can push the country into default. It pays a high interest rate, but still is able to roll over the debt. In the world of Conesa and Kehoe (2012), these are the governments that are gambling for redemption. They borrow high level of debt expecting that tomorrow times will get better.

The depicted regions can be larger or smaller depending on the parameters. Further I look at how changes in the signal or its precision affect the optimal government decision.

Figure 1.1: Bond policy function for non informative signals

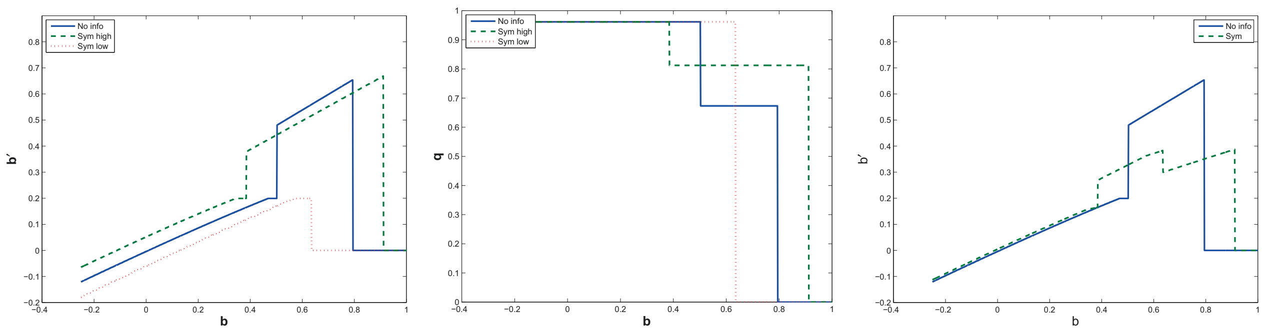


1.1.5 Symmetric information

Figure 1.2 shows how a more precise symmetric signal affects the optimal government decision. In this case, government and lenders receive a commonly known more informative signal, $\psi = 0.7$. The left panel depicts three cases. The solid line stands for the benchmark case, that is when agents receive a noisy signal. Here the signal does not carry any information, therefore the optimal decision depends only on the probability of receiving a low endowment and the current debt. When signal is more informative, optimal decision depends also on the signal that is received by the agents. The dashed line shows the case when they receive a high signal and the dotted line - the case when they observe a low signal.

When agents receive a low signal, government's optimal debt level decreases. In this particular case, government's highest level of debt is the risk free one. For higher level of debt it defaults without even entering in the zone of risky contracts. There are two forces at play. Government expects bad times to come and demands a relatively low debt. This can be clearly noticed by a lower level of debt in the region where government is not constrained. The same time, lenders observe a similar bad signal, expecting government to default more likely, and shift downwards the price schedule. As a result, when signal is more informative

Figure 1.2: Bond and price schedule for non informative and informative symmetric signals



(a) Bond policy function (b) Bond price schedule (c) Unconditional debt holdings

Notes: The first two panels show the bond holdings and bond price schedule for the cases when agents receive a non informative signal, $\psi = 0.5$, and symmetric informative, $\psi = 0.7$, high and low signals. The furthest right panel compares the unconditional bond policy function for non informative and informative signal. The functions are weighted by the long run probability of signal shock.

government has to pay a higher cost for the same level of debt and decreases the demand for the new debt even further.

When agents receive a high signal, the offered bond price increases. Driven by the smooth consumption hypothesis, government demands higher level of debt. It borrows more when it is not resource constrained and enters in the risky zone holding lower level of current debt in comparison to the non informative signal case. In the risky zone, government ends up demanding lower level of debt. Lower cost of debt allows to enjoy higher cumulative resources today (qb'), but repay less tomorrow. The same time, lower debt cost permits to rollover higher amounts of borrowings, therefore government defaults when it holds higher level of debt. The differences in the optimal price schedule for different signal precisions are depicted in figure 1.2b.

Figure 1.2c plots the debt holdings unconditional on the received signal. The debt is weighted by the long run probability of the signal shock. As it is expected, government will contract a higher amount of debt when it has relatively low level of debt and when it is on the edge of defaulting. For the region where it has to contract a risky debt, optimal borrowing level decreases due to decrease in costs. The infinite horizon model for symmetric case information has been studied in Durdu, Nunes, and Sapriza (2013).

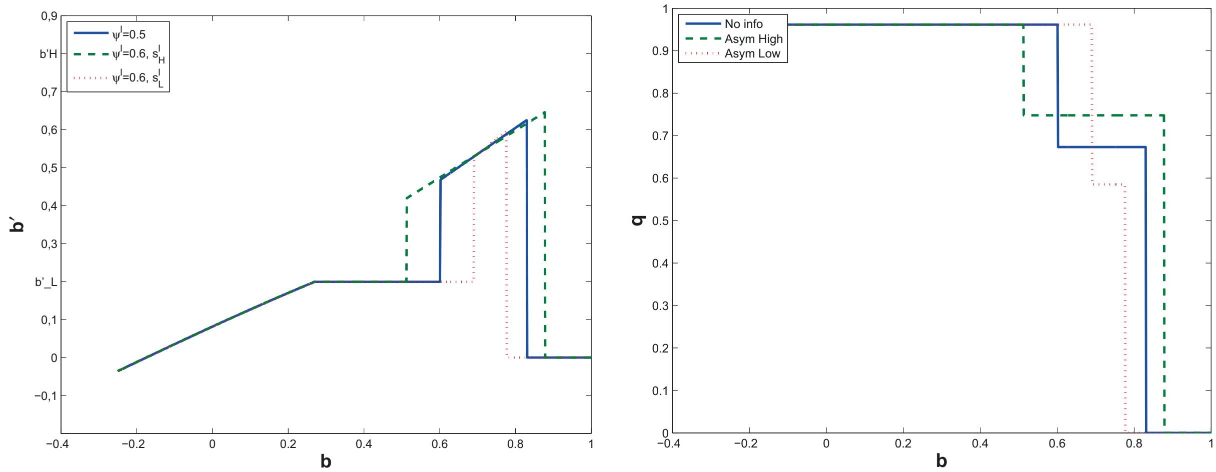
1.1.6 Asymmetric information

The aim of this section is to show how government's optimal decision changes when agents hold asymmetric information and precisely when government receives more informative signal than lenders do. Can it be the case that government can take advantage of lenders' lack of precision of information and contract higher amount of debt?

Figure 1.3 describes the main intuition behind the asymmetric information case. It shows the results when government receives more informative signal than lenders. Precisely it depicts the cases when lenders observe more accurate signal regarding future endowment realization, given that government's precision and signal stays the same. I assume that government receives a good signal with precision, $\psi = 0.7$. The signal that government receives does not affect the qualitative results. The solid line presents the case when foreign lenders receive a noisy signal. Since the information is totally opaque, the price set by lenders for a given amount of initial assets is the same when lenders observe low or high signals. Once the precision of received signal increases, the amount of optimal borrowing changes depending on whether the signal is high or low.

When lenders receive a signal that tomorrow's endowment will be high, the expected country's probability of default perceived by them goes down. As a result, lenders offer a higher price for the same amount of bonds and government, on average, demands more debt (depicted by the dashed line in figure 1.3a). The latter chooses a higher level of debt in the regions where it is constrained by the resource equation. Hence, the region two described above will shorten, as the debt level will jump to a higher level given the same amount of initial assets. Similarly, the optimal debt will be higher in the region that neighbors the one of default decision. When the price of asset increase, government is able to roll-over the debt for higher levels of initial assets. The only region that stays unchanged is one where government is not resource constrained.

Figure 1.3: Debt and Bond price schedule under asymmetric information



(a) Bond policy function

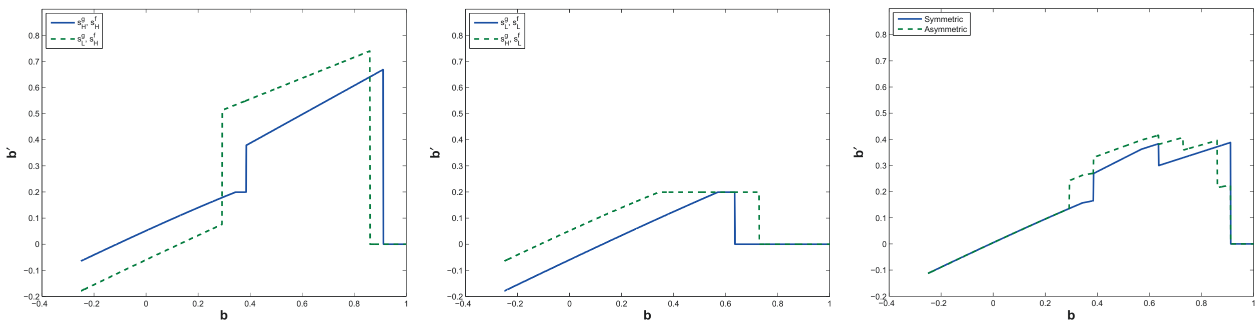
(b) Bond price schedule

Notes: Government receives a signal that tomorrow endowment will be high with precision, $\psi^g = 0.7$.

A different story can be told for the case when foreign lenders receive a signal that tomorrow is going to be a low realization of endowment. Similarly to the previous case, the zone that does not change is the one where government has low level of current borrowing and is not resource constrained. As the level of initial assets increases, government demands higher debt and touches the maximum level of debt offered at a risk free rate. Since the signal received by lenders is low, the price offered for the same level of initial debt is lower in comparison to the case of noisy information. This increases the second region. Thus government sustains the risk free level of debt for higher initial bond holdings. For the same reason it chooses to default holding smaller amount of current debt.

It is important to note that when government and lenders observe the signal with the same precision, and, in particular, receive a similar signal, the equilibrium bond holdings would look the same for symmetric and asymmetric information cases. However, the unconditional bond holdings given that agents receive the same precision are different (see figure 1.4c). The reason is that, under asymmetric informations agents may receive different signals and in these cases government borrows on average more. Figure 1.4 shows the debt policy functions when agents receive information about future endowment with the same precision, but the

Figure 1.4: Bond holdings given the same precision of signal



(a) Bond holdings when s_H^f (b) Bond holdings when s_L^f (c) Unconditional bond holdings

Notes: Agents observe the signals with similar precision, $\psi = 0.7$. In the left and central panels lenders observe respectively high and low signals. The right panel plots the optimal bond holdings independent of the received signal. *Symmetric* means that the agents observe a common signal, while *Asymmetric* means that government and lenders may receive different signals.

signal they observe may differ.

Figure 1.4a compares the cases when government receives a good and a bad signal, given that lenders receive a good signal. In this case, price schedule offered by lenders does not change. Therefore, observing a bad signal, government takes advantage of relatively good price and borrows more in the risky zone. Figure 1.4b shows the debt policy functions when lenders observe a bad signal. As it was explained before, given that government expects a good outcome tomorrow it will borrow more today driven by the desire of keeping the consumption path stable overtime. Therefore, on average, government borrows more when the agents observe signals that are not common information to everybody, although the precision of the signal is the same.

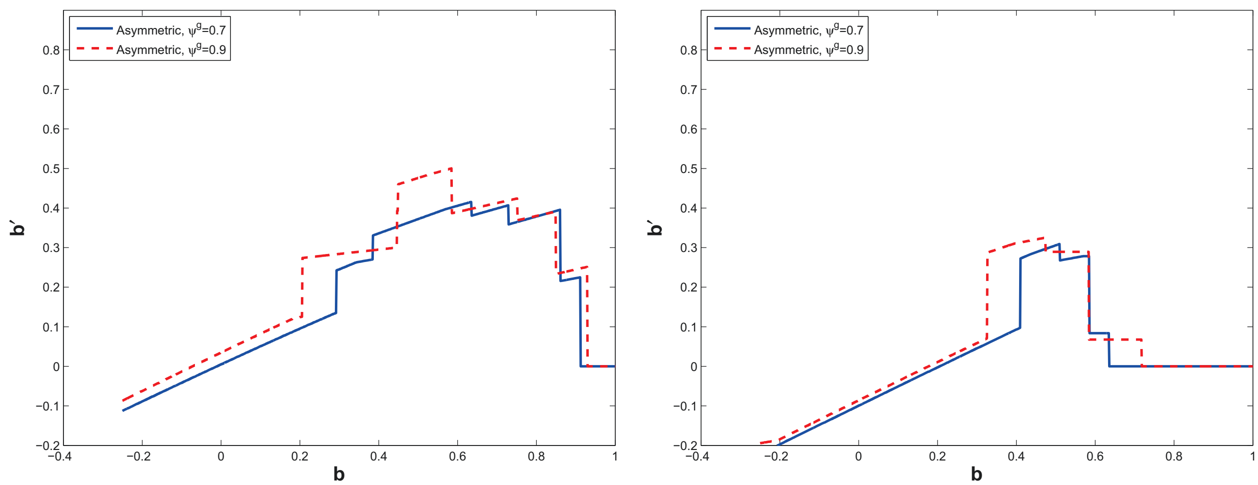
Figure 1.4c shows the unconditional equilibrium debt policy function for these two cases. The dashed line shows the optimal bond holdings when information is symmetric and the information is commonly known to both government and lenders. And the solid line plots the case when they receive different signals, although their precision is similar.

Next section will develop more on the optimal government's behavior when it observes more informative signals than lenders do.

1.1.7 Signal accuracy and debt

This section aims at showing the changes in debt policy function as government observes more accurate information than lenders. Figure 1.5 compares the mentioned above case of agents observing the similar precision signals with the case when government observes a more accurate signal, with precision $\psi^g = 0.9$. The two panels in the figure show the results for different probabilities of receiving the low endowment tomorrow.

Figure 1.5: Unconditional bond holdings under asymmetric information



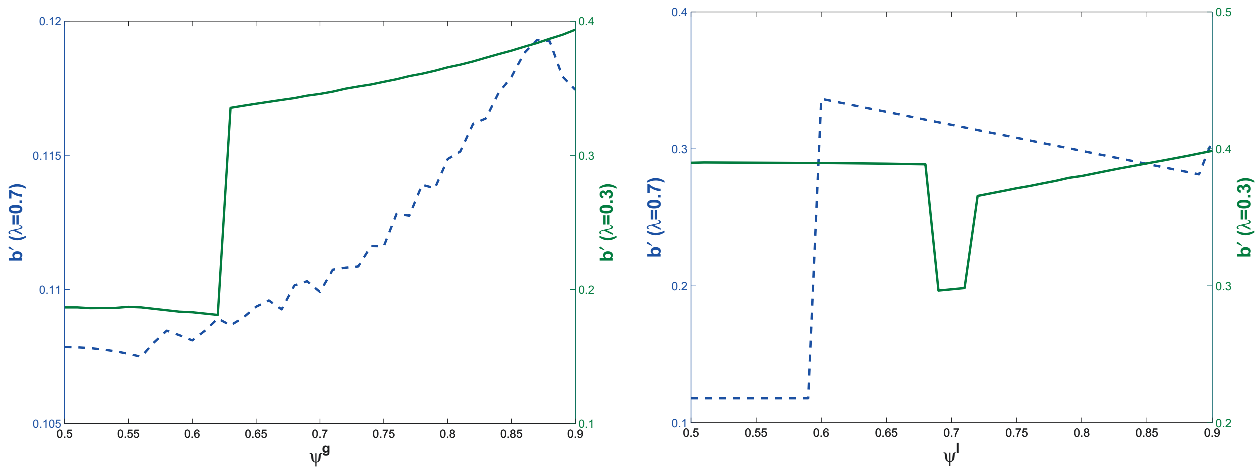
(a) Unconditional bond holdings, $\lambda = 0.3$ (b) Unconditional bond holdings, $\lambda = 0.7$

Notes: Lenders observe the signals with the precision $\psi^l = 0.7$. In the left panel, probability of being in bad times tomorrow is $\lambda = 0.3$ and in the right one is $\lambda = 0.7$.

When the probability of receiving tomorrow a low endowment is low (figure 3.1), government on average contracts a higher level of debt when it receives more precise signal. Government expects better times tomorrow with higher probability, therefore it demands more debt to smooth the consumption between periods. However, for higher levels of debt the increase in debt is minimum since it is reluctant to contract a high level of debt at relatively high cost offered by less informed lenders.

When probability of receiving the low endowment tomorrow is high (figure 1.5b), government also contracts on average a higher level of debt. But, in comparison to the previous case, for high levels of current debt holdings it demands relatively much more bonds. Given that the bond price does not change, government takes advantage of relatively low cost of borrowing conditional on its own information, being able to rollover higher amounts of debt.

Figure 1.6: Unconditional bond holdings under asymmetric information



(a) Unconditional bond holdings, $\psi^l = 0.5$

(b) Unconditional bond holdings, $\psi^g = 0.9$

Notes: In the plot, current bonds are at 0.675. Left panel keeps the lenders' signal precision constant at $\psi^l = 0.5$ (noisy signal). In the right panel, government's signal precision is constant at $\psi^g = 0.9$ (accurate signal). Solid line (the right axis) depicts the optimal level of debt when $\lambda = 0.3$; and the dashed line (the left axis) depicts the optimal level of debt when $\lambda = 0.7$.

Figure 1.6 shows the optimal level of borrowing as a function of agents' signal precision. The plot shows the borrowings when low endowment is expected with low and high probabilities. In order to illustrate the results using two-dimensional charts, I keep some of the variables shut. As it was shown above, when government is less resource constrained, it contracts on average higher amount of debt as it observes more precise information. The picture is less clear when government is currently highly indebted. Therefore, I present the results for a given current level of debt, which is at the higher end of the grid, $b = 0.675$. A plot of optimal level of debt as a function of the whole grid of bonds is shown in the appendix A1.

In the left panel (fig. 1.6a), lenders are assumed to observe a noisy signal with precision $\psi^l = 0.5$. As it is expected, the government increases its level of debt when it receives more accurate information. This is in line with the empirical literature findings that with more precise information, forecasts become more accurate and debt management more efficient. Higher probability of being tomorrow in a good state results in a monotonic increase in the level of debt as a function of government signal precision. However, when the likelihood of being in a good state decreases, government's optimal level of debt increases up to a point, after which it goes down. This kink is observed for high current level of debt. Driven by the consumption smoothing behavior government increases its level of debt with precision. However, as soon as it observes more accurate information and expects the low endowment tomorrow with higher probability, it starts demanding less debt.

The limiting case discussed in Arellano (2008) is given by the point when both government and lenders can not extract any information from the signal about the future endowment. For a given level of debt, this point is depicted in Fig. 1.6a at the beginning of the grid scale. Increase in the asymmetry of signal precision increases the level of debt, the fact that this strand of literature find it hard to match.

In the second case, government is assumed to have a highly precise signal about the future endowment. Figure 1.6b plots the optimal level of debt as a function of lenders' signal precision. It shows that the assets that are contracted are higher when good times are more likely to come tomorrow. Similar to the previous case the government can contract a higher debt if lender's signals about future endowment are relatively more accurate. The price of debt decreases when the lender is less opaque and the probability of having good times tomorrow is higher. Government contracts more debt at a lower cost. This gives a positive relationship between precision and the level of debt. This result is different when bad times are more likely to come tomorrow. The debt increases slightly when accuracy of lender's signal increases. This is due to the fact that there is still small probability that government gets a high signal. It increases the prices of sold bonds and respectively the optimal debt. But it will start decreasing onwards for higher precision of the signal. This result is intuitive.

When the accuracy increases, receiving the high signal is less likely. This fact increases the probability of default tomorrow as perceived by lenders and they offer a lower price.

This in turn decreases the demand of sold bonds. Therefore, when government faces bad times it is willing to be less transparent in order to take advantage of contracting higher debt. This fact has been noticed in recent debt crisis (2009-2011). If full information has been immediately available to investors, markets would arbitrage it away, avoiding such large accumulation of unsustainable debt.[2]

1.2 Conclusion

Asymmetry in information plays an important role in optimal government's behaviour. Even when government and lenders receive a similar accuracy signals, government contracts more debt when received information is not shared with lenders. When government observes more accurate information the optimal debt level increases even further. There are two effects taking place. As likelihood of being tomorrow in good times increases, government contracts on average higher level of debt despite relatively high cost, due to consumption smoothing behaviour. If the probability of receiving a low endowment tomorrow is higher, then government takes advantage of relatively low cost offered by uninformed lenders and as a result borrows more.

Furthermore, for high level of outstanding debt government can borrow higher amounts when lender's precision is slightly higher. This is in line with the observed fact that developed countries can sustain a higher level of debt than emerging economies that are known to provide less qualitative information.

[2] Greek government revised twice its budget deficit for 2008 during one year, first from a number of under 10% to 12.9% and then added up 1% of GDP more to its official number.

Chapter 2

Sovereign debt and asymmetric market information: Infinite Horizon

2.1 Infinite horizon model

In this chapter, I extend the above studied two-period model to show the behavior of asymmetric information in a model calibrated for a real economy. I build an infinite horizon model of endogenous sovereign default where information between government and lenders is asymmetric.

2.1.1 Environment

We consider an environment of a small open economy. Time is discrete and the economy lasts indefinitely, $t = 0, 1, ..$. The economy is inhabited by a representative household and a government. Outside the economy there is a large set of competitive risk neutral lenders.

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 (f) observe the government's current level of debt, current endowment received by the government and their own signal regarding government's future output,s_t^f . The latter is incorporated in the asset price function.

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}.

I assume agents have an asymmetric information structure, which is described below.

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

Assumption about lenders. Lenders observe their own signal, but can not observe government's signal and neither update their signal after observing the debt contracted by the government. If lenders could back out the government's signal, the model would collapse to a symmetric information case. One alternative way of microfounding the model is to allow lenders extract the government's signal from its demanded level of debt. This approaches complicates considerably the setting, so we prefer to go with the simple ad-hoc approach to understand the effects of asymmetric information.

The assumption that government has better information is based on the fact that often official data is little reliable and government hides the weaknesses in financial systems as it is documented by Reinhart and Rogoff (2011). Romer and Romer (2000) also argue that indeed government may posses information about the state of economy that is not known by the public due to vast resources that it devotes to forecasting.

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

2.1.2 Signal specification

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

$$\log(y_t) = \rho \log(y_{t-1}) + \varepsilon_t, \quad |\rho| < 1 \tag{2.1}$$

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, $\forall i = \{f, g\}$, regarding next period's endowment. Signal's set $\mathcal{S}^i$ for both parties has the same size and we consider that $|\mathcal{Y}| = |\mathcal{S}^g| = |\mathcal{S}^f|$. The superscripts g and f stand for 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.

We interpret precision as the ability of the received signal to predict the future output. Or, in more formal way, precision is the probability of receiving a signal regarding a particular endowment conditional on receiving it in the future. If the received signal regarding a particular output is inaccurate (i.e. signal is not precise) then, the probability of receiving the latter is similar to the case when the agent receives no signal. When the signal is more precise the probability of receiving this particular output increases. Given the precision of the signals for the government and the lenders, we can specify the joint process of the signals and the endowment shock. The forecast conditional on current information is given by Bayes theorem.

$$\Pr(y_{t+1} = k | y_t = n, s_t^g = m) = \frac{\Pr(s_t^g = m | y_{t+1} = k) \Pr(y_{t+1} = k | y_t = n)}{\sum_j \Pr(s_t^g = m | y_{t+1} = j) \Pr(y_{t+1} = j | y_t = n)}; \tag{2.2}$$

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

2.1.3 Environment

Preferences. The government's goal is to maximize the utility of the representative household. The household's preferences are given by the expected utility:

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

where $u(c_t)$ is strictly increasing, concave and continuously differentiable. The discount factor is $\beta \in (0, 1)$. For simulated economy we use a CRRA utility function. Given the current endowment, y_t, outstanding assets, b_t, private signal, s_t^g and the bond price, q_t, government decides every period whether to default or to repay the current debt. If it repays it decides upon the new level of debt.

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

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

where $V^{ND}(b, y, s^g, s^f)$ 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:

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

Besides the temporal autarky, default imposes additional cost in the form of lost output that is given by:

$$y^{def} = \min\Big\{y, \phi E(y)\Big\}, \tag{2.3}$$

where $\phi < 1$. This assumption follows exactly Arellano (2008). Mendoza and Yue (2012) develop a theoretical model that explains the rising cost of default with higher output. Also Furceri and Zdzienicka (2011) document that the cost of default is an increasing function of endowment.

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

$$V^{ND}(b,y,s^g,s^f) = \max_{b'}\Bigg\{u\Big(y+b-q(b',y,s^f)b'\Big)+\beta \sum_{y',s^{g\prime},s^{f\prime}} V_0(b',y',s^{g\prime},s^{f\prime})\Pi(y',s^{g\prime},s^{f\prime}|y,s^g)\Bigg\}. \tag{2.4}$$

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, 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:

$$\mathcal{D}(b) = \{(y,s^g,s^f) \in \mathcal{Y} \times \mathcal{S}^g \times \mathcal{S}^f : V^{ND}(b,y,s^g,s^f) < V^D(y,s^g)\}. \tag{2.5}$$

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

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

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 today the bond at a price q and expect to receive tomorrow its face value with the probability, δ_t^f, that government does not default.

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

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

The lender computes the government's probability of default given its signal, that is given by:

$$\delta_t^f(b_{t+1}, s_t^f, y_t) = E\left[\mathbf{1}\left\{(V^{ND}(b, y, s^g, s^f) < V^D(y, s^g) | s^f)\right\}\right]. \tag{2.6}$$

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

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

2.2 Quantitative analysis

This section aims at analysing the behaviour of the debt level along several dimensions. The main ingredients are the signals accuracies and the optimal level of future bond holdings. The idea is to compare the outcome of the model of endogenous default, developed by Eaton and Gersovitz (1981) with the model that includes signal precision described in the previous section.

The basic mechanism of the model has been thoroughly discussed in 1.1. Herein, I show how the model behaves for a simulated real economy. I calibrate the model for Argentina, so that I can compare the results across several papers (Arellano (2008), Durdu, Nunes, and Sapriza (2013)).

2.2.1 Parameterization

Our baseline model is calibrated exactly as the one presented in Arellano (2008).

Table 2.1: 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^f	$\left[\frac{1}{\lvert S\rvert}, 0.9\right]$

The limiting case when both government and lenders receive a noisy signal (i.e. $\psi^g = \psi^f = 1/\mathcal{S}$) represents the benchmark model.

The utility function takes the CRRA form:

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

Our goal is to show the behavior of the government when it has more accurate information about the future endowment. More precisely we want to show the effects of increasing transparency[1] and information accuracy on the level of contracted assets and the default risk.

We set the risk aversion parameter, $\sigma = 2$, value extensively used in the literature. Default

[1]Higher transparency is equivalent to lower discrepancy in government's and lenders' signals precisions.

Table 2.2: Business Cycle Moments in the data

	Emerging Markets	**Developed Economies**
$\sigma(c)/\sigma(y)$	1.45	0.94
$\rho(y, c)$	0.72	0.66
$\rho(y, nx/y)$	-0.51	-0.17
$\rho(y, spread)$	-0.55	0.20

Source: Durdu, Nunes, and Sapriza (2013)

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 US series of 5 year quarterly yield of treasury bonds. Probability of re-entering the credit market after being in autarky is set according to estimates in Gelos, Sahay and Sandleris (2004).

In order to simulate a small open economy we discretized the bond grid in 100 equidistant points. The stochastic process of output is assumed to be log-normal AR(1) process described in section 2.1.2. 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 statistics reported in table 2.3 are averages of 200 samples of 74 observations before default[2]. The simulated series are logged and filtered with a linear trend.

Table 2.3 presents the business cycle statistics for 3 cases: when both government and lenders receive noisy signal, when they receive a very accurate signal and when government observes a very precise signal, while lenders receive a noisy one. Durdu, Nunes, and Sapriza (2013) associate the first two cases respectively with the emerging markets and the developed economies.

It is important to notice that the business cycle moments, for the case when lenders

[2]The number 74 is chosen to have the same number of periods between defaults in Argentina (Q3.1983-Q4.2001)

observe worse quality information than government about latter's fundamentals, are much closer to the values observed in the data for emerging markets, presented in table 2.2. Hence, transparency and asymmetry of information between lenders and governments may play an important role in explaining the differences between these two camps.

Table 2.3: Business Cycle Statistics

	$\psi^f = 1/\mathcal{S}$	$\psi^f = 0.9$	$\psi^f = 1/\mathcal{S}$
	$\psi^g = 1/\mathcal{S}$	$\psi^g = 0.9$	$\psi^g = 0.9$
$\sigma(c)/\sigma(y)$	1.11	1.03	1.23
$\rho(y, c)$	0.97	0.86	0.84
$\rho(y, nx/y)$	-0.26	0.17	-0.16
$\rho(y, spread)$	-0.23	-0.14	-0.39

2.2.2 Simulation Results

Figure 2.1 plots the optimal level of assets holdings as a function of current debt(savings) for different levels of signals accuracy. The future period asset holdings are weighted by the long run probabilities of output and signal shocks, which causes the non-monotonicity of the policy function.

Figure 2.1a shows the case when lenders have a noisy signal. It depicts the borrowing policy function for 2 values of government's signal precision. When government has more information than lenders about future output, it contracts on average higher amount of debt. Government is less uncertain about the future output and, therefore, its demand for precautionary savings decreases. This drives the downward shift of the debt policy function.

In figure 2.1b, I plot the changes in the asset policy function when transparency decreases and lenders catch up to the government's signal precision. I compare the 2 cases, when the lenders receive a noisy signal with the one where it observe a more informative signal. I assume that, in both cases, government receives a highly accurate signal. Increasing transparency shifts the asset policy function up, therefore, government borrows less for the same amount of current debt. As it was discussed in section 1.1, government demands on average more debt when it observes a different signal from lenders. But, when the lenders' signal accuracy increases, the probability of receiving the same signal as government rises also. Therefore, optimal debt level goes down. However, the changes in government's demand for borrowing are relatively smaller for the lower level of initial debt in comparison to the case when it is highly indebted.

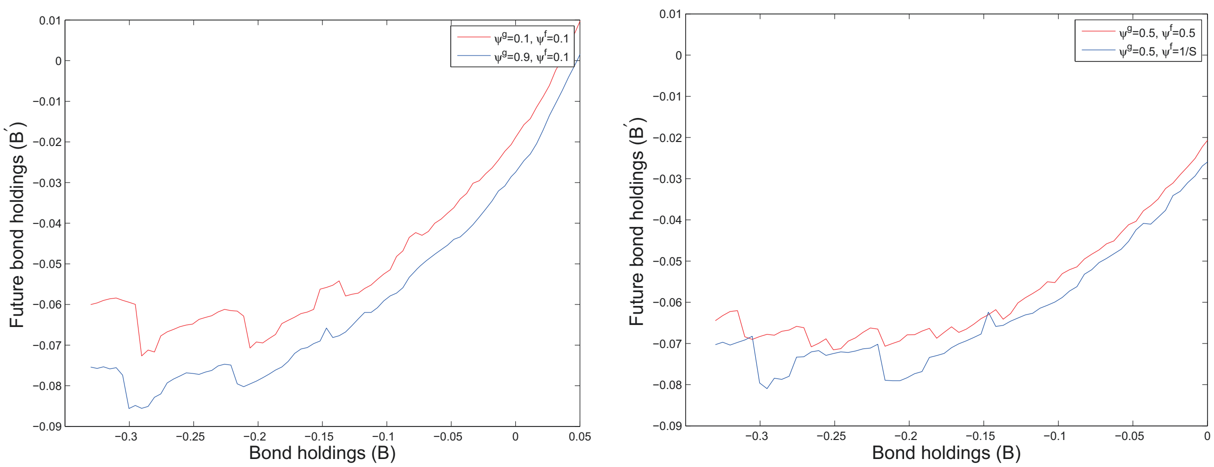
When government is less constrained, it has to rollover smaller amounts of debt and therefore changes in price affect less the changes in the demanded debt. However, when government is highly indebted and requires higher amounts of debt, it reacts much stronger to smaller changes in prices. The mechanism has been studied for a two period model in section 1.1. The idea is that whenever government observes a different signal from lenders',the former takes advantage of uninformative lenders and borrows more where it needs it the most, or in risky zones. Therefore, the relative change in optimal amount of debt when lenders receive a more accurate signal differs for low and higher amounts of government's current asset holdings.

In addition, the two figures in 2.1 show that less uncertainty regarding future endowment decreases the borrowing cost, therefore government can afford a higher level of debt. This is consistent with the empirical observation that more developed economies with better information system are able to borrow higher amounts of debt and has been studied by Durdu, Nunes, and Sapriza (2013).

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

The figure 2.2 illustrates the changes in shape and surface of default region due to changes

Figure 2.1: Unconditional policy functions



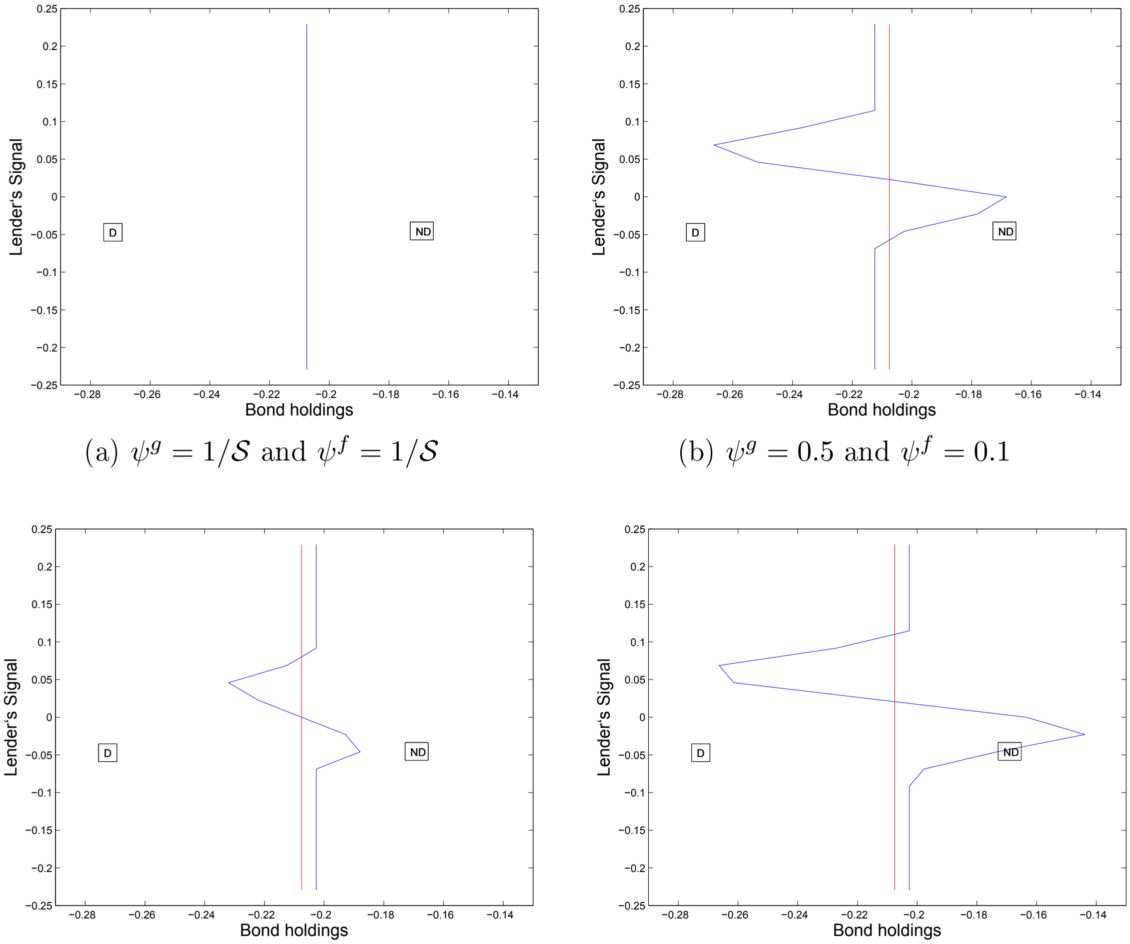
(a) Government's signal precision increases. (b) Lenders' signal precision increases.

Note: The figure shows the level of future bond holdings given the current debt\savings for different levels of signal precision. The debt is weighted by the long run probabilities of signal and output shocks.

in the signal precision of the agents. The horizontal axis is the level of initial borrowing and the y axis is the signal shock received by lenders. Zero stands for lenders receiving the signal that output will continue to stay in the steady state. Higher numbers show that lenders receive a signal that future output will be higher tomorrow. The graphs are plotted for output being in the steady state and the government receiving the signal that output tomorrow will not change. The upper panel shows the changes in default behavior when government receives more accurate information. The lower panel shows the changes in the shape and the surface of default region when lenders catch up the government's signal precision.

Figure 2.2a shows the case when both government and lenders receive uninformative signals. This case depicts the benchmark model. When the signal is inaccurate, the only information agents rely upon is the expected level of output tomorrow. Since the endowment distribution is commonly known information for all the parties, and the signal does not add any additional information, the contour of default region is a straight line. Default in this case depends only on the current debt holdings, output and the distribution of the latter.

Figure 2.2: Default space and level of precision



(a) $\psi^g = 1/\mathcal{S}$ and $\psi^f = 1/\mathcal{S}$

(b) $\psi^g = 0.5$ and $\psi^f = 0.1$

(c) $\psi^g = 0.1$ and $\psi^f = 0.5$

(d) $\psi^g = 0.5$ and $\psi^f = 0.5$

Notes: The graphs show the default state for different levels of agents' signals accuracy as a function of current bond holdings and lenders' signal. Endowment is in steady state and government receives a signal that output is in steady state.

Once the signal becomes more informative, the shape of default region changes. In figure 2.2b both, the information precision for the government rises, with a relatively lower increase in the signal's accuracy for lenders. This implies that the price function changes slightly. When the lenders receive a signal that output tomorrow will increase it offers a better price, the opposite happens when it observes a lower output signal. Hence government defaults having higher level of debt when lenders have positive expectations, and vice-versa when it has negative ones. It is reflected in the "S" shape of the default region. It is important to notice that the signals that predict level of endowment considerably different from the current one do not impact the default decision. This is due to the fact that output follows a Markov process, therefore given that some y_t is realized, some values of future output are unlikely to realize and are discounted appropriately.

Government's signal regarding future output does not change, but changes its predictability power. In addition, government can extract lenders' signal when participates in the market. More precise is the information that government receives, more pronounced is the curvature of default region contour. This is easier to notice by comparing the figures 2.2c and 2.2d.

The lower panel shows the changes in the default region when lenders receive a more informative signal. In figure 2.2c, the lenders observe a relatively more precise signal than government. Since government has less accurate information, it demands higher precautionary savings and therefore the contour of default region smooths. In addition, higher lenders' signal accuracy shifts the default regions slightly rightwards. Hence, when lenders observe more accurate information, government defaults having a lower level of debt in comparison to the case when lenders' signal is noisy.

When lenders receive a more precise signal, the changes in government's default behavior is more pronounced if lenders receive a signal that output tomorrow will decrease. Given that the signal and government's information precision does not change, it will postpone the default as long as it can. As a consequence, the changes in lenders' price when they receive good news will not alter government's decision much. However, when lenders receive accurate bad news, the slightest change in the price affects considerably government's decision to default. Government can not afford paying a higher cost and defaults having lower current debt. The asymmetric response to lenders' signal precision will affect the final result. More accurate lenders' signal, on average, makes government default having lower debt. As a result, the sustained debt in equilibrium will also be smaller.

Having higher transparency leads to following conclusion. If lenders have accurate in-

Table 2.4: Debt and Probability of Default Statistics

	$\psi^f = 1/\mathcal{S}$	$\psi^f = 1/\mathcal{S}$	$\psi^f = 1/\mathcal{S}$	$\psi^f = 0.5$	$\psi^f = 0.9$
	$\psi^g = 1/\mathcal{S}$	$\psi^g = 0.5$	$\psi^g = 0.9$	$\psi^g = 0.9$	$\psi^g = 0.9$
Mean debt (% of output)	6.1	13.7	16.6	11.7	8.2
Probability of default (%)	3	17.1	20.1	11.5	2.5

formation government is able to borrow higher levels of debt for a given level of current liabilities. The same time the default region on average expands with higher signal precision and does not allow borrowing higher amounts of debt.

2.2.3 Signal precision and debt level

In the previous section we analyzed the behavior of the policy functions as a result of an increase in the government's and lenders' signal accuracy. Herein, we show the quantitative performance of the model when introducing information asymmetry. Precisely, we simulate the economy for different levels of precision for the government and lenders and plot the debt level and default as a function of these two.

Table 2.4 displays the results for 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 increases substantially the default rate. However, as soon as the difference in signal's precision between government and lenders shrinks, the level of debt to output ratio goes down. Hence, the model can generate a higher level of debt and a higher probability of default, moments that are still challenging to retrieve in this class of models.

The upper panel of figure 2.3 depicts the average debt to output ratio and the maximum debt to output ratio during period that does not include a default as a function of lender's signal precision, ϕ^f. The lower panel shows the associated probability of default. Every graph in figure 2.3 shows the behavior for a given level of government's signal accuracy, ϕ^g.

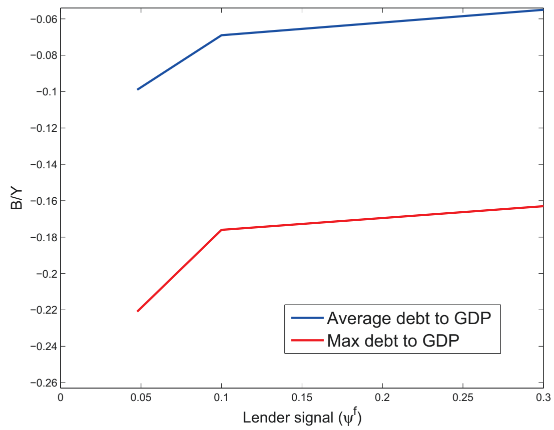
The minimum contracted debt is attained when both government and lenders have the same level of precision, that is when there is no asymmetry in information. Once the signal's precision diverges, government ends up having a higher debt to GDP ratio.

It is important to note that when both parties are better informed about the future output and there is no asymmetry in information, government contracts higher amount of debt. This fact is in line with the observation that more developed countries with better information systems are able to effectively manage the debt and sustain a higher level of debt to GDP ratio.

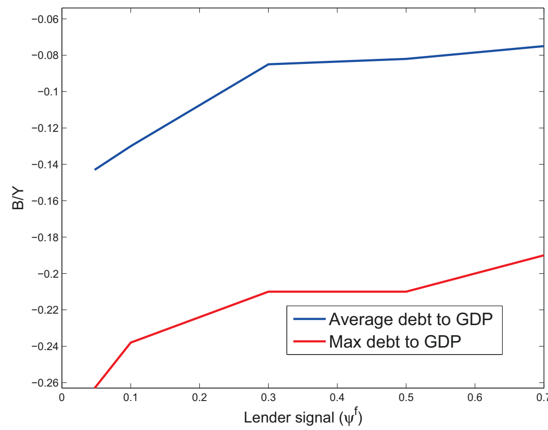
However, when asymmetry of information is present and one of the parties has better information regarding future output than the other, the debt level soars up. When the government is less uncertain about the future output it can more effectively manage its flows and demands less precautionary savings. As a result, it borrows more. Signal accuracy plays and especially important role when government has 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 default is higher. However, when government is on the edge of defaulting the price affects a lot the amount of debt. If lenders receive a good signal, government is able to sustain the high level of debt. But, if lenders receive a bad signal, the cost of borrowing goes up and government defaults. In addition, given the government's signal, lenders' bad signal causes much more variation in default region when the precision increases in comparison to the good signal. This is reflected in the optimal default behavior in figures 2.2b and 2.2d.

Therefore, when lenders observe a noisy bad signal the cost of borrowing is lower in comparison to the case when they receive a precise bad signal. Government takes advantage of lower cost and contracts more when lenders are less informed. Since this overweights the effects of lenders receiving an informed good signal, government ends up borrowing more when lenders have a less precise information regarding future output.

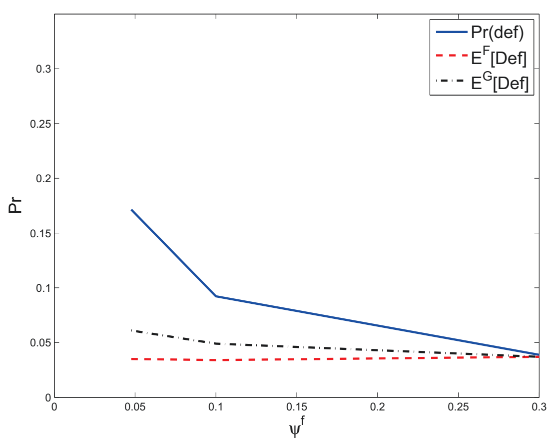
Figure 2.3: Debt, probability of default and signals accuracy



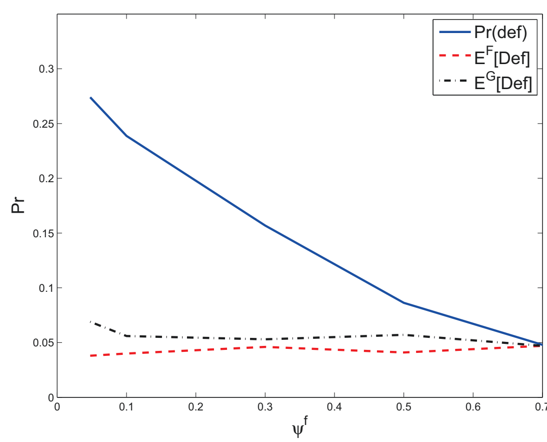
(a) $\psi^g = 0.3$



(b) $\psi^g = 0.7$



(c) $\psi^g = 0.3$



(d) $\psi^g = 0.7$

Notes: The upper panel presents the average level of debt and the maximum level of debt as function of lenders signal accuracy when governemnt has a relatively low and high signal precision. The lower panel shows the average probability of default (bold line) as well as the expected probability of default as perceived by governemnt (dash-dotted line) and lenders (dashed line).

2.3 Conclusion

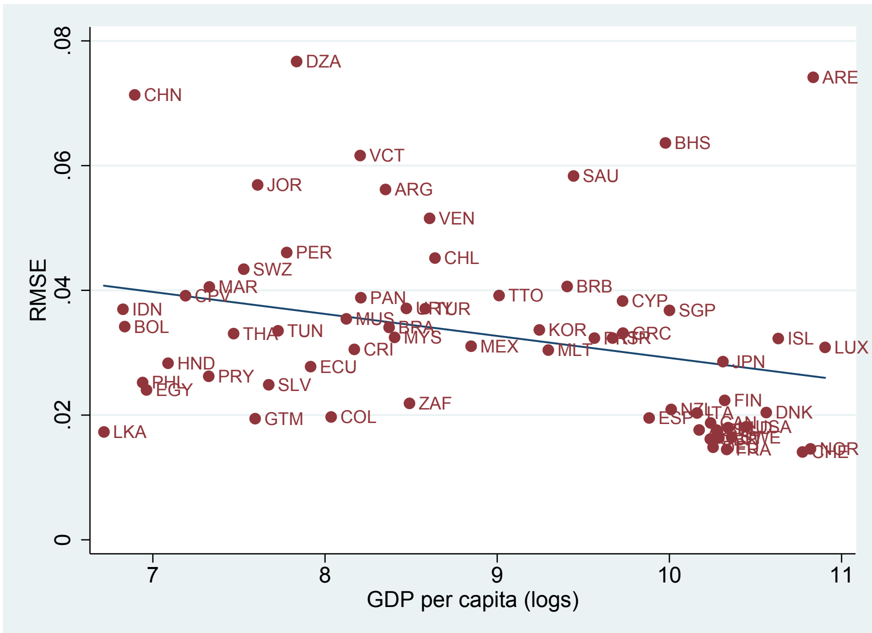
Recent crisis showed that transparency and asymmetry in information are characteristic not only to emerging markets. In order to explore why governments are not opening their books and enjoy the lower interest rates, we construct a model of endogenous sovereign default where government and lenders receive different quality of information about future fundamentals. In our framework, lenders and government receive signals that contain information regarding future output and affect the asset price and the ultimate level of debt and default.

The quantitative results show that when government has more precise information regarding future fundamentals than lenders, it holds on average higher levels of debt. Precisely, if government's signal is fully informative and lenders' is not, it contracts triple to what it does in a symmetric non-informative case. This is a result of the fact that government's benefits from being transparent when news are good than costs when they are bad.

Appendices

.1 Empirical Evidence

Figure 4: RMSE of GDP per capita growth rate and GDP per capita (logs)



.2 RMSE data

Table 5: RMSE for high (1) and low (3) income countries

income group	country	Mean RMSE
1	BDI	.0580491
1	BEN	.0306461
1	BGD	.0406941
1	BTN	.043358
1	CIV	.0485088
1	CMR	.0549011
1	ETH	.0667862
1	GHA	.0409194
1	GIN	.0141529
1	GMB	.0339201
1	IND	.03194
1	KEN	.0453614
1	KGZ	.0656688
1	LSO	.0538296
1	MDA	.0982793
1	MNG	.0306838
1	MRT	.0597908
1	MWI	.0525543
1	NAM	.0314214
1	NGA	.080203
1	NIC	.0647323
1	NPL	.0258773
1	PAK	.0223099
1	PNG	.0406445
1	RWA	.1136188
1	SDN	.0518931
1	SEN	.0357423
1	SLB	.055529
1	SLE	.0560663
1	TCD	.0832142
1	TJK	.0902591
1	UGA	.0271526
1	YEM	.0099188
1	ZAR	.0584319
1	ZMB	.0458734
1	ZWE	.0567703
Total		.0505473

income group	country	Mean RMSE
3	AUS	.0176155
3	AUT	.016329
3	BEL	.0175984
3	CAN	.0187354
3	CHE	.014087
3	DEU	.0148434
3	DNK	.0204088
3	ESP	.0195385
3	FIN	.0223607
3	FRA	.0144907
3	GBR	.0161528
3	GRC	.0331447
3	ISL	.0322819
3	ITA	.0203318
3	JPN	.0285742
3	LUX	.0308592
3	MLT	.0304221
3	NLD	.0179926
3	NOR	.014582
3	NZL	.0209088
3	PRT	.0323398
3	SWE	.0164335
3	USA	.0181273
Mean		.02122

Table 6: RMSE for middle income countries

income group	**country**	**Mean RMSE**	**incgroup**	**country**	**Mean RMSE**
2	ALB	.0890506	2	LBN	.1705097
2	ARE	.0741588	2	LCA	.069006
2	ARG	.0561755	2	LKA	.0172959
2	BGR	.0406419	2	LTU	.0677144
2	BHR	.0436759	2	LVA	.0659089
2	BHS	.063633	2	MAR	.0405525
2	BLR	.0474818	2	MEX	.031046
2	BLZ	.0353564	2	MUS	.0354314
2	BOL	.0341891	2	MYS	.032461
2	BRA	.0340571	2	OMN	.1012077
2	BRB	.0406246	2	PAN	.038818
2	BWA	.0346334	2	PER	.0460667
2	CHL	.045179	2	PHL	.025225
2	CHN	.0713379	2	POL	.035466
2	COL	.0196984	2	PRY	.0262226
2	CPV	.0391409	2	RUS	.0503158
2	CRI	.030532	2	SAU	.0583384
2	CYP	.0382916	2	SGP	.0367886
2	CZE	.0439801	2	SLV	.0248622
2	DJI	.0260774	2	SUR	.0530784
2	DZA	.0766946	2	SVK	.0395866
2	ECU	.0277729	2	SVN	.0347823
2	EGY	.02403	2	SWZ	.0433942
2	FJI	.0454387	2	SYC	.0502852
2	GAB	.0935701	2	THA	.0330636
2	GEO	.0883974	2	TON	.0259387
2	GRD	.04227	2	TTO	.0391712
2	GTM	.0194259	2	TUN	.0335144
2	GUY	.0499468	2	TUR	.0370637
2	HND	.0283159	2	UKR	.0569041
2	HUN	.0537934	2	URY	.0371054
2	IDN	.0369673	2	VCT	.061619
2	ISR	.0323486	2	VEN	.0515477
2	JOR	.056908	2	VUT	.0507817
2	KAZ	.0484273	2	WSM	.0305096
2	KOR	.0336559	2	ZAF	.0218793
continue..			**Mean**		.04637

.3 Joint distribution of endowment and signal shocks

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

$$p(s_{t+1}^g = i, s_{t+1}^\ell = j, y_{t+1} = k | s_t^g = m, y_t = n) = \frac{p(s_{t+1}^g = i, s_{t+1}^\ell = j, y_{t+1} = k, s_t^g = m, y_t = n)}{p(s_t^g = m, y_t = n)} =$$
$$= \frac{p(s_{t+1}^g = i, s_{t+1}^\ell = j | y_{t+1} = k, y_t = n, s_t^g = m) p(y_{t+1} = k | y_t = n, s_t^g = m) p(y_t = n, s_t^g = m)}{p(y_t = n, s_t^g = m)} =$$
$$= p(s_{t+1}^g = i, s_{t+1}^\ell = j | y_{t+1} = k, y_t = n, s_t^g = m) p(y_{t+1} = k | y_t = n, s_t^g = m);$$

$$p(s_{t+1}^g = i, s_{t+1}^\ell = j | y_{t+1} = k, y_t = n, s_t^g = m) =$$
$$= p(s_{t+1}^g = i | y_{t+1} = k, y_t = n, s_t^g = m) p(s_{t+1}^\ell = j | y_{t+1} = k, y_t = n, s_t^g = m) =$$
$$= p(s_{t+1}^g = i | y_{t+1} = k) p(s_{t+1}^\ell = j | y_{t+1} = k);$$

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

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

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

Part II

Optimal Transparency

Chapter 3

Optimal Government Transparency

3.1 Introduction

Government transparency is an important characteristic in guaranteeing fiscal discipline and reducing economic uncertainty. Over the last few decades, it has received a lot of attention both from academic and non-academic literature. In 2001, the IMF published the Manual on Fiscal Transparency and developed codes of good practices that guide governments into being more transparent, accountable and deliver reports that would be understood by general public.[1]

There is a significant body of literature showing the negative effects of a lack of transparency. Among others, Gelos and Wei (2005) provide evidence that less transparent countries receive less investment and that during crisis they are more likely to experience high capital outflows.[2] Marques, Gelos, and Melgar (2013) document that more opaque countries suffer more from financial globalization. Several economic crisis have been partially worsened by lack of transparency. For instance, in the recent Asian crisis, the Thai government has been accused of allowing an extremely opaque financial sector to flourish. It is considered to

[1] Report on the Observance of Standards and Codes designed by IMF (World Bank) is just one of many other reports that are performed at request by a country that assesses government's transparency.

[2] See Gande and Parsley (2014), Bernoth and Wolff (2008), Gavazza and Lizzeri (2009), Alt, Lassen, and Rose (2006), etc, for different aspects of economy that can be affected by lack of transparency.

be one of the key elements that triggered the financial turmoil in 1997. A decade later, in one of the worst recessions since Great Depression, hidden debts of Greek government added more panic to already vulnerable sovereign bond markets in 2009-2010.

Even though various evidence suggests that government opaqueness has negative effects, in practice there are economies that still choose to have less accountable and less transparent finances. A recent policy paper by the IMF[3] estimated that 23% of the unexpected increase in general government debt was due to incomplete information about the government's underlying fiscal position. In the present chapter, I want to emphasize some of the economic conditions when governments choose to be less transparent. In particular, I focus on such macroeconomic aspects as level of debt, probability of expected recession and severeness of the expected economic downturn.

I develop a dynamic model of endogenous sovereign default with private information. I build a small open economy that lasts for three periods and is inhabited by a representative household, a government, that can borrow in an external credit market, and a continuum of foreign risk neutral lenders. At the beginning of the first period, nature draws the state in which the economy will be in the next few periods. This information is privately observed by the government. Before observing its future state, government decides whether to credibly disclose it to the general public or not. Government smooths its consumption by borrowing one-period debt in the credit market. The market is not perfect due to government's private information and contingent debt servicing. Therefore, the borrowing cost bears a risk that the latter may default on the contracted debt. The probability of government being in a good state and repaying its outstanding debt is updated through Bayes rule, based on the repayment and borrowing level decisions.

The government that expects a good state is better off if lenders know its type and offer a higher bond price. The government that expects a bad state would like to mimic former's behavior so that it can contract higher levels of debt than would otherwise be affordable.

[3] approved by Cottarelli (2012)

Since the commitment regarding disclosure of government's future state is made before it is drawn, the government faces a trade-off: greater transparency increases the benefits in good times, but leaves it without additional funds when it needs them the most. Therefore, one would expect that lack of transparency is especially tempting when probability of the crisis is higher.

In present paper, contrary to this intuition, I show that government actually prefers to be less transparent when it is more likely to have better times; and commits to disclose fully its state when it expects more likely to have bad times.

If the probability of an upcoming crisis is very high, uninformed lenders increase the costs of borrowing. As a result, the optimal amount of debt under no transparency is close to the one that government in a crisis can borrow even if it reveals its state. Therefore, government prefers to be fully transparent and enjoy higher consumption if it ends up in a good state during high probability of a crisis.

If a recession is less likely, government is better off by being less transparent. When probability of a bad state is lower, the price offered by foreign lenders increases and the amount of debt that a non-transparent government can borrow is higher. As a result, the loss in welfare if the government is in good times almost vanishes, while the gains if it is in bad times increases. However, the lower the level of initial indebtedness, less will government prefer to be opaque. Less financially constrained government incurs lower gains by mimicking the behavior of a booming economy. Moreover, since the likelihood of experiencing a recession is also low, the expected welfare of the government before observing its future state is higher if it is fully transparent.

The results resemble the recent episode of Greek sovereign debt default. During late 90's, Greece was preparing for the access to Eurozone, criteria for which was having a higher transparency and meeting a series of other economic indicators as budget deficit, level of debt, etc. In June 2000, its candidacy was accepted by the EU parliament and in 2001 it was already enjoying its new membership in Eurozone. The high confidence among investors granted to a new member that just met the Euro area access criteria opened the doors to cheap funds. The economies were booming in Greece and around the world. Even the 2004 Eurostat report, saying that statistics for the budget deficit have been underreported, was not taken much into consideration by lenders that continued lending at low cost. Greece debt was growing and possibility of rolling it over without hiding its deficit and level of debt was less straightforward. The lower probability of an upcoming crisis and high level of debt pushed the Greek government into continuing its less transparent policies. However, the turmoil in financial market that followed in 2008 questioned the transparency of Greek's finance and hence its solvency. In 2010, extremely high borrowing costs led to a subsequent default in 2011. At the same time, more transparent Belgium, that also suffered from relatively high levels of debt and budget deficits as well as political instability, did not face any major constraints in rolling over its debt during crisis.

This paper builds on models of sovereign endogenous default started by Eaton and Gersovitz (1981). It is closely related to Sandleris (2008) that studies a model where government has private information about its fundamentals. He focuses on incentives that makes government repay its non-contingent debt, besides the classical motivations of reputation and sanctions. Other papers that include asymmetric information in models of sovereign endogenous default are Alfaro and Kanczuk (2005) and D'Erasmo (2008). They present infinite horizon models where government has private information about its type. In their models, governments differ in their patience level. D'Erasmo (2008) tries to generate a higher amount of debt that would match the economic data. Alfaro and Kanczuk (2005) study a model of adverse selection where government chooses whether to borrow an exogenously given amount of debt. Also, in their model the impatient government always defaults. Another closely related stream of literature of asymmetric information, but with a focus on consumer debt is represented by Chatterjee, Corbae, and Rios-Rull (2008), Yogo, Perez-Reyna, and Ordonez (2013). They study models of credit markets where borrowers have private information about their types. Papers are focusing on revelation mechanisms and incentives of borrowers to signal their type. Present paper contributes to above literature by building a model of sovereign default where government can choose the level of transparency and study the economic conditions that determine it.

Another stream of literature that is related to optimal transparency is the probabilistic voting models studied by Gavazza and Lizzeri (2009) and political agency models represented by Besley and Smart (2007). Their model focuses on voters that do not observe the electoral promises and the competition among different political parties. Gavazza and Lizzeri (2009) found that transparency on the expenditure side is welfare improving, while on the revenue side can be counterproductive. Contrary to their model, I study a different aspect of government transparency, in particular I build a small open economy and focus on the interaction between the latter and foreign lenders.

The rest of the paper is organized as follows. I set up the theoretical model in section 3.2. In section 3.3, I define and characterize the equilibrium. Section 3.4 explains the main results of the paper.

3.2 Model

In this section, I extend the model described in Part I and allow agents to act strategically. Government receives private information, which lenders can infer from the actions that the former is taking. I develop a simple setting of a small open economy, where the world's interest rate is taken as given. The economy is inhabited by a representative household, a government and a continuum of risk-neutral competitive foreign lenders. The economy lasts for 3 periods, $t = 0, 1$ and 2.

3.2.1 Environment

The government starts with an endowment y_0 and a signal that nature draws about its future state of economy. The signal is perfectly informative for the government and it tells whether the economy will be in a boom and will receive a stream of high endowment or it will be in a crisis and will receive a lower endowment. I assume that the economy will permanently stay in the initially drawn state starting from period $t = 1$.

Household is maximizing consumption over the 3 periods. Every period, the household consumes the observed endowment and a transfer received from the government. It is not allowed to participate in the credit market, therefore the government acts on its behalf and transfers to it the proceedings.

The capital market is not perfect and government trades one period non-contingent bonds. The debt is not enforceable, therefore the latter may choose to default. If the government defaults, it is not allowed to participate in the credit market anymore and bears an additional cost in the form of lower future utility.

The foreign lenders are willing to buy any amount of bonds as long as the expected returns equal to the profits received by trading in the outside risk free market. Since the government may default, the price offered by lenders reflects the likelihood of government's reneging on its outstanding debt contract.

The future state of economy drawn by nature is known to the government, but is not observed by lenders. Before observing the state, government commits to either reveal the information to lenders, $full\ transparency$, or keep it privately, $null\ transparency$. When government is fully transparent, lenders do not face any uncertainty and hence the interest rate does not include any risk premium for default. When government is opaque, lenders can not distinguish whether the government is in good or bad state, but they know its probability distribution. As a result, they offer a price that also reflects the expected probability of the government receiving a low endowment. Unlike in the analysis in the previous chapters, herein lenders can infer government's received endowment by observing its actions, precisely the debt level the former contracts and the default/repayment decision it takes.

Timeline: Time period $t = 0$ starts.

1. Government starts with the endowment y_0 and zero initial debt, $b_0 = 0$;

2. At the beginning of period, $t = 0$, government decides the level of transparency;

3. Nature draws the state, crisis (c) or boom (b), in which the economy will be for the rest of the periods;

4. Government announces the state it will be, if it decided to be transparent;

5. Government chooses the level of debt, b_1;

6. Lenders observe the debt and set the price, $q_1(b_1)$;

7. Government transfers the lump-sum from the market operations to the household;

8. The household consumes.

Time period $t = 1$ starts.

1. Government receives the endowment y_i, $\forall i \in \{c, b\}$, depending on state the nature draws;

2. Government decides whether to default or not;

3. Conditional on the previous decisions, it consumes the endowment if it defaults; or, it may borrow additionally to the endowment, if it repays the current debt;

4. Lenders observe the actions, update theirs beliefs regarding government's state of economy and revise the price schedule;

5. The household consumes.

Time period $t = 2$ starts.

1. Government decides whether to repay and enjoy the terminal value V^{Ndef} or default and bear the additional cost in form of lower terminal value of utility $V^{Def} < V^{Ndef}$;

2. The household consumes.

3.2.2 Household

The representative household maximizes the expected utility:

$$U = u(c_0) + \beta u(c_1) + \beta^2 u(c_2),$$

where c_t is the consumption in period t and $\beta \in (0,1)$ is the discount factor. Utility is strictly increasing, weakly concave and twice differentiable. For qualitative analysis, utility has the log functional form, $u(c) = \log(c)$. The household consumes the endowment and the lump-sum transfer it receives from the government.

3.2.3 Government

Government maximizes households' utility. It participates in the foreign credit market to smooth the consumption over time. It sells one period non-contingent bonds at a price q and repays next period the face value, b. The debt is non-enforceable and government may decide to default. The government starts with zero debt and receives the endowment y_0 known to lenders. Next period the economy may end up in a "boom" and generate $\bar{y}$ for the next two periods, or it may be in the "crisis" and receive a persistent endowment $\underline{y}$, where $0 < \underline{y} < \bar{y}$. Probability of receiving a low endowment is $\Pr(\underline{y}) = \lambda$.

The information about the state of the economy is known to the government privately. Before observing the signal about future states, it decides whether to be fully transparent and reveal the information to the lenders or keep it privately. Although government can decide to be non transparent, its state may still be revealed through the actions it takes, specifically the default decision and the level of debt it demands. Default decision is taken by comparing the benefits from the two states, default and non default. Defaulting has a cost in the form of lower future value, V^{Def}, and permanent autarky. The latter is a standard approach to explain the government's willingness to repay the debt. Sandleris (2008) shows that in a model with private information it is possible to sustain a positive amount of debt without any reputation or direct sanctions from creditors. However, his model features additional agent that punishes government through lower investment in case of default. Since, the question of the present paper is not explaining the government's willingness to repay, I abstract from any additional complexities to my model and allow government to incur direct default costs. In addition, Mendoza and Yue (2012) show in a theoretical framework that economy suffers an endogenous cost of output when defaults.

Then, if government decides to repay the debt, the economy's resource constraint in period $t = 0, 1$ is:

$$c_t = y_t - b_t + q(b_{t+1})b_{t+1}, \qquad \forall t = 0, 1,$$

and, if it defaults:

$$c_t = y_t.$$

It is convenient to write the government's problem starting in the last period, by working it backward. Let $D_{i,t}$ be the debt level where government is indifferent between defaulting and not defaulting in period t. The i subscript stands for government being in one of the two states, "crisis" or "boom", $i \in \{c, b\}$. Government will repay the face value of the withstanding debt if it is lower than $D_{i,t}$.

In period T=2, government receives the endowment depending on its state. If it borrowed in the previous period it decides whether to default or not. Government's utility is given by:

$$V_{i,2} = \begin{cases} \log(y_i - b_{i,2}) + \beta V^{NDef} & \text{if } b_{i,2} \leq D_{i,2} \\ \log(y_i) + \beta V^{Def} & \text{if } b_{i,2} > D_{i,2}. \end{cases}$$

The terminal utility values V^{Def} and V^{NDef} ensure that government bears a cost of default. Without any cost, the only sustainable debt level suggested by sovereign debt literature is $b = 0$ (see Alfaro and Kanczuk (2005), Bulow and Rogoff (1989)).

At time T=1, the government begins with output y_i and with some debt $b_{i,1}$. Depending on its default decision, it may borrow a new level of debt, $b_{i,2}$. The utility is given by:

$$V_{i,1} = \begin{cases} \log(y_i - b_{i,1} + q_{i,2}(b_{i,2})b_{i,2}) + \beta V_{i,2} & \text{if } b_{i,1} \leq D_{i,1} \\ \log(y_i) + \beta(\log(y_i) + \beta V^{Def}) & \text{if } b_{i,1} > D_{i,1}, \end{cases}$$

In period T=0, government takes sequentially two decisions depending on the information it has at hand. Firstly, government choses whether to be transparent or not, and then it decides upon the optimal level of debt. I abstract from the trivial case of default in the first period and assume that government starts with zero debt. Note however, that the initial endowment y_0 can be interpreted as the net output after repaying the outstanding debt. A lower y_0 is equivalent to having a high initial debt. I adopt this interpretation for further discussion.

In the first step, government knows y_0, the probability distribution of the future states and the price function which will be described below. It maximizes the value of the three periods and chooses whether to reveal the information or not:

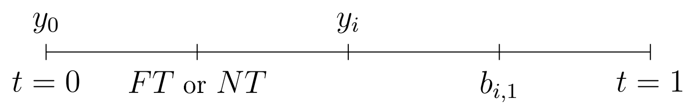
$$V_0 = \max\{V_0^{FT}, V_0^{NT}\},$$

where FT stands for the full transparency and NT for the null transparency cases. The decision is taken before observing the state in which it will be tomorrow, therefore government takes expectations over the endowment set. The value function, at time $t = 0$, is given by:

$$\begin{aligned} V_0 = \quad & \max_{d=\{0,1\},b_{i,1}} d\mathbb{E}\left\{ u(y_0 + q_{i,1}(b_{i,1})b_{i,1}) + \beta V_1(y_i, b_{i,1}) \right\} \\ & +(1-d)\mathbb{E}\left\{ u(y_0 + q_{i,1}(b_{i,1})b_{i,1}) + \beta V_1(y_i, b_{i,1}) \right\}, \qquad \forall\ i \in \{b, c\} \end{aligned} \tag{3.1}$$

where d is an indicator if government is fully transparent or not.

In step 2, it observes the future endowment and, given the commitment it made in the previous step, decides the level of debt. The sequence of events and decisions can be visualized in the timeline below, where in the upper part I specify the available information, and below - the decisions government takes at each point of time.



3.2.4 Lenders

The foreign lenders are risk neutral, act competitively and can lend or borrow any amount in the outside market at a risk free interest rate, r. They have perfect information about economy's state in period $t = 0$, but they do not observe the realization of the future endowments. Instead, lenders know the future income distribution and can update their beliefs about government's state by observing the repayment decision and the amount of newly contracted debt.

Let the lenders' initial beliefs of government being in a boom, π_{-1}, equal to probability of receiving a high endowment, $1 - \lambda$. Given that government repays the debt in period $t = \{0, 1\}$, lenders subjective probability that government is in a boom updates through Bayes rule:

$$\pi_t = \frac{\pi_{t-1} \Pr\Big(\{b_{t-1} \leq D_{b,t-1}\} \cap \{b_t = b_{b,t}\}\Big)}{\pi_{t-1} \Pr\Big(\{b_{t-1} \leq D_{b,t-1}\} \cap \{b_t = b_{b,t}\}\Big) + (1 - \pi_{t-1}) \Pr\Big(\{b_{t-1} \leq D_{c,t-1}\} \cap \{b_t = b_{c,t}\}\Big)}. \tag{3.2}$$

The numerator, $\Pr\Big(\{b_{t-1} \leq D_{i,t-1}\} \cap \{b_t = b_{i,t}\}\Big)$ takes into account the probability of both facts: the government repaying the debt contracted in the previous period, b_{t-1} and borrowing the optimal level $b_t = b_{i,t}$, $\forall \in \{b, c\}$.

In period $t = 2$, government does not contract any debt, therefore beliefs are formed only upon observing the repayment decision. The lenders' beliefs in the last period are:

$$\pi_2 = \frac{\pi_1 \Pr\Big(b_2 \leq D_{b,2}\Big)}{\pi_1 \Pr\Big(b_2 \leq D_{b,2}\Big) + (1-\pi_1)\Pr\Big(b_2 \leq D_{c,2}\Big)}. \tag{3.3}$$

If government defaults in period t, it finds itself in a permanent autarky and is not allowed to borrow. As a result, lenders form the beliefs only upon observing the default-repayment decision:

$$\pi_t = \frac{\pi_{t-1} \Pr\Big(b_t \leq D_{b,t}\Big)}{\pi_{t-1} \Pr\Big(b_t \leq D_{b,t}\Big) + (1-\pi_{t-1})\Pr\Big(b_t \leq D_{c,t}\Big)}. \tag{3.4}$$

For the full characterization of the problem, it's necessary to specify the beliefs off the equilibrium path. I assume that, whenever government finds it optimal to default regardless of its state, it is assumed to be in a boom.

Assumption 1. *Lenders beliefs off the equilibrium paths are:*

$$\pi_t = 1 \text{ if } \Pr(\{b_{t-1} \geq D_{b,t-1}\}) = \Pr(\{b_{t-1} \geq D_{c,t-1}\}) = 1.$$

Lenders are competitive, therefore the price is determined by zero profit condition. They brake even when the expected repayment, discounted at risk free rate, equals the value of debt. Therefore, given lenders beliefs, the price is given by the expected probability of repayment weighted by the likelihood of government being in one of each state. It follows from the following equality:

$$q_t b_t = \pi_t \frac{\Pr(\{b_t < D_{b,t}\})}{1+r} b_t + (1-\pi_t)\frac{\Pr(\{b_t < D_{c,t}\})}{1+r} b_t. \tag{3.5}$$

If the assets level is negative $b_t < 0$, i.e. government saves, then the price equals to the one paid for a risk free asset. If government is expected to default on debt in both states, lenders offer a zero price and the only sustainable level of debt is, $b_t = 0$. If government is expected to default in one of the states, the price is lower than the risk free one. As it will be shown below, government is likelier to default during bad states. Therefore, under null commitment government in good state will overpay for the issued debt and will underpay if it is in the bad one. This trade-off ensures that for some conditions, government is willing to reveal its state and for some conditions is willing to be silent.

3.3 Equilibrium characteristics

The competitive equilibrium of this economy can be defined as following:

Definition 3.3.1. *A competitive equilibrium is: (i) a set of belief updating functions* π_t^* $\forall t \in \{0, 1, 2\}$*; (ii) a set of borrowing prices* q_1^* *and* q_2^**; (iii) a set of borrowing* b_1^* *and* b_2^**; (iv) a set of transparency decisions* d^* *such that:*

1. b_1^*, b_2^* *and* d^* *solve the government's problem (3.1) given prices;*

2. q_1^* *and* q_2^* *are determined by market clearing condition (3.5);*

3. *beliefs* π_t^* $\forall t \in \{0, 1, 2\}$ *are consistent with Bayes rules (3.2), (3.3) and (3.4).*

The strategy of each player (government and lenders) is the mapping from her information set, that includes all the actions taken by the counterpart before her move, to each player's action set.

3.3.1 Government's problem

Government's problem is solved backwards. In period 2, government's only decision is whether to default or not. Government, being in state $i \in \{b, c\}$, repays if the level of debt is lower than the threshold $D_{i,2}$:

$$D_{i,2} = \frac{\delta - 1}{\delta} y_i > y_i, \tag{3.6}$$

where $\log(\delta) = \beta(V^{ND} - V^{D})$ is the discounted cost of default. Note, that the default threshold is smaller than the maximum amount of debt implied by the feasibility constraint, $b_{i,2} - y_i \geq 0$.

In period 1, government decides whether to default or not. And, if it repays, chooses the optimal level of borrowing, $b_{i,2}$:

$$b_{i,2} = \quad \arg\max_{b_{i,2}} \quad \log(y_i - b_{i,1} + q_{i,2}(b_{i,2})b_{i,2}) + \beta V_{i,2} \tag{3.7}$$

Government repays, if the previous period contracted debt is lower than the default boundary $D_{i,1}$:

$$D_{i,1} = y_i + q(b_{i,2})b_{i,2} - y_i \min\left\{ \left(\delta \frac{y_i - b_{i,2}}{y_i}\right)^{-\beta}, 1 \right\} < y_i + q(b_{i,2})b_{i,2}. \tag{3.8}$$

Similar to the previous case, the default boundary is smaller than the feasible amount the government can actually repay.

In period $t = 0$, government decides whether to be fully transparent or not, and the level of borrowing, $b_{i,1}$. It solves the following problem:

$$V_0 = \max\{V_0^{FT}, V_0^{NT}\},$$

where V_0^j, $\forall j \in \{FT,\ NT\}$ is given by:

$$V_0^j = \max_{b_{i,1}^j} \mathbb{E}\left\{ u(y_0 + q_{i,1}^j(b_{i,1}^j)b_{i,1}^j) + \beta V_{i,1}^j(y_i, b_{i,1}^j) \right\}, \quad \forall i \in \{b, c\}. \tag{3.9}$$

3.3.2 Full Transparency

The only piece of private information in the model is the government's future state. When government decides to commit to reveal its state, it can borrow at a risk free rate any amount of debt which is lower than the threshold $D_{i,t}$. Since lenders perfectly observe government's fundamentals, they will not lend above the level government can repay next period. Hence, the debt is riskless. Under full information case, due to endowment persistence government that receives a higher endowment, is able to sustain a higher level of debt to output.

3.3.3 Null Transparency

When private information is present, lenders can not tell apart the state of the government, unless the latter does any actions to reveal it. Therefore, they charge a higher interest rate, expecting that government is also likely to be in a recession. If the government is in a boom, it would like to signal about its state through the debt/default decision so that it can enjoy the lower interest rates. The government in a crisis would like to mimic the actions of the government in boom in order to take advantage of lower cost of borrowing and the possibility of borrowing higher amount of debt, which otherwise would not be affordable.

The following lemma proves that there might exist a separating equilibria, where government in good state repays and the government in bad state defaults.

Lemma 3.3.2. *The default threshold for the government being in a boom is higher than the one when it is in crisis, that is* $D_{b,t} > D_{c,t}$.

Proof: See Appendix.

In present model, there is only one piece of uncertainty, which is the endowment government receives. Therefore, the actions taken by the government either reveal entirely its state or not at all. Consequently, the lenders' beliefs regarding government's probability of being in a good state will either update to one if the actions are revealing or stay the same if not.

If government chooses to be opaque and has not revealed its state so far, lenders can tell apart the former's state only by observing a default. The reason is the following. Government can borrow in the following two regions: (i) region, where the debt is lower than the threshold the government in crisis can repay next period, $b_t < D_{c,t}$; and (ii) one, where the debt is in between the two thresholds of default, $D_{c,t} < b_t < D_{b,t}$. Government will not borrow more than it can repay in the good state, since the price for debt $b_t > D_{c,t}$ equals to zero. If government contracts a level of debt in region (i), next period it will repay independent of the received endowment. If government borrows in region (ii), it repays if it is in good state and defaults otherwise. Therefore, lenders will be able to know government's state only if it defaults. The revelation through the chosen level of debt is equivalent to playing the full information. Note that it is the government that receives the low endowment would like to mimic the actions of the one being in a boom. If it borrows a level of debt that is different from the one it is optimal for the government in boom, then a priori government is better off if it is transparent.

Note also that by the end of the game, in period $t = 2$, government will reveal its state entirely. However, the information is relevant only in the first two periods, $t = 0, 1$. In the final period, the government state does not affect any more the price or the debt level, since the only decision it takes is whether to repay the outstanding debt or not. Hence, even though the state of the government is revealed in equilibrium, lenders can not affect any future debt decision. The following three lemmas formalize each one of the observed equilibrium under null transparency.

Lemma 3.3.3 (Separating equilibrium). *Suppose government borrows $b_1 > D_{c,1}$ in period $t = 0$, then its state is revealed in period $t = 1$.*

Let $b_1 > D_{c,1}$, then the state the nature draws is fully revealed in period 1. The government in boom repays the debt , $b_1 < D_{b,1}$, and contracts any amount of debt, $b_2 < D_{b,2}$ at a risk free interest rate. While the government in crisis defaults and stays in permanent autarky.

Lemma 3.3.4 (Pooling equilibrium). *Suppose the government borrows $b_1 < D_{c,1}$ and $b_2 > D_{c,2}$, then the government's state is revealed in period $t = 2$.*

Let $b_1 < D_{c,1}$, and $b_2 > D_{c,2}$, then government, independently of its state, repays the debt $b_1 < D_{c,1} < D_{b,1}$ in period $t = 1$ and defaults in period $t = 2$ if it finds itself in recession.

Since government does not reveal its state in period 1, lenders carry on their beliefs that government can be in a bad state with probability $1-\lambda$. As a result, government in boom will pay a higher cost for otherwise similar amount of debt if lenders knew its true state and government in crisis will contract debt that otherwise would be unaffordable.

Lemma 3.3.5. *Suppose the government borrows $b_t < D_{c,t}$ in any period t. Independently of its state, government repays the debt entirely and private information is not revealed.*

However some of these equilibria are not sustainable. The following propositions establish the conditions and the type of equilibrium that arises in the problem.

Proposition 3.3.6. *If government that is in boom finds optimal to contract a debt level smaller than government in crisis can repay, $b_{b,t} < D_{c,t}$, then for the latter will be optimal to borrow $b_{c,t} \neq b_{b,t}$ and reveal its type.*

Proof. Assume government borrows the optimal level of debt $b^*_{b,1} = \frac{(1+q)}{1+\beta(1+\beta)} y_b - \frac{\beta}{1+\beta(1+\beta)} \frac{1}{q} y_0 < D_{c,1}$ and $b^*_{b,2} = \frac{y_b}{1+\beta} - \frac{\beta}{1+\beta} \frac{1}{q}(y_b - b^*_{b,1}) < D_{c,2}$, where $q = \frac{1}{1+r}$. Given that the maximum amount of debt it can borrow is the one it can repay next period, the government in crisis either mimics the actions of the one in boom or borrows the optimal amount of debt available at a risk free rate. Since, $b'_2(b^*_1) > 0$ and $b^{*\prime}_1(y) > 0$, the government in crisis, which receives an endowment $y_c < y_b$, is better of by borrowing $b^*_{c,1} < b^*_{b,1}$ and $b_{c,2}(b^*_{c,1}) < b_{b,2}(b^*_{b,1})$. ∎

The intuition behind is the following. Since the government in boom finds it optimal to borrow in the safe region, where the interest rate is $(1+r)^{-1}$, the government in crisis can not mimic the former's actions by borrowing higher debt in the risky zone. In the safe region the government in crisis can borrow any amount of debt and, since it receives a different endowment, it is better off by borrowing a different from the booming government's debt level.

Lemma 3.3.7. *Government contracts a decreasing stream of debt over time, if it plays the pooling equilibrium, that is $b_1 > b_2$.*

Proof: See Appendix.

Proposition 3.3.8. *The pooling equilibrium is not sustainable.*

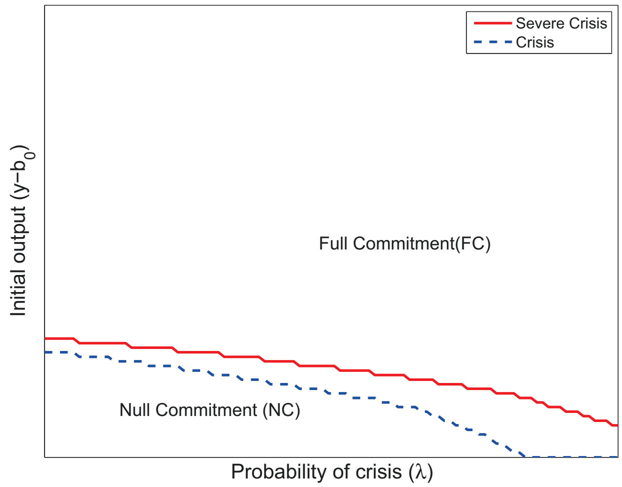
Proof. Assume there exist a pooling equilibrium, and there exist an optimal amount of debt $b_2 > D_{c,2}$, $b_1 < D_{c,1}$ and $b_1 > b_2$ by lemma 3.3.7. Then, in period 2, the government in crisis defaults and default threshold $D_{c,1} = qb_2 < b_2$. It follows immediately that $b_1 < D_{c,1} = qb_2 < b_2$. This is true only if $b_1 < b_2$, which contradicts the lemma 3.3.7. ■

In present model, the only type of equilibrium which is optimal to play under the null commitment is the separating equilibrium. It is not uncommon that in the signaling models the only sustainable equilibrium is the separating one. The set of pooling equilibria is generally sensitive to assumptions of the model and the beliefs that are off the equilibrium path. In this environment, the government in crisis mimics the behavior of the government in boom and contracts a high level of debt in the first period, on which it defaults eventually. The government in boom overpays for the debt borrowed in the risky region and reveals its type by repaying it next period. Therefore, in the second period it is able to borrow at a risk free rate any amount below $b_2 < D_{c,2}$. The benefits from higher debt if government is in crisis and the costs that come from lower debt due to higher interest rate paid by the government in boom generate the trade-off that ensures the optimal level of transparency. In the next section, I will discuss which are the conditions that determine the level of transparency.

3.4 Optimal Transparency

The main question of this paper is to analyze the conditions when government chooses to be less transparent. I will analyze the results in the following three dimensions: the probability of having a crisis (λ), the initial endowment or the level of indebtedness (y_0) and the severeness of the crisis ($\underline{y}/\bar{y}$). The summary of the results is presented in figure 3.1 which depicts the regions of government commitment to be transparent or not about its future state of economy. The government prefers to hide its state when it has a bigger initial debt, expects a more severe crisis, but with lower probability.

Figure 3.1: Transparency Regions of the Parameter Space



Notes: The regions of full and null commitment as functions of initial endowment, probability of receiving a low endowment and the severeness of crisis measured by $\underline{y}/\bar{y}$. As the last fraction decreases (crisis is more severe), the region of null commitment shifts rightwards. The dashed line stands for the threshold characteristic to a more mild crisis than the bold red line.

It is rather intuitive that government with higher debt would like to be less transparent about the received endowment. An overindebted government depends more on the external resources to finance its consumption. The uninformed lenders can offer a relatively better price during bad times and therefore government can roll over higher amounts of debt. It is also true that government that experiences good times will have to pay a higher cost for the same amount of borrowing. However, a transparent government will be unable to roll over the debt if lenders know it is going to be in a recession. Therefore, since the government that receives a high endowment will be able to repay the higher debt and to smooth the consumption, it would a priori prefer to pay a higher cost during good times so that it can borrow if a crisis comes.

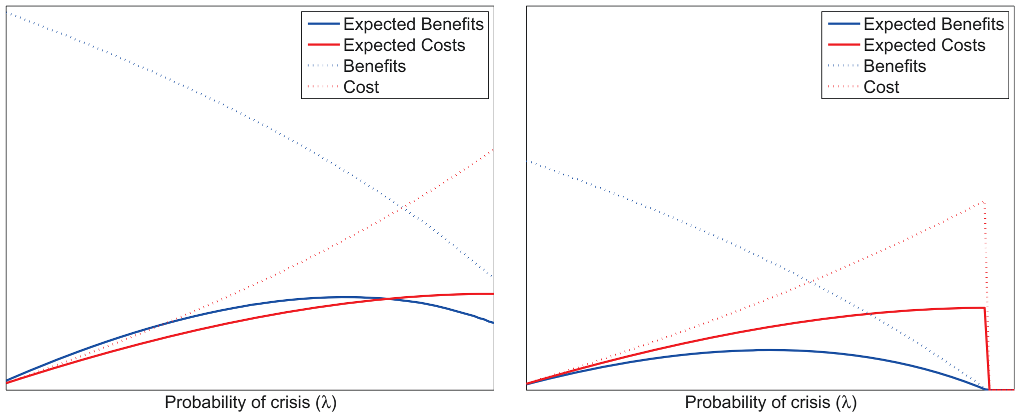
A similar story could be told about government's willingness to be non-transparent when it expects a bigger shortfall in the output. If the endowment is very low, government's ability to repay a debt decreases. If lenders were able to observe perfectly its state, government wouldn't be able to borrow much. Hence, the benefits from mimicking the behavior of a government in a good state are higher than the costs from paying a higher interest rate and contracting a lower amount of debt when in boom.

Government's preferences to commit to reveal its state when probability of crisis is high is less intuitive. However, it should be recalled that lenders know the probability distribution of states of economy. Since this determines directly the borrowing cost, higher is the probability of receiving a low endowment higher is the cost of debt. In this case, the amount of borrowing that a government in boom would be willing to contract in order to play the separating equilibrium would be approaching the default threshold of the government in crisis. Consequently, the latter would rather prefer contracting the debt in the risk free region and be able to smooth the consumption by borrowing additionally in the next period. Since government in boom is always better off when lenders know its type, government prefers being fully transparent for high likelihood of being in a recession.

However, when government is less likely to experience a crisis, lenders offer a better price. The actual net benefits from non-commitment strategy when government observes its state increase and hence, its desire to be opaque. At the same time, lower is the likelihood of a recession, lower are the expected benefits at the time when government does not know its state, and higher is the willingness to be more transparent. Therefore, the optimal transparency decision additionally depends on the degree a government is financially constrained and the severeness of the potential crisis. As it was mentioned above, when government is initially less indebted and/or expects the crisis to be less severe, it prefers to commit to reveal its state.

The actual and expected cost / benefit graphs as functions of probability of receiving a low endowment are plotted in figure 3.2. Benefits represent the surplus in welfare once the government observes its bad state and it chosen to not disclose it to the general public. The costs are the foregone welfare if the government prefers to be opaque and, eventually, receives a high endowment. Figure 3.2a depicts the cost and benefits of being non transparent when

Figure 3.2: Benefits and Costs from playing the Non Commitment strategy



(a) Highly Indebted at $t = 0$ (b) Lowly Indebted at $t = 0$

Notes: The graphs show the gained and foregone welfare from having lower transparency for different level of initial indebtedness (or the size of initial endowment). The dotted lines show the benefits/costs once the governemnt observes its state and the bold lines show the expected values weighted by the probability of receiving the boom or crisis. Left panel show the case of higher initial indebtness, or lower y_0. Graphs are plotted for a given level of $\underline{y}/\bar{y}$.

the level of initial indebtedness is high (y_0 is low). When government has a low initial endowment and the probability of being in a bad state is also low, the discrepancies between costs and benefits from being opaque are very high. The intuition is the following. When the likelihood of observing a crisis is low, the interest rate charged by lenders, if government is opaque, is very close to the risk free interest rate. As a result, the level of debt almost reaches the one a good government could borrow if it were transparent. Hence, the actual cost is almost zero and the benefits are high. But, since the probability of being in a crisis is also low, the expected benefits are slightly above the expected costs.

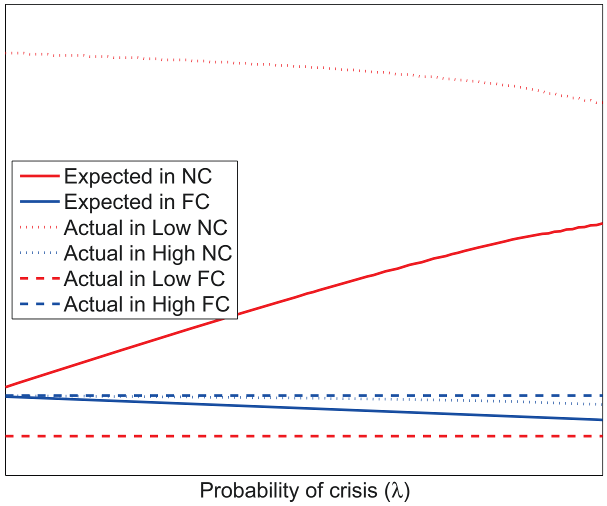
In the region where actual benefits overpass the costs, but the expected benefits do not, government has an incentive to renege on its commitment once it observes that it is going to be in a recession. However, I assume that it is hard to break the commitment. One could think that government can easily hide its state by providing less information, but it is harder for it to manipulate it.

The higher is the level of initial indebtedness or higher is the ratio of endowments between the two states, the lower is the actual surplus and hence the desire to be non transparent. Figure 3.2b shows the case when government has a relatively high initial endowment, y_0, and the expected costs surpass the expected benefits from being non-transparent. Although the actual benefits from being opaque are higher, the probability of a crisis event is so low that government is better off by committing to be fully transparent. The sudden jump to zero depicts the point where the government that experiences a recession is better off by revealing its state and contracting a level of debt that is different to the one if it were in a boom. When the probability of crisis is high, the borrowing cost increases and government in boom prefers a lower level of debt. Since the government is less financially constrained, it prefers to smooth the consumption and to be able to borrow in both states rather than defaulting on a level of debt that is marginally higher than its default threshold.

The mechanism above could be observed in two distinct crisis events, in Thailand (1997) and in Greece (2009). Both of these economies, before the crisis, enjoyed higher than regional and OECD GDP real growth values, low inflation and pegged exchange rates to strong currencies like US dollar, and respectively Euro. As a result, they enjoyed low interest rates which allowed them to accumulate an unsustainable level of debt. Also, as it turned out later, suffered from lack of transparency in finance. Lower expectations about the upcoming crisis allowed them to mimic the good government's behavior and rollover high levels of foreign debt. However, once the regional and world economy have been hit by the financial shocks, the growth slowed down and a series of irregularities and hidden transaction scandals emerged. As a result, governments had to default due to surging borrowing costs.

Figure 3.3 plots the average level of debt to output ratios for expected and actual state of economies. As it can be seen, the highest level of debt to GDP is attained by a non-transparent bad economy. The lowest ratio is observed for the economy that is in crisis if it is fully transparent. Therefore, an economy that expects a low endowment will always be tempted to mimic good government's behavior so that it can enjoy a higher level of debt and eventually higher consumption. Consistent with findings in the previous chapters, the

Figure 3.3: Debt to GDP ratios



Notes: The graph shows the averaged over periods debt to output ratios for different cases. Low stands for the case when government receives low endowment, and high, respectively the high. Actual shows the debt to output ratio that government has after it knows all the information. Expected values are the weighted actual values by the probability of receiving a crisis/boom state.

expected level of debt to GDP ratio is higher for a government that has better information about its state of economy. A similar result has been found in Gavazza and Lizzeri (2009) in a principal - agent framework, where voters have less information than political parties.

Despite a higher level of debt that a non-transparent government can enjoy, it is not always optimal for the bad government to be non-transparent. A high probability of crisis increases the cost of borrowing, and therefore increases the level of debt, although the net inflow might be lower. As a result, the cost of foregone utility from failure of the consumption smoothing rises and the government in bad state prefers the full transparency.

3.5 Conclusion

The literature that studies the effects of transparency on economic outcome highlight the beneficial effects of the later. However, during several financial crises, we witnessed distinct events when governments were less transparent about their fundamentals. The recent cases like the opaqueness of financial sector in Thailand before 1997 crisis, hidden debts of local governments in Spain, manipulation of statistics of Greek government show that there are cases when a government prefers to be less transparent about its state of economy. In the present paper, I tried to emphasize different economic conditions that makes governments prefer being more opaque about its economic strength. In a model of endogenous sovereign default, I found that a government prefers to be non transparent when it is overindebted, expects a more severe crisis, but expects it with a lower probability.

When the probability of an upcoming crisis is low, price offered by lenders is very close to the risk free interest rate. As a result, the cost from being opaque almost vanishes, while the benefits if it is in bad state increase. Therefore, a highly indebted government that expects along with lenders a booming economy prefers to be less transparent about its future state.

Appendices

.1 Proof of Lemma 3.3.2

It is straightforward from eq. (3.6) that $D_{b,2} > D_{c,2}$.

$D_{b,1} > D_{c,1}$. Let's consider the case of *null information*. Under null information, government in a boom, in period 2, will default for higher level of debt than the one being in the crisis. Also, government does not borrow more than $b_2 \leq D_{b,2}$. Hence,

$$D_{b,1} = y_b + q(b_2)b_2 - y_b\Big(\delta\frac{y_b - b_2}{y_b}\Big)^{-\beta} > q(b_2)b_2.$$

The government in crisis will default for $D_{b,2} \geq b_2 > D_{c,2}$. Hence,

$$D_{c,1} = y_c + q(b_2)b_2 - y_c = q(b_2)b_2 < D_{b,1}. \tag{10}$$

When the optimal level of debt is lower than the lower bound of default in period 2, the government's problem is similar to the one under full information. The government in crisis can borrow in period 1, only if the government in boom is not playing the separating equilibrium, by contracting debt, $b_1 > D_{c,1}$. Hence, in both periods, the government in boom is contracting debt in the safe region, at a risk free rate. In this case, the government in crisis does not find it optimal to mimic, as it is not able to take advantage of borrowing higher amounts of debt than it is actually able to repay back. In both, pooling and separating equilibria the government in crisis finds itself in default state in the last period. Therefore, inequality 10 holds for all the cases under non-commitment strategy.

Under *full information*, government chooses the level of debt depending on the state, and can borrow only in the risk free zone ($q_t = 1/(1+r)$). The optimal level of debt contracted in period 1,2 are $b_{i,1} = \frac{(1+q)}{1+\beta(1+\beta)}y_i - \frac{\beta}{1+\beta(1+\beta)}\frac{1}{q}y_0$ and $b_{i,2} = \frac{y_i}{1+\beta} - \frac{\beta}{1+\beta}\frac{1}{q}(y_i - b_{i,1})$, respectively. And the default threshold level for the government being in state $i \in \{b, c\}$ is:

$$D_{i,1} = y_i + qb_{i,2} - y_i\Big(\delta(1 - \frac{b_{i,2}}{y_i})\Big)^{-\beta}.$$

Under full information, lenders observe the type of government therefore they will not lend more than government is able to repay, therefore the min term disappears, where $\Big(\delta(1-\frac{b_{2,i}}{y_i})\Big)^{-\beta} < 1$. Let's check if the inequality $D_{b,1} - D_{c,1} > 0$ is true.

$$D_{b,1} - D_{c,1} = y_b + qb_{b,2} - y_b\Big(\delta(1-\frac{b_{b,2}}{y_b})\Big)^{-\beta} - \Big(y_c + qb_{c,2} - y_c\Big(\delta(1-\frac{b_{c,2}}{y_c})\Big)^{-\beta}\Big).$$

Normalizing $y_b = 1$, and plugging in the optimal solutions for $b_{i,j}$, $\forall i \in \{b, c\}$ and $\forall j \in \{1, 2\}$, the following inequality holds:

$$\delta^{\beta}(1-\gamma+q(b_{b,2}-b_{c,2})) > \Big((1-\frac{b_{b,2}}{1})\Big)^{-\beta} - \gamma\Big((1-\frac{b_{c,2}}{\gamma})\Big)^{-\beta},$$

and, respectively,

$$\delta^{\beta}(1-\gamma)\Big(1+\frac{q}{1+\beta}(1+\frac{\beta}{q}\frac{q-\beta(1+\beta)}{1+\beta(1+\beta)})\Big) > \Big(1-\frac{b_{b,2}}{1}\Big)^{-\beta} - \gamma\Big(1-\frac{b_{c,2}}{\gamma}\Big)^{-\beta} \tag{11}$$

Hence, $D_{b,1} > D_{c,1}$ holds for both, full and null information cases.

.2 Proof of Lemma 3.3.7

The government solves the following problem when it is playing the pooling equilibrium:

$$\max_{b_1,b_2} \quad \log(y_0 + \tfrac{1}{1+r}b_1) + \beta\log(\bar{y} - b_1 + \tfrac{1-\lambda}{1+r}b_2) + \beta^2\log(\bar{y} - b_2) + \beta V^{Ndef} \tag{12}$$

$$\text{s.t. } D_{1,c} - b_1 \geq 0, \tag{13}$$

where $D_{1,c} = qb_2$, as the government in crisis is not able to repay in period 3.

For, $\gamma \geq 0$, the F.O.C. wrt to b_2 is:

$$\frac{1-\lambda}{1+r}u'(c_1) - \beta u'(c_2) + \gamma\frac{1-\lambda}{1+r} = 0.$$

The following inequalities hold:

$$\frac{1-\lambda}{1+r}u'(c_1) - \beta u'(c_2) \leq \frac{1-\lambda}{1+r}u'(c_1) - \beta u'(c_2) + \gamma\frac{1-\lambda}{1+r} = 0, \tag{14}$$

and

$$u'(c_1) \leq \frac{\beta(1+r)}{1-\lambda}u'(c_2). \tag{15}$$

Let's consider the case when the constraint is not binding, $\gamma = 0$, then

$$u'(c_1) = \frac{\beta(1+r)}{1-\lambda}u'(c_2). \tag{16}$$

Given $\beta(1+r) = 1$, then $\frac{\beta(1+r)}{1-\lambda} > 1$ and $u'(c_1) > u'(c_2)$. Hence, $\bar{y} - b_1 + \frac{1-\lambda}{1+r}b_2 < \bar{y} - b_2$ and $b_1 > (1 + \frac{1-\lambda}{1+r})b_2 > b_2$.

Let's consider the case when constraint is binding, $\gamma > 0$ and $D_{1,c} = b_1^* = qb_2$. By definition of pooling equilibria, government in good time finds optimal to contract $b_2^* > D_{2,c}$. Let's assume that the government in crisis finds it optimal to mimic government in boom and contracts the same level of debt. The government in crisis then consumes its endowment in period 1 and defaults in period 2. Hence, the terminal value of utility in period 2, equals to V^{Def}. As a result, it has the following utility function:

$$V_0(b_1^*, b_2^*) = \log(y_0 + \frac{1}{1+r}b_1^*) + \beta\log(\underline{y}) + \beta^2\log(\underline{y}) + \beta^3 V^{Def}.$$

The same stream of consumption government in crisis can have if it consumes $b_2 = 0$ and hence not default in the last period. Therefore, the terminal value of consumption is $V^{NDef} > V^{Def}$ and the utility obtained by mimicking the government in boom is lower, $V_0(b_1^*, b_2^*) < V_0(b_1^*, b_2) = 0$. As a result government in crisis finds it optimal to deviate and the equilibrium when the constraint is binding is not sustainable.

Chapter 4

Closing Remarks

In the present work, I study different aspects of government transparency in a model of endogenous sovereign default. In part I, I find that a more informed government is able to sustain and rollover higher levels of debt. Part II emphasizes the conditions when government prefers to be opaque about its state of economy. It shows that government prefers to be less transparent when it is highly indebted, expects a more pronounced recession, but with lower probability.

The thesis is a contribution to literature that study models of endogenous sovereign defaults and asymmetric information that appears among the market participants. However, further research can improve our understanding about the issues covered in the present work. I will suggest several points that could be interesting to develop further:

- The model described in part I can be improved by relaxing the assumption that lenders are constantly irrational and do not update their signal after observing government's debt. In order to set up a signal extracting problem one should add an additional noise to the problem. One potential source of noise can be the current level of endowment. In such an environment, lenders are not able to disentangle whether the higher debt decision comes from expected higher endowment or lower current output received by the government. Firstly, solving such a problem will be a contribution to the existing literature. To my best knowledge, in such type of models, agents are not choosing an optimal level of debt, but rather are given the option to choose a particular exogenous level of debt or default.[1] Additionally, signal extraction models might bring additional insights to government's behavior and contracted levels of debt.

- Following the above idea and related to the model in part II, it will be interesting to study a model where government can choose the optimal noisiness of the signal or the amount of information it provides to lenders. The problem is interesting to analyze with respect to level of contracted debt as well as in relation to the other government instruments like taxes. Similar to monetary policy transparency idea, government may increase the total welfare if general public is less aware of the expected taxes. If investors expect an increase in taxes, they might be less interested in bringing their money into the economy. At the same time, they are less likely to invest in less transparent economies. Therefore, government may be willing to choose a middle point so that it can extract most of the benefit.

- Another interesting contribution would be to find a way to quantify the signals and use it, eventually, for quantitative research and policy analysis. One way to tackle this problem is to construct signal noisiness indicators based on surveys of professional forecasters or other indices that measure economic uncertainty and government transparency.

[1] See for example Chatterjee, Corbae, Nakajima, and Rios-Rull (2007), Alfaro and Kanczuk (2005)

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