# ESSAYS IN INTERNATIONAL AND FINANCIAL ECONOMICS

by

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**ESSAYS IN INTERNATIONAL AND FINANCIAL ECONOMICS**

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This dissertation is a collection of three essays in international and financial economics. In these essays, I focus on government debt and firm financing decisions over the business cycle. In the first essay, I study the role of income inequality in government's borrowing and default decisions. To explore the relationship between default risk and income inequality, I extend the standard endogenous default model to allow for heterogeneous agents. The main finding of this paper is that inequality shocks can increase the default risk significantly. The model can also generate high consumption volatility of poor households relative to rich households, consistent with the data. I extend the model by introducing progressive income taxes and show that as the progressivity of the tax increases, the probability of default decreases.

In the second essay, I address how the financing of working capital plays a role in the default risk and the business cycle characteristics observed in emerging market economies. I propose a general equilibrium model with endogenous sovereign default risk and working capital conditions and study the role of labor markets in generating the drops in output observed in defaults. I find that the working capital condition increases the default risk through a feedback loop. I show that this model is able to match the countercyclical interest rates, high volatility of consumption relative to output and countercyclical trade balance observed in Argentina.

The third essay analyzes the role of binding financing constraints on manufacturing firms' investment decisions in the U.S., using the Great Recession period as a natural case study. The main finding of this paper is that firms that do not borrow from public bond markets experienced binding liquidity constraints on their R&D investments during the recession.

The paper also compares the evidence on financial constraints in R&D investments to the evidence about capital and inventory investments. Firms without bond ratings show the highest liquidity sensitivity for inventory investments, and investment-liquidity sensitivity is greater for capital than it is for R&D investments.

# PREFACE

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# 1.0 INTRODUCTION

This dissertation is a collection of three essays in international and financial economics. The essays focus on government debt and firm financing decisions over the business cycle. Sovereign defaults are rare events, but they are very destructive because they are usually linked with banking or financial crises that have long-run effects on the economy. So far, the literature has considered mainly the role of fluctuations in output in sovereign risk over the business cycle. In the first and second essays, I focus on two channels that have not been studied in the literature. The first essay explores the role of income inequality in generating sovereign risk. The second essay studies how private credit and firms' labor demand decision are connected with sovereign risk. The third essay investigates the effects of financial crises on firm investment. In particular, I study firms investment behavior and financial constraints during the Great Recession and identify financially-constrained firms using the last recession period as a natural case-study.

The first essay, titled *"Income Inequality and Sovereign Default,"* is presented in Chapter 2. In this paper, I study the role of income inequality in government's borrowing and default decisions. I address the question of whether higher income inequality increases the probability of default. First, I present some empirical evidence for the effect of inequality on the creditworthiness of sovereign bonds. I show that an increase in a country's Gini index in a given year is associated with a decrease in the creditworthiness of sovereign bonds in the next year. To explore the relationship between endogenous default risk and income inequality, I consider a stochastic general equilibrium model following an approach similar to that of Eaton and Gersovitz (1981). I model a small open economy with two types of households. In addition to output shocks that affect the average level of endowment, I introduce shocks that affect its distribution, which I call inequality shocks. The economy is subject to aggregate uncertainty about future endowments, and households cannot completely insure against the shocks. There is also a utilitarian government that can issue non-state contingent, one-period bond contracts to borrow from risk-neutral foreign lenders, retaining the option to default at any time. The government internalizes how its borrowing decisions affect both the default risk and the price of bonds, which determines the interest rates.

The main finding of this paper is that inequality shocks can increase the default risk significantly. The key intuition for this result is that when the economy is subject to both adverse inequality and output shocks, the marginal utility of consumption of the poor increases significantly relative to that of the rich. This generates a large tax burden, particularly on poor households, and the government chooses to default more often to wipe out the debt burden. Therefore, the government uses default as a redistribution mechanism between households. I calibrate the model to match the business cycle statistics of Argentina and Mexico and find that the model explains the business cycle statistics observed in both countries well. In addition, it can also generate high consumption volatility of poor households relative to rich households. Incomplete asset markets, together with output and inequality shocks, are key for this result. This is an important contribution of the paper that the prior literature has not addressed. As a policy exercise, I extend the model by introducing progressive income taxes and analyze the effect of these taxes on debt levels and default probability. I show that as the progressivity of the tax increases, the probability of default decreases. The tax system helps eliminate the effect of inequality shocks in the model and reduces the dispersion in the marginal utilities of consumption between households. Therefore, I obtain larger debt in the simulated economies.

In Chapter 3, titled *"Sovereign Risk and Private Credit in Labor Markets,"* I propose a theory that can explain three observations pertaining to emerging market economies. First, as Neumeyer and Perri (2005) show, emerging markets are characterized by countercyclical interest rates. Second, during default episodes, there are large drops in labor and output. Third, Arteta and Hale (2008) show that during sovereign debt crises, there is a significant decline in foreign credit to private firms. Firms can use private credit to finance their working capital, and there can be a feedback loop between sovereign risk and the cost of private credit. In this paper, I investigate the nexus among firms' labor demand decision, private credit and government's borrowing decisions, focusing on the role of labor markets. Particularly, I am interested in how private credit and government's default risk are related to the drops in output observed after sovereign defaults.

I find that the working capital condition serves as a channel that increases the default risk. When the economy receives a low TFP shock, firms demand less labor and cut down production. This increases the governments incentives to borrow more. Because shocks are persistent, foreign lenders ask for a higher premium when they lend to the government. Higher interest rates on the government bonds increase the default risk, and the finance of working capital becomes more costly for firms. This generates further reductions in output and higher spreads on the government bond, which is the feedback loop in the model. I show that this model is able to match the business cycle statistics observed in Argentina, as well as the large drops in output and labor during default episodes.

Chapter 4 presents the third essay, titled *"R&D Investment and Financial Constraints During the Great Recession."* It analyzes the role of binding financing constraints on firms' investment decisions, using the Great Recession period as a natural case study. The recession started with the emergence of the subprime loan crisis, which created turmoil in the housing market and had subsequent real effects on the economy. This aspect of the recession makes it a good setting in which to analyze firms' investment behavior after being hit by an exogenous shock. Since R&D projects involve high uncertainty, it is expensive for firms to find external sources of finance–and it becomes even more expensive during financial crises. This implies that R&D is sensitive to internal resources during recessions. This sensitivity is even greater for financially-constrained firms, such as firms without access to bond markets. In order to test for the existence of financial constraints, I estimate the effect of liquidity at the beginning of the recession on the growth rate of R&D stocks over the recession, controlling for firm profitability, size and age, as well as for industry characteristics.

The main finding of this paper is that firms that do not borrow from public bond markets experienced binding liquidity constraints on their R&D investments during the recession. The evidence for liquidity constraints is also documented for various subsamples that are likely to face financial constraints, such as small firms, young firms and firms that do not pay dividends. Sensitivity of R&D investment to liquidity is, again, strongest for those firms without bond ratings in these subsamples. I also compare the evidence for financial constraints in R&D investments to the evidence about capital and inventory investments. I find that firms without bond ratings show the highest liquidity sensitivity for inventory investments, and investment-liquidity sensitivity is greater for capital than for R&D investments. The results confirm the business cycle properties of these series–i.e., inventory investment is the most volatile and R&D investment the least volatile type of investment.

# 2.0 INCOME INEQUALITY AND SOVEREIGN DEFAULT[1]

## 2.1 INTRODUCTION

Emerging markets are characterized by countercyclical spreads, countercyclical trade balance and high volatility of consumption relative to output over the business cycle. Sovereign debt and default risk have significant effects on business cycle characteristics and the financial sector in emerging markets. Therefore, it is very important to understand the channels that play a role in generating sovereign risk. The endogenous sovereign default literature has focused mainly on the effects of output shocks on default risk. In this paper, we investigate another channel, which is the role of income inequality in government's borrowing and default decisions. This paper addresses the following two questions: Does higher income inequality increase the probability of default? Furthermore, how do changes in income inequality compare to changes in output in explaining the variation in default risk?

In order to explore the relationship between endogenous default risk and income inequality, we consider a stochastic general equilibrium model following an approach similar to that of Eaton and Gersovitz (1981). We model a small open economy with two types of households. In addition to output shocks that affect the average level of endowment, we introduce shocks that affect its distribution, which we call inequality shocks.[2] The economy is subject to aggregate uncertainty about future endowments, and households cannot completely insure against the shocks. The output and inequality shocks have different effects on the endowments; an adverse output shock lowers the endowments of both types, but an adverse

[1] This research is a joint work with Kiyoung Jeon.

[2] Even though our model treats the changes in income inequality as exogenous, these shocks can be motivated by the fact that idiosyncratic labor earnings risk exhibits countercyclical volatility, as shown by Storesletten et al. (2004).

inequality shock raises the endowment of the rich households and reduces the endowment of the poor households, increasing the dispersion between the endowments. There is also a benevolent government that represents the preferences of the households and can issue non-state contingent, one-period bond contracts to borrow from risk-neutral foreign lenders, retaining the option to default at any time. We assume that default entails exogenous drops in output and that the economy goes into autarky temporarily. The government internalizes how its borrowing decisions affect the default risk, as well as the price of bonds, which determines the interest rates.

In our model, the government would like to borrow on behalf of households for two reasons. First, the government uses bond contracts and rebates the proceeds of debt operations equally across households to help them smooth consumption. Second, the equilibrium interest rate is lower than the discount rate of the government, so the government would like to shift future consumption to today by borrowing. The level of existing debt and the size of the shocks are crucial for government's borrowing decision. As the debt accumulates, it becomes harder to roll over because the benefits of borrowing diminish. Defaults are particularly more attractive in recessions, in high inequality states and when there is high debt accumulation because foreign lenders offer bond contracts that have higher interest rates in those states, which creates a borrowing constraint for the government. The government's goal is to maximize household's expected lifetime utilities, so it achieves this goal by trying to equalize the marginal utilities of consumption between households and across time. Default can reduce the gap in the marginal utilities of consumption between the two types of households because the burden of debt payment can be eliminated. Consequently, in our model, default can serve as a redistribution mechanism that improves households' welfare. The main finding of this paper is that inequality shocks can increase the default risk significantly. The key intuition for this result is that when the economy is subject to both adverse inequality and output shocks, the marginal utility of consumption of the poor increases significantly relative to the marginal utility of consumption of the rich. This generates a large tax burden, particularly on poor households, and the government chooses to default more often to wipe out the debt burden.

When we consider the role of each shock, we find that default risk is slightly higher when there are output shocks than inequality shocks. This is because the implied default penalties are different in the two models. In the case of output shocks, the default penalty is higher in good states of the world and smaller otherwise. So with smaller penalty and tighter borrowing constraints in bad states, we observe a larger default rate. On the other hand, in case of inequality shocks the default penalty is constant across all states because aggregate output is constant. This generates a lower probability of default in this model because the cost of default is higher. However, each shock alone can generate only about one sixth of the probability of default observed when there are both shocks in the model. Thus, we show that the joint effect of these shocks helps the model generate a default probability consistent with the data. The reason behind this result is the VAR(1) process estimated from the Argentine data. Based on the estimates of the structural parameters, we find that high inequality at time $t-1$ leads to lower output at time $t$. Also, the estimates of the covariances of the shocks are negative, which implies that there is more likely to be an adverse output shock together with an adverse inequality shock. These characteristics play an important role in lenders' and the government's expectations about the future state of the economy. An adverse inequality shock not only amplifies the effect of a low output shock today, but also creates a deep-seated pessimism that the recession will be more severe in the future. As a result, foreign lenders ask for a higher premium even for smaller levels of debt. This increases the borrowing constraints for the government, and default becomes the optimal decision.

The model is calibrated using Argentine data between 1990-2002, and we simulate the model to generate the business cycle statistics. Our model's results regarding the default probabilities can be compared to the results in Aguiar and Gopinath (2006).[3] Similar to Aguiar and Gopinath (2006), the default probability when the economy is hit by an output shock is quite low, only 0.52 percent. Aguiar and Gopinath (2006) also use shocks to the trend of output and generate a default probability of around two percent. On the other hand, the inequality shocks generate a default probability of 0.32 percent. Using shocks to both output and inequality, our model can match countercyclical interest rates, high volatility of

[3] Aguiar and Gopinath (2006) assume a representative agent model; yet their default penalty structure and calibration strategy are similar to ours.

consumption and output, and countercyclical trade balance. In addition to that, inequality is countercyclical with output and positively correlated with interest rate spreads.

We also calibrate the model to match the business cycle statistics of Mexico. We find that the model can explain the business cycle statistics observed in Mexico well. In addition, it can also generate high consumption volatility of the poor households relative to the rich households. We find that the ratio of the volatilities is close to its data counterpart. Incomplete asset markets together with output and inequality shocks are key for this result. In the model, income inequality shocks amplify the effect of output shocks particularly on the poor households' endowment. Since there are no other assets that the households can use to insure against these shocks, poor households have higher volatility of consumption than the rich households. This is an important contribution of the paper that has not been shown by the existing papers in the literature before.

As a policy implication, we extend the model by introducing progressive income taxes and analyze the effect of these taxes on the debt levels and the default probability. When it is costly to borrow for the government, i.e. the proceeds of the debt operations are negative, the government finances the existing debt by issuing progressive income taxes. We adopt the progressive tax regime that Heathcote et al. (2014) present. However, when it is cheap to borrow, the government does not tax households, it simply distributes the transfers across households. We show that as the progressivity of the tax increases, the probability of default decreases. The tax system helps eliminate the effect of inequality shocks in the model and reduces the dispersion in the marginal utilities of consumption between households. Therefore, we obtain larger debt in the simulated economies.

This paper relates to the recent quantitative models that explore emerging markets' business cycles and sovereign debt. We contribute to the sovereign default literature by incorporating the role of income inequality as an additional source of default risk. The endogenous sovereign default literature starts with the seminal paper of Eaton and Gersovitz (1981) and continues with Aguiar and Gopinath (2006), Arellano (2008), Martin and Ventura (2010), Yue (2010), Pitchford and Wright (2011), Chatterjee and Eyigungor (2012a), Amador and Aguiar (2014) and Gennaioli et al. (2014), some of which were mentioned above.[4] Hatchondo and Martinez (2009), Arellano and Ramanarayanan (2012), and Chatterjee and Eyigungor (2012b) consider long maturity bonds in a representative agent framework. Cuadra and Sapriza (2008) and Hatchondo et al. (2009) study the role of political uncertainties in sovereign default risk. Martin and Ventura (2010) and Broner et al. (2008) show that well-functioning secondary markets can eliminate the default risk. All these papers use representative agent models and focus on the role of output shocks. Our paper is also closely related to D'Erasmo and Mendoza (2012) and D'Erasmo and Mendoza (2013), the main focus of which is the relationship between wealth inequality and default using a heterogeneous agent framework. D'Erasmo and Mendoza (2012) have endogenous wealth heterogeneity that comes from idiosyncratic income shocks; however, the amount of bonds is determined by a fiscal reaction function and does not come from the maximization of household utility. As mentioned above, in our model, the government optimally chooses the level of next-period bonds taking into account the welfare of the households. Furthermore, we show that income inequality shocks tend to have a systematic relationship with output shocks, so we incorporate this dimension into our model to generate inequality. D'Erasmo and Mendoza (2013) study the distributional effects of sovereign debt default in a two-period, closed economy model, assuming an exogenous initial wealth distribution. In their closed economy setup, they study optimal debt and default decisions on domestic debt. However, in our model, we focus on borrowing and default on external debt in a small open economy. In this sense, our paper is complementary to these two papers. Cuadra et al. (2010) study fiscal policy and default risk using a representative agent model, in which tax on consumption is endogenously determined and the revenues are used to finance public goods. In our paper, we assume progressive taxes on income.

Our paper is also related to the immense empirical literature that studies the determinants of sovereign default. Cantor and Packer (1996) show that income, external debt and economic development are significant determinants of credit risk. Reinhart et al. (2003) show that a country's past behavior about meeting its debt obligations can be a good predictor of its ability to pay future debt, pointing out the importance of financial institutions.

[4] Also see Panizza et al. (2009), Wright (2011) and Aguiar and Amador (2013) for good reviews of this literature.

Hatchondo et al. (2007) argue that countries are more likely to default during periods with low resources, high borrowing costs and changes in political circumstances, and González-Rozada and Yeyati (2008) examine the role of global factors, such as liquidity, risk appetite and contagion, in explaining the emerging market spreads.

The rest of the paper is organized as follows: We provide a more formal analysis of the empirical results, showing the relationship between income inequality and credit scores in Section 2.2. We then present the model and define the recursive equilibrium in Section 2.3. We discuss the calibration, the quantitative analysis of the model and the simulation results with counterfactual experiments in Section 2.4. Section 2.5 presents the business cycle statistics obtained for Mexico and discusses the differences in consumption volatilities between rich and poor households. Section 2.6 shows the effects of income taxes. Section 2.7 concludes.

## 2.2 EMPIRICAL MOTIVATION

In this section, we provide empirical results that support the relationship between income inequality and default risk. We use credit ratings dataset as a measure of default risk. Reinhart (2002) shows that credit ratings can predict defaults well.[5] First, we show that income inequality is positively correlated with the creditworthiness of sovereign bonds. Next, we provide evidence on the fact that income inequality is countercyclical over the business cycle.

### 2.2.1 Income Inequality and Credit Ratings

Reinhart et al. (2003) show that there is a strong relationship between external debt and credit ratings. In order to present some empirical evidence for the effect of inequality on the creditworthiness of sovereign bonds, we follow an approach similar to that in Reinhart et al. (2003). We use the following specification to estimate the effect of inequality on credit

[5] They show that this relationship is robust using various credit-score datasets such as Institutional Investor ratings, Standard and Poor's and Moody's.

scores:

$$\begin{aligned} \textit{Credit Score}_{i,t} &= \alpha_0 + \alpha_1 \text{Gini}_{i,t-1} + \alpha_2 \textit{Debt-to-GDP}_{i,t-1} \\ &+ \alpha_3 \textit{GDP per capita}_{i,t-1} + u_i + z_t + \textit{error}_{i,t} \end{aligned} \tag{2.1}$$

To measure the creditworthiness of sovereign bonds, we use the Fitch credit ratings data for long-term bonds that are issued under foreign currency. This dataset covers a period between 1994 and 2012. For income inequality, we use the Gini indices provided by the Standardized World Income Inequality Database (SWIID) (Solt, 2009). This is an unbalanced panel dataset that has information on inequality for 153 countries covering 1960 to 2012. Debt-to-GDP ratio is the external debt-to-GDP ratio from the Reinhart-Rogoff series that extends until 2010. Most of this dataset comes from IMF's Standard Data Dissemination Service, and it is defined as the outstanding amount of those actual current liabilities that require payments of principal and/or interest that residents of an economy owe to non-residents (Statistics, 2003). The GDP per capita series is from the World Bank, and we take its log for this estimation. The Net foreign assets-to-GDP (NFA/GDP) data used in Table 1 are from the External Wealth of Nations Mark II database by Lane and Milesi-Ferretti (2007). This series includes net foreign assets (NFA) using FDI or equity assets and liabilities estimated using different methodologies. NFA is defined as the sum of the net debt position, the net equity position and the net FDI position in Lane and Milesi-Ferretti (2001). In order to perform a regression using the credit ratings, we assign a numerical value similar to that in Cantor and Packer (1996) and Reinhart (2002). Table 28 shows the conversion of the ratings to scores in Appendix A.3.

We expect to obtain a negative coefficient on Gini and debt-to-GDP ratio and a positive coefficient on GDP per capita. This implies that higher inequality in country $i$ at time $t-1$ reduces the credit score in the next period. The credit score of a country shows how risky that country's bond is, and higher inequality increases the riskiness, which is reflected by a lower credit score.

Table 1 shows the summary statistics for the variables used for the regression sample, which covers the period 1994-2010 and contains 45 countries. A couple of differences stand out when we compare observations of emerging markets and advanced economies. First,

Table 1: Country ratings, debt, income inequality, GDP per capita and net foreign assets

| Country | Average Fitch Rating | Average external debt/GDP | Average Inequality | Average GDP per capita | Average NFA/GDP |
|---|---|---|---|---|---|
| | | *Emerging market economies* | | | |
| Argentina | CCC-/CCC | 72.49 | 45.19 | 4,483 | -21.82 |
| Bolivia | CCC+/B- | 55.64 | 50.16 | 1,086 | -64.71 |
| Brazil | B+/BB- | 28.82 | 50.22 | 4,739 | -32.47 |
| Bulgaria | BB-/BB | 85.21 | 28.38 | 3,613 | -53.71 |
| Chile | BBB+/A- | 47.71 | 49.34 | 7,131 | -30.29 |
| China | BBB+/A- | 12.99 | 48.27 | 1,573 | 8.65 |
| Colombia | BB/BB+ | 30.64 | 50.38 | 3,386 | -25.00 |
| Costa Rica | BB- | 29.18 | 44.08 | 4,680 | -21.82 |
| Dominican Rep. | CCC+ | 26.71 | 45.80 | 3,928 | -35.65 |
| Ecuador | CCC-/CCC | 49.55 | 50.02 | 3,005 | -49.82 |
| Egypt, Arab Rep. | BB/BB+ | 33.13 | 35.43 | 1,220 | -11.76 |
| El Salvador | BB-/BB | 40.51 | 45.47 | 2,698 | -38.53 |
| Ghana | B-/B | 75.86 | 40.01 | 504 | -53.53 |
| India | BB/BB+ | 19.45 | 49.57 | 762 | -19.71 |
| Indonesia | B/B+ | 65.47 | 55.45 | 1,283 | -60.76 |
| Korea, Rep. | BBB+/A- | 31.30 | 31.60 | 16,643 | -12.94 |
| Malaysia | BBB-/BBB | 46.50 | 47.61 | 5,296 | -21.18 |
| Mexico | BB/BB+ | 30.22 | 47.03 | 7,586 | -34.94 |
| Nigeria | B+ | 18.33 | 42.46 | 920 | -57.76 |
| Panama | BB/BB+ | 56.91 | 49.64 | 4,747 | -77.94 |
| Peru | BB-/BB | 40.70 | 50.92 | 3,038 | -41.59 |
| Philippines | BB-/BB | 62.05 | 50.79 | 1,195 | -42.29 |
| Romania | BB- | 38.69 | 30.06 | 4,447 | -28.47 |
| Russia | BB | 43.34 | 30.31 | 4,928 | 1.24 |
| Sri Lanka | CCC+/B- | 44.52 | 41.16 | 1388 | -45.24 |
| Thailand | BB+/BBB- | 46.69 | 52.70 | 2,623 | -39.59 |
| Turkey | B/B+ | 43.44 | 45.29 | 6,584 | -35.29 |
| Uruguay | B+/BB- | 43.91 | 43.18 | 5,447 | -11.53 |
| Venezuela | B/B+ | 35.65 | 41.59 | 5,500 | 5.71 |
| | | *Advanced economies* | | | |
| Australia | AA-/AA | 59.96 | 31.32 | 30,7901 | -54.47 |
| Canada | AA/AA+ | 69.65 | 30.18 | 30,870 | -18.47 |
| Denmark | AA/AA+ | 96.08 | 22.40 | 43,164 | -12.53 |
| Finland | AA-/AA | 72.71 | 22.35 | 29,175 | -46.24 |
| Greece | BBB/BBB+ | 93.64 | 33.64 | 19,689 | -53.94 |
| Hungary | BBB-/BBB | 85.08 | 28.36 | 9,881 | -81.76 |
| Italy | A+/AA- | 84.03 | 33.60 | 29,355 | -17.53 |
| Japan | AA-/AA | 33.66 | 28.38 | 34,743 | 33.94 |
| New Zealand | AA-/AA | 84.00 | 32.38 | 27,242 | -84.35 |
| Norway | AA+ | 44.65 | 23.41 | 57,064 | 38.59 |
| Poland | BB/BB+ | 41.43 | 30.01 | 6,960 | -39.41 |
| Portugal | A-/A | 138.62 | 35.05 | 17,497 | -59.29 |
| Singapore | AA/AA+ | 154.52 | 42.92 | 25,595 | 1.78 |
| Spain | AA/AA+ | 90.52 | 32.88 | 23,920 | -47.76 |
| Sweden | AA- | 92.11 | 23.39 | 34,421 | -25.41 |
| United States | AA+ | 60.68 | 36.80 | 41,165 | -14.76 |

List of countries used in the panel regression. Time period covers 1994-2010. Data sources from left to right: Fitch, Rainhart-Rogoff series, SWIID, the World Bank and the External Wealth of Nations Mark II database.

emerging markets have low ratings even though their debt-to-GDP ratios are not very high. When the ratio of net foreign assets to GDP is considered, emerging markets are, on average, more indebted than advanced countries. Second, they also have higher income inequality and lower GDP per capita than advanced economies have.

We estimate equation 2.1 using year ($z_t$) and country ($u_i$) fixed effects. We are interested in analyzing the effect of inequality that varies over time; therefore, country fixed effects will control for time-invariant characteristics unique to a country. In the first specification, we find that an increase in a country's external debt-to-GDP ratio is associated with lower creditworthiness in the next period. This is a standard result in the literature, as well. In the second specification, we introduce GDP per capita in log terms, and we find that an increase in income is associated with an increase in country's creditworthiness. Finally, the last specification shows the relationship between income inequality and credit ratings. We find that an increase in Gini index is negatively associated with the creditworthiness in the next period. The estimate is significant at ten percent and robust to country and time fixed effects. In order to get an economic interpretation of the estimates, we do a simple back-of-the-envelope calculation based on the third specification. The median score in the sample is 13, which corresponds to BB+. We estimate the third specification separately for each country. Then, we increase each variable by its one standard deviation and compare their effects on the score for each country. We find that, on average, a one standard deviation increase in external debt reduces the credit score by 0.97 and a one standard deviation increase in log GDP increases the credit score by only 0.01 point. On the other hand, a one standard deviation increase in Gini reduces the credit score by 0.21 point. The largest effect comes from the external debt-to-GDP, but the change in the Gini index also has a substantial effect.

### 2.2.2 Income Inequality over the Business Cycle

In order to support our theory that income inequality plays a role in default decisions, we also need to determine whether there is countercyclical inequality over the business cycle. Using household-level data from several countries, Krueger et al. (2010) show that during

Table 2: Panel regressions explaining creditworthiness with debt ratios, GDP per capita and inequality

| | Dependent Variable: Score of country $i$ in year $t$. | | |
|---|---|---|---|
| Independent Variable | (1) | (2) | (3) |
| External debt-to-GDP at $t-1$ | $-0.0221^{***}$ | $-0.0146^{***}$ | $-0.0122^{**}$ |
| | (0.0057) | (0.0050) | (0.0048) |
| GDP per capita at $t-1$ | – | $9.5976^{***}$ | $10.0130^{***}$ |
| | | (2.5606) | (2.5013) |
| Gini at $t-1$ | | | $-0.0698^{*}$ |
| | | | (0.0360) |
| Year fixed effects | Yes | Yes | Yes |
| Country fixed effects | Yes | Yes | Yes |
| No of countries | 45 | 45 | 45 |
| $N$ | 568 | 568 | 568 |

Sample period is between 1994 and 2010. The dependent variable is the credit score of country $i$ in year $t$. Estimation is by robust standard errors. Standard errors are reported in parentheses. Per capita GDP is in logs. (***,**,* represent significance level at 1%, 5% and 10%, respectively.)

recessions, earnings inequality increases.[6] We perform a similar exercise using our country-level data. We use the countries that have continuous series for Gini and GDP, leaving us with 77 countries. We compute the correlation between detrended GDP and inequality and find that, on average, inequality is countercyclical over the business cycle, with a mean correlation equal to $-0.02$. This result is robust to using the Gini series from The World Bank, as well. In this sample, there are only 46 countries and the mean correlation is equal to $-0.03$. Both results support the idea inequality is, on average, countercyclical over the business cycle in our sample.

[6]They have several inequality measures, such as Gini coefficient, variance of logs, 50/10 and 90/50 percentile ratios, and the countries they study are Canada, Germany, Italy, Mexico, Russia, Spain, Sweden and the USA.

## 2.3 MODEL

In this section, we present a model economy in order to structurally analyze the role of inequality in sovereign debt default. Our model is similar to the model presented by Arellano (2008) and belongs to the class of models in the standard framework of Eaton and Gersovitz (1981). We consider a discrete time, small open economy inhabited by heterogeneous agents that are hand-to-mouth and differ in the stochastic endowments they receive. The endowment is subject to aggregate output and inequality shocks that cannot be completely insured against. There is a benevolent government that represents the preferences of households and has access to international markets. The government can issue one-period bonds to foreign lenders and rebate the proceeds of the debt operations to the households. The government can choose to default fully on its debt at any time, because contracts are not enforceable. The penalty for default is that the economy is forced into financial autarky for a period of time, and there is an exogenous drop in output. Now, we move on to the details of the model.

### 2.3.1 Households

There are two types of infinitely-lived households indexed by $i = 1, 2$, and their preferences over consumption of the good, $c_t$, is assumed to be

$$u(c_t^i) = \frac{c_t^{i,1-\sigma}}{1-\sigma} \tag{2.2}$$

where $\sigma$ is the constant relative risk-aversion parameter, and $\sigma > 0$ and $\sigma \neq 1$. The type 1 household receives a stochastic stream of a tradable good, $\frac{(1+\gamma)y}{2}$, and type 2 receives $\frac{(1-\gamma)y}{2}$, where $y$ and $\gamma$ denote output and inequality, respectively. The output $y$ and the inequality $\gamma$ follow a Markov process with a transition function $f(y', \gamma' | y, \gamma)$. Households also receive an equal amount of transfer from (or pay taxes on goods to) the benevolent government in a lump sum fashion. Households live hand-to-mouth, which means they do not make any individual saving or borrowing decisions.

### 2.3.2 Government

The government of the economy can trade one-period, non-state contingent bonds with foreign lenders that are risk neutral and competitive. As in a standard default model, when the government defaults, the economy faces two types of exogenous default penalties: direct output costs and a temporary exclusion from borrowing in the debt markets. The government's goal is to maximize social utility, which is the expected discounted sum of lifetime utilities of both types with equal weights given as

$$E_0 \sum_{t=0}^{\infty} \beta^t \left[ u(c_t^1) + u(c_t^2) \right], \tag{2.3}$$

where $\beta$ denotes the discount parameter and $\beta \in (0,1)$. The government makes two decisions in this model. First, it decides whether to repay or default on its existing debt. Second, conditional on not defaulting, it chooses the amount of one-period bonds, $B'$, to issue or buy. If the government chooses to buy bonds, the price it needs to pay is given as $q(B', y, \gamma)$. The discount bonds, $B'$, can take a positive or negative value. If it is negative, this means that the government borrows $-q(B', y, \gamma)B'$ amounts of period $t$ goods and promises to pay $B'$ units of goods in the next period, if it does not default. Similarly, if $B'$ is positive, then this implies that the government saves $q(B', y, \gamma)B'$ amounts of period $t$ goods and will receive $B'$ units of goods in the next period. The bond price function $q(B', y, \gamma)$ depends on the size of the bonds, $B'$, income shock, $y$, and inequality shock, $q$. Government internalizes how its borrowing decisions affect the default risk and the price of the bond.

When the government chooses to repay its debt, the resource constraint for household 1 is

$$c^1 = \frac{(1+\gamma)y}{2} + \frac{B - q(B', y, \gamma)B'}{2}, \tag{2.4}$$

and the resource constraint for household 2 is

$$c^2 = \frac{(1-\gamma)y}{2} + \frac{B - q(B', y, \gamma)B'}{2}. \tag{2.5}$$

The economy faces three types of uncertainty that cannot be insured away with non-state-contingent bonds. The first one is the dispersion in incomes induced by shocks to $\gamma$. The second one is the output shock $y$ that affects the aggregate output in the economy. Finally, the third one is the endogenous default risk. The goal of the government is to maximize the expected utilities of households, and it achieves this goal by trying to equalize the marginal utilities of consumption between households and across time. One government policy is to choose optimal $B'$ that satisfies its goal, and the level of existing debt and the size of the shocks are crucial for this decision. As debt accumulates, it becomes harder to roll it over because of increasing default risk.

When the government chooses to default, consumption of the types are:

$$c^1 = \frac{1+\gamma}{2} y^d \tag{2.6}$$

and

$$c^2 = \frac{(1-\gamma)}{2} y^d, \tag{2.7}$$

where $y^d$ is the level of output in default and $y^d = y - \kappa(y)$. The penalty is a function of the output such that $\kappa(y) = \min\{y, \max\{0, d_0 y + d_1 y^2\}\}$. The default penalty is higher, if default happens in the good states of the world. This default penalty structure has been used in many papers in the literature, such as Chatterjee and Eyigungor (2012b).

### 2.3.3 Foreign Creditors

Foreign creditors can perfectly monitor the state of the economy and have perfect information about the shock processes. They can borrow loans from international credit markets at a constant interest rate $r > 0$, which is the risk-free interest rate for this model. Taking the bond price function $q(B', y', \gamma)$ as given, they choose loans $B'$ that maximize their expected profits $\phi$, given as

$$\phi = q(B', y, \gamma)B' - \frac{1 - \delta(B', y, \gamma)}{1+r} B', \tag{2.8}$$

where $\delta(B', y, \gamma)$ is the probability of default and it is determined endogenously.

$$q(B', y, \gamma) = \begin{cases} \frac{1}{1+r} & B' \geq 0 \\ \frac{1-\delta(B',y,\gamma)}{1+r} & B' < 0. \end{cases}$$

The price function depends on the sign of $B'$. It is never optimal to default when the government saves ($B' \geq 0$), so in that case, the price is a constant function of the risk-free interest rate. On the other hand, if the government borrows ($B' < 0$), then the price reflects the default probability. This implies that as the default probability increases, the price of the bond falls.

### 2.3.4 Timing

The timing in the model is as follows.

1. The government starts with initial assets $B$.
2. The output shock $y$ and the inequality shock $\gamma$ are realized.
3. The government decides whether to repay its debt obligations or default.
   a. If the government decides to repay, then taking as given the bond price schedule $q(B', y, \gamma)$, the government chooses $B'$ subject to the resource constraint. Then creditors, taking $q(B', y, \gamma)$ as given, choose $B'$. Finally, households consume $c^1$ and $c^2$ with respect to their types.
   b. If the government chooses to default, then the economy is in financial autarky and remains in autarky in the next period with probability $\theta$. Households simply consume their endowments.

### 2.3.5 Recursive Equilibrium

We focus on a recursive equilibrium, in which there is no enforcement. Based on the foreign creditors' problem, government's debt demand is met as long as the gross return on the bond equals $(1 + r)$. Given loan size $B'$, inequality state $\gamma$ and income state $y$, the bond price is

$$q(B', y, \gamma) = \frac{1 - \delta(B', y, \gamma)}{1 + r}. \tag{2.9}$$

The value function for the government that has the option to default or pay its debt is given as $v^o(B, y, \gamma)$. Government chooses the option that maximizes the welfare of agents. The default option will be optimal only if the government has debt. The value of default is denoted by the function $v^d(y, \gamma)$, and the value of repayment is denoted by $v^c(B, y, \gamma)$.

$$v^o(B, y, \gamma) = \max_{c,d}\{v^c(B, y, \gamma), v^d(y, \gamma)\}. \tag{2.10}$$

The value of default is expressed by

$$\begin{aligned} v^d(y, \gamma) &= u\left(\frac{(1+\gamma)y^{def}}{2}\right) + u\left(\frac{(1-\gamma)y^{def}}{2}\right) \\ &+ \beta \int_{\gamma'} [\theta v^o(0, y', \gamma') + (1-\theta)v^d(y', \gamma')] f(y', \gamma'|y, \gamma) d(\gamma', y'). \end{aligned} \tag{2.11}$$

Under default, individuals only consume their income. The government can gain access to debt markets with probability $\theta$, and the economy stays in autarky with probability $1 - \theta$. The transition probabilities are given by the joint density function, $f$. Similarly, the value of staying in contract is

$$\begin{aligned} v^c(B, y, \gamma) &= \max_{B'} u\left(\frac{(1+\gamma)y - q(B', y, \gamma)B' + B}{2}\right) + u\left(\frac{(1-\gamma)y - q(B', y, \gamma)B' + B}{2}\right) \\ &+ \beta \int_{y',\gamma'} v^o(B', y', \gamma') f(y', \gamma'|y, \gamma) d(\gamma', y'). \end{aligned} \tag{2.12}$$

If the government chooses to repay its debt, the value function for this choice reflects the future options for default and staying in contract. The government chooses the optimal bond contract that maximizes the sum of utilities of the households and expected discounted future value of option.

We can characterize the government's default policy by default and repayment sets. Let $A(B)$ be the set of $y$ and $\gamma$ for which repayment is optimal when assets are $B$, such that

$$A(B) = \left\{(y, \gamma) \in (\mathbb{Y}, \Gamma) : v^c(B, y, \gamma) \geq v^d(y, \gamma)\right\}, \tag{2.13}$$

and let $D(B) = \tilde{A}(B)$ be the set of $y, \gamma$ for which default is optimal for a level of assets B:

$$D(B) = \left\{(y, \gamma) \in (\mathbb{Y}, \Gamma) : v^c(B, y, \gamma) < v^d(y, \gamma)\right\}. \tag{2.14}$$

**Proposition 1.** *Given an output shock $y$, inequality shock $\gamma$ and bond positions $B^1 < B^2 \leq 0$, if default is optimal for $B^2$ then default will be optimal for $B^1$, and the probability of default at equilibrium satisfies $\delta(B^1, y, \gamma) > \delta(B^2, y, \gamma)$.*

*Proof.* See Appendix A.1.1. □

This proposition formally states a feature of the model that Eaton and Gersovitz (1981) also have. It shows that in equilibrium default sets expand and the probability of default increases as the level of debt in a country increases. The following proposition states that equilibrium bond price decreases as the level of debt increases.

**Proposition 2.** *Given an output shock $y$, inequality shock $\gamma$ and bond positions $B^1 < B^2 \leq 0$, equilibrium bond price satisfies $q(B^1, y, \gamma) \leq q(B^2, y, \gamma)$.*

*Proof.* See Appendix A.1.2. □

Now we define the recursive equilibrium for this economy. Let $s = \{B, y, \gamma\}$ be the set of aggregate states for the economy.

**Definition 1.** *The recursive equilibrium for this economy is defined as a set of policy functions for (i) consumptions $c^1(s)$, $c^2(s)$; (ii) government's asset holdings $B'(s)$, repayment sets $A(B)$, and default sets $D(B)$; and (iii) the price function for bonds $q(B', y, \gamma)$ such that:*

1. *Agents' consumption $c^1(s)$ and $c^2(s)$ satisfy the resource constraints, taking the government policies as given.*
2. *The government's policy functions $B'(s)$, repayment sets $A(B)$, and default sets $D(B)$ satisfy the government optimization problem, taking the bond price function $q(B', y, \gamma)$ as given.*
3. *Bonds prices $q(B', y, \gamma)$ reflect the government's default probabilities and default probabilities satisfy creditors' expected zero profits.*

In equilibrium, the bond price function should satisfy both the government's optimization problem and the expected zero profits in the lenders' problem. As mentioned, the probability of default endogenously affects the bond price. Using the default sets, we can express the probability of default such that:

$$\delta(B', y, \gamma) = \int_{D(B')} f(y', \gamma' | y, \gamma) d(y', \gamma'). \tag{2.15}$$

When default sets are empty, default is never optimal at the asset level $B'$, so the probability of default equals zero, independent of the realized shock. When $D(B') = (\mathbb{Y}, \Gamma)$, government always chooses to default for all shock levels. Default sets are shrinking in assets.

## 2.4 QUANTITATIVE ANALYSIS AND SIMULATION

### 2.4.1 Quantitative Analysis

In this section, we describe the estimation procedure for the shock processes and then explain the calibration strategy. We use the model to analyze the debt dynamics in Argentina between 1990-2002, quantitatively. Focusing on an Argentine default episode enables us to compare our results with the ones in the existing literature.

**2.4.1.1 Calibration and Functional Forms** We solve the model assuming that both output and inequality shocks are in play. We call this the benchmark model. In the benchmark model, output and inequality shocks are modeled as a VAR process. Next, in order to quantify the role of each shock and to assess the importance of the shocks in matching the high volatilities and particularly high default rates observed in emerging economies, we solve the model subject to only one shock at a time. Model II has only output shocks, and we assume that output follows an AR(1) process. Model III has only inequality shocks and, again, the inequality shock is modeled as an AR(1) process.

In the benchmark model, we assume that the VAR process for log output and inequality is as follows:

$$\begin{bmatrix} log(y_t) \\ \gamma_t \end{bmatrix} = \begin{bmatrix} c_y \\ c_\gamma \end{bmatrix} + \begin{bmatrix} \rho_{yy} & \rho_{y\gamma} \\ \rho_{\gamma y} & \rho_{\gamma\gamma} \end{bmatrix} \begin{bmatrix} log(y_{t-1}) \\ \gamma_{t-1} \end{bmatrix} + \begin{bmatrix} \varepsilon_{yt} \\ \varepsilon_{\gamma t} \end{bmatrix},$$

where

$$\begin{bmatrix} c_y \\ c_\gamma \end{bmatrix} = \left[ \boldsymbol{I} - \begin{bmatrix} \rho_{yy} & \rho_{y\gamma} \\ \rho_{\gamma y} & \rho_{\gamma\gamma} \end{bmatrix} \right] \begin{bmatrix} \mu_y \\ \mu_\gamma \end{bmatrix}$$

$$\boldsymbol{\varepsilon} = \begin{bmatrix} \varepsilon_{yt} \\ \varepsilon_{\gamma t} \end{bmatrix}$$

$$E[\boldsymbol{\varepsilon}] = \mathbf{0} \quad \text{and} \quad Var[\boldsymbol{\varepsilon}] = \begin{bmatrix} \sigma_y^2 & \sigma_{y\gamma} \\ \sigma_{\gamma y} & \sigma_\gamma^2 \end{bmatrix}.$$

The estimated values are derived from Argentina's GDP and income inequality data between 1991Q1 and 2005Q2. We use real output in quarterly, seasonally adjusted, real series and covering the period 1993Q1 to 2001Q4 from the dataset in Arellano (2008).[7] We take logs of GDP and detrend these series using an HP filter. The data pertaining to inequality are constructed using the distribution of income series in World Development Indicators provided by the World Bank. We choose the same period as for GDP. In order to construct the inequality measure, we compute the total income share of the upper 50th percentile and lower 50th percentile. Then, we take the difference of the income shares and divide it by two, which gives us the dispersion from the mean income. Since only annual data are available, we adopt the Boots-Feibes-Lisman method to disaggregate the annual data into quarterly data. Both output and inequality shocks are then discretized into a 21-state Markov chain, using Tauchen (1986).

The discount factor $\beta$, and default penalty parameters $d_0$ and $d_1$ are jointly calibrated to target a default probability of 3 percent, debt-to-GDP ratio of 5.53 percent and mean spread of 6.23. We set the probability of reentry to 0.25, which implies it takes a year to gain access to bond markets.[8]

[7] Arellano (2008) uses the data provided by the Ministery of Finance of Argentina.

[8] The calibrated value of $\beta$ and the value of $\theta$ are close to the values used in the default literature. For instance, Yue (2010) assumes that $\beta = 0.72$, and Aguiar and Gopinath (2006) assume that $\beta = 0.8$. The value of parameter $\theta$ implies that, on average, autarky takes four quarters, assuming that the distribution of default lengths is exponential (Tomz and Wright (2007) and Pitchford and Wright (2011)). Dias et al. (2007) empirically show that it takes 5.7 years, on average, for countries to regain partial access to international capital markets and Gelos et al. (2011) document that average exclusion from the international markets declined to two years in the 1990s; however, endogenous sovereign default models with exogenous entry to the debt markets calibrate the parameter $\theta$ around 0.25. (Arellano (2008) chooses 0.282 and Aguiar and Gopinath (2006) choose 0.10).

Table 3 shows the parameters that we use for the benchmark model's calibration. We set the risk-free interest rate to 1.7 percent to match the US five-year Treasury bond quarterly yield. The risk-aversion parameter $\sigma$ is set to 2, as it is standard in the macro literature. We also report the estimates of the parameters in the stochastic shock process. Note that the correlation of the output at $t$ and the inequality at $t-1$, $\rho_{y\gamma}$, is negative. This means that high inequality generates low output in the next period. Similarly, since $\rho_{\gamma y}$ is equal to zero, the output in the previous quarter does not affect the inequality in the current period. This relationship between inequality and output is not unique to Argentina. We find that other frequently defaulting economies, such as Brazil, Costa Rica, Dominican Republic, Ecuador and Uruguay, also have similar results in terms of the signs of the estimates. These results are reported in Table 29 in the Appendix A.3.

Table 3: A priori parameters for model I

| Name | Parameters | Description |
|---|---|---|
| Risk-free interest rate | $r = 1.7\%$ | US 5-year bond quarterly yield |
| Risk aversion | $\sigma = 2$ | |
| Probability of reentry | $\theta = 0.25$ | |
| Stochastic structure | $\begin{bmatrix} \rho_{yy} & \rho_{y\gamma} \\ \rho_{\gamma y} & \rho_{\gamma\gamma} \end{bmatrix} = \begin{bmatrix} 0.95 & -0.38 \\ 0.00 & 0.95 \end{bmatrix}$ | Argentina's GDP |
| | $\begin{bmatrix} \sigma_y^2 & \sigma_{y\gamma} \\ \sigma_{\gamma y} & \sigma_\gamma^2 \end{bmatrix} = \begin{bmatrix} 0.0003 & -0.0001 \\ -0.0001 & 0.0001 \end{bmatrix}$ | and income inequality |
| | $\begin{bmatrix} c_y \\ c_\gamma \end{bmatrix} = \begin{bmatrix} 0.12 \\ 0.01 \end{bmatrix}$ | |

Table 4: Calibrated parameters for model I

| Name | Parameters | Calibrated Parameter | Target | Value Target |
|---|---|---|---|---|
| Discount rate | $\beta$ | 0.925 | Default probability | 3 percent |
| Default penalty | $d_0$ | -0.691 | Debt service-to-GDP | 5.45 percent |
| | $d_1$ | 0.095 | Mean spread | 6.23 |

For Model II, we remove the stochastic inequality shocks by setting the level of inequality to the mean inequality up to the default episode. This corresponds to setting $\gamma$ equal to

0.66. The stochastic process for output is assumed to be a log-normal AR(1) process such that

$$log(y_t) = \rho_y log(y_{t-1}) + \epsilon_{yt}, \tag{2.16}$$

where $E[\epsilon_{yt}] = 0$ and $E[\epsilon_{yt}^2] = \sigma_y^2$, which are estimated from Argentina's GDP. We again discretize the output process into a 21-state Markov chain using the Tauchen method. We keep all else the same as in the benchmark model. Table 5 presents the parameters for the second model.

Table 5: A priori parameters for model II

| Name | Parameters | Description |
|---|---|---|
| Risk-free interest rate | $r = 1.7\%$ | US 5-year bond quarterly yield |
| Risk aversion | $\sigma = 2$ | |
| Discount rate | $\beta = 0.925$ | |
| Default penalty | $d_0 = -0.691$ | |
| | $d_1 = 0.095$ | |
| Probability of reentry | $\theta = 0.25$ | |
| Inequality | $\gamma = 0.66$ | Mean income inequality in Argentina |
| Stochastic structure | $\rho_y = 0.9351$ | Argentina's GDP |
| | $\sigma_y = 0.0190$ | |

Similarly, we need to estimate the stochastic inequality process for Model III. We estimate the following AR(1) process:

$$\gamma_t = (1 - \rho_\gamma)\mu_\gamma + \rho_\gamma \gamma_{t-1} + \epsilon_{\gamma t}, \tag{2.17}$$

where $E[\epsilon_{\gamma t}] = \mu_\gamma$ and $Var(\epsilon_{\gamma t}) = \sigma_\gamma^2$, which are estimated from Argentina's inequality data. As with Model III, we discretize the inequality process into a 21-state Markov chain using the Tauchen method. We keep all else the same as in benchmark model. The parameters for the third model are presented in Table 6.

Table 6: A priori parameters for model III

| Name | Parameters | Description |
|---|---|---|
| Risk-free interest rate | $r = 1.7\%$ | US 5-year bond quarterly yield |
| Risk aversion | $\sigma = 2$ | |
| Discount rate | $\beta = 0.925$ | |
| Default penalty | $d_0 = -0.691$ | |
| | $d_1 = 0.095$ | |
| Probability of reentry | $\theta = 0.25$ | |
| Stochastic structure | $\rho_\gamma = 0.9851$ | Argentina's Inequality |
| | $\sigma_\gamma = 0.0037$ | |
| | $\mu_\gamma = 0.38$ | |

### 2.4.2 Model Solution

In this section, we begin with the analysis of the benchmark model's results and then elaborate on the intuition behind the workings of the model. Our solution algorithm is given in the Appendix A.2.

In our model, the benevolent government has two policy decisions to make: whether to repay the existing debt or default; and how much to borrow or save using one-period bonds. The government borrows to help households have smooth consumption and to shift future consumption to today because the equilibrium interest rate is lower than government's discount rate. The level of optimal debt depends on the current assets and the state of the world. Since lenders have full information about the state of the world and contracts are not state-dependent, borrowing constraints can bind for the government, particularly in bad states of the world, such as high inequality and low output. Therefore, we observe that bond prices depend on the level of assets and the types of shocks that the economy is subject to.

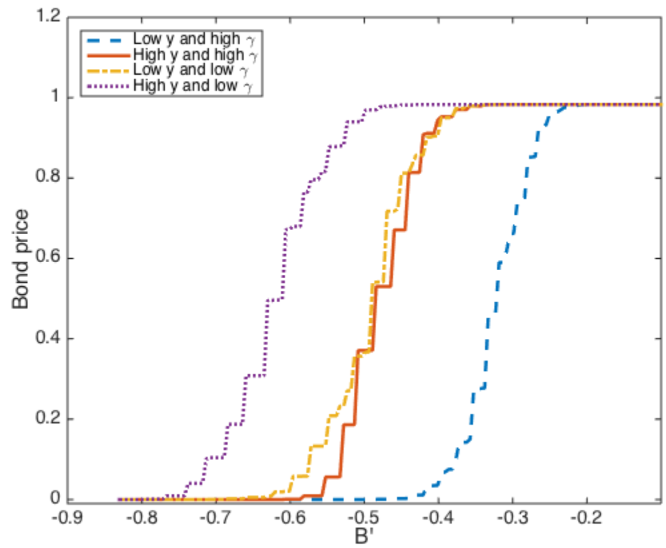
In the model, since the endowment is shared unequally among households, even in the absence of the shocks, the poor agents' marginal utility of consumption is higher than that of rich agents. An adverse output shock increases both agents' marginal utility of consumption, but an adverse inequality shock raises the marginal utility of the poor and reduces the marginal utility of the rich, increasing the dispersion between the marginal utilities of consumption. Defaults are more likely when there are adverse shocks and high levels of debt because the lenders offer bond contracts that have higher interest rates in these states. This makes the government borrowing-constrained and imposes large taxes on households in order to finance the debt. An adverse inequality shock exacerbates the burden of the tax, particularly on the poor, because it increases the poor's marginal utility of consumption disproportionately. In this case, the government can choose to default and use default as a redistribution mechanism. This policy improves welfare because, by eliminating the tax burden, the government can alleviate the dispersion.

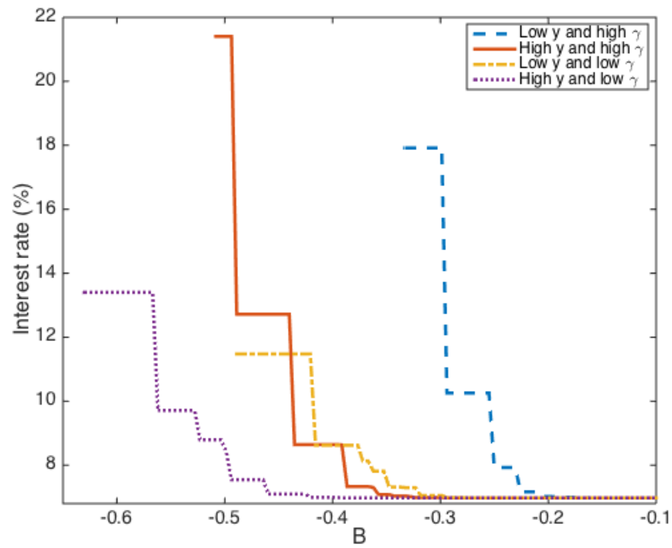
First, we analyze our results related to policy functions and value functions in the benchmark model. We report the results based on four different combinations of output and inequality shocks. A low (high) shock is one standard deviation below (above) its mean for each type of shock. The level of assets is denoted as a fraction of GDP. Then, we look at the business cycle statistics that the model generates.

Figure 1 shows the bond price schedule and the interest rate generated by the model. On the x-axis we have assets as a fraction of output. Similar to the results presented in the standard default literature, such as Arellano (2008) and Aguiar and Gopinath (2006), we observe that bond prices are an increasing function of assets, such that high levels of debt entail a low bond price and a high interest rate. Fixing the level of inequality shocks, we observe that it is easier to borrow during expansions than during recessions. However, the results also show that the effect of a high output shock can be dominated by the effect of a high inequality shock. In other words, an economy that is subject to both high output and high inequality shocks can have a bond price that is lower than that when there are low output and low inequality shocks.

The lower panel in Figure 1 shows the annual equilibrium interest rates generated by the model. The interest rate is calculated as $1/q(B', y, \gamma) - 1$. Inequality shocks generate another

Figure 1: Bond prices and interest rate (model I)




source of risk that is reflected in interest rates. The highest level of borrowing is possible when there is high output and low inequality in the economy. Government borrowing is subject to higher interest rates, even for small amounts of debt that are above the level of default in high-inequality and or low-output states.

The top panel in Figure 2 shows the saving policy function conditional on not defaulting.

Our results show that the government borrows more in expansions and when there is low inequality. This result is consistent with the countercyclical interest rates, since it becomes more costly to borrow in bad states of the world. The bottom panel of Figure 2 is the value function for the option to default or repay as a function of assets. Again, inequality plays a significant role in the default decision. The flat regions of the value function show the range of debt for which default is optimal. The value functions show that the highest debt can be supported, when there is high output and low inequality in the economy.

### 2.4.3 Business Cycle Results

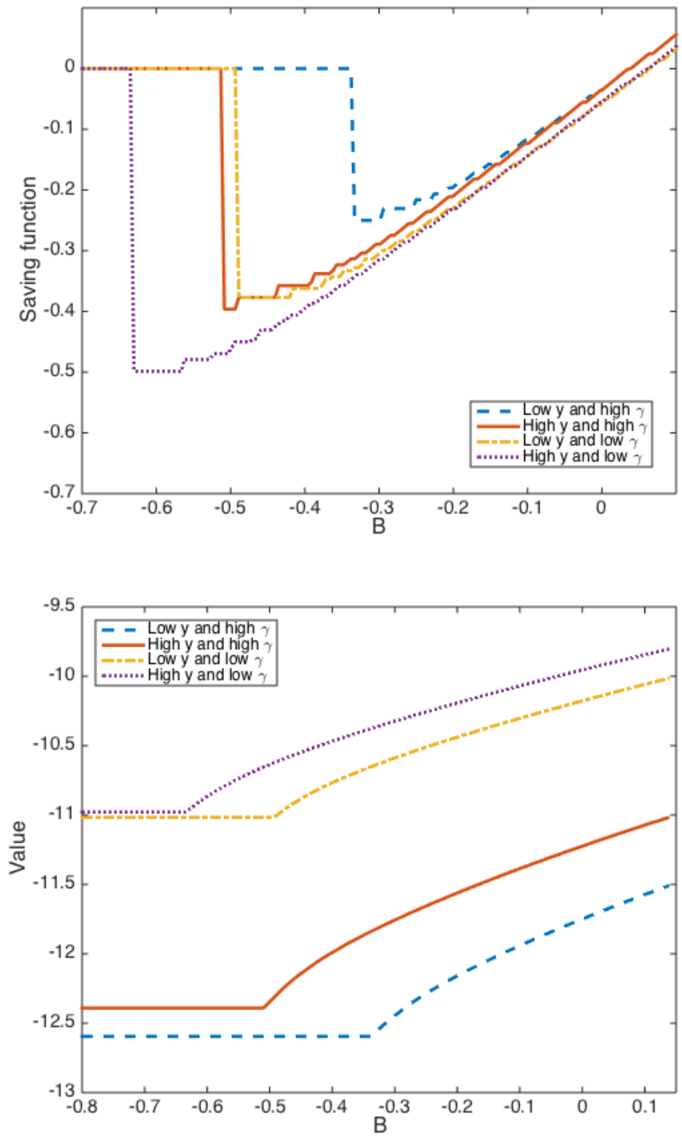
**2.4.3.1 Data** First, we document the business cycle characteristics of the Argentine economy. For the business cycle statistics, we use real output, consumption and trade balance data in quarterly, seasonally adjusted, real series for the period 1993Q1 and 2001Q4 from the dataset in Arellano (2008).[9] We take logs of GDP and consumption series and apply a linear trend on these series following Arellano (2008).[10] The trade balance data are a fraction of GDP. We also borrow Arellano (2008)'s spread data, which are defined as the difference between the interest rate in Argentina and the yield of the five-year U.S. treasury bond. The interest rate series is EMBI for Argentina and starts from 1983Q3. For the mean and standard deviation of the spread we use the period between 1993Q1 and 2001Q1. The inequality series is the one we constructed to generate a shock process, as explained in the previous section.

Table 7 presents the business cycle statistics of all the data available up to the default episode that started on December 26, 2001. Consumption and output in the first column show the deviations from the trend, and the other values are in levels in the first quarter of 2002. Relative to the average inequality in the series, in the default episode, inequality increased by 8.6 percent. The second column shows the standard deviations up to the default episode. We find that consumption is more volatile than output. The third and the fourth columns present the correlations of each variable with the output and the interest rate

[9] Arellano (2008) uses the data provided by the Ministry of Finance of Argentina.

[10] Analysis using HP filtered series (with smoothing parameter 1600) also produces similar results for correlations.

Figure 2: Savings and value functions (model I)




spread, respectively. It has been shown that emerging market economies are characterized by countercyclical spread rates and net exports. Also, their consumption is highly correlated with output. We see similar empirical results for Argentina in column 3. In addition, we show that inequality is countercyclical with output, so the economy has high inequality during recessions. The interest rate spread is negatively correlated with consumption and output, and positively correlated with trade balance. The data show that inequality is positively correlated with the spread, which implies that inequality increases during times of risky borrowing.

Table 7: Business cycle statistics for Argentina

| | Default episode $x$: Q1-2002 | std($x$) | corr($x, y$) | corr($x, r^c$) |
|---|---|---|---|---|
| Interest rate spread (%) | 28.60 | 2.77 | -0.88 | |
| Trade balance (% of GDP) | 9.90 | 1.75 | -0.64 | 0.70 |
| Consumption (% deviation from trend) | -16.01 | 8.59 | 0.98 | -0.89 |
| Output (% deviation from trend) | -14.21 | 7.78 | | -0.88 |
| Inequality (% deviation from mean ineq.) | 8.6 | 1.71 | -0.23 | 0.55 |

**2.4.3.2 Simulation Results** Next, we move on to the business cycle statistics generated by the benchmark model and evaluate the performance of the model with Argentine data. The upper panel of Table 8 presents the simulation results for the benchmark model, which generates a default probability of 2.80, debt-to-GDP ratio of 5.53 percent and mean spread of 4.90. High volatility of interest rates is a consequence of high default probability. We observe a large increase in the spread during default episodes, which is close to the data. In Argentina, in the couple of months following the default, quarterly spreads reached to 5,000-6,000 basis points. The model also generates large drops in consumption and output during default episodes. Inequality increases by 9.09 percent relative to its mean, which is also close to the increase observed during the default episode (8.60 percent). The model can also generate high volatility in consumption and output. The volatility of inequality is slightly lower than the value observed in the data.

In terms of correlations with output, the simulations can generate a positive correlation with consumption and a negative correlation with the interest rate spread.[11] We also obtain a negative correlation between output and trade balance. The reason is that when there are only output shocks, households can consume more than the level of the output during

[11]See Neumeyer and Perri (2005), Uribe and Yue (2006) and Aguiar and Gopinath (2007) for the role of countercyclical interest rates in emerging markets.

Table 8: Simulation results for the benchmark model

| | Default episodes | std(x) | corr(x,y) | $corr(x, r^c)$ |
|---|---|---|---|---|
| **Model I: Shocks to output and inequality** | | | | |
| Interest rate spread (%) | 59.82 | 9.94 | $-0.20$ | - |
| Trade balance (% of GDP) | $-0.01$ | 0.91 | $-0.12$ | 0.29 |
| Total Consumption (% deviation from trend) | $-7.19$ | 5.82 | 0.99 | $-0.25$ |
| Output (% deviation from trend) | $-7.29$ | 5.63 | – | $-0.20$ |
| Inequality (% deviation from mean ineq.) | 7.45 | 0.70 | $-0.28$ | 0.16 |
| *Other Statistics* | | | | |
| Mean debt (percent output) | 5.53 | Mean spread | | 4.90 |
| Default probability | 2.80 | | | |

expansions because the government can borrow easily. On the other hand, when there is a recession, borrowing is constrained; therefore, the consumption is less than the output. This generates a countercyclical trade balance over the business cycle. We see a positive correlation between the spread and the trade balance. Since the spread reflects the risk due to both inequality and output shocks, it is more correlated with the bad states of the world, in which the government is more likely to face borrowing constraints and experience large trade balances. As we expected, inequality is negatively correlated with output and positively correlated with the spread. Table 9 shows our model's performance relative to Arellano (2008). The benchmark model does quantitatively a similar job with Arellano (2008) in terms of matching the data.

We solve and simulate Model II and Model III, in order to assess the role of output shocks and inequality shocks in the default risk. The simulation results for Model II and Model III are given in Table 10. We find that the default probability is around 0.52 percent when there are output shocks and 0.32 percent when there are inequality shocks. We obtain a probability of default when the economy is subject to output shocks that is slightly higher than the model with inequality shocks because the default penalties are different in two models. In the case of output shocks, the default penalty increases in good states of the world and decreases in

Table 9: Simulation results for the benchmark model: comparison with Arellano (2008)

| | Data | Benchmark Model | Arellano (2008) |
|---|---|---|---|
| **Volatilities** | | | |
| $\sigma(c)/\sigma(y)$ | 1.09 | 1.04 | 1.10 |
| $\sigma(tb)/\sigma(y)$ | 0.17 | 0.16 | 0.26 |
| **Correlations** | | | |
| corr(y,spread) | −0.88 | −0.20 | −0.29 |
| corr(y,c) | 0.98 | 0.98 | 0.97 |
| corr(y,tb) | −0.64 | −0.12 | −0.25 |
| corr(y,inequality) | −0.23 | −0.28 | – |
| corr(spread,c) | −0.89 | −0.25 | −0.36 |
| corr(spread,tb) | 0.70 | 0.29 | 0.43 |
| corr(spread,inequality) | 0.55 | 0.16 | – |
| **Other Statistics** | | | |
| Mean Debt (percent output) | 5.53 | 5.41 | 5.95 |
| Mean Spread | 6.23 | 4.90 | 3.54 |
| Default Probability | 3.00 | 2.80 | 3.00 |

Table 10: Simulation results for model II and model III

| | Model II | | Model III | |
|---|---|---|---|---|
| | Default episodes | std(x) | Default episodes | std(x) |
| Interest rate spread (%) | 9.70 | 1.46 | 1.78 | 0.68 |
| Trade balance | −0.03 | 2.15 | −0.02 | 0.98 |
| Total Consumption | −2.78 | 5.65 | −2.92 | 0.99 |
| Output | −8.00 | 4.46 | −7.99 | 0.00 |
| Inequality | 0.00 | 0.00 | 2.63 | 1.15 |
| *Other Statistics* | | | | |
| Mean debt (percent output) | 52.76 | | 48.46 | |
| Default probability | 0.52 | | 0.32 | |
| Mean Spread | 0.63 | | 0.44 | |

bad states of the world; thus with smaller penalty and tighter borrowing constraints in bad states, we observe a larger default rate. On the other hand, in model III the default penalty is constant across all states because aggregate output is constant. This generates a lower probability of default in model III because the default cost is higher.

We also find that the default risk in both Model II and Model III is lower than that in the benchmark model. This is strong evidence that shows that the amplification effect comes from the underlying joint shock process. The reason behind this result is the VAR(1) process that we systematically estimated from the Argentine data. Based on the estimated process, it is more likely to have adverse output and inequality shocks together. Moreover, high inequality at time $t-1$ leads to lower output at time $t$. These characteristics play an important role in altering the expectations of foreign lenders and the government about the future state of the economy. An adverse inequality shock not only amplifies the effect of an adverse output shock today, but also generates pessimism that the recession with increasing inequality may be long-lasting.[12] As a result, foreign lenders ask for a higher premium, even for smaller levels of debt. This increases the borrowing constraints on the government, and default becomes an optimal decision.

### 2.5 ALTERNATIVE CALIBRATION

We obtain the main results regarding the effects of inequality shocks using Argentine data. In this section, we calibrate the model for Mexico. Our goal in this exercise is to see whether the model can match the business cycle statistics of Mexico and whether the model can also explain differences in consumption volatilities across income groups that we observe in the data. Since we do not have the consumption distribution data for Argentina, we focus on Mexican economy for this exercise. Like Argentina, Mexico experienced several default episodes. We focus on the crises in the last century when we compute the default

[12] In order to disentangle the effect of inequality on output in the next period, when we generate the Markov process, we assume that $\rho_{y\gamma} = 0$ and $\rho_{\gamma y} = 0$ . Under this specification, we find that the probability of default falls to 1.96 percent. This result shows that two thirds of the default risk comes from the fact that the covariances of the shocks are negative.

probability. According to Reinhart and Rogoff (2011), Mexico experienced external default or restructuring in 1914, 1928 and 1982 and it was near default in 1994. Depending on whether we include the last incidence, we get a default probability between 3-4 percent; therefore we choose 3.5 percent as the default rate.[13]

Table 11: A priori parameters for Mexico

| Name | Parameters | Description |
|---|---|---|
| Risk-free interest rate | $r = 1.7\%$ | US 5-year bond quarterly yield |
| Risk aversion | $\sigma = 2$ | |
| Probability of reentry | $\theta = 0.25$ | |
| Stochastic structure | $\begin{bmatrix} \rho_{yy} & \rho_{y\gamma} \\ \rho_{\gamma y} & \rho_{\gamma\gamma} \end{bmatrix} = \begin{bmatrix} 0.90 & -0.17 \\ 0.02 & 0.94 \end{bmatrix}$ | Mexico GDP |
| | $\begin{bmatrix} \sigma_y^2 & \sigma_{y\gamma} \\ \sigma_{\gamma y} & \sigma_\gamma^2 \end{bmatrix} = \begin{bmatrix} 0.0001 & 0.0002 \\ 0.0002 & 0.00005 \end{bmatrix}$ | and income inequality |
| | $\begin{bmatrix} c_y \\ c_\gamma \end{bmatrix} = \begin{bmatrix} 0.05 \\ 0.02 \end{bmatrix}$ | |

We repeat the steps for Argentina when we estimate the shock processes for Mexico. Table 11 shows a-priori parameters that we used in the simulations in order to obtain the business cycle statistics for Mexico. We use the same values for the risk-free interest rate and the risk aversion parameter as in the previous sections. The stochastic shock processes come from the VAR estimations based on Mexico's GDP and income distribution data. The data cover the period between 1995-2012. We find the estimate for $\rho_{y\gamma}$ is negative and it implies that inequality in the previous period reduces the output in the current period. However the covariances of the errors are not negative, which implies that Mexico is more likely to receive a low inequality shock together with a low output shock.

We follow the same calibration strategy. Table 12 shows the calibrated parameter values. We jointly calibrate the discount rate ($\beta$) and the output cost in autarky parameters ($d_0$ and $d_1$), in order to match the default probability of 3.5 percent, debt service-to-GDP ratio of

[13] If we count the number of default or restructuring episodes starting from the country's year of independence, then we consider the period between 1828 and 2015 for Mexico. There are in total 9 crises episodes, which lead to a higher default rate around 4-5 percent. The data on external debt crisis are from (Reinhart and Rogoff, 2011). An external debt crisis is defined as the failure to meet the principal or interest payment on the due date by Reinhart and Rogoff (2011). The episodes also include instances where the principal or interest payment is rescheduled at less favorable terms than the original contract.

Table 12: Calibrated parameters for Mexico

| Name | Parameters | Calibrated Parameter | Target | Value Target |
|---|---|---|---|---|
| Discount rate | $\beta$ | 0.90 | Default probability | 3.5 percent |
| Default penalty | $d_0$ | -1.37 | Debt service-to-GDP | 4.5 percent |
| | $d_1$ | 0.15 | Mean spread | 4.2 |

4.5 percent and the mean spread 4.2 in Mexico.[14] We compute the business cycle statistics using quarterly seasonally adjusted real GDP, real consumption and trade balance data from FRED, Federal Reserve Bank of St. Louis. We detrend the consumption and output series and we focus on the period between 1993q1 and 2012q4.

The simulation results are given in Table 13. In terms of matching the targets, the model does well except that it generates higher debt service-to-GDP ratio than we observe in the data. We see that the model can match the main business cycle characteristics for Mexico, such as spreads that are countercyclical, consumption that is procyclical over the business cycle and consumption that is highly correlated with output. We get high volatility of consumption relative to output. Also, the trade balance is positively correlated with the spread; however, it is acyclical with output.

We can also compute consumption volatilities for the rich and poor households using this model. We use Mexico Household Income and Expenditure Survey data between 1992 and 2008. Since the survey is not conducted every year, we interpolated the data for the missing years. We compute the consumption of the upper and lower 50 percentile of the households in order to make the statistics comparable with the model. In the data, we find that consumption volatility of the poor household is slightly higher than the rich household's and the ratio of volatilities is 1.09. Since survey data set is annual, using the simulated results and aggregating the data we convert the consumption of the poor and rich households to

[14] We borrow debt service-to-GDP statistic from Cuadra et al. (2010). Debt service to GDP data cover the years from 1980 to 2007 and the spread covers the period from 2000q1 to 2012q4. We compute the spread as the difference between the interest rates on government securities and treasury bills of Mexico and the U.S., both data are retrieved from FRED database provided by Federal Reserve Bank of St. Louis.

Table 13: Business cycle statistics for Mexico

| Mexico | Simulation | Data |
|---|---|---|
| corr(spread, y) | -0.57 | -0.52 |
| corr(spread, tb) | 0.44 | 0.68 |
| corr(spread, tc) | -0.72 | -0.53 |
| corr(tb, y) | 0.01 | -0.87 |
| corr(tc, y) | 0.86 | 0.97 |
| std(tc)/std(y) | 1.19 | 1.09 |
| std($c_{poor}$)/std($c_{rich}$) | 1.05 | 1.10 |
| *Targets* | | |
| Default probability | 3.78% | 3.5% |
| Debt service-to-GDP | 9.9% | 4.5% |
| Mean spread | 4.44 | 4.20 |

Total consumption and trade balance are denoted by tc and tb, respectively. The consumption volatilities of the rich and poor are yearly, the rest of the statistics are at quarterly frequency.

annual frequency. In our model, consumption volatility of the poor households is also higher than that of the rich and the ratio is close to its data counterpart. Incomplete asset markets together with income shocks are key for this result. In our model income inequality shocks amplify the effect of output shocks particularly on the poor households' endowment. Since there are no other assets that the households can use to insure against these shocks, poor households have higher volatility of consumption than rich households.

## 2.6 PROGRESSIVE INCOME TAXES

In the previous sections, we assume that government distributes the proceeds of the debt payments equally between the households. As mentioned above, these proceeds can function as taxes when they are negative and they can function as transfers, otherwise. Since these payments are lump sum, the burden (benefit) of taxes (transfers) relative to endowment is quite different across the households. Particularly, the burden of lump sum taxes is on the poor. Therefore, this brings up the question: How would the probability of default change in an economy if the government could use progressive income taxes to finance the debt when it is costly to borrow?

We impose the following tax regime:

$$T(y^i) \quad = \quad \begin{cases} 0 & B - qB' \geq 0, \\ y^i - \lambda(y^i)^{1-\tau} & B - qB' < 0. \end{cases}$$

As $\tau$ increases the tax function becomes more progressive, and when $\tau = 1$, both types of households consume equally. The parameter $\lambda$ is called the shift parameter and determines the average tax rate. If $B - qB'$ is positive, the government only distributes the proceeds of the debt operations across households as transfers similar to the benchmark model. If $B - qB'$ is negative, then the government uses the revenues from the taxes to finance the debt. The budget constraint of the government for the latter case is given as:

$$T(y^1) + T(y^2) + B - qB' = 0. \tag{2.18}$$

One can solve for $\lambda$ using the budget constraint of the government:

$$\begin{aligned} y^1 - \lambda(y^1)^{1-\tau} + y^2 - \lambda(y^2)^{1-\tau} + B - qB' &= 0 \\ y - \lambda[(y^1)^{1-\tau} + (y^2)^{1-\tau}] + B - qB' &= 0 \\ \lambda[(y^1)^{1-\tau} + (y^2)^{1-\tau}] &= y + B - qB' \\ \lambda &= \frac{y + B - qB'}{(y^1)^{1-\tau} + (y^2)^{1-\tau}}. \end{aligned}$$

The disposable incomes are denoted by $\tilde{y}^i$ for each type of household $i$. When $B - qB' < 0$, we get:

$$
\begin{aligned}
\tilde{y}^1 &= \lambda(y^1)^{1-\tau}, \\
&= \frac{(y + B - qB')(y^1)^{1-\tau}}{(y^1)^{1-\tau} + (y^2)^{1-\tau}}. \\
\tilde{y}^2 &= \lambda(y^2)^{1-\tau}, \\
&= \frac{(y + B - qB')(y^2)^{1-\tau}}{(y^1)^{1-\tau} + (y^2)^{1-\tau}}.
\end{aligned}
$$

We can write the budget constraints of the households if the government does not choose to default as:

$$
c^1 = \begin{cases} y^1 + \frac{B-qB'}{2} & B - qB' > 0, \\ \frac{(y+B-qB')(y^1)^{1-\tau}}{(y^1)^{1-\tau}+(y^2)^{1-\tau}} & B - qB' \leq 0. \end{cases}
$$

$$
c^2 = \begin{cases} y^2 + \frac{B-qB'}{2} & B - qB' > 0, \\ \frac{(y+B-qB')(y^2)^{1-\tau}}{(y^1)^{1-\tau}+(y^2)^{1-\tau}} & B - qB' \leq 0. \end{cases}
$$

If the government chooses to default, we assume that the progressive taxes are in effect. The budget constraints during autarky are:

$$
\begin{aligned}
c^1 &= \frac{y^d (y^{d,1})^{1-\tau}}{(y^{d,1})^{1-\tau} + (y^{d,2})^{1-\tau}}, \\
c^2 &= \frac{y^d (y^{d,2})^{1-\tau}}{(y^{d,1})^{1-\tau} + (y^{d,2})^{1-\tau}}.
\end{aligned}
$$

We recalibrate the model in order to match 3 percent default probability and mean spread of 6.3, when $\tau = 0$[15]. We simulate the model for five different values of $\tau \in$

[15] The calibrated parameters are $\beta = 0.895$, $d_0 = -0.56$ and we fix $d_1 = 0.095$.

Table 14: Effect of $\tau_1$ on the default probability and debt

| | $\tau = 0$ | $\tau = 0.1$ | $\tau = 0.20$ | $\tau = 0.3$ | $\tau = 0.4$ |
|---|---|---|---|---|---|
| Mean debt (% output) | 26.32 | 27.44 | 28.02 | 28.65 | 28.98 |
| Mean spread (%) | 5.43 | 4.78 | 4.60 | 4.50 | 4.28 |
| Probability of default (%) | 2.92 | 2.32 | 1.85 | 1.68 | 1.46 |

$\{0, 0.1, 0.2, 0.3, 0.4\}$ and analyze how the progressivity of the tax system affects the probability of default and debt-to-output ratio. Table 14 shows the results. The model with $\tau = 0$ has mean debt of 26.32 percent. As $\tau$ increases, we obtain higher mean debt. Moving from $\tau = 0$ to $\tau = 0.4$, the probability of default decreases from 2.92 percent to 1.68 percent. The reason is that taxes reduce the dispersion in marginal utilities of consumption between households, by taxing the rich more than the poor. As the dispersion gets smaller, the government has less incentive to default. Therefore, foreign lenders lend higher levels of debt to the government and the mean spread declines monotonically.

## 2.7 CONCLUSION

This paper studies the role of changes in income inequality in sovereign borrowing and default decisions using a stochastic general equilibrium model with endogenous default risk. By introducing heterogeneous agents and shocks to the distribution of income, we predict a default probability of 2.8 percent and also match the business cycle characteristics observed in the data when calibrated to Argentina. Our model's contribution is to highlight the redistributive effects of default. The model can also explain the differences in consumption volatilities across different income groups, which has not been shown in the previous literature. Our paper emphasizes the role of changes in income inequality as another channel that leads to debt crises. We show that changes in income inequality can generate default episodes that coincide with recessions. Since these crisis episodes have long-lasting effects on the economy, we believe that the policies we suggest in this paper are critical to preventing future crises.

## 3.0 SOVEREIGN RISK AND PRIVATE CREDIT IN LABOR MARKETS[1]

### 3.1 INTRODUCTION

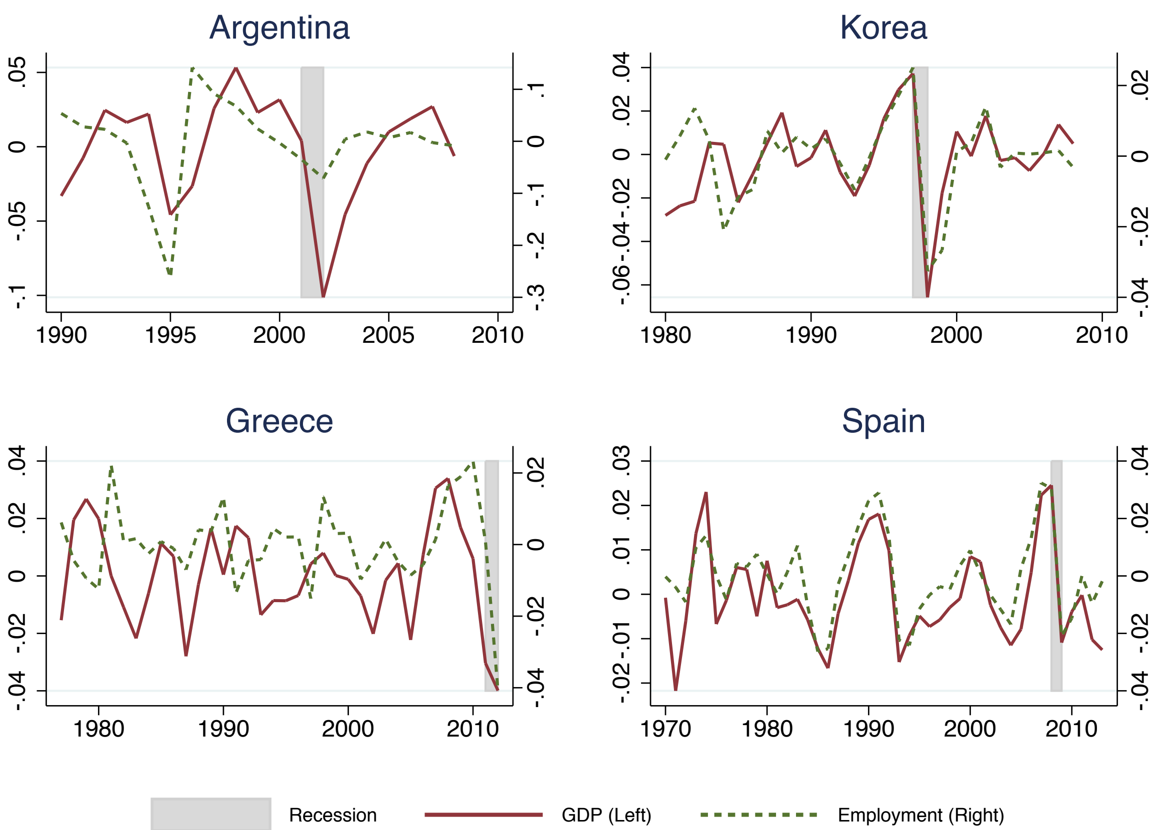
In this paper, we propose a theory that can explain three observations pertaining to emerging market economies. First, as Neumeyer and Perri (2005) show, emerging markets are characterized by countercyclical interest rates. Second, during default episodes, there are large drops in labor and output. Third, Arteta and Hale (2008) show that during sovereign debt crises, there is a significant decline in foreign credit to private firms. Firms can use private credit to finance their working capital, and there can be a feedback loop between sovereign risk and the cost of private credit. In this paper, we investigate the nexus among firms' labor demand decision, private credit and government's borrowing decisions, focusing on the role of labor markets. Particularly, we are interested in how private credit and government's default risk are related to the drops in output observed after sovereign defaults.

The stylized empirical facts for emerging economies are presented in Figure 3, focusing on a subset of countries that includes Argentina, Korea, Greece, and Spain. We look at the detrended real GDP and employment for these countries. Consistent with the findings in the literature shown by Li (2011), Neumeyer and Perri (2005) and Uribe and Yue (2006), we find that employment tends to move together with real GDP in these four emerging countries over the business cycle. In addition, in recession, the labor drops with the output drops in these economies.

In this paper, we examine these features of emerging markets using a stochastic general equilibrium model in a small open economy. The economy is subject to aggregate uncertainty about productivity. The problem of the representative households is standard in that they

[1]This research is a joint work with Kiyoung Jeon.

Figure 3: GDP and employment in emerging countries




make consumption and labor decisions that optimize their life time utility subject to a budget constraint that entails wages, transfers from the government and profits from the firms. Similar to standard models with endogenous default, there is a benevolent government that can borrow from foreign lenders by issuing one-period, non-state contingent bonds, which are not enforceable and the government transfers the proceeds of debt operations to households. The government's incentives to borrow comes from the fact that the government tries to help households have smooth consumption across time, using these transfers. Foreign lenders extend loans to the government, taking into account the default risk. Endogenous default risk is associated with the government's default or repayment decisions and it depends on the level of bonds the government would like to issue and the size of the productivity shock. Default is more likely, if the economy is subject to low TFP shocks and has high levels of debt because they lead to an increase in the premium that the foreign lenders ask when they lend to the government. As foreign lenders ask for a higher premium, it becomes harder for the government to roll over its debt, so it has to incur large taxes on households to finance the existing debt. If this is the case, then default can become an optimal policy because it can help eliminate the tax burden and improve households utility. However, the government faces a trade-off. If the government chooses to default, the government is banned from the loan markets for a temporary period of time. This means government cannot issue bonds to help households have smooth consumption during this period.

To generate endogenous drops in output, we assume that firm's production requires the finance of working capital loans used to pay a fraction of the wage bill. Adopting the working capital condition from Neumeyer and Perri (2005) enables us to examine the role of labor in sovereign defaults. Firms maximize their profits by making labor decisions and taking into account the interest they need to pay on the working capital loans. They demand less labor as working capital loans become more expensive due to the increase in sovereign default risk. The drops in labor demand result in lower production. When the government decides to default on its debt, the firms can still borrow from foreign lenders, but at a high interest rate, even though the government cannot. In this sense, the high interest rate on working capital loans acts as a default penalty on firms. This assumption is consistent with the empirical findings in the literature. Arteta and Hale (2008) show that during sovereign debt crises, there is a significant decline in foreign credit to private firms. The paper suggests that the decrease in amount of credit available to private firms can be an important channel that generates large drops in output observed in defaults.

In addition, we assume that the debtor still has debt arrears following defaults. In a standard default model such as Arellano (2008), the defaulters start with zero debt when they again enter into the debt market. However, this assumption does not account for the debt restructuring in emerging countries. Benjamin and Wright (2009) show that the creditors lose 44 percent of their lending on average through the renegotiation process after the default. Partial default makes our model closer to the actual debt restructuring of the defaulters. It can play a role as another form of penalty on default because the debt arrears lower the future value of default, and therefore it affects the decision on default.

The model explains the main features of the business cycles observed in the emerging markets well, such as countercyclical spreads, countercyclical trade balance, and high consumption and output volatility, when calibrated to Argentine data. In addition, the model can generate reasonable drops in labor and output in defaults. We also obtain procyclical labor over the business cycles and the labor volatility is similar to Argentine economy. We obtain a procyclical labor supply because two things change when the economy is hit by an adverse TFP shock; first, the shock has a direct effect on production and it reduces output because productivity is lower and firms demand less labor, which is a standard result of an RBC model. Second, the shock has an indirect effect on production through the increase in endogenous default risk. Because the government is more likely to default, the interest rate on the working capital loan is also higher, which makes the production even more costly for the firms and it dampens firms' labor demand even more. Equilibrium wages also drop because they are inversely related with interest rates and positively related with the TFP shock. Because we assume that households have Greenwood-Hercovitz-Huffman (GHH) type of preferences, the substitution effect dominates the income effect and the households are willing to supply less labor.[2] Overall this generates even larger drops in output. When households' income drops so much due to the decreases in labor income, the government would like to borrow even more from foreign lenders, so that households can have smooth consumption. However, since the shocks are persistent, the foreign lenders adjust their expectations about the future state of the economy, such that they ask for an even higher premium on the government bonds. This generates a vicious cycle, in which output, labor, consumption and wages decrease further and it becomes harder for the government to roll over its debt. Consequently, the government may choose to default to eliminate the tax burden necessary to finance the existing debt, especially when the level of existing debt is already very high.

[2] The advantage of GHH preference specification is that it generates the right comovement between labor supply and production. GHH specification was introduced by Greenwood et al. (1988) and has been used in many papers with small open economy models, such as Mendoza (1991), Correia et al. (1995), Neumeyer and Perri (2005), and many others.

Our paper is related to the endogenous sovereign default literature that starts with the seminal paper of Eaton and Gersovitz (1981) and continues with Aguiar and Gopinath (2006), Arellano (2008), Pitchford and Wright (2011), Chatterjee and Eyigungor (2012b) and Amador and Aguiar (2014), some of which were mentioned above.[3] These papers assume an exogenous output process and penalty in their models. Our paper is closely related to Mendoza and Yue (2011) in that they consider working capital conditions and endogenous sovereign default. They also combine the international business cycle model and the sovereign default model by considering the interaction between households, firms, government and foreign lenders, as we do in this paper. However, their work is different than ours in many dimensions. First, in their model the efficiency loss from sovereign default generates an endogenous output cost because firms should substitute imported inputs into other imported or domestic inputs, which are imperfect substitutes. However, in our model the default cost stems from the interest rate on working capital and the debt renegotiation. In addition, while their model adopts working capital conditions for imported intermediate goods, our model use working capital conditions for labor demand. Second, on the firms' side they assume that firms are excluded from the international debt market when the government decides to default. In our model, firms can still access to the international debt markets, but borrow at a high interest rate. In addition, our paper is related to papers on debt renegotiation and default such as D'Erasmo (2008), Bi (2008), Benjamin and Wright (2009), Yue (2010), and Pitchford and Wright (2011). Finally, our paper is related to the literature that studies the business cycle properties of labor market variables in emerging markets. Li (2011) explains countercyclical interest rates and procyclical wages in emerging economies by assuming exogenous default risk. As mentioned above we have endogenous default risk and working capital conditions in our model that generate fluctuations in labor together with productivity shocks.

The rest of the paper is organized as follows: Section 3.2 presents the model and defines the recursive equilibrium. Section 3.3 discusses the calibration, the quantitative analysis of the model. Section 3.4 discusses the simulation results. Section 3.5 concludes.

[3] Also see Panizza et al. (2009), Wright (2011) and Aguiar and Amador (2013) for good reviews of this literature.

## 3.2 MODEL

In this section, we present a model economy in order to understand the role of labor supply on sovereign debt default. Basically, our model belongs to the class of models in the standard framework of Eaton and Gersovitz (1981), but richer in the sense that it has households, firms, foreign lenders and the government. We consider a discrete time, small open economy inhabited by representative households. Households choose optimal consumption and labor paths that maximize their lifetime utilities subject to the budget constraint. They receive transfers from the government, wages for supplying labor and profits from the ownership of the firms. Firms face stochastic TFP shocks and finance working capital before production takes place similar to Neumeyer and Perri (2005). There is a benevolent government that represents the preferences of households and has access to international markets. The government can issue one-period bonds to foreign lenders and distribute the proceeds of the debt payments to the households. The government can choose to default on its debt at any time, because contracts are not enforceable. The penalty for default is that the government is forced to stay in financial autarky for a period of time and the firms need to pay higher interest rates on their working capital. In addition, if the government gains access to the international bond markets, it needs to pay the debt arrears. That is, we allow for partial default.

### 3.2.1 Households

We assume that the households have GHH preferences which are used in open economy models by many international business cycle literatures. The GHH preferences are often adapted because they improve the performance of the model in terms of the business cycle statistics. In addition, these preferences remove the wealth effect on labor supply and the labor supply is determined independently of intertemporal considerations. The functional form of preference is:

$$u(c,l) = \frac{\left(c - \frac{l^{\omega}}{\omega}\right)^{1-\sigma} - 1}{1-\sigma}$$

where $\omega > 1$ and $\sigma > 0$.

The households have different budget constraints that depend on whether the government is in autarky or not. If the government decides to repay its debt, the household problem is given as:

$$\max_{c_t, l_t} E_t \left[ \sum_{t=0}^{\infty} \beta^t u(c_t, l_t) \right]$$
$$\text{subject to } c_t = w_t l_t + \pi_t + (B_t - q_t B_{t+1}).$$

If the government is in autarky, the budget constraint becomes $c_t = w_t l_t + \pi_t$. The optimal labor supply satisfies that

$$l_t^{\omega-1} = w_t. \tag{3.1}$$

### 3.2.2 Firms

Firms choose labor demand that maximizes their profits. Profits are equal to revenues net of the wage bill and interest payments on working capital loans. Firms have to borrow a certain fraction of the labor cost in order to complete production.

When the government decides to repay its debt, the interest rate on working capital, $r_t$, is equal to the interest rate on the government's debt.

$$\max_{l_t} z_t k^{\alpha} l_t^{1-\alpha} - w_t l_t - r_t \theta w_t l_t$$

where $z_t$ is the TFP shock that is assumed to follow a Markov process with a transition function $f(z', z)$. The fraction of the labor cost that needs to be borrowed from foreign lenders at the interest rate, $r_t$, is denoted by $\theta$.

When the government chooses to default, the firms' problem is:

$$\max_{l_t} z_t k^{\alpha} l_t^{1-\alpha} - w_t l_t - r_d \theta w_t l_t,$$

where $r_d$ is the interest rate on working capital loans in default. It will be specified in detail in the government's problem.

In addition, we assume that $r_d$ is an upper bound on the interest rate on working capital even when the government decides to repay its debt and the bond price is close to zero.

From the firm's problem, the wage should satisfy the following optimality condition obtained from the firm's problem:

$$w_t = \begin{cases} \frac{1-\alpha}{1+\theta r_t} z_t k^\alpha l_t^{-\alpha} & \text{(Repayment)} \\ \frac{1-\alpha}{1+\theta r_d} z_t k^\alpha l_t^{-\alpha} & \text{(Default).} \end{cases} \tag{3.2}$$

### 3.2.3 Government

The government of the economy can trade one period, non-state contingent bonds with foreign lenders that are risk free and competitive. Unlike standard default models, when the government defaults, the economy does not face direct output costs, but the government is in a temporary exclusion from borrowing in the debt markets. When the government gains access to the debt markets, it needs to pay a fraction of the debt, which is denoted by $\kappa$. In this sense, we allow for only partial default in our model. The government's goal is to maximize the households' expected lifetime utility, given as:

$$E_0\left[\sum_{t=0}^{\infty} \beta^t u(c_t, l_t)\right], \tag{3.3}$$

where $\beta$ denotes the discount parameter and $\beta \in (0,1)$.

The government makes two decisions in this model. The first one is whether to repay or default on its existing debt. Second, conditional on not defaulting, it chooses the amount of one-period bonds, $B'$ to issue or buy. If the government chooses to buy bonds, the price it needs to pay is given as $q(B', z)$. The discount bonds, $B'$, can take positive or negative values. If it is negative, it means that the government borrows $-q(B', z)B'$ amounts of period $t$ goods and promises to pay $B'$ units of goods in the next period, if it does not default. Similarly, if $B'$ is positive, then it implies that the government saves $q(B', z)B'$ amounts of period $t$ goods and it will receive $B'$ units of goods in the next period. The bond price function $q(B', z)$ depends on the size of the bonds, $B'$, and TFP shock, $z$. Government's incentive to default and the price functions are both endogenous.

The government's value of option is the maximum of value of default ($v^d$) or value of repayment ($v^c$) and it is given as:

$$V(B_t, z_t) = \max_{c,d} \left\{ v^c(B_t, z_t), v^d(B_t, z_t) \right\}.$$

The value of repayment is represented by

$$\begin{aligned} v^c(B_t, z_t) &= \max_{B_{t+1}} u(c_t, l_t) + \beta E_t \left[ V(B_{t+1}, z_{t+1}) \right] \\ &\quad \text{subject to } c_t = z_t k^\alpha l_t^{1-\alpha} - r_t \theta w_t l_t + B_t - q_t(B_{t+1}, z_t) B_{t+1}. \end{aligned}$$

If the government chooses to repay its debt, the value function for this choice reflects the future options for default and staying in contract. The government chooses the optimal bond contract that maximizes the utility of the households and the discounted future value of option.

The value of default is given as:

$$\begin{aligned} v^d(B_t, z_t) &= u(c_t, l_t) + \beta E_t \left[ (1-\phi) v^d(B_t, z_{t+1}) + \phi v^c(\kappa B_t, z_{t+1}) \right] \\ &\quad \text{where } c_t = z_t k^\alpha l_t^{1-\alpha} - r_d \theta w_t l_t \end{aligned}$$

The probability of having access to bond markets in the next period is denoted by $\phi$. The value of default is equal to the utility of household plus the future expected discounted value that entails the value of default weighted by $1-\phi$ and value of option in the next period weighted by $\phi$. The value of option has $\kappa B_t$ as the state variable because the government enters into the international debt market with the debt arrears $\kappa B_t$ due to debt renegotiation process.

### 3.2.4 Foreign Lenders

Foreign creditors can perfectly monitor the state of the economy and have perfect information about the shock processes. They can borrow loans from international credit markets at a constant interest rate, $r^* > 0$, which is the risk free interest rate in this model. Taking the bond price function $q(B_{t+1}, z_t)$ as given, they choose loans $B_{t+1}$ that maximize their expected profits $\pi$, given as:

$$\pi(B_{t+1}, z_t) = \begin{cases} q(B_{t+1}, z_t) B_{t+1} - \frac{B_{t+1}}{1+r^*} & (\text{if } B_{t+1} \geq 0) \\ \frac{1-\delta(B_{t+1}, z_t) + \delta(B_{t+1}, z_t)\kappa\phi}{1+r^*} B_{t+1} - q(B_{t+1}, z_t) B_{t+1} & (\text{if } B_{t+1} < 0), \end{cases} \tag{3.4}$$

where $\delta(B_{t+1}, z)$ is the probability of default and is determined endogenously.

Because we assume that the market for new sovereign debt is completely competitive, the foreign investors' expected profit is zero in equilibrium. Hence, we have the bond price as following:

$$q_t(B_{t+1}, z_t) = \begin{cases} \frac{1}{1+r^*} & (\text{if } B_{t+1} \geq 0) \\ \frac{1-\delta(B_{t+1},z_t)+\delta(B_{t+1},z_t)\kappa\phi}{1+r^*} & (\text{if } B_{t+1} < 0), \end{cases} \tag{3.5}$$

That is, the bond price reflects both the default risk and the risk of debt restructuring.

Using the bond price function, the interest rate on working capital loans can be written as:

$$r_t(B_{t+1}, z_t) = \begin{cases} \frac{1}{q_t(B_{t+1},z_t)} - 1 & (\text{if } r_t < r_d) \\ r_d & (\text{otherwise}). \end{cases} \tag{3.6}$$

When the government saves ($B_{t+1} > 0$) or does not default on it debt, the interest rate on working capital loans is a function of the bond price. However, if the government decides to default on its debt, then the interest rate is the maximum level in the economy, which is exogenously set in the model.

### 3.2.5 Recursive Equilibrium

We focus on a recursive equilibrium, where there is no enforcement. Based on the foreign creditors' problem, government's debt demand is met as long as the gross return on the bond equals to the risk free rate, $1 + r$.

We can characterize the government's default policy by default and repayment sets. Let $A(B)$ be the set of $z$ for which repayment is optimal when assets are $B$, such that

$$A(B) = \left\{z \in \mathbb{Z} : v^c(B, z) \geq v^d(B, z)\right\}, \tag{3.7}$$

and let $D(B) = \tilde{A}(B)$ be the set of $z$ for which default is optimal for a level of assets B:

$$D(B) = \left\{z \in \mathbb{Z} : v^c(B, z) < v^d(B, z)\right\}. \tag{3.8}$$

Also, let $s = \{B, z\}$ be the set of aggregate states for the economy.

**Definition 2.** *The recursive equilibrium for this economy is defined as a set of policy functions for (i) consumption $c(s)$; (ii) government's asset holdings $B'(s)$, repayment sets $A(B)$, and default sets $D(B)$; (iii) the wage function $w(B', z)$; and (iv) the price function for bonds $q(B', z)$ such that:*

1. *Households' consumption $c(s)$ satisfies the resource constraints, taking the government policies as given.*
2. *The government's policy functions $B'(s)$, repayment sets $A(B)$, and default sets $D(B)$ satisfy the government optimization problem, taking the bond price function $q(B', z)$ as given.*
3. *The optimal wage function $w(B', z)$ satisfies firms' optimization problem, taking the interest rate on working capital loans $r(B', z)$ as given.*
4. *Bonds prices $q(B', z)$ reflect the government's default probabilities and default probabilities satisfy creditors' expected zero profits.*
5. *Labor market clears.*

At the equilibrium, the bond price function should satisfy both the government's optimization problem and the expected zero profits in the lenders' problem, so that probability of default endogenously affects the bond price. Using the default sets, we can express the probability of default such that:

$$\delta(B', z) = \int_{D(B')} f(z', z) dz'.$$

## 3.3 QUANTITATIVE ANALYSIS

We solve the model numerically. In this section, we describe the estimation procedure for the shock processes. We calibrate the model to analyze the debt dynamics quantitatively, using Argentine data between 1990-2002.

### 3.3.1 Data

First, we begin with documenting the business cycle characteristics of the Argentine economy. For the business cycle statistics we use real output, consumption and trade balance data in quarterly, seasonally adjusted, real series covering the period 1993Q1 and 2001Q4 from the dataset in Arellano (2008)[4]. We take logs of GDP and consumption series and detrend these series using an HP filter with a smoothing parameter of 1600. The trade balance data are reported as a fraction of GDP. We also borrow the spread data from Arellano (2008), which are defined as the difference between the interest rate in Argentina and the yield of the five-year US Treasury bond. The interest rate series is EMBI for Argentina and start from 1983Q3. The quarterly wage series are available in International Financial Statistics (IFS) and Instituto Nacional de Estadistica y Censos (INDEC). We take logs and detrend the series using an HP filter with a smoothing parameter equal to 1600. For the labor data, we use the weekly hours of work from INDEC. However, these are only available starting from 1997. Hence, we use a short time series for labor.

Table 15 presents the business cycle statistics of all the data available up to the default episode that started in December 26, 2001. The first column shows the standard deviations up to the default episode. We find that consumption, wage, and labor are more volatile than output. The second and the third column present the correlations of each variable with the output and the interest rate spread, respectively. It has been shown that emerging market economies are characterized by countercyclical spread rates and net exports. Also, their consumption is highly correlated with output. We see similar empirical results for Argentina in the second column. In addition, we see that labor and wage are procyclical with output. The interest rate spread is negatively correlated with consumption and output, and positively correlated with trade balance. Wages and the labor are negatively correlated with the spread rate.

[4] Arellano (2008) uses the data provided by the Ministery of Finance of Argentina.

Table 15: Business cycle statistics for Argentina from 1993Q1 to 2001Q4

| | std($x$) | corr($x, y$) | corr($x, r^c$) |
|---|---|---|---|
| Interest rates spread | 3.08 | −0.74 | – |
| Trade balance | 1.75 | −0.58 | 0.70 |
| Consumption | 3.75 | 0.97 | −0.68 |
| Output | 3.33 | – | −0.74 |
| Wage | 4.18 | 0.49 | −0.34 |
| *Labor** | 3.69 | 0.58 | −0.85 |
| **Other Statistics in default in 2002** | | | |
| Output drop | 12.01 | | |
| Consumption drop | 12.86 | | |
| Wage drop | 13.88 | | |
| Labor drop | 18.46 | | |
| Default probability | 2.78 | | |

* Quarterly labor data are available only between 1997Q1 and 2001Q4

### 3.3.2 Calibration

The model is solved quantitatively. In the numerical solution, we define one period as a quarter. Our calibration strategy is largely based on Argentine data. Table 16 shows the calibrated parameter values.

The utility function represents GHH preferences. The risk aversion parameter, $\sigma$, is set to two, the risk-free interest rate is set to one percent, and the capital share to 0.32 percent, which are standard values in macroeconomics literature. The curvature parameter of labor in GHH preference is set to 1.455 which determines Frisch wage elasticity by $\frac{1}{\omega-1} = 2.2$. The debt recovery rate $\kappa$ is set to 0.27 following Benjamin and Wright (2009). Benjamin and Wright (2009) estimate the recovery rate for all the default episodes in recorded history. For Argentina's default in 2001, they estimate it as 27 percent.

For the TFP shock process, we assume that it follows an AR(1) process:

$$\log z_t = \rho_z \log z_{t-1} + \epsilon_t$$

with $\epsilon \sim N(0, \sigma_z^2)$. We use the quadrature method in Tauchen (1986) to construct a Markov approximation with 21 realizations. Data for labor is not available for 1993Q1 to 1996Q4, so we set $\rho_z$ and $\sigma_z$ to target the standard deviation and first-order autocorrelation of quarterly HP filtered GDP data of Argentina. We use seasonally-adjusted quarterly real GDP data from Arellano (2008) for the period 1980Q1 to 2005Q4. The standard deviation and autocorrelation of the cyclical component of GDP are 3.3 percent and 0.86, respectively. To match these targets, we set $\rho_z = 0.952$ and $\sigma_z = 0.017$.

Table 16: Calibration

| Name | Parameters | Description |
|---|---|---|
| Risk-free interest rate | $r^* = 0.010$ | Standard RBC value |
| Risk aversion | $\sigma = 2.000$ | Standard RBC value |
| Capital share | $\alpha = 0.320$ | Mendoza (1991) |
| Curvature parameter of labor supply | $\omega = 1.455$ | Frisch wage elasticity=2.2 |
| Debt recovery rate | $\kappa = 0.270$ | Benjamin and Wright (2009) |
| Calibration | Values | Target statistics |
| Autocorrelation of TFP shocks | $\rho_z = 0.952$ | GDP autocorrelation = 0.860 |
| Standard deviation of TFP shocks | $\sigma_z = 0.017$ | GDP std. deviation = 0.033 |
| Discount factor | $\beta = 0.877$ | Default probability = 2.78% |
| Interest rate on working capital in default | $r_d = 0.350$ | Wage drop in default = 13.88% |
| Probability of reentry | $\phi = 0.150$ | Trade Balance Volatility = 1.75 |
| Fraction of working capital | $\theta = 0.145$ | Output drop in default = 12.01% |

Table 16 shows our calibration strategy. The discount parameter $\beta$, the working capital interest rate in default $r_d$, the probability of reentry into international debt market, $\phi$, and the fraction of working capital, $\theta$, target default probability, wage drop in default, output drop in default, and trade balance volatility. We use SMM method to match these targets and the parameters are calibrated, such that $\beta = 0.877$, $r_d = 0.35$, $\phi = 0.150$, and $\theta = 0.145$.

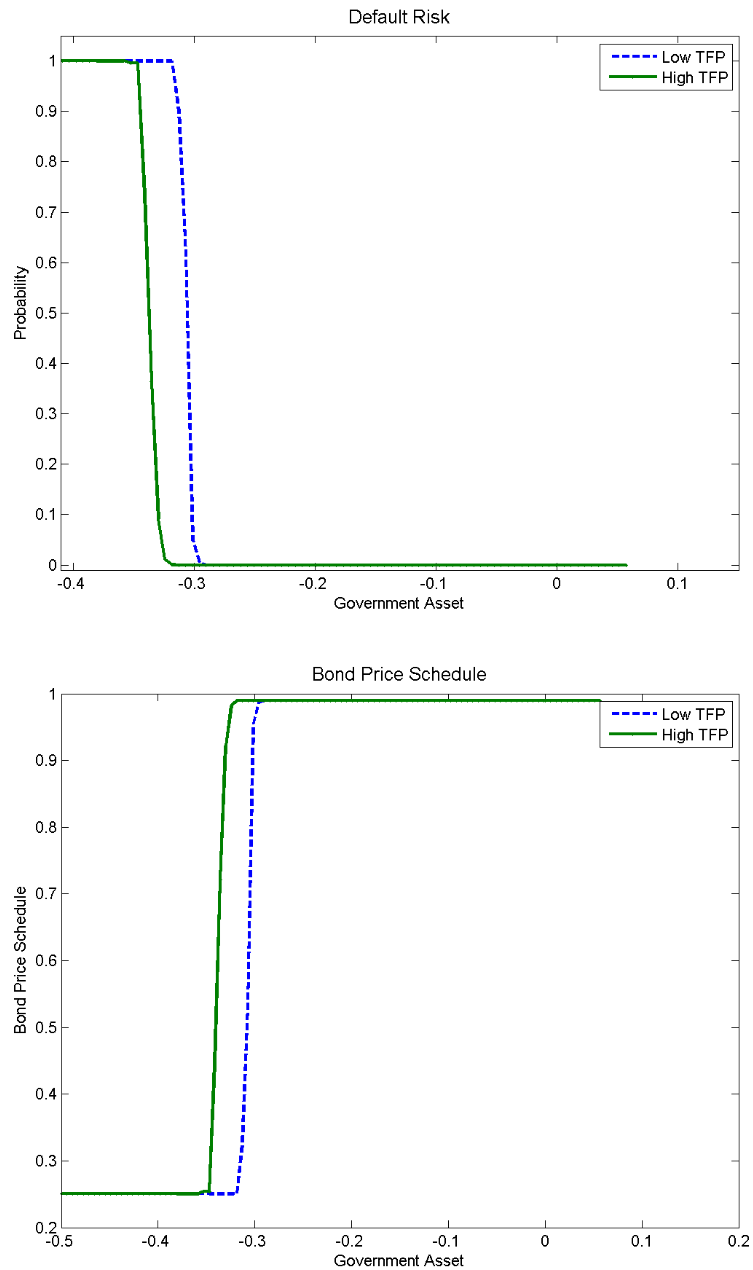
### 3.4 SIMULATION RESULTS

In this section, we begin with the analysis of the benchmark model's results and we also elaborate on the intuition on the workings of the model. To solve the model numerically, we use the discrete state-space method. We discretize the asset space, making sure that the minimum and the maximum points on the grid do not bind when we compute the optimal debt decision.

Figure 4 shows the default risk and the bond price schedule generated by the model. As the model suggests the more the government borrows, the higher the default risk becomes. In addition, default risk increases as the economy is hit by low TFP shocks. Similar to the results presented in standard default literature, such as Arellano (2008) and Aguiar and Gopinath (2006), we observe that the bond price is an increasing function of the assets, such that high levels of debt entails a low bond price. The bond price schedule is determined by not only the default risk, but also the risk of debt restructuring and the expected bond price in default $q_d$, which is constant regardless of the TFP shock's size. Even though the government is not able to borrow in default, its debt arrears are evaluated at the bond price in default, $q_d$. In addition, the bond price is an increasing function in TFP shock. That is, the economy with high TFP shock pays less interest on its debt than the one subject to low TFP shock.

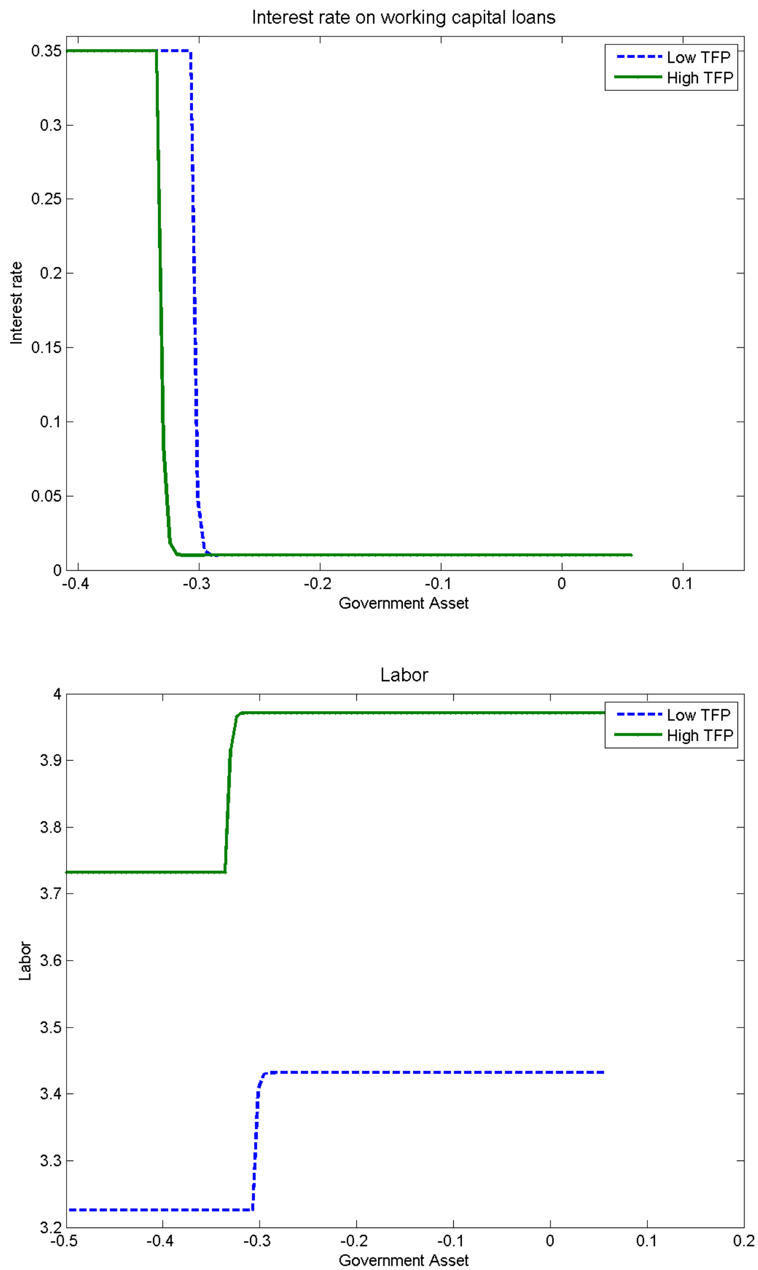
The first panel in Figure 5 shows the interest rates on working capital loans generated by the model. The interest rate is calculated using (3.6). Unlike the standard sovereign default models, the interest rate on working capital has an upper bound of $r_d$ and it is the level that the firms need to pay for borrowing working capital, when the sovereign declares

Figure 4: Default risk and bond prices



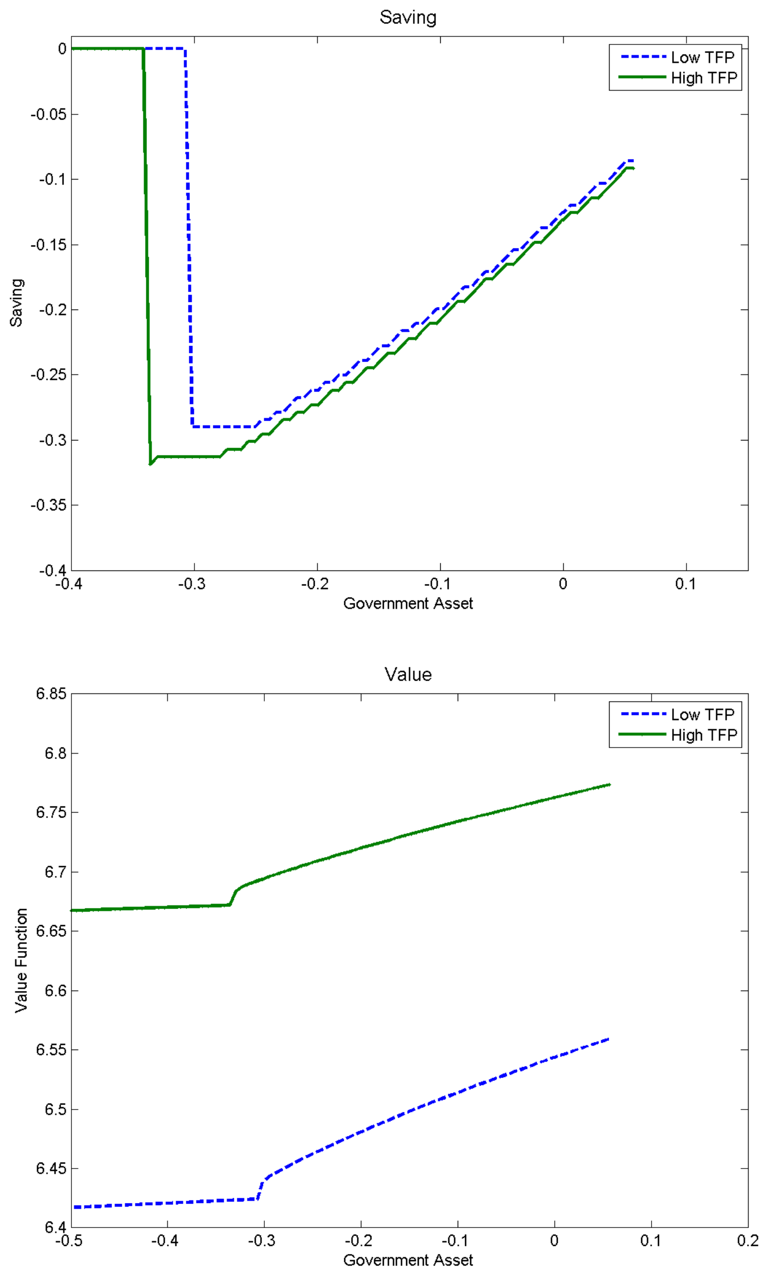

default. The interest rate on working capital is a decreasing function in government assets and TFP shocks. Firms in the economy with high TFP shock and low debt pay less interest on working capital compared to those in the economy with low TFP shock and high debt. On

Figure 5: Interest rate on working capital and labor supply




the second panel in Figure 5, we show that the labor supply increases as the government assets increase and the state of the world gets better. Intuitively, wages increase in expansions, so households are willing to supply more labor. Also, firms face lower interest rates on working

Figure 6: Saving and value functions




capital loans, which reduces labor costs, therefore in equilibrium they demand more labor during expansions.

The first panel in Figure 6 shows the saving policy function conditional on not defaulting, which is similar with the standard default model. Our results show that the government borrows more in expansions and is less likely to default in good states of the world. This result is consistent with countercyclical interest rates, since it becomes more costly to borrow in bad states of the world. The second panel of Figure 6 is the value of option as a function of assets. The small kink shows the level of assets above which repayment is optimal.

Next, we move on to the business cycle statistics generated by the benchmark model and we evaluate the performance of the model with Argentine data. The simulation results for the benchmark model are presented in Table 17. The benchmark model generates a default probability of 0.03 percent, which is relatively smaller than the data (3 percent). In our model, we don't have ad-hoc default penalty as other literatures on sovereign default. Even without this type of output penalty, the simulation results from our model are fairly similar to the business cycle statistics in Argentina. The model also generates large drops in output and wage during default episodes as in the data. The model can also generate high volatility in labor supply.

In terms of correlations with output, consumption shows a positive correlation and the interest rate spread shows a negative correlation consistent with the data. Moreover, there is a negative correlation between output and trade balance. The reason is that households can consume more than their income from wages and profits during expansions, because the government can borrow easily. On the other hand, when there is a recession, borrowing is constrained, therefore the consumption is less than the income from wages and profits of the firms. This generates a countercyclical trade balance over the business cycle. Correlations with interest rate show consistent results with the data.

Our model also performs well in terms of generating a procyclical labor supply. We obtain a procyclical labor supply because two things change when the economy is hit by an adverse TFP shock; first, the shock has a direct effect on production and it reduces output because productivity is lower and firms demand less labor, which is a standard result of an RBC model. Second, the shock has an indirect effect on production through the increase in endogenous default risk. Because the government is more likely to default, the interest rate on the working capital loan is also higher, which makes production even more costly for the firms and it dampens firms' labor demand even more. Equilibrium wages also drop

Table 17: Statistical moments in the benchmark model and in the data

| Statistics | Data | Model | Model ($\theta = 0$) |
|---|---|---|---|
| $\sigma(labor)$ (%) | 3.69 | 5.96 | 7.36 |
| $\sigma(c)$ / $\sigma(y)$ | 1.13 | 1.01 | 0.97 |
| $\sigma(labor)$ / $\sigma(y)$ | 0.86 | 0.69 | 0.68 |
| corr(y,spread) | -0.74 | -0.25 | - |
| corr(y,tb) | -0.58 | -0.22 | 0.99 |
| corr(y,labor) | 0.58 | 1.00 | 1.00 |
| corr(spread,tb) | 0.70 | 0.02 | - |
| corr(spread,labor) | -0.85 | -0.25 | - |
| Other statistics in default | | | |
| Output drop (%) | 12.01 | 20.12 | - |
| Consumption drop (%) | 12.86 | 23.03 | - |
| Wage drop (%) | 13.88 | 7.79 | - |
| Target | | | |
| Output drop (%) | 12.01 | 20.12 | |
| Labor drop (%) | 18.46 | 17.12 | |
| Default probability (%) | 2.78 | 0.02 | |
| Average debt/GDP ratio (%) | 33.20 | 30.60 | |

because they are inversely related to interest rates and positively related to the TFP shock. Because of the GHH preferences, the substitution effect dominates the income effect and the households are wiling to supply less labor. Overall this generates even larger drops in output. When households' income drops so much due to the decreases in labor income, the government would like to borrow even more from foreign lenders so that households can have smooth consumption. However, since the shocks are persistent, the foreign lenders adjust their expectations about the future state of the economy, such that they ask for an even higher premium on the government bonds. This generates a vicious cycle, in which output, labor, consumption and wages decrease further and it becomes harder for the government to roll over its debt. Thus, the government may choose to default to eliminate the tax burden necessary to finance the existing debt, especially when the level of existing debt is already very high.

To look at the role of the working capital condition, we set $\theta$ equal to zero. We find that this model generates no default. In addition, consumption becomes less volatile than output and the trade balance becomes procyclical. The results show that the financing of working capital plays an important role in generating default risk.

## 3.5 CONCLUSION

This paper studies the relationship between endogenous default risk and labor decisions using a stochastic general equilibrium model in a small open economy. With the assumptions on working capital loans and the debt renegotiation in default, our model performs well in matching the business cycle characteristics of the Argentine economy. We obtain countercyclical interest rates and procyclical labor. An increase in default risk yields a lower bond price and it implies a high interest rate on working capital loans. As the cost of production increases, firm's labor demand decreases. Since equilibrium wages also drop and the substitution effect dominates the income effect, the households are willing to supply less labor. In equilibrium we find that both production and labor are lower, when the economy is hit by an adverse TFP shock. The reduction in labor income and output induces the government to want to borrow more from foreign lenders; however, the lenders ask for higher premiums due to the endogenous default risk. This makes borrowing even harder for the government and the government may choose to default to eliminate the tax burden necessary to finance the existing debt.

This paper investigates the feedback loop between the financing of firms working capital and sovereign default risk. Firms' demand for labor and the cost of private credit play an important role in generating endogenous drops in output and employment that are observed during default episodes. The model also explains how the aggregate variables move over the business cycle. Thus, the paper connects the default risk to the real business cycles in small open economies.

## 4.0 R&D INVESTMENT AND FINANCIAL CONSTRAINTS DURING THE GREAT RECESSION

### 4.1 INTRODUCTION

In 2010, R&D expenditures totaled $363,434$ million dollars (constant 2005 prices) or 2.8 percent of the national GDP.[1] Even though this seems small compared to other forms of investment, the literature has shown that R&D plays an important role in increasing efficiency and creating technical change, thus contributing to the overall growth of the economy. Financing of R&D activities is particularly interesting since R&D cannot be easily collateralized. Many papers in the literature point out that there is a wedge between external and internal sources of finance for R&D investments, making financial constraints more prominent.[2] The empirical approach to test for the presence of financial constraints on R&D investment builds on the vast literature that explores the sensitivity of investment to financial variables. However, this approach has been criticized because the causal connection between investment and financial variables is hard to document due to endogeneity issues.[3] Not only is it difficult to find a good instrument for the financial variables, but including control variables for investment demand and firm productivity also comes with the caveat that measurement errors can lead to biased estimates.[4] More recent papers estimate dynamic R&D regressions over a period of time using a systems GMM approach. They include

[1]Source: National Science Foundation (NSF) Report, 2011.

[2]See Hall and Lerner (2010) for a detailed discussion of financing of R&D and a review of the literature related to financial constraints on R&D investment.

[3]Using investment-cash flow sensitivity to test for the presence of financial constraints started with Fazzari et al. (1988). See Kaplan and Zingales (1997) for possible endogeneity issues in this approach.

[4]See Erickson and Whited (2000) on measurement error problems in Tobin's Q.

variables to control for investment demand as a remedy for endogeneity issues.[5]

As an alternative way to identify financial constraints, this paper takes advantage of a natural experiment by focusing on the Great Recession period. The recession started with the emergence of the subprime loan crisis, which created turmoil in the housing market and had subsequent real effects on the economy. This aspect of the recession makes it a good setting in which to analyze firms' investment behavior after being hit by an exogenous shock. The key question in this paper is whether the R&D investment of U.S. manufacturing firms was liquidity-constrained during the Great Recession. I focus on the investment behavior of publicly traded, non-federally funded, high-technology manufacturing firms in the U.S. over the period 2007Q4-2008Q4 using data obtained from the Compustat database. In order to test for the existence of financial constraints, I construct R&D stocks using the perpetual inventory method. I estimate the effect of liquidity at the beginning of the recession on the growth rate of R&D stocks over the recession, controlling for firm profitability, size and age, as well as for industry characteristics. The key predictions of this estimation are that the coefficient on liquidity is positive and that the coefficient on liquidity interacted with the bond dummy is negative for financially-constrained firms. In this sense, the paper uses a methodology similar to that of Stein et al. (1994), which focus on inventory investments during the 1981-82 recession to identify bank-dependent firms. In this paper, I also perform a cross-sectional empirical test to show that financial constraints become more binding in a recession, and I analyze their effect on R&D investments.

The main finding of this paper is that firms that do not borrow from public bond markets experienced binding liquidity constraints on their R&D investments during the recession. Liquidity has a significant positive effect for firms without bond ratings, even after controlling for firm size, age and profitability. The estimates suggest that if the liquidity were increased by one standard deviation, the R&D stocks would increase by around 7.3 percentage points, which is about one third of the actual increase observed during the recession period. The evidence for liquidity constraints is also documented for various subsamples that are likely to face financial constraints, such as small firms, young firms and firms that do not pay

[5]Highly cited papers are Brown et al. (2009) and Brown and Petersen (2009), Brown and Petersen (2014) for R&D investment in the U.S. and Brown et al. (2012) in Europe.

dividends. Sensitivity of R&D investment to liquidity is, again, strongest for those firms without bond ratings in these subsamples. I also test for the presence of liquidity constraints on capital and inventory investments of firms that also do R&D.[6] I find that firms without bond ratings experienced tighter constraints in all three types of investments compared to firms with bond ratings. Firms without bond ratings show the highest liquidity sensitivity for inventory investments, and investment-liquidity sensitivity is greater for capital than it is for R&D investments. This result also supports the fact that these firms adjust their inventories more rapidly, compared to capital and R&D investments, when they are hit by a bad shock. On the other hand, the investment behavior of firms with bond ratings shows less sensitivity to liquidity for all three types of investments. Overall, the results confirm the business cycle properties of these series– i.e., inventory investment is the most volatile and R&D investment is the least volatile type of investment. The evidence for financial constraints is also robust to various procedures used to construct R&D stocks and capital stocks, which assume different depreciation rates. Financial constraints seem to be a concern mainly for non-federally funded high-technology firms since I do not obtain similar results for funded high-technology firms or for low-technology firms in the manufacturing sector.

This paper is related mainly to the R&D investment and financial constraints literatures. Papers in the financial constraints literature use some proxies to group firms based on their dependence on cash flow, and they check for investment-cash flow sensitivity separately for these groups of firms to test for the presence of financial constraints.[7] Fazzari et al. (1988), Hoshi et al. (1991), Lamont (1997), and Hubbard (1998) focus on constraints in capital investments. As mentioned, Stein et al. (1994) check for the constraints in inventory investments of bank-dependent firms. In this paper, I use similar proxies (i.e., firm age, firm size, dividend payment and existence of a bond rating) to identify potentially constrained firms in my sample. Brown et al. (2009) and Brown and Petersen (2009) try to explore the role of internal finance in aggregate R&D investments in the U.S. Similar to the findings of this paper, they show that particularly small and young firms show higher investment-

[6]For this analysis, I construct capital stock series for each firm, using the perpetual inventory method and capital expenditures data. Inventory stock data are available on the Compustat database.

[7]Erickson and Whited (2000), Almeida and Campello (2007), and Hennessy and Whited (2007) emphasize the importance of finding exogenous proxies in these estimations.

cashflow sensitivity for R&D investments.

This paper also contributes to the recent literature that explores the relationship between investment and cash flow and finds that investment-cash flow sensitivity has been declining over time. Brown et al. (2009) studying the period 1970-2006, show that investment-cash flow sensitivity has declined considerably for capital investments, but that it still remains significant for R&D investments. They state that the decline in sensitivity is due to the development in equity markets that firms rely on stock issues more than on debt in financing investments. Chen and Chen (2012) use time series variance as an identification strategy and show that R&D investment sensitivity disappeared during the last recession. Therefore, they conclude that investment-cash flow sensitivity cannot be a good measure of financial constraints. These findings suggest that it is important to use other measures to identify constraints that are not subject to demand-side effects. In this paper, using a well known measure– i.e., liquidity-investment sensitivity and using a natural experiment as an identification strategy, I find evidence for the constraints. The natural experiment approach used in this paper eliminates the endogeneity problem between investment and the financing decision. As a result, this paper shows that the identification strategy is very important in showing clear evidence of financial constraints.

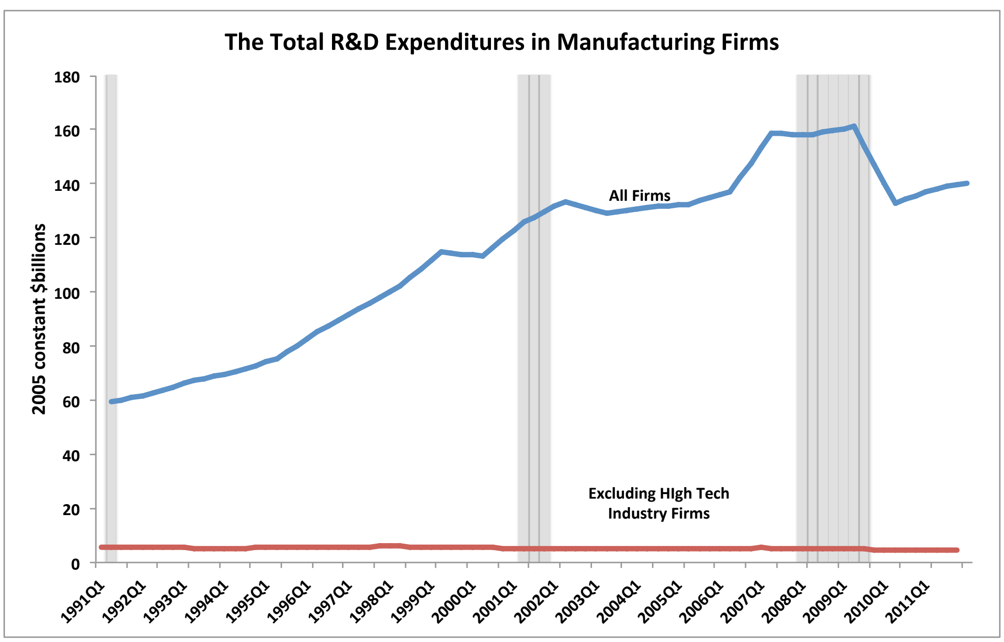
The remainder of the paper is organized as follows: Section 4.2 presents the data and summary statistics about the R&D investment behavior of firms during the Great Recession and describes the regression sample. The empirical specification is explained in Section 4.3. Section 4.4 lays out the main results for firms' R&D investments. Section 4.5 presents the sample when capital and inventory investments are also considered, describes the specification and discusses the results. Section 4.6 provides a robustness analysis. Section 4.7 concludes.

## 4.2 DATA AND SUMMARY STATISTICS

In the U.S., most R&D investment is done by firms in high-technology industries. Using micro-level data from the Compustat database, one can compare the level of investment in publicly traded manufacturing firms in high-tech and low-tech industries.[8] High-tech industries with two-digit SIC codes (reported in parentheses) are chemicals and allied products (28); industrial and commercial machinery and computer equipment (35); electronic and other electrical equipment and components, except computer (36); transportation equipment (37); and measuring, analyzing and controlling instruments (38). Figure 7 shows the total R&D expenditures of firms in the manufacturing sector between 1991Q1-2011Q4, including and excluding high-tech industry firms. The figure illustrates that, in the sample, low-tech industry firms do very little R&D compared to high-tech industry.[9] A large drop in the R&D investment of high-tech firms during the Great Recession is also evident.

Figure 7: The total R&D expenditures in manufacturing between 1991-2011

The figure plots the total R&D expenditures of firms in the manufacturing sector between 1991-2011 using the Compustat database. The data belong to firms that have their headquarters in the U.S. and have two-digit SIC numbers between 20-39. Firms that do not report a stock price and employment data and that have nonpositive R&D expenditures are eliminated. The data are deflated using the GDP deflator. Firms that have the following two-digit SIC codes are classified as high-tech: 28, 35, 36, 37 and 38. The gray bars indicate the recession periods.




A similar comparison can be made between federally funded and non-federally funded

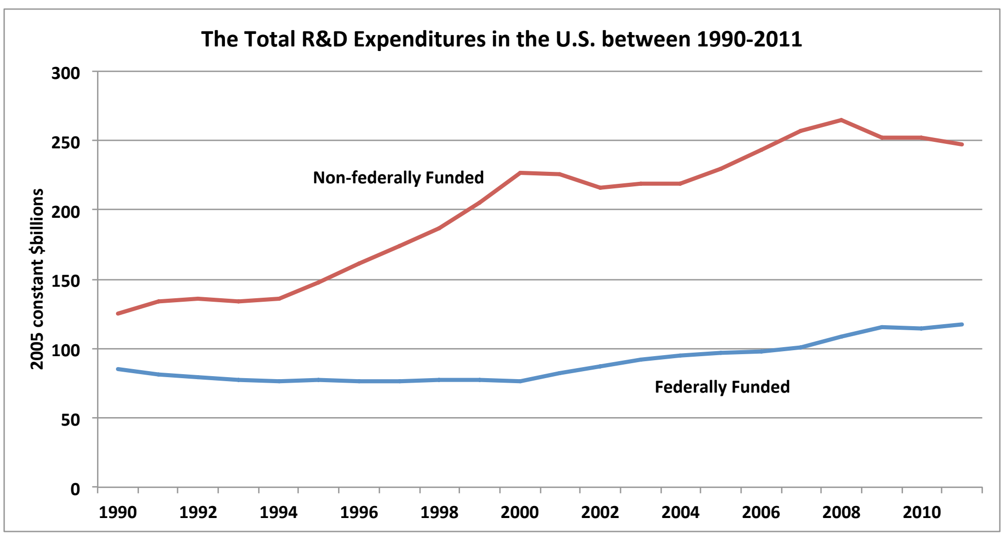
[8]The steps that I followed to construct the datasets for Figures 7 and 9 are explained in detail in the Appendix B.1. The grey bars indicate recession periods.

[9]These results are in line with Brown et al. (2009), which includes all firms, not only manufacturing.

firms in the U.S. Figure 8, which is based on a National Science Foundation (NSF) report, shows the total annual expenditures on R&D. Non-federally funded R&D expenditures have been at least twice as high as federally funded R&D expenditures in the last decade. The level of non-federally funded R&D expenditures decreased between 2007 and 2009, while federally funded R&D expenditures showed an increasing trend during that period. These results suggest that mostly non-federally funded firms' R&D expenditures were potentially constrained during the recession.

Figure 8: The total R&D expenditures in manufacturing between 1991-2011 (grouped by funding)

The figure plots the total R&D expenditures of non-federally funded and federally funded firms in the manufacturing sector between 1991-2011 using data from National Science Foundation reports.




Next, I analyze the average R&D expenditure-to-assets and the average liquidity (i.e., cash and short-term investments as a fraction of total assets) in the sample of non-funded, high-tech firms between 1990Q4 and 2011Q4. The non-funded, high-tech industries with three-digit SIC codes (reported in parentheses) are drugs (283); computer and office equipment (357); communications equipment (366); electronic components and accessories (367); measuring and controlling devices (382); and food and related products (384).[10] The ex-

[10]The list of non-federally funded, high-tech industries was obtained from Brown et al. (2009).

istence of a bond rating has often been used as a proxy for potential financial strength.[11] Thus, it is crucial to discuss the differences in R&D investment and cash-holding behavior among firms with and without bond ratings.

Figure 9 shows these differences, and three points are worth mentioning. First, the firms with bond ratings experienced a significantly lower reduction in liquidity during the recession. For these firms, the average liquidity fell from 46 percent to 33 percent and then increased to 38 percent by the end of the recession. On the other hand, at the onset of the recession, the average liquidity was 74 percent for the firms without access to bond markets. By the end of the four quarters, it had fallen to 42 percent and then recovered to 48 percent by the end of the recession. This observation can be due to the precautionary motive of firms without access to bond markets. From the outset of the recession, they exploited liquidity for their investments, since external sources of finance became too costly for them. Second, the graphs show that it is mainly firms without bond ratings that invest in R&D expenditures. For these firms, the average R&D expenditure is much higher. In the last decade, in particular, it has fluctuated between 15 percent and 40 percent, whereas for firms with bond ratings, it has remained quite flat, at around 20 percent. One potential reason for this result is that almost all of the large and/or mature firms in the sample have bond ratings, and in the U.S., small and/or young firms' share of total R&D is substantial.[12] Thus, it is possible that large and/or mature firms with bond ratings may have lowered the average R&D expenditure. Third, the average R&D expenditure for the firms without bond ratings is much more volatile than that for firms with bond ratings. The volatility of the R&D expenditure can be interpreted as evidence of liquidity constraints since, due to the high adjustment costs, firms prefer to smooth their R&D investments.

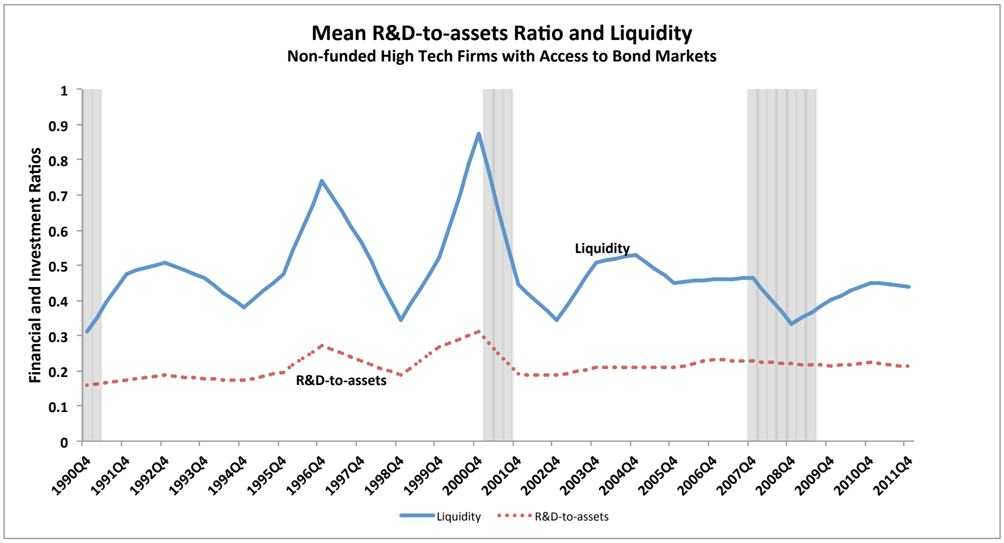
Table 18 shows the main summary statistics for the regression sample.[13] The majority of the firms have a bond rating from Standard & Poor's. Firms are also classified based on their age, size, and dividend payments. Firm age is computed based on the year in which the first observation of closing-price data is found in the Compustat database. If the firm

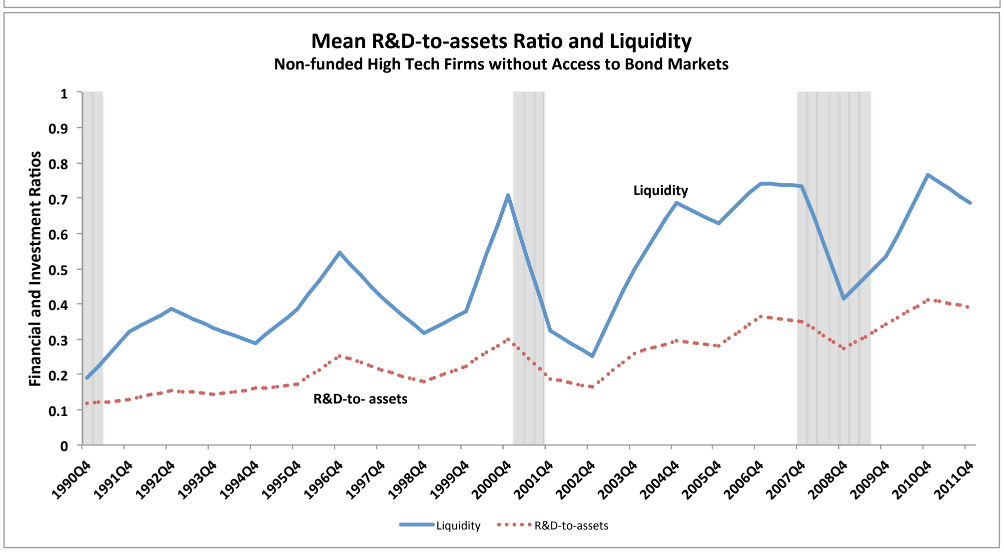
[11] Early papers that use the existence of bond ratings to identify potentially constrained firms are Fazzari et al. (1988) and Whited (1992) for capital investments and Stein et al. (1994) for inventory investments.

[12] This fact is well documented by Brown et al. (2009). See Table 30 for the composition of firms in the sample.

[13] The steps that I take in constructing the regression sample are explained in detail in the Appendix B.2.

Figure 9: Investment behavior of firms with/without bond ratings




The figures plot the mean R&D-to-assets ratio and liquidity of non-funded high-technology firms with/without a bond rating from Standard & Poor's using data from Compustat database. The data cover the period 1991-2011. The data belong to firms that have their headquarters in the U.S. and have the following three-digit SIC numbers: 283, 357, 366, 367, 382 and 384. Firms that do not report a stock price and employment data and that have nonpositive R&D expenditures are eliminated. The data are deflated using the GDP deflator. Liquidity is defined as cash and short-term investments as a fraction of total assets. The R&D-to-assets ratio is defined as the ratio of R&D expenditures to total assets. All variables are Winsorized at one percent. The gray bars indicate the recession periods.

Table 18: Summary statistics for non-funded high tech firms

| Variable | All Firms | Young Firms | Small Firms | D=0 Firms |
|---|---|---|---|---|
| *Number of firms at the beginning of recession* | | | | |
| whole sample | 577 | 334 | 430 | 473 |
| without bond rating | 88 | 83 | 85 | 84 |
| with bond rating | 489 | 251 | 345 | 389 |
| *Median liquidity at the beginning of recession* | | | | |
| whole sample | 0.38 | 0.48 | 0.49 | 0.42 |
| without bond rating | 0.71 | 0.73 | 0.73 | 0.71 |
| with bond rating | 0.33 | 0.42 | 0.46 | 0.37 |
| *Median (nominal) assets at the beginning of recession* | | | | |
| whole sample | $133.1 M | $99.0 M | $71.8 M | $109.6 M |
| without bond rating | $58.5 M | $64.7 M | $56.9 M | $62.6 M |
| with bond rating | $154.2 M | $127.9 M | $75.0M | $134.3 M |
| *Median % change in real R&D stock* | | | | |
| whole sample | 11.96% | 14.36% | 12.00% | 13.02% |
| without bond rating | 21.82% | 22.13% | 21.50% | 22.29% |
| with bond rating | 11.40% | 12.29% | 11.08% | 11.86% |

The regression sample is obtained using data from the Compustat database. The procedure that is used to construct the regression variables is explained in the Appendix B.2.

has data for less than 15 years after the first observation of price data, it is listed as young; otherwise, it is labeled as mature. Overall, there are 334 young firms, 251 with bond ratings. Firm size is computed based on the number of employees. A firm in the upper quartile of the sample for number of employees is listed as large; otherwise, the firm is labeled as small. In the regression sample, there are 430 small firms, 345 with bond ratings. Firms with positive cash dividends (DV, data item #127) are labeled as D=1 firms. In the sample, there are 473 firms with zero or negative cash dividends (D=0 firms), 389 with bond ratings.

In the whole sample, the median firm has a liquidity of 38 percent. Firms without bond ratings keep around twice as much liquidity as firms with bond ratings. The median young firm, small firm, or no-dividend-payment firm also keeps more liquidity than the median of the whole sample. In these subcategories, the median firm without a bond rating keeps significantly more liquidity than the median firm with a bond rating. The summary statistics support the possibility that firms without bond ratings, small firms, young firms, and firms with no dividend payments are financially weaker and, therefore, keep higher levels of liquidity as a means of precautionary saving.

Based on asset size, firms with bond ratings are also larger than the average. Young, small, or no-dividend-payment firms have smaller assets. Another noteworthy observation is that young firms, small firms, and no-dividend-payment firms have markedly higher increases in their R&D stocks. Also, firms without bond ratings experience higher growth of R&D stocks. Again, these points are consistent with the observation that small and young firms do most of the R&D investment, as reported in the literature. The figures also support these facts. Thus, if there were financial constraints that could have been eliminated, one would have expected an even larger increase in their R&D stocks.

## 4.3 EMPIRICAL SPECIFICATION

In order to test for the existence of financial constraints, I look at investment-liquidity sensitivity. I estimate:[14]

$$\Delta log(RD) = \alpha_0 + \alpha_1 LIQ_{-1} + \alpha_2 LIQ_{-1} * B_{-1} + \alpha_3 Q_{-1} + Size + Age + Ind + Error. \quad (4.1)$$

The dependent variable represents the growth rate of the R&D stocks over the period between 2007Q4 and 2008Q4. The independent variables are the liquidity ($LIQ$) measured in the 2007Q4 and liquidity interacted with the bond dummy ($LIQ * B$). The bond dummy ($B$) is equal to one, if the firm has access to bond markets. As mentioned above, Q is the market-to-book ratio and is included to control for the profitability of the investment. This specification also controls for the effects of industry-specific factors that may play a role in investment decisions with the two-digit industry dummies ($Ind$). Furthermore, I include firm size and age dummies, which take binary values. It has been shown that especially young or small firms face larger financial constraints, so these dummies control for the firm characteristics. $Size$ dummy is equal to 1 if the firm is large, and $Age$ dummy is equal to 1 if the firm is mature. In order to eliminate further endogeneity issues, all terms involving $LIQ_{-1}$ are instrumented by the lagged liquidity term (i.e., liquidity at the end of 2006Q4), and the specification is estimated using instrumental variables and generalized method of moments (IV-GMM) estimation. To verify that liquidity is important for R&D investments and to show that liquidity constraints are present, I expect to get a positive coefficient for $\alpha_1$ and a negative coefficient for $\alpha_2$. This implies that $LIQ$ matters less in the R&D investments of firms that can borrow from the bonds markets. Also, I anticipate a positive estimate for $\alpha_3$.

As mentioned in the introduction, the main endogeneity problem arises from the fact that liquidity may be a proxy for the profitability of investment, instead of for the presence of financial constraints. It might be the case that firms that make higher profits are also the ones that keep high levels of liquidity and choose to invest more. The panacea for the

[14] This specification is similar to the one used by Stein et al. (1994), in which they test for bank-dependence in inventory investments of the firms.

endogeneity problem is to focus on the Great Recession period, which forms a natural case study with a negative exogenous shock to the economy increasing the financial constraints on firms. As a result, I expect that investment-liquidity sensitivity will be more significant for firms that face tighter liquidity constraints. In this paper, the main comparison is among firms with and without access to bond markets, and I anticipate that the latter are more liquidity-constrained.

In addition, I control for the future profitability of investment by including the initial market-to-book ratio (Q) that the firms had at the start of the recession.[15] One caveat pertaining to this control is measurement problems. It has been debated in the literature that market-to-book ratio may be mismeasured, particularly for small firms or young firms, which are more likely to be constrained. Especially for newly established small firms, there might be less information on their performance. If this is the case, Q will also have less information about investment profitability than it does for the unconstrained firms. This measurement problem may result in an estimation of liquidity that is biased upwards because the explanatory power will be shifted away from Q to the liquidity variable. To check this, I run the regressions with and without Q. Such a problem does not seem to be present, especially in small or young firms. Other commonly used control variables in the literature are the amount of dividends and debt holdings of the firm. Again, the main problem with these control variables is the presence of possible endogeneity issues, as they may be simultaneously determined with investment decisions. Thus, I do not include them. On the other hand, the existence of a bond rating is exogenous since the bond rating is based on the judgement of an agency that depends on the firms' past performance for an adequate length of time.[16]

The sample-splitting technique according to firm size, age, dividend payments or the existence of a bond rating has often been used in the literature in order to ascertain firms with a high cost of external resources. Unfortunately, with this specification, it is not possible to make a direct comparison between young vs. mature, small vs. large or D=0 vs. D=1

[15] Another control variable that is commonly used in the literature for future profitability of investment is the initial sales-to-assets ratio. In regressions, the sales-to-assets ratio never appears with a significant sign, so it is not reported in the results.

[16] See Gilchrist and Himmelberg (1995) and Erickson and Whited (2000) for detailed discussions of the control variables and of Tobin's Q. Alti (2003) shows that Tobin's Q can be a noisy measure for investment opportunities for young firms.

firms because almost all mature, large, or D=1 firms in the sample have access to bond markets. Therefore, I split the sample and run the regressions on young, small or D=0 firms only to see if any of the full sample results also hold for these firms. The sample-splitting test among firms with and without access to bond markets is possible, though. I expect the coefficient on $LIQ$ to be large and significant for firms without access to bond markets and small and not significant for firms with access to bond markets. This test is less powerful since it allows for the intercept to differ across B=0 and B=1 firms.

## 4.4 RESULTS

Table 19 shows the results of the estimation of equation 4.1 for all firms, controlling for different firm and industry characteristics. The coefficient for LIQ is positive and highly significant in the specifications, where it is included by itself. When the interaction term between liquidity and the bond dummy is included, its coefficient is negative and strongly significant. These results imply that liquidity plays an important role in R&D investments for all firms. However, for firms with bond ratings, its overall significance is smaller.

This result is also robust to inclusion of control variables, such as initial market-to-book value (Q) and sales. Market-to-book value has coefficients near zero but is highly significant. In all of the estimates, initial sales are estimated insignificantly, so they are not reported in the results. The estimate for size dummy suggests that the average difference in the growth rate of R&D stocks between large and small firms is small and positive. The difference between young and mature firms is small and negative.

Table 20 shows the results from the sample splits. In all firms in the sample, the coefficient of liquidity is 0.25 for the firms without access to bond markets and 0.07 for the firms with access to bond markets. The estimates of LIQ are statistically different at ten percent. Similar results are obtained for the subsamples. In the young firms sample, LIQ is significant and positive (0.27) for B=0 firms and insignificant and close to zero (0.01) for B=1 firms. The difference between the coefficients on LIQ of B=0 and B=1 firms is statistically significant at the one percent level. Also, in small firms and D=0 firms samples, firms with bond ratings

Table 19: IV-GMM estimation: financial constraints in R&D investment

| Whole Sample | | | | | | |
|---|---|---|---|---|---|---|
| *LIQ* | 0.10*** | 0.18*** | 0.10*** | 0.17*** | 0.12*** | 0.20*** |
| | (3.36) | (4.39) | (3.30) | (4.42) | (3.62) | (4.61) |
| $LIQ * B$ | – | −0.13*** | – | −0.13*** | – | −0.12*** |
| | | (−343) | | (−3.48) | | (−3.30) |
| *Q* | – | – | 0.00** | 0.00** | 0.00** | 0.00*** |
| | | | (2.28) | (2.46) | (2.40) | (3.03) |
| *Size* | – | – | – | – | 0.06*** | 0.06*** |
| | | | – | – | (3.10) | (3.00) |
| *Age* | – | – | – | – | −0.03** | −0.02 |
| | | | – | – | (2.22) | (−1.36) |
| $R^2$ | 0.03 | 0.05 | 0.05 | 0.07 | 0.07 | 0.09 |
| *N* | 577 | 577 | 577 | 577 | 577 | 577 |

Estimation is by IV-GMM robust standard errors. Industry dummies are included. Z-statistics are reported in parentheses. (***,**,* represent significance level at 1%, 5% and 10%, respectively.)

show more sensitivity to liquidity than firms without bond ratings.

Overall, these results confirm that liquidity matters for R&D investment, especially for firms without access to bond markets. The fact that these results hold for young, small or $D = 0$ firms is also consistent with findings from the financial constraints literature.

Are these results economically meaningful? It is not possible to draw any conclusions on the size of the financial constraints or to make a structural interpretation since this is only a reduced-form estimation. However, following a back-of-the-envelope calculation exercise similar to that in Stein et al. (1994), it is possible to get a suggestive role of liquidity in R&D investment. In the sample, the median firm without a bond rating had around 71 percent liquidity, with a standard deviation of 29 percent at the beginning of the recession. The median firm without a bond rating increased its R&D stock by 22 percent. The coefficient

Table 20: IV-GMM estimation: financial constraints in R&D investment - sample splits

| | All Firms | | Young | | Small | | D=0 | |
|---|---|---|---|---|---|---|---|---|
| | $B=0$ | $B=1$ | $B=0$ | $B=1$ | $B=0$ | $B=1$ | $B=0$ | $B=1$ |
| $LIQ$ | 0.25*** | 0.07** | 0.27*** | 0.01 | 0.25** | 0.08*** | 0.26** | 0.05 |
| | (2.02) | (2.15) | (2.08) | (0.29) | (2.08) | (2.62) | (2.12) | (1.39) |
| $Q$ | 0.01*** | 0.00*** | 0.01*** | 0.00 | 0.01*** | 0.00*** | 0.01*** | 0.00*** |
| | (3.13) | (3.23) | (3.15) | (1.09) | (3.30) | (3.46) | (3.31) | (2.72) |
| $R^2$ | 0.14 | 0.06 | 0.14 | 0.04 | 0.15 | 0.06 | 0.15 | 0.04 |
| $N$ | 88 | 489 | 83 | 251 | 85 | 345 | 85 | 393 |

Estimation is by IV-GMM robust standard errors. Industry dummies are included. Z-statistics are reported in parentheses. (***,**,* represent significance level at 1%, 5% and 10%, respectively.)

of $LIQ$ is estimated as 0.25 for this type of firm. As a result, if the liquidity were increased by one standard deviation, the R&D stock would increase by roughly another 7.3 percentage points. This is about one third of the actual increase in R&D stocks, which could be considered a substantial amount.

### 4.5 LIQUIDITY CONSTRAINTS ON CAPITAL AND INVENTORY INVESTMENTS

In this section, I will extend the above methods to test for the presence of financial constraints on capital and inventory investments in order to compare them with R&D investments. Such a comparison is interesting, since the financing of R&D is different from other types of investments due to the lack of collateral value.[17] Thus, one might expect that R&D

[17]See Hall and Lerner (2010) for a discussion of why there is often a large wedge between internal and external sources of finance for R&D investments compared to other types of investments.

investments faced higher constraints during the last recession. However, the time series characteristics of these investments are different in terms of their volatilities, inventories being the most and R&D being the least volatile. This is due to the fact that inventories respond to shocks more quickly than other types of investments do. Consequently, focusing on a four-quarter-long period, one may observe higher investment-liquidity sensitivity for inventories than for R&D investment.

The construction of the regression sample and the estimation of capital stocks are explained in detail in the Appendix B.2. This analysis requires firms to report all three types of investments. Additionally, I choose firms that have their fiscal years end in the fourth quarter. This step restricts the sample to firms that experienced similar macroeconomic conditions, especially since the start of the recession coincided with the beginning of a new fiscal year.[18]

The empirical specification uses the same right-hand-side variables as equation 4.1, but with different dependent variables, which makes the comparison between different investment types feasible. In order to test for the presence of financial constraints on the capital investment, the left-hand-side variable for capital investment is the log difference of capital stocks between 2007Q4 and 2008Q4. For inventory investment, the dependent variable is the log difference of inventories between 2007Q4 and 2008Q4.

Table 21 reports the summary statistics. Between the R&D-only sample and this sample, three observations are different. First, the number of firms is reduced by almost fifty percent. Second, these firms keep lower liquidity and hold larger assets. Third, the percentage change in R&D stocks is also larger for all types of firms. Similar to the previous sample, firms with bond ratings keep larger assets. The median young, small, no-dividend-payment firm, or the firm without a bond rating increases its R&D stocks more than the average firm. These firms also increase their capital and inventory stocks more than the median firm in the full sample.

Table 22 reports the results of R&D, capital and inventory investments, respectively. In these estimations, I again control for the age and size of the firms, as well as $Q$ and industry

[18] Stein et al. (1994) apply this step before they test for the liquidity constraints on the inventory investment of the firms. The results are quite robust to the exclusion of this step.

Table 21: Summary statistics for non-funded high tech firms (all types of investment)

| Variable | All Firms | Young Firms | Small Firms | D=0 Firms |
|---|---|---|---|---|
| *Number of firms at the beginning of recession* | | | | |
| whole sample | 287 | 173 | 194 | 228 |
| without bond rating | 33 | 33 | 33 | 33 |
| with bond rating | 254 | 140 | 161 | 195 |
| *Median liquidity at the beginning of recession* | | | | |
| whole sample | 0.32 | 0.39 | 0.42 | 0.36 |
| without bond rating | 0.55 | 0.55 | 0.55 | 0.55 |
| with bond rating | 0.29 | 0.35 | 0.40 | 0.32 |
| *Median (nominal) assets at the beginning of recession* | | | | |
| whole sample | $194.9M | $144.2M | $94.8M | $156.5M |
| without bond rating | $93.2M | $93.2M | $93.2 | $93.2M |
| with bond rating | $278.3M | $203.5M | $94.8 | $197.4M |
| *Median % change in real R&D stock* | | | | |
| whole sample | 12.12% | 14.52% | 12.94% | 13.82% |
| without bond rating | 26.06% | 26.06% | 26.06% | 26.06% |
| with bond rating | 11.47% | 12.37% | 11.27% | 12.21% |
| *Median % change in real capital stock* | | | | |
| whole sample | 3.18% | 5.01% | 2.76% | 4.06% |
| without bond rating | 9.89% | 9.89% | 9.89% | 9.89% |
| with bond rating | 2.55% | 3.51% | 2.03% | 3.18% |
| *Median % change in real inventory stock* | | | | |
| whole sample | 8.77% | 11.94% | 13.53% | 6.92% |
| without bond rating | 21.26% | 21.26% | 21.26% | 21.26% |
| with bond rating | 8.03% | 9.00% | 12.78% | 5.95% |

The regression sample is obtained using data from the Compustat database. The procedure that is used to construct the regression variables is explained in the Appendix B.2.

Table 22: IV-GMM estimation: financial constraints in R&D, capital and inventory investments

| Whole Sample | R&D | | Capital | | Inventory | |
|---|---|---|---|---|---|---|
| *LIQ* | 0.12*** | 0.21*** | 0.07 | 0.19 | 0.01 | 0.21 |
| | (1.89) | (3.23) | (0.85) | (1.26) | (0.08) | (1.20) |
| $LIQ * B$ | – | −0.12** | – | −0.16 | – | −0.26* |
| | | (−2.13) | | (−1.32) | | (−1.74) |
| *Q* | 0.01 | 0.01 | 0.01** | 0.01** | 0.02** | 0.02*** |
| | (1.08) | (1.09) | (1.93) | (1.99) | (2.53) | (2.56) |
| *Size* | 0.04 | 0.04 | 0.02 | 0.02 | 0.08 | 0.08 |
| | (1.27) | (1.28) | (0.89) | (0.89) | (1.49) | (1.49) |
| *Age* | −0.01 | −0.00 | −0.06*** | −0.05*** | −0.10 | −0.09 |
| | (−0.57) | (−0.21) | (−3.27) | (−2.63) | (−1.52) | (−1.29) |
| $R^2$ | 0.07 | 0.08 | 0.14 | 0.15 | 0.07 | 0.07 |
| *N* | 287 | 287 | 287 | 287 | 287 | 287 |

Estimation is by IV-GMM robust standard errors. Industry dummies are included. Z-statistics are reported in parentheses. (***,**,* represent significance level at 1%, 5% and 10%, respectively.)

dummies. Since the sample size is small (particularly for B=0 firms), some of the estimates lose significance. For all forms of investments, the role of liquidity is smaller for B=1 firms. As before, liquidity plays an important role in R&D investments, but for firms with bond ratings, its overall significance is smaller. As can be seen, of the three forms of investments, the coefficient on $LIQ * B$ term is the smallest for inventories and the largest for R&D, respectively. This suggests that the inventory investment of B=0 firms seems to benefit more from higher liquidity, relative to B=1 firms.

The regression results on sample splits based on access to bond markets, presented in Table 23, support the results in Table 22. Had the constrained firms received higher liquidity in the recession, the inventory investment would have responded to this increase the most,

Table 23: IV-GMM estimation: financial constraints in R&D, capital and inventory investments - sample splits

| | R&D | | Capital | | Inventory | |
|---|---|---|---|---|---|---|
| | $B=0$ | $B=1$ | $B=0$ | $B=1$ | $B=0$ | $B=1$ |
| $LIQ$ | 0.03 | 0.08 | 0.33 | 0.03 | $1.01^{**}$ | $-0.16$ |
| | (0.17) | (1.60) | (0.82) | (0.62) | (1.99) | $(-1.10)$ |
| $Q$ | $0.01^{***}$ | 0.00 | $0.02^{***}$ | 0.01 | $0.03^{**}$ | $0.02^{**}$ |
| | (2.91) | (0.67) | (3.63) | (1.60) | (2.12) | (2.38) |
| $R^2$ | 0.40 | 0.04 | 0.14 | 0.08 | 0.28 | 0.04 |
| $N$ | 33 | 254 | 33 | 254 | 33 | 254 |

Estimation is by IV-GMM robust standard errors. Industry dummies are included. Z-statistics are reported in parentheses. (***,**,* represent significance level at 1%, 5% and 10%, respectively.)

and R&D investment would have responded the least. This result suggests that inventory investment experienced the tightest constraints for B=0 firms during the recession. It also supports the fact that firms adjust their inventories more quickly, compared to capital and R&D investments, when they are hit by a bad shock. On the other hand, for B=1 firms, I obtain the opposite results. R&D investment shows some sensitivity to liquidity, but there is no significant evidence for liquidity constraints on capital and inventory investments.

## 4.6 ROBUSTNESS CHECKS

### 4.6.1 R&D Investment-Liquidity Sensitivity in All Manufacturing Firms

In the above analysis, the focus is on non-funded high-tech manufacturing firms. To test whether R&D investment-liquidity sensitivity is also evident for other manufacturing firms, I include all of the firms with a two-digit SIC between 20-39, excluding the non-federally funded high-tech firms. Therefore, this sample not only has federally funded high-technology firms, but also has low-technology firms. Table 24 shows the results. It appears that these firms did not experience liquidity constraints on R&D investments. Next, I choose federally funded high-technology firms only. The results pertaining to this sample again show no evidence of financial constraints. As a result, during the last recession, R&D investment-liquidity sensitivity existed for the non-federally funded, high-technology manufacturing firms only.

### 4.6.2 Relaxing the Growth Rate and Depreciation Rate Assumptions used in R&D Stocks

In this section, the R&D stocks are constructed using a constant growth rate, eight percent, as Hall (1990) suggests. Table 25 reports the results of the estimations. The regression results do not seem to be very sensitive to the choice of growth rate. In all panels, $LIQ$ is estimated significantly, and the size of the coefficients are similar to the ones reported in Table 19.

Next, I change the depreciation rate, which is initially set to 15 percent, and test the effect of a lower and a higher depreciation rate, ten percent and 20 percent, respectively. Table 26 shows the results for the whole sample of firms and shows that the results are robust to the choice of depreciation rate.

Table 24: IV-GMM estimation: financial constraints in R&D investment for various samples of firms

| Manufacturing Firms | | | | |
|---|---|---|---|---|
| | Whole Sample | Exc. nonfunded hightech | Funded hightech | |
| $LIQ$ | $-0.09$ | $0.09$ | $-0.11^{*}$ | $0.02$ |
| | $(-1.40)$ | $(0.41)$ | $(-1.79)$ | $(-0.10)$ |
| $LIQ * B$ | – | $-0.21$ | – | $-0.12$ |
| | | $(-1.02)$ | | $(-0.68)$ |
| $Q$ | $0.00$ | $0.00$ | $0.00$ | $0.00$ |
| | $(0.74)$ | $(0.86)$ | $(0.68)$ | $(0.77)$ |
| $Size$ | $-0.01$ | $-0.01$ | $-0.03^{*}$ | $-0.03^{*}$ |
| | $(-0.69)$ | $(-0.68)$ | $(-1.71)$ | $(-1.72)$ |
| $Age$ | $-0.03$ | $-0.03$ | $-0.02$ | $-0.01$ |
| | $(-1.48)$ | $(-0.68)$ | $(-0.81)$ | $(-0.73)$ |
| $R^2$ | $0.10$ | $0.11$ | $0.06$ | $0.08$ |
| $N$ | 202 | 202 | 152 | 152 |

Estimation is by IV-GMM robust standard errors. Industry dummies are included. Z-statistics are reported in parentheses. (***,**,* represent significance level at 1%, 5% and 10%, respectively.)

### 4.6.3 Capital Stocks Assuming Double-Declining Balance

Another common way of constructing capital stocks is to assume a double-declining balance, which implies that the depreciation rate is equal to $\frac{2}{L_j}$ instead of $\frac{1}{L_j}$.[19] The results are reported in Table 27. Assuming a double-declining balance does not affect the results for the liquidity sensitivity of capital investment.

[19] Eberly et al. (2008) is an example of research that uses double-declining balance.

Table 25: IV-GMM estimation: financial constraints in R&D investment (fixed g)

| | Whole Sample | | $B=0$ | $B=1$ |
|---|---|---|---|---|
| $LIQ$ | $0.12^{***}$ | $0.18^{***}$ | $0.25^{**}$ | $0.08^{**}$ |
| | (3.66) | (3.87) | (2.09) | (2.50) |
| $LIQ*B$ | – | $-0.08^{**}$ | – | – |
| | | (−2.26) | | |
| $Q$ | $0.00^{**}$ | $0.00^{**}$ | $0.01^{***}$ | $0.00^{***}$ |
| | (2.33) | (2.43) | (3.56) | (3.29) |
| $Size$ | $0.06^{***}$ | $0.06^{***}$ | −0.02 | $0.06^{***}$ |
| | (3.34) | (3.25) | (−0.25) | (3.24) |
| $Age$ | −0.02 | −0.01 | 0.05 | −0.01 |
| | (−1.47) | (−0.80) | (0.86) | (−1.10) |
| $R^2$ | 0.08 | 0.09 | 0.24 | 0.07 |
| $N$ | 582 | 582 | 91 | 491 |

Estimation is by IV-GMM robust standard errors. Industry dummies are included. R&D stocks are constructed using a constant growth rate of eight percent. Z-statistics are reported in parentheses. (***,**,* represent significance level at 1%, 5% and 10%, respectively.)

## 4.7 CONCLUSION

This paper examines whether the R&D investments of non-funded, high-tech manufacturing firms in the U.S. were constrained during the Great Recession. Using data from the Compustat database, I show that there were significant liquidity constraints on the R&D investments of firms without access to bond markets. This result is also observed in young firms, small firms and firms with no dividend payments, which are likely to face financial constraints. Even though it is not possible to measure the economic importance of these

Table 26: IV-GMM estimation: financial constraints in R&D investment (different depreciation rates)

| $\delta = 0.10$ Whole Sample | All Firms | | $B = 0$ | $B = 1$ |
|---|---|---|---|---|
| *LIQ* | 0.11*** | 0.20*** | 0.24** | 0.06** |
| | (3.65) | (4.90) | (2.02) | (2.04) |
| $LIQ * B$ | – | −0.13** | – | – |
| | | (−3.82) | | |
| *Q* | 0.00** | 0.00** | 0.01*** | 0.00*** |
| | (2.35) | (2.51) | (3.16) | (3.38) |
| *Size* | 0.06*** | 0.06*** | −0.02 | 0.06*** |
| | (3.22) | (3.10) | (−0.27) | (3.14) |
| *Age* | −0.04** | −0.02** | −0.01** | −0.02* |
| | (−2.99) | (1.97) | (−0.13) | (−1.94) |
| $R^2$ | 0.08 | 0.11 | 0.15 | 0.06 |
| *N* | 577 | 577 | 88 | 489 |

| $\delta = 0.20$ Whole Sample | All Firms | | $B = 0$ | $B = 1$ |
|---|---|---|---|---|
| *LIQ* | 0.13*** | 0.20*** | 0.27** | 0.08** |
| | (3.58) | (4.30) | (2.02) | (2.26) |
| $LIQ * B$ | – | −0.11*** | – | – |
| | | (−2.74) | | |
| *Q* | 0.00** | 0.00** | 0.01** | 0.00*** |
| | (2.42) | (2.53) | (3.08) | (3.08) |
| *Size* | 0.06*** | 0.06*** | 0.02 | 0.06*** |
| | (2.96) | (2.88) | (0.19) | (2.84) |
| *Age* | −0.02 | −0.01 | 0.03 | −0.02 |
| | (−1.63) | (−0.92) | (0.54) | (−0.99) |
| $R^2$ | 0.07 | 0.08 | 0.14 | 0.05 |
| *N* | 577 | 577 | 88 | 489 |

Estimation is by IV-GMM robust standard errors. Industry dummies are included. R&D stocks are constructed assuming different depreciation rates, $\delta = 0.10$ or $\delta = 0.20$. Z-statistics are reported in parentheses. (***,**,* represent significance level at 1%, 5% and 10%, respectively.)

constraints, a simple calculation shows that if the constraints had been eliminated, the R&D stocks of the median firm without access to bond markets could have increased by another

Table 27: IV-GMM estimation: financial constraints in capital investment - double-declining balance for capital stocks

| Whole Sample | All Firms | | $B = 0$ | $B = 1$ |
|---|---|---|---|---|
| $LIQ$ | 0.08 | 0.16 | 0.37 | 0.03 |
| | (0.80) | (1.01) | (0.83) | (0.46) |
| $LIQ * B$ | – | −0.12 | – | – |
| | | (−0.89) | | |
| $Q$ | 0.01** | 0.01** | 0.02*** | 0.01* |
| | (2.09) | (2.12) | (3.43) | (1.70) |
| $Size$ | 0.03 | 0.03 | – | – |
| | (1.12) | (1.13) | | |
| $Age$ | −0.02** | −0.04* | – | – |
| | (−2.09) | (−1.76) | | |
| $R^2$ | 0.12 | 0.13 | 0.13 | 0.08 |
| $N$ | 287 | 287 | 33 | 254 |

Estimation is by IV-GMM robust standard errors. Industry dummies are included. Capital stocks are constructed assuming double- declining balance. Z-statistics are reported in parentheses. (***,**,* represent significance level at 1%, 5% and 10%, respectively.)

7.3 percentage points. This is a substantial change, since it is about one third of the actual increase in R&D stocks. When capital and inventory investments are also considered, firms without access to bond markets experience the tightest constraints on inventory investments and the weakest constraints on R&D investments. The result also supports the time series characteristics of these investments, inventories being the most and R&D being the least volatile.

This paper contributes to the financial constraints literature by showing that financial factors played an important role in firm investment during the Great Recession. It also provides insights into the fact that financial strength has a significant effect on R&D, which is a crucial factor for economic growth. The paper shows a direct link between liquidity and R&D investments, liquidity being an important internal financial resource. The results are less likely to be prone to endogeneity issues since the analysis focuses on the Great Recession period as an exogenous case study. Furthermore, it shows that investment-liquidity sensitivity can be a good measure of financial constraints for U.S. manufacturing firms.

# APPENDIX A

# CHAPTER 2

## A.1 PROOFS OF PROPOSITIONS

### A.1.1 Proof of Proposition 1

The proof is similar to Arellano (2008).

First we show that value of repayment is increasing i asset holdings. For all $\{y, \gamma\} \in D(B^2)$,

$$\begin{aligned}\frac{y(1-\gamma)}{2} + \frac{B^2 - q(B', y.\gamma)B'}{2} &> \frac{y(1-\gamma)}{2} + \frac{B^1 - q(B', y, \gamma)B'}{2}, \\ \frac{y(1+\gamma)}{2} + \frac{B^2 - q(B', y.\gamma)B'}{2} &> \frac{y(1+\gamma)}{2} + \frac{B^1 - q(B', y, \gamma)B'}{2}.\end{aligned}$$

So

$$\begin{aligned}u\left(\frac{y(1-\gamma)}{2} + \frac{B^2 - q(B', y.\gamma)B'}{2}\right) &+ u\left(\frac{y(1+\gamma)}{2} + \frac{B^2 - q(B', y.\gamma)B'}{2}\right) + \beta E v^o(B', y', \gamma') \geq \\ u\left(\frac{y(1-\gamma)}{2} + \frac{B^1 - q(B', y.\gamma)B'}{2}\right) &+ u\left(\frac{y(1+\gamma)}{2} + \frac{B^1 - q(B', y.\gamma)B'}{2}\right) + \beta E v^o(B', y', \gamma').\end{aligned}$$

Therefore, for all $\{y, \gamma\} \in D(B^2)$,

$$\begin{aligned}&u\left(\frac{y(1-\gamma)}{2}\right) + u\left(\frac{y(1+\gamma)}{2}\right) + \beta E[\theta v^o(0, y', \gamma') + (1-\theta)v^d(y', \gamma')] > \\ &u\left(\frac{y(1-\gamma)}{2} + \frac{B^2 - q(B', y.\gamma)B'}{2}\right) + u\left(\frac{y(1+\gamma)}{2} + \frac{B^2 - q(B', y.\gamma)B'}{2}\right) + \beta E v^o(B', y', \gamma') \geq \\ &u\left(\frac{y(1-\gamma)}{2} + \frac{B^1 - q(B', y.\gamma)B'}{2}\right) + u\left(\frac{y(1+\gamma)}{2} + \frac{B^1 - q(B', y.\gamma)B'}{2}\right) + \beta E v^o(B', y', \gamma').\end{aligned}$$

Hence, any pair of $\{y, \gamma\}$ that is in $D(B^2)$, we have $\{y, \gamma\} \in D(B^1)$.

Let $d(B, y', \gamma')$ denote the equilibrium default decision rule. Default probability satisfies

$$\delta(B, y', \gamma') = \int d(B, y', \gamma') f((y', \gamma'), y, \gamma) d(y', \gamma')$$

Since any $\{y, \gamma\} \in D(B^2)$, we have $D(B^2) \subseteq D(B^1)$, if $d(B^2, y', \gamma') = 1$, then $d(B^1, y', \gamma') = 1$. Hence, $\delta(B^1, y, \gamma) \geq \delta(B^2, y, \gamma)$. $\square$

### A.1.2 Proof of Proposition 2

The bond price is defined as $q(B', y, \gamma) = \frac{1-\delta(B', y, \gamma)}{1+r}$. Using Proposition 1, we have $B^1 < B^2 \leq 0$ and $\delta(B^2, y, \gamma) < \delta(B^1, y, \gamma)$. Hence, we get $q(B^2, y, \gamma) > q(B^1, y, \gamma)$. $\square$

## A.2 SOLUTION ALGORITHM

To solve the model numerically, we use the discrete state-space method. We discretize the asset space using a finite set of grid points, making sure that the minimum and the maximum points on the grid do not bind when we compute the optimal debt decision. Our solution algorithm for the benchmark model is the following:[1]

1. Guess that the initial price is the reciprocal of the risk-free interest rate, and the initial value function is equal to the autarky value.
2. Given a price $q(B', y, \gamma)$ and $v^o(B, y, \gamma)$, solve for the optimal policy functions and update the value of option given as equation (2.10) by comparing $v^c(B, y, \gamma)$ and $v^d(y, \gamma)$.
3. Given the price function, compute the default probabilities.
4. Update the price function using equation (2.9).
5. We simultaneously check whether the initial guesses for price and the value of option are close enough to their updated values. If not, we update the initial values and iterate steps 2-4 until both bond price and the value of option functions converge.

[1] We use the same algorithm to solve the models with a single type of shock. For instance, for Model II, the price function is denoted as $q(B', y)$, and value of option for default or repayment is denoted as $v^o(B, y)$.

## A.3 TABLES

Table 28: Rating conversion

| Fitch Rating | Score |
|---|---|
| AAA | 23 |
| AA+ | 22 |
| AA | 21 |
| AA- | 20 |
| A+ | 19 |
| A | 18 |
| A- | 17 |
| BBB+ | 16 |
| BBB | 15 |
| BBB- | 14 |
| BB+ | 13 |
| BB | 12 |
| BB- | 11 |
| B+ | 10 |
| B | 9 |
| B- | 8 |
| CCC+ | 7 |
| CCC | 6 |
| CCC- | 5 |
| CC | 4 |
| C | 3 |
| DDD | 2 |
| D | 1 |
| RD | 1 |

Table 29: VAR estimations for different countries

| Country | $\rho_{yy}$ | $\rho_{y\gamma}$ | $\rho_{\gamma y}$ | $\rho_{\gamma\gamma}$ | $\sigma_y^2$ | $\sigma_{y\gamma}$ | $\sigma_{\gamma y}$ | $\sigma_\gamma^2$ |
|---|---|---|---|---|---|---|---|---|
| Brazil | 0.34 | -0.25 | 0.09 | 0.64 | 5.6x10$^{-4}$ | 5x10$^{-5}$ | 5x10$^{-5}$ | 8x10$^{-5}$ |
| Colombia | 0.44 | 0.09 | -0.15 | 0.33 | 1.4x10$^{-4}$ | 2x10$^{-5}$ | 2x10$^{-5}$ | 8x10$^{-5}$ |
| Costa Rica | 0.33 | -0.07 | 0.05 | 0.74 | 4.5x10$^{-5}$ | -1x10$^{-5}$ | -1x10$^{-5}$ | 9x10$^{-5}$ |
| Dominican Republic | 0.26 | -0.33 | 0.07 | 0.71 | 6x10$^{-4}$ | -1.3x10$^{-5}$ | -1.3x10$^{-5}$ | 9x10$^{-5}$ |
| Ecuador | 0.01 | -0.33 | 0.20 | 0.82 | 1.3x10$^{-3}$ | -1.8x10$^{-4}$ | -1.8x10$^{-4}$ | 2.3x10$^{-4}$ |
| Paraguay | -0.74 | 0.24 | -0.05 | 0.73 | 4x10$^{-4}$ | -4x10$^{-5}$ | -4x10$^{-5}$ | 7x10$^{-5}$ |
| Uruguay | 0.26 | -0.33 | 0.07 | 0.71 | 6x10$^{-4}$ | -1.3x10$^{-5}$ | -1.3x10$^{-5}$ | 9x10$^{-5}$ |
| Argentina | 0.28 | -0.56 | 0.05 | 0.79 | 1.2x10$^{-3}$ | -2x10$^{-4}$ | -2x10$^{-4}$ | 1.3x10$^{-4}$ |

In this VAR analysis, we assume that log output and the inequality follow a VAR(1) process such that

$$\begin{bmatrix} log(y_t) \\ \gamma_t \end{bmatrix} = \begin{bmatrix} c_y \\ c_\gamma \end{bmatrix} + \begin{bmatrix} \rho_{yy} & \rho_{y\gamma} \\ \rho_{\gamma y} & \rho_{\gamma\gamma} \end{bmatrix} \begin{bmatrix} log(y_{t-1}) \\ \gamma_{t-1} \end{bmatrix} + \begin{bmatrix} \varepsilon_{yt} \\ \varepsilon_{\gamma t} \end{bmatrix}$$

where

$$\boldsymbol{\varepsilon} = \begin{bmatrix} \varepsilon_{yt} \\ \varepsilon_{\gamma t} \end{bmatrix}$$

$$E[\boldsymbol{\varepsilon}] = \mathbf{0} \quad \text{and} \quad Var[\boldsymbol{\varepsilon}] = \begin{bmatrix} \sigma_y^2 & \sigma_{y\gamma} \\ \sigma_{\gamma y} & \sigma_\gamma^2 \end{bmatrix}$$

# APPENDIX B

# CHAPTER 4

## B.1 CONSTRUCTION OF THE DATA FOR THE FIGURES 8 AND 10

- Use the annual frequency data from the Compustat database for the years 1990-2011 and keep firms that have their headquarters located in the U.S.
- Keep firms that have two-digit SIC numbers between 20-39. This eliminates all non-manufacturing firms.
- Keep firms that report a stock price and firms that have employment data. These steps improve consistency within the regression sample.
- Keep firms that report positive R&D expenditure (XRD, data item #46) data. Convert the data into real values using the GDP deflator.[1]
- Classify firms with the following three-digit SIC codes as non-funded, high-tech firms: 283, 357, 366, 367, 382 and 384.
- Determine whether firms have access to bond markets using the existence of a bond rating by Standard & Poor's.
- Liquidity is defined as the ratio of cash and short-term investments as a fraction of total assets.
- R&D-to asset ratio is defined as the ratio of R&D expenditures to total assets.
- Winsorize variables at one percent from both tails.

[1] I used the FRED (Federal Reserve Economic Data) database from the Federal Reserve Bank of St. Louis to assemble the data used herein.

- Convert the data into quarterly units using linear interpolation.

## B.2 CONSTRUCTION OF THE VARIABLES AND REGRESSION SAMPLES

### B.2.1 R&D Capital Stocks

The real R&D expenditures are calculated using the GDP deflator[2] and R&D expenditure data from the Compustat database (XRD, data item #46). Real R&D capital stock is computed by a perpetual inventory method at the firm level by using the following equation:

$$RD_{i,t} = (1 - \delta)\ RD_{i,t-1} + XRD_{i,t}. \tag{B.1}$$

where $RD_{i,t}$ represents the R&D stock; $XRD_{i,t}$ represents the real R&D expenditures of firm $i$ at time $t$; and $\delta$ is the depreciation rate. In order to obtain the initial R&D stock, the first observation of the real R&D expenditure is divided by a constant rate of depreciation ($\delta$) plus a growth rate (g).[3] Following Hall et al. (2005), I use 15 percent as the constant rate of depreciation.

The average growth rate of the R&D expenditure is calculated for each industry in the sample. For a firm that has the first R&D expenditure data at year t, g is the average growth rate of R&D expenditures in the industry that the firms belongs to in the period between the first year the data are observed at the industry level and the year t. This procedure generates different growth rates for firms that belong to different industries. Also, I remove the firms that have their first observation of the R&D expenditures after 2006.

[2]I used the FRED (Federal Reserve Economic Data) database from the Federal Reserve Bank of St. Louis to assemble the data used herein; see the references for information on the specific series.

[3]Some studies in the literature suggest taking a constant growth rate that applies to all firms, which is around five or eight percent (Hall (1990), Hall (1993), Hall and Mairesse (1995)). Hall and Mairesse (1995) point out that the choice of growth rate has an effect on the initial stock, but it declines in importance as time passes. More-recent studies choose growth rates that differ at the firm or industry level (Parisi et al. (2006) and Lyandres and Palazzo (2012)). In this paper, the main results are obtained by using different growth rates at the industry level. The results, obtained by using a fixed growth rate, are also reported as a robustness check.

### B.2.2 Capital Stocks

Compustat reports the book value of capital (PPEGT, data item #7) and capital expenditures (CAPX, data item #145); however, for this analysis, the replacement value of capital stock is relevant. Following Salinger and Summers (1983), Fazzari et al. (1988) and Eberly et al. (2008), the replacement value of capital stock is computed by using the following recursion:

$$K_{i,t} = \left( K_{i,t-1} \frac{P_{K,t}}{P_{K,t-1}} + CAPX_{it} \right) \left( 1 - \frac{1}{L_j} \right) . \tag{B.2}$$

The initial value for $K_i$ is set to the first observation in the PPEGT series for firm, $i$. $P_{K,t}$ refers to the price of capital and is the implicit price deflator for nonresidential investment obtained from FRED.[4] $L_j$ refers to the useful life of capital goods in industry $j$. The useful life of capital goods is calculated as

$$L_j = \frac{1}{N_j} \sum_{i \in j} \frac{PPEGT_{i,t-1} + DP_{i,t-1} + CAPX_{i,t}}{DP_{it}} . \tag{B.3}$$

$DP_{it}$ refers to the depreciation and amortization (Compustat Data Item #14) for firm $i$ at year $t$. $N_j$ refers to the number of firms in industry $j$.

### B.2.3 Other Variables

- Tobin's Q (Market-to-book ratio of firm's assets) is defined following Brown and Petersen (2011):

  $$Q = \frac{(CSHO \cdot PRCCF) + AT - CEQ}{AT_{-1}} ,$$

  where the first variable in the numerator is the market value of equity, which is equal to common shares outstanding (CSHO, data item # 25) times price close (PRCCF, data item #199). Then, total assets (AT, data item #120) net of common equity (CEQ, data item # 60) are added.
- SALES is defined as net sale (SALE, data item #117) divided by total assets (AT, data item #120).

[4] I used the FRED (Federal Reserve Economic Data) database from the Federal Reserve Bank of St. Louis to assemble the data used herein.

- Liquidity is denoted by LIQ and defined as cash and short-term investments (CHE, data item #1) divided by total assets (AT, data item #120).

Firm Age is computed based on the year in which price close data (PRCCF) are first observed in the Compustat database. If the firm has data for less than 15 years after the first observation of PRCCF, it is listed as young; otherwise, it is considered mature. Firm Size is computed based on its number of employees (EMP, data item #29). If the firm's number of employees is below (above) the 75th percentile of the whole sample of firms, then it is listed as small (large).

#### B.2.4 R&D Regression Sample

The dataset is between the years 2006 and 2008 and is in quarterly frequency. The dataset is obtained from the Compustat database. I choose firms that are in the manufacturing sector and have no missing data on 2006Q4, 2007Q4 and 2008Q4. I keep firms that have their headquarters in the U.S. (based on Compustat variable, LOC). I remove firms that have gone through mergers and acquisitions during this period (i.e., for these firms, DSLRN is equal to one). Firms without any employment data, R&D stock data, or stock price data are also removed.

#### B.2.5 R&D, Capital and Inventory Regression Sample

I applied steps similar to those of the construction of the R&D sample. Besides the R&D stock, firms should also have capital stock, and real inventory data for 2006Q4, 2007Q4 and 2008Q4. The inventory data (INVT, data item # 3 ) are deflated using the CPI.[5]

[5]I used the OECD (Organization for Economic Co-operation and Development) database to assemble the data used herein.

## B.3 TABLES

Table 30: Firm size, age and access to bond markets

| B=1 | Small | Large | Total |
|---|---|---|---|
| Young | 80 | 3 | 83 |
| Mature | 5 | 0 | 5 |
| Total | 85 | 3 | 88 |
| B=1 | Small | Large | Total |
| Young | 204 | 47 | 251 |
| Mature | 141 | 97 | 238 |
| Total | 345 | 134 | 489 |

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