

International Crisis Transmission and Asymmetric Recoveries

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Abstract

This paper examines the role of collateral constraints in the international transmission of crises, and in the uneven pace of recoveries across countries. In the presence of collateral constraints, depressed asset prices caused by a negative shock in a large creditor country generate feedback cycles in a smaller debtor country, in which the decline in borrowing capacity and the collapses of investment and output reinforce each other. As a consequence, a negative shock in a creditor country can have disproportionately large and persistent impacts on investment and output of another debtor country. The debtor country's recovery can also be sluggish, particularly if the country is highly leveraged, since the collateral constraint prevents it from quickly borrowing and accumulating capital. The model's predictions find strong empirical support in the 2008-2010 global crisis and recovery data.

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1 Introduction

The 2008-2009 financial crisis without doubt is the most severe crisis since the Great Depression. Initially thought to be limited within the U.S.'s sub-prime housing market, the crisis quickly spread across sectors and countries after the collapse of Lehman Brothers in September 2008. Many countries saw large declines in investment and output, many of which were even larger than those in the U.S. (see Figure 1). Moreover, the recoveries since then have been asymmetric. While many countries have bounced back strongly, many others, particularly highly indebted ones, have had slow and fragile recoveries or even further declines. For example, Figure 2 shows that Mexico and Thailand, which had relatively little external debt before the crisis, have weathered the crisis well and recovered early. On the other hand, Latvia and Ireland were highly indebted and have had a much more difficult time. The on-going debt crisis in Greece and the recent downgrade of Portugal and Italian debts are other developments that have drawn much attention. These observations call for explanations about how a crisis can transmit from one country to another and why the recoveries in many countries are strong and speedy and in others slow and difficult.

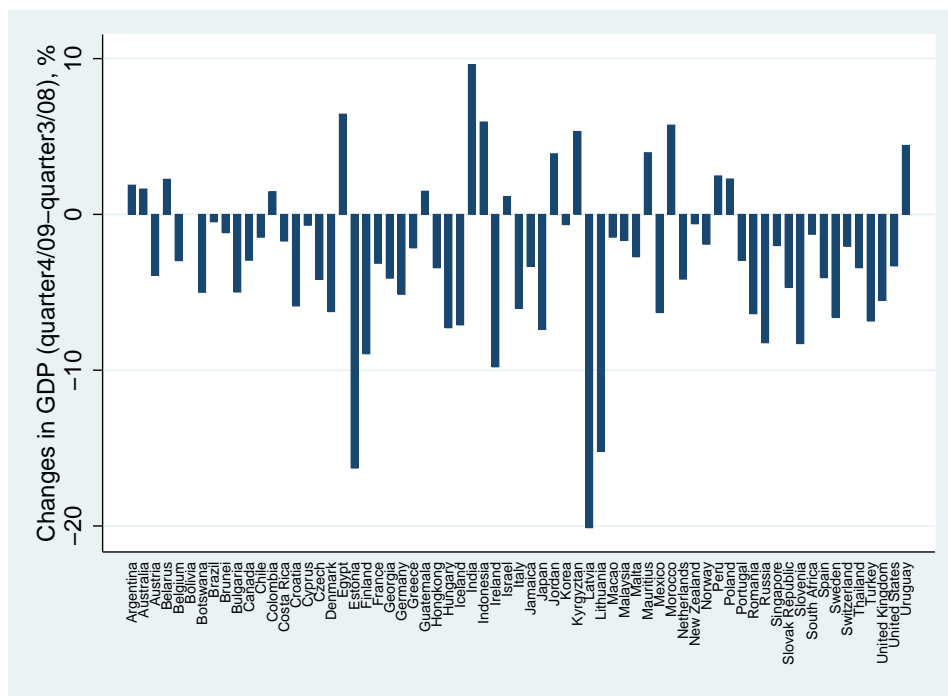


Figure 1: GDP growth in the crisis- Source: International Financial Statistics

The first question of interest is why a negative shock in one economy can have large and persistent impacts on another country's investment and output. Many factors have

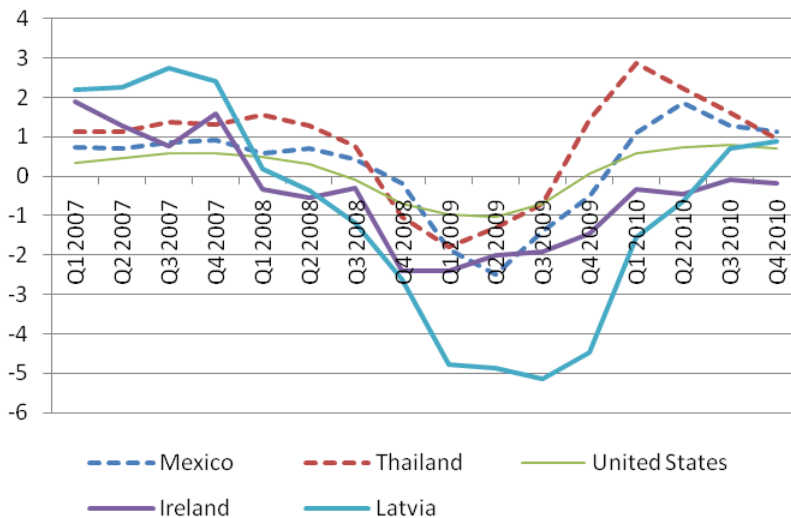


Figure 2: Quarterly GDP growth rates 2007-2010 (%)

been discussed, including the trade links, the global banking and liquidity provision, as well as the responses of monetary and fiscal authorities. In this paper, I study a mechanism that works through the decline of international asset prices and the tightening of debtor countries' collateral constraints. The details are as follows: a negative productivity shock in a large creditor economy drives down international asset prices. If a small country has to collateralize its assets to borrow funds to invest, falling asset prices worsen its ability to borrow and hence to reinvest. Investment in the debtor country declines, and capital repatriates to the creditor country. As less capital now can be pledged as collateral, the debtor country's asset value further drops, which further tightens its credit constraint and leads to another round of decline in investment. This generates a downward spiral that causes a large output loss to the debtor country. The country's recovery is also sluggish, since the credit constraint prevents it from quickly borrowing and accumulating capital.

The mechanism use in this paper builds on the collateral constraint friction that is featured in a large class of "sudden stop" models ^{1,2} A contribution of this paper is that it generates a sudden stop in a debtor country in response to a negative shock to a large creditor country, while the sudden stop literature tends to model the debtor country as a small

¹See for example Calvo (1998), Caballero and Krishnamurthy (2001), Gopinath (2004), Gertler, Gilchrist, and Natalucci (2007), and Mendoza (2010).

²Firm-level data (the World Bank's Enterprise Survey) indicate that collateral borrowing is prevalent. Simple averages of all firms across countries across time show that 80% of loans from financial institutions require collateral, and the value of collateral needed for a loan is about 150.5% of the loan amount.

open economy and has little to say about contagion. In this paper, contagion is front and center. With an asymmetric two-country setup, the paper examines explicitly this transmission mechanism and arrives at a set of interesting results. In particular, a negative shock to a creditor country can have larger negative effects on economic activities in the debtor country than in the creditor country itself. Although the negative shock takes place in the creditor country, capital actually repatriates to it, instead of flowing away as a standard model would predict. The recovery in the debtor country can be slower and longer than that in the creditor country. And finally, the model implies that more highly leveraged countries have slower and longer recoveries. These predictions are consistent with the pattern in the 2008-2009 global crisis and with the recoveries so far. A two-country setup also provides a clearer framework for international coordination in crises. To the extent that relaxing credit constraints helps countries raise capital and boost investment, the analysis in this paper implies that some amount of assistance from advanced economies or international financial institutions in bad times can help debtor countries cope with negative external shocks.

The mechanism finds empirical support in the 2008-2010 crisis data. First, countries that saw larger initial declines in stock prices when the crisis first hit in quarter 4, 2008 experienced statistically significantly larger declines in capital inflows, lower investment growth and output growth in 2009. Second, countries with higher pre-crisis external debt also have been seeing statistically significantly less capital inflows, lower investment growth and output growth both during and after the crisis. The detailed evidence is presented in section 2. The empirical evidence regarding external debt and output growth during the crisis is broadly consistent with existing studies. For example, Blanchard, Faruquee, and Das (2010) find an adverse impact of large external debt position on output growth of emerging markets between the last quarter of 2008 and the first quarter of 2009. At the micro level, Tong and Wei (2009) using firm level data in 24 emerging countries to show that credit crunch took place in the crisis, and pre-crisis exposure to non-FDI capital inflows worsened the credit crunch.

I use a modified version of Kiyotaki and Moore (1997) (henceforth KM) to study the mechanism. The model features a small country that borrows funds and faces a collateral-based credit constraint (i.e. debtor country), and a larger country that lends to the debtor country. The model shows that when the debtor country is credit constrained, a negative productivity shock in the creditor country can cause disproportionately large negative impacts on the debtor country, particularly if the debtor country is highly leveraged. In those instances, adverse external shocks can be particularly damaging to these debtor countries,

even more so than domestic shocks do.

My analysis assumes a perfectly integrated asset market: in the model, international asset prices move in lock steps. As in KM, I simply assume the two countries use the same type of capital and there is a competitive spot market where agents in both countries can buy and sell capital at the market price. While the assumption is not the most realistic, this is for the paper to focus on the link between the fall of asset prices and the declines of economic activities in debtor countries, via credit constraints. Nevertheless, empirical evidence indicates increasingly integrated international financial markets and asset price co-movements. For example, Didier, Love, and Martinez-Peria (2010) show clear co-movements between the U.S.'s and international stock prices in the 2008-2009 crisis.

This paper contributes to a large literature on crisis transmission across countries, of which Kaminsky, Reinhart, and Vegh (2003) is a good starting survey. A large number of papers focus on trade linkages as a key mechanism for crisis transmission. Recent literature has begun to argue that financial linkages play a more important role, especially for countries that are more financially integrated³. Among recent papers, Paasche (2001) uses a version of the KM model to investigate a transmission mechanism between two developing countries, via adverse terms of trade shocks which are amplified by credit constraints. Pavlova and Rigobon (2008) also look at crisis transmission between two “periphery” developing countries via the portfolio constraints in the “center” country. More recently, Devereux and Yetman (2010) and Dedola and Lombardo (2009) examine collateral-constraint based crisis transmission among major economies.

However, there are important differences between my paper and the literature. In KM, Paasche (2001), Pavlova and Rigobon (2008) and many other papers along the same theme, the focuses are put on direct negative shocks to credit demanders. Instead, I focus on shocks to credit suppliers and show that these shocks can even be more detrimental to credit demanders. My paper also differs to Devereux and Yetman (2010) and Dedola and Lombardo (2009). Their papers employ symmetric two-country models to explain symmetric crisis transmission among major economies. My paper makes very different points: that adverse shocks on creditor countries can have disproportionately large and persistent negative impacts on debtor countries's output, and that recoveries are also asymmetric across countries. Gilchrist (2003) is probably the most closely related paper. It uses the “financial accelerator” mechanism following Bernanke, Gertler, and Gilchrist (1999) to

³Among other papers, see Kaminsky and Reinhart (2000), Calvo and Mendoza (2000), Paasche (2001), Gilchrist (2003), Chari and Kehoe (2004), Pavlova and Rigobon (2008), Devereux and Yetman (2010), Dedola and Lombardo (2009)...

discuss the transmission from a developed to a developing country. My paper differs to Gilchrist (2003) in the emphasis on a mechanism based on collateral constraints, and in the additional focus on asymmetric recoveries of countries.

My paper also relates to a small but growing literature on the 2008-2009 financial crisis, most of which has focused on the U.S. However a few empirical papers have studied the global transmission of the crisis, and they seem to point to financial channels as the key transmitter, at least in the short run. Dooley and Hutchison (2009) find that emerging markets responded very strongly to the deteriorating situation in the U.S. financial system and real economy after September 2009. Didier, Love, and Martinez-Peria (2010) also find that the stock markets in many countries fell even more than the U.S.'s stock market, and the main channel that drives the co-movement between the US return and other countries' stock returns is financial. Blanchard, Faruqee, and Das (2010) look at GDP growth of 33 countries before and after the collapse of Lehman Brother in September 2008, and show that a higher level of external debt pre-crisis is instrumental to the decline of a country's GDP growth. Similarly, Lane and Milesi-Ferretti (2010) find that among others, countries' external vulnerabilities-including a large external debt position- are helpful in understanding the intensity of the crisis. Looking at the medium run, Comin, Loayza, Pasha, and Serven (2009) explore a different channel of transmission in which crises disrupt the technology transfer process between advanced economies and developing ones, hurting developing countries in the medium run.

The paper is organized as follows. Some motivating facts are presented in section 2. Section 3 describes the model. The solution of the model and the dynamics are analyzed in Section 4. Finally, section 5 concludes.

2 Empirical motivation

In this section, I present some empirical motivation for the mechanism I outlined. I show that countries with larger initial declines in stock indices when the crisis first hit in quarter 4, 2008 experienced stronger declines in private debt inflows (Figure 3), in investment and output during the global crisis in 2009 (Figures A1 and A2 in the appendix). In addition, countries with larger pre-crisis private external debts suffered stronger declines in private debt inflows (Figure 4) , in investment and output during the crisis (Figures A3 and A4), and are recovering more slowly after the crisis (Figures 5, A5 and A6).

Before proceeding to present the evidence, I'd like to define the period of the global crisis and discuss the pertaining variables used for the motivation. The global crisis is defined from

the beginning of quarter 4, 2008- when the U.S. had its first negative quarterly growth - to the end of quarter 4, 2009-when the U.S. had its first positive quarterly growth again. Ideally one would prefer to have quarterly data from quarter 4, 2008 to quarter 4, 2009 for the analysis. However, since quarterly data are more limited, I focus on 2009 annual data. The detailed variables are as follows: changes in stock indices are percentage changes of stock indices from August 2008 to December 2008 (stock index data are from Bloomberg). The pre-crisis external debt measure is the private, non-guaranteed external debt in 2007, as percentage of 2007 GDP. The change in private debt inflows is calculated as the private debt net inflows in 2009 *minus* those in 2007, measured as percentage of 2007 GDP. The investment measure is gross fixed investment in constant local currencies. The output measure is GDP per capita in constant local currencies. Data on the private non-guaranteed external debt, on investment and output are annual data from the World Development Indicator.

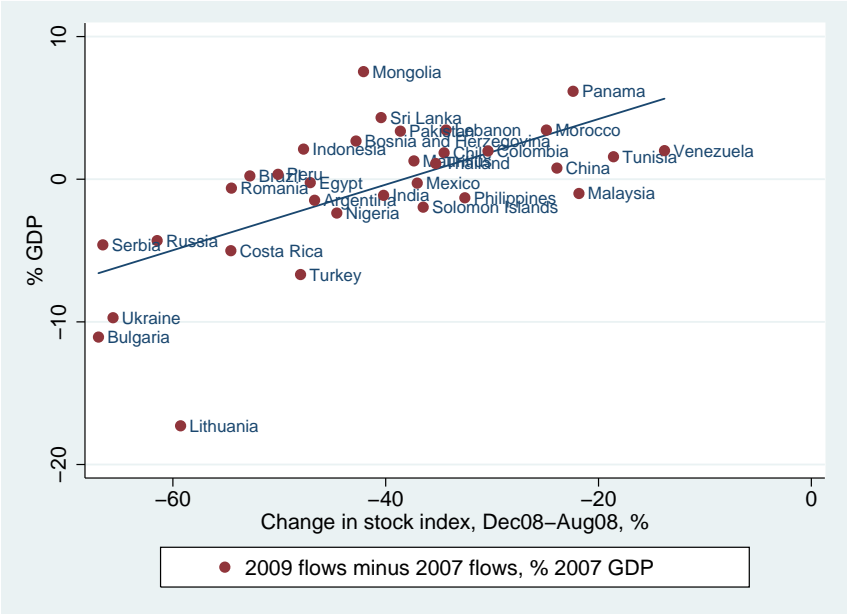


Figure 3: Changes in stock indices and debt inflows during crisis

The motivation starts with the correlations regarding the changes in stock indices. Figure 3 shows a significant and positive relationship between the declines of stock indices in the last four months of 2008 and the relative declines of inflows in private non-guaranteed external debt in 2009. The positive correlation is significant at 1% level. The result is consistent with an implication of the model that the declines in stock prices lower the collateral value of countries' assets and hence relatively reduce their borrowing capacity. Similarly, figures A1 and A2 in the appendix show significant and positive correlations between the changes

in stock indices and the growth of investment and output in 2009. The correlations are significant at 1% and 5% level respectively. The significance is robust to the exclusion of the U.S., or G.7 countries, or highly developed countries. It is also robust if I replace investment and output growth by their respective de-trended growth (i.e. the difference between growth in 2009 and the average growth between 2000-2007).

Second, I show the correlations regarding the private debt before the crisis. The argument is that highly indebted countries are more likely to face binding credit constraints during the crisis and suffer more severely. They also recover more slowly because the constraints prevent them from quickly accumulating capital. Data show that there was a sharp increase in the inflows of non-guaranteed private external debt across countries. On average, private debt inflows rose from about 4% of countries' GDP in 1990 to 10.2% of their GDP in 2007. For Eastern Europe countries, the increase was more dramatic: private debt inflows rose from almost nothing in 1990 to 16.3% of their GDP in 2007. In retrospect, the pre-crisis inflows paved the way for the massive declines in investment and output of the countries during and after the crisis. Empirical evidence seems to confirm the intuition. Figure 4 below shows a negative relationship between pre-crisis private external debt and the change in private debt inflows during the crisis. The relationship statistically significant at 5% level. Figures A3 and A4 in the appendix also shows significant and negative relationships between pre-crisis external debt and investment and output growth in 2009. The correlations are significant at 1% level and remain so if we change from growth to de-trended growth.

In addition, I show that highly indebted countries recover more slowly than less indebted ones. This point has not been explored in the literature, and is examined in Figures 5, A5 and A6. Figure 5 focuses on longer-run changes of GDP beyond the global crisis period. The y-axis represents changes in GDP from 2008 to 2010. Many countries with little private debt such as China, India, Lebanon are recovering strongly, with their output 10-20% higher than the 2008 level. On the other hand, many highly indebted ones, most notably Eastern Europe countries, still witness stagnation: their output is well below the 2008 level. Overall, the correlation between pre-crisis private external debt and 2008-2010 output growth is negative and significant at 1% level. The same is true with 2009-2010 output growth: the correlation between it and pre-crisis private external debt is negative and significant at 5% level (Figure A5 in the Appendix).

Another angle to confirm the empirical results is to look at the speed of the recoveries, proxied by the latest one-quarter GDP growth. Figure A6 shows that one-quarter GDP

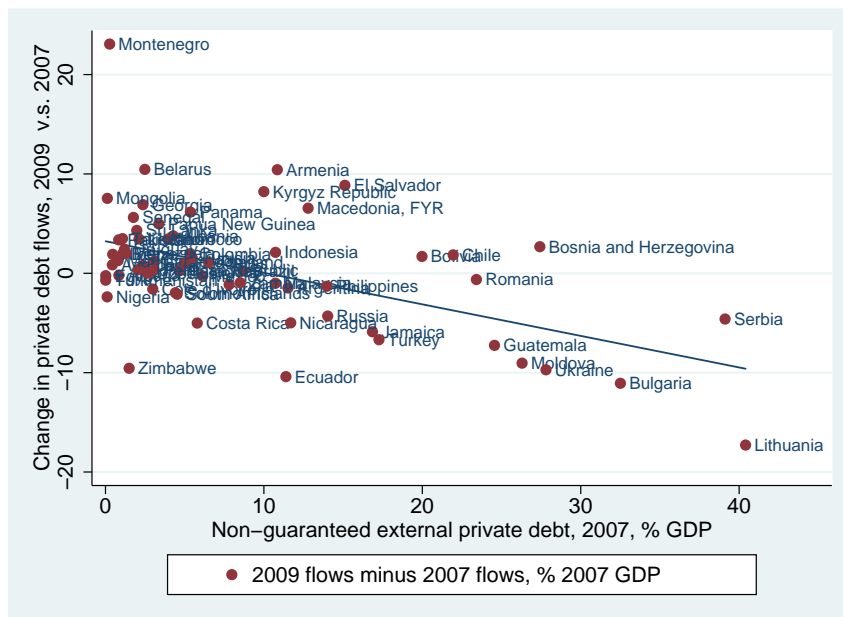


Figure 4: Pre-crisis private external debt and debt inflows during crisis

growth at quarter 4, 2010⁴ is negatively correlated to the level of pre-crisis private external debt, although the correlation is not significant. The correlation becomes so if we replace quarterly growth by de-trended quarterly growth (i.e. quarter 4, 2010 growth *minus* the pre-crisis long run quarterly growth). Nevertheless, caution should be given about the results given the small size of observations.

A major concern is that the measure of private, non-guaranteed external debt might reflect not only countries' indebtedness but also some other characteristics, such as the overall exposure to international financial risk and/or financial openness. Thus a negative correlation between pre-crisis private external debt and countries' performance during the crisis might capture the countries' overall vulnerability to international financial markets. I address that concern by controlling for financial openness, proxied by the 2007 Chinn-Ito financial openness index (Chinn and Ito 2006). After controlling for the index, the measure of pre-crisis private external debt is still significant for every relationship. This suggests the external debt measure captures additional factors beyond the countries' overall exposure to international financial markets. Another important point to make is the subtle difference between a country's actual borrowing (i.e. external debt) and its ability to borrow (which is harder to measure). Heavy indebtedness needs not imply binding credit constraints if the country's borrowing capacity is large. I attempt to control for countries' borrowing ca-

⁴Quarter 4, 2010 is the latest quarter with data available for a sizable set of countries.

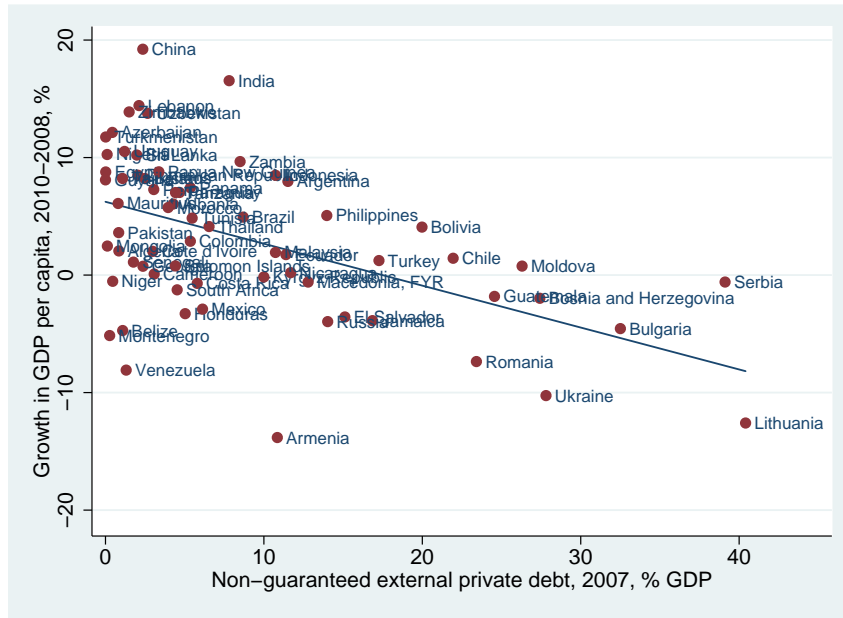


Figure 5: Pre-crisis external debt and GDP growth after the crisis

capacity by using the “Contract Enforcement” index, from the World Bank’s Doing Business survey . The index reports the percentage of claims that can be recovered through courts, which reflects the extent to which businesses can retrieve their losses through courts if their counterparts breach the contracts. After controlling for the index, interpreted as countries’ borrowing capacity, pre-crisis external debt is still significantly correlated to countries’ inflows, investment and growth during and beyond the crisis period. I also control for country’s pre-crisis foreign reserve holdings and countries’ growth in total factor productivity (TFP) in 2008 (data are from the Conference Board; 2009 data on TFP are not available). Detailed cross countries regressions with all the control variables are shown Tables A1-A4 in the appendix.

3 The model

3.1 Model setup

Consider a two-country world that consists of a large creditor economy (called country C) and a small debtor country (called country D). Country D faces a collateral-based credit constraint, and country C does not. The two countries have the same decreasing returns to scale production technology, but the creditor (usually more advanced) country has accumulated

more capital (per capita). This implies that the marginal product of capital in country C is lower than that of country D. If the collateral constraint were not present, country D would borrow from country C and accumulate more capital until the two countries have the same level of capital. As in KM, the collateralized credit constraint captures imperfect financial markets: lenders can not force borrowers to repay their debt unless the debt is secured.

There are two kinds of goods: a durable asset (capital) and a non-durable good. It is assumed, as in KM, that the total stock of capital is fixed. One can think of the total capital stock as the total world saving, which does not change rapidly over a short period of time⁵. Capital does not depreciate and there is a competitive spot market where agents in both countries can buy and sell capital at the market price.

Consider country D. The country maximizes its life-time discounted utility:

$$\max E_0 \sum_{t=0}^{\infty} \beta^{*t} \frac{c_t^{*1-\sigma}}{1-\sigma}$$

subject to the budget constraint:

$$c_t^* + R_t b_t^* + q_t k_{t+1}^* = z_t^* k_t^{*\alpha} + b_{t+1}^* + q_t k_t^* \quad (1)$$

where z_t^* follows an AR(1) process:

$$z_t^* = \rho z_{t-1}^* + \varepsilon_t^*$$

and b_{t+1}^* is the borrowing of a representative household/firm of country D, R_t is the interest rate, q_t is the market price for capital (in units of consumption). The country uses its output, its borrowing and the value of its asset/capital to finance consumption, debt repayments and the purchase of capital for production next period. Capital has two functions: it is used as an input in the production process and also as collateral. Country D can only borrow up to a fraction of their asset value:

$$b_{t+1}^* \leq \phi q_t k_{t+1}^*$$

In a standard macroeconomic model without collateral constraints, the debtor country borrows more for investment, increases production and grows through the accumulation of capital. The marginal productivity of the two countries are equalized in the equilibrium. When the credit constraint is present however, the debtor country's borrowing capacity is

⁵Relaxing this assumption would not change the intuition of the model.

limited: it has a lower level of capital stock than the creditor country. As a result, it has a higher marginal productivity and it is optimal for them to invest as much in capital as the borrowing constraint allows.

Consider the creditor economy (country C). The country has an identical production function as country D, but has accumulated more capital and hence their marginal productivity of capital is lower.

The country maximizes its life-time discounted utility:

$$\max E_0 \sum_{t=0}^{\infty} \beta^t \frac{c_t^{1-\sigma}}{1-\sigma}$$

subject to:

$$c_t + b_{t+1} + q_t k_{t+1} = z_t k_t^\alpha + R_t b_t + q_t k_t \quad (2)$$

where z_t also follows an AR(1) process

$$z_t = \rho z_{t-1} + \varepsilon_t$$

and b_{t+1} is the lending from a representative household/firm of country C. Here I assume $\beta > \beta^*$. This assumption ensures that country D is more impatient and borrows from country C.

I also assume the two countries are different in their sizes. I normalized the size of country D to one, and denote N as the size of country C. The market clearing conditions for the debt market, the capital market, and the good market respectively:

$$N b_{t+1} = b_{t+1}^* \quad (3)$$

$$N k_{t+1} + k_{t+1}^* = \bar{K} \quad (4)$$

$$N c_t + c_t^* = N z_t k_t^\alpha + z_t^* k_t^{*\alpha} \quad (5)$$

3.2 The equilibrium

The first order conditions for the debtor country are:

$$c_t^{*\sigma} = \beta^* E_t c_{t+1}^{*\sigma} R_{t+1} + \lambda_t \quad (6)$$

$$q_t c_t^{*\sigma} = \beta^* E_t c_{t+1}^{*\sigma} (\alpha z_{t+1}^* k_{t+1}^{*\alpha-1} + q_{t+1}) + \lambda_t \phi q_t \quad (7)$$

λ_t is the shadow value of relaxing the collateral constraint. A positive λ_t implies that

the constraint binds: the debtor country would like to borrow more for production and consumption but cannot.

The first order conditions for the creditor country are:

$$c_t^{-\sigma} = \beta E_t c_{t+1}^{-\sigma} R_{t+1} \quad (8)$$

$$q_t c_t^{-\sigma} = \beta E_t c_{t+1}^{-\sigma} (\alpha z_{t+1} k_{t+1}^{\alpha-1} + q_{t+1}) \quad (9)$$

Equation (9) states that the marginal utility loss of investing one additional unit of capital equals the expected marginal utility gain from investing that unit. The gain consists of the marginal product from that unit, and the potential increase in asset/capital prices. (9) indicates that at the margin, capital is priced by the creditor country.

Substituting (8) to (9):

$$E_t c_{t+1}^{-\sigma} \left(q_t - \frac{1}{R_{t+1}} q_{t+1} - \frac{1}{R_{t+1}} \alpha z_{t+1} k_{t+1}^{\alpha-1} \right) = 0 \quad (10)$$

Denoting $u_t \equiv q_t - \frac{1}{R_{t+1}} q_{t+1}$, following KM, u_t is defined as the user cost of capital. In the case of $\sigma = 0$ (risk neutral agents) and no uncertainty, we would obtain the same result as in KM: the marginal productivity of the creditor country equals the user cost of capital.

The equilibrium is defined as a sequence of capital holdings, debt outstanding, prices of capital, consumption and interest rate $\{k_t, k_t^*, b_t, b_t^*, q_t, c_t, c_t^*, R_t\}$ that satisfies the first order conditions and the market clearing conditions.

3.3 The transmission mechanism

Before proceeding to solve the model, it is useful to examine the transmission mechanism in which a shock can spread across countries. Consider a negative shock to country C. After the shock, asset prices falls. Falling asset prices worsen country D's ability to borrow and reinvest. Its borrowing and capital stock decline as a consequence. This leads to a further decline in the value of its total assets, further tightening the borrowing constraint and reducing its capital stock. This constitutes a downward spiral that could cause severe damage to the debtor country's output. The mechanism is summarized in the diagram below:

$$z_t \Downarrow \implies q_t \Downarrow \implies \phi q_t k_{t+1}^* \Downarrow \implies b_{t+1}^* \Downarrow \implies \phi q_t k_{t+1}^* \Downarrow \dots$$

Why does the asset price fall on impact? It falls via the following channels: the first

one is the expected decrease in future productivity in country C due to the persistence of the shock. The second channel, which is more important, is the change in the marginal rate of substitution. Note that after the shock, consumption falls. Since agents are risk averse, falling consumption reduces their marginal rate of substitution: the marginal utility of current consumption increases, that is, agents value current consumption more. This pushes the interest rate up, and asset prices go down as a consequence:

$$z_t \Downarrow \implies c_t \Downarrow \implies MRS \Downarrow \implies R_t \Uparrow, q_t \Downarrow$$

Note that in this model, capital repatriation is not the main factor that drives the asset prices down. This is an important difference to KM. In the KM model, asset prices decline because capital moves from more efficient producers (i.e. farmers) to less efficient producers (i.e. gatherers). This is not the case here: although capital does move from the debtor country to the creditor country, where it has a lower return, it does not significantly change the creditor country's capital stock, and hence has only a marginal impact on the asset price. The decline in consumption, combined with risk aversion is the main factor that generates the decline of the asset prices⁶. The role of risk aversion is crucial here, because if agents are risk neutral, as in KM, a decrease in consumption has no impact on marginal utility.

4 Solution of the model

I solve for the first order approximation of the model. The risk aversion and the discount factors of country C and D are chosen as standard, in which the discount factor of C is larger than D. Persistent and standard deviation of the shocks are also within range of the literature (e.g. see Coeurdacier, Kollmann, and Martin (2010)). For the borrowing constraint coefficient, following Korinek (2010), I choose $\phi = 0.5$. Regarding the size of the two countries, I set $N = 5$, i.e. the population of country C is 5 times larger than country D.

⁶Jeanne and Korinek (2010) describe a similar mechanism in which a reduction in asset prices operates through a decline in consumption.

σ	Risk aversion	2
β	Discount factor country C	0.96
β^*	Discount factor country D	0.94
α	Share of capital in production	0.33
ϕ	Borrowing constraint coefficient	0.5
ρ_z	Persistence of AR(1) shocks	0.75
σ_z	Standard deviation of AR(1) shocks	0.015
\bar{K}	Total Capital	5
N	Relative size of country C	5

Table 1: Benchmark parameter values

4.1 The deterministic steady state

In the steady state, the first order conditions of the two countries are as follows:

$$qc^{-\sigma} = \beta c^{-\sigma}(\alpha z k^{\alpha-1} + q) \quad (11)$$

$$c^{-\sigma} = \beta c^{-\sigma} R \quad (12)$$

$$qc^{*\sigma} = \beta^* c^{*\sigma}(\alpha z k^{*\alpha-1} + q) + \lambda \phi q \quad (13)$$

$$c^{*\sigma} = \beta^* c^{*\sigma} R + \lambda \quad (14)$$

From (11), we can derive the price of capital in the steady state:

$$q = \frac{\beta}{1 - \beta} \alpha z k^{\alpha-1} \quad (15)$$

Equation (15) states that the price of capital equals the discounted stream of the marginal product of capital in the creditor country. The more capital the creditor country holds, the lower the price of capital.

From (12) and (14):

$$\lambda c^{*\sigma} = 1 - \frac{\beta^*}{\beta} \quad (16)$$

From (16) and $\beta^* < \beta$, we can see that $\lambda > 0$. This implies that the collateral constraint binds in the steady state equilibrium. The debtor country borrows as much as it can from the creditor country and its marginal productivity is higher than that of the creditor country. In the neighborhood of the steady state, the collateral constraint always binds, as in KM.

The values of the variables in the steady state are given in the table below:

The steady state values are reasonable. Consumption and output per capita of country C are about 15-20% higher than those of country D. This is comparable to the range of for

k	k^*	y	y^*	c	c^*	b	b^*	q	R	λ
0.8769	0.615	0.957	0.85	0.98	0.74	0.268	2.68	8.73	1.042	0.0382

Table 2: Steady State Values

example, Germany and Greece’s output and consumption per capita. Borrowing of country D in the steady state is about three times as large as their output, which is not outside the range of countries’ pre-crisis external debt.

4.2 Dynamics

4.2.1 Without collateral constraints

This section considers a benchmark case with no collateral constraint and with the same discount factors for both countries. This is for us to contrast the different responses in terms of capital movements and output with the case when the constraint is in place.

Without the collateral constraint, the two countries have the same level of capital (per capita) in the long run and no borrowing takes place. Suppose there is a 1% negative productivity shock in the creditor country. Figure 6 below shows the impulse responses of relevant variables:

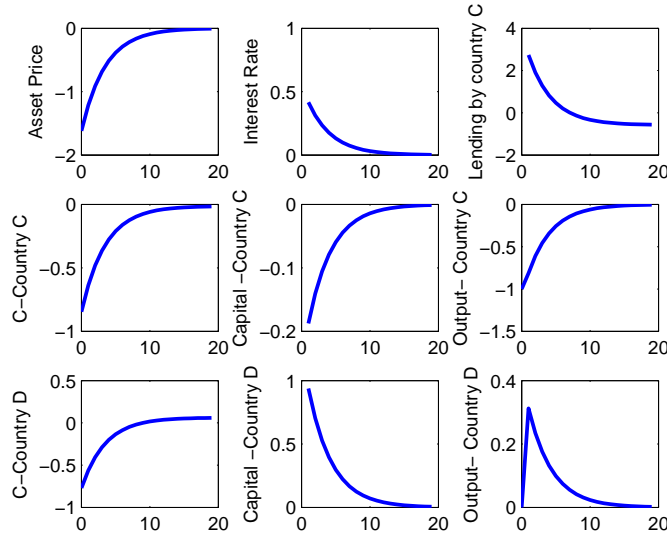


Figure 6: Impulse Responses to a -1% negative productivity shock to the Creditor economy- No collateral constraints

After the shock, the asset price falls via the following channels: first is the expected decrease in future productivity due to the persistence of the shock. Second is the change in the marginal rate of substitution. As section 3.3 explains, the second channel is the main mechanism in which the asset price falls. Persistence of the shocks seems to play a smaller role, because the asset price also falls by about the same amount if the shocks are *iid*, as seen in Figure A7 in the appendix.

Notice that decoupling occurs: capital flows from country C to country D to take advantage of the relatively higher productivity. Country D borrows from country C to finance the purchase of capital, and gradually returns the debt. This is a standard result. If the collateral constraint is in place, capital movements will be different. A falling asset price will have negative implications on the borrowing capacity of country D: country D will not be able to borrow due to a decline in their collateral's value. We will witness capital outflows from country D, as the subsequent section will analyze.

4.2.2 With collateral constraints

This section first considers the dynamics of the world economy after an unexpected negative productivity shock to the creditor economy (country C). It shows the impact of the shock on the debtor country can be more severe and persistent than that on the creditor economy.

I also examine the dynamics of the world economy after a negative productivity shock of the same size to the debtor country (country D). I show that a domestic negative shock to the debtor country can actually be less damaging to the debtor country than a negative external shock does.

Finally I consider the dynamics of the system when the debtor country is more leveraged. I will show that a more leveraged debtor country suffers more.

Let us start with a -1% technology shock on country C (Figure 7). The values on the Y-axis represent percentage deviations from the steady state values, with one exception. The Y-axis of the top right panel represents absolute deviation lending from the steady state value. The responses are as follows: after the negative shock, output in country C returns to the normal level. Output in country D does not change on impact, but declines afterward due to the decline in its capital stock. Why does its capital stock decline? Here the negative productivity shock in the creditor economy depresses the asset price. As should be clear by now, the falling asset price worsens the debtor country's ability to borrow and reinvest. The falling asset price, the collapse of investment and a tightened budget constraint form a self-enforcing mechanism that causes severe damage to the debtor country's output. The

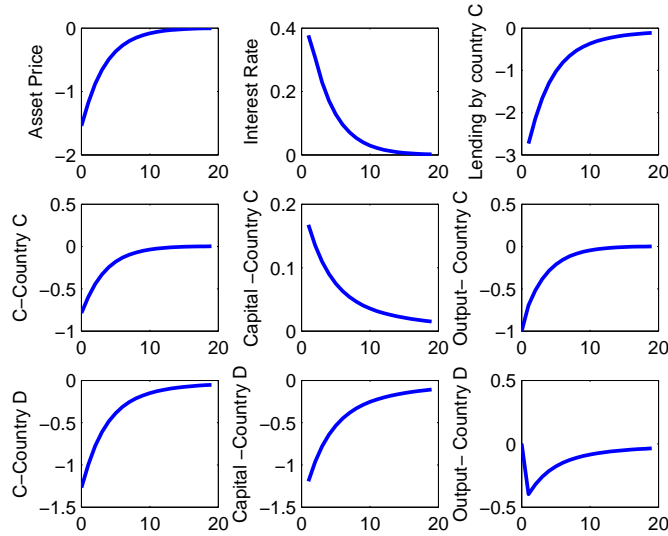


Figure 7: Impulse Responses to a -1% negative productivity shock to the Creditor economy

downward spiral happens in period 1 after the shock.

As in the case with no collateral constraints, the asset price decreases mostly because of the change in the marginal rate of substitution. The decrease in the asset price, in combination with the presence of collateral constraints, generates a fundamentally different direction of capital flows to the benchmark case: in response to negative shocks in creditor countries, capital actually repatriates from debtor countries to developed ones. This is an interesting result that is in line with what has happened in the current crisis. It is fair, however, to note that in the model, I assume the total stock of world capital is fixed, so if a country is credit constrained, capital has to go to the other country. Having said that, if one thinks of \bar{K} as the total world saving, which does not change rapidly over a short period of time, the model describes an interesting phenomenon in the current crisis.

Going back to the impulse responses, output in the debtor country gradually returns to the normal level because the country's capital slowly accumulates, which limits their ability to borrow. The sluggish return of country D's output to the normal level explains why in the long run, output of country D can be more volatile than that of country C, even in the case that the technology shocks only occur in country C.

A fall in country D's capital stock implies that country C accumulates more capital, which drives the marginal productivity of capital and the asset price down. However due to a larger size of country C, a reallocation of capital out of country D would have little impact

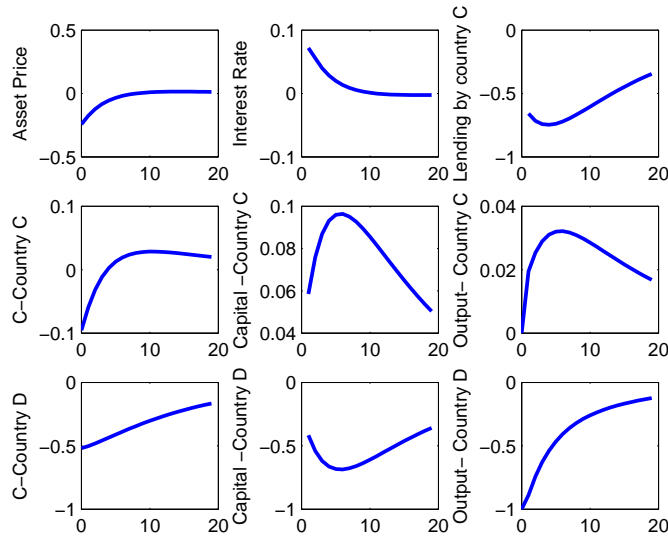


Figure 8: Impulse Responses to a -1% negative productivity shock to the Debtor economy

on the capital stock of country C. This has implications when we consider a -1% productivity shock in country D.

Figure 8 shows the responses to a -1% technology shock on country D. The dynamic is similar to what we see above. A negative productivity shock lowers the asset price and tightens country D’s credit constraint, generating capital outflows. But now since country C is much larger, the shock in country D has little impact on country C’s capital stock, output and consumption. The international asset price drops much more moderately (compared to a shock of the same size in country C). Consequently, country D’s borrowing capacity is less affected, and capital flows to country C are more modest. Country D’s output hence recovers more quickly from the initial decline.

It is interesting to note that a negative productivity shock in country D causes less damage to country D’s output than an external shock of the same size does. This illustrates the power of financial integration and financial frictions in transmitting and amplifying shocks across countries. In this case, a small but leveraged economy is vulnerable to dangerous “sudden stops”- sudden withdrawals of foreign capital when the value of the country’s assets plummets.

Obviously, if the debtor country relies more on outside funds (i.e. it is more leveraged), the impact of the external shock is more severe. Figure 9 shows the impulse responses in the case of $\phi = 0.7$. With a higher leverage level, the debtor country witnesses larger declines in

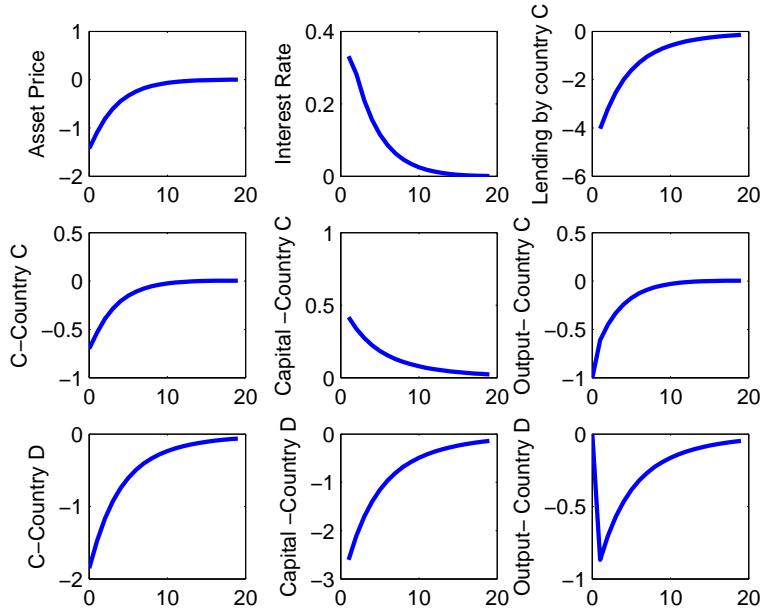


Figure 9: Impulse Responses to a -1% negative productivity shock to the Creditor economy, the Debtor country is more leveraged

borrowing, investment and output in responses to negative shocks in the creditor country. The larger decline in borrowing is not due to the interest rate however, as the interest rate rises to a similar level as before. Instead, it is due to a sharper deterioration of their borrowing capacity. As a result, the debtor country's capital outflows, its investment and output declines are larger, and its recovery is more sluggish. These results are prominent featured in the current crisis: highly indebted countries are still having a very difficult economic time three years after the crisis.

In the last section, I conduct a simple simulation exercise to show that, due to the transmission of shocks, debtor countries' business cycles can be more volatile than the those of creditor countries. At each simulation, I generate 100 histories, each of 100 periods. I run three separate simulations. First, in the benchmark simulation, I keep both productivity shocks (z and z^* with $\sigma_z = 0.015$) and the benchmark leverage ratio ($\phi = 0.5$). In the second simulation, I shut down the z^* shocks (productivity shocks of country D) and only leave the z shocks (productivity shocks of country C). Finally, I repeat the exercise with a different value of the leverage ratio ($\phi = 0.7$). Table 3 reports averaged simulated standard deviations of countries' output. Numbers in brackets are the standard deviations of the statistics. As can be seen from the table, at the benchmark value $\phi = 0.5$, when country D's productivity shock

is shut off, its output becomes less volatile than C's. However, when we increase the leverage ratio, its output becomes more volatile than C's. This implies that collateral constraints, combined with high indebtedness may contribute to the volatile nature of emerging markets' business cycles.

	Stdev of A's output	Stdev of D's output
$\phi = 0.5$, both z and z^*	0.0212 (0.0036)	0.0277 (0.0057)
$\phi = 0.5$, only z	0.0211 (0.0030)	0.0098 (0.0019)
$\phi = 0.7$, only z	0.0195 (0.0029)	0.0210 (0.0042)

Table 3: Output Volatility with Different Leverage Ratios

5 Conclusion

This paper presents a simple model to examine a transmission mechanism in which adverse shocks originating from a creditor economy can have asymmetrically large and persistent impacts on a debtor country's investment and output. The impact can be particularly devastating if the debtor country is highly leveraged. In addition, the debtor country's recovery can be slow because the credit constraint prevents it from quickly borrowing and accumulating capital. The mechanism finds empirical support in the 2008-2010 crisis and recovery data: there are statistically significant and negative relationships between pre-crisis external debt and GDP growth during and after the global crisis.

The crisis transmission works through the global integration of asset markets- an increasingly accurate feature of international financial markets- and the collateral constraints of debtor countries. Falling asset prices tighten the credit constraints of the countries and generate downward spirals that may cause large output losses. To the extent that falling asset prices trigger the feedback loop, adverse shocks to developed countries need not be productivity for the mechanism to take place. They can also be of other types as long as they depress the asset prices.

To the extent that relaxing credit constraints in bad times will help debtor countries raise capital and boost investment significantly, this paper implies that some amount of assistance, in the form of grants or long term debt, from advanced economies or international financial institutions, can help debtor countries recover from a recession caused by a negative external shock.

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A Appendix

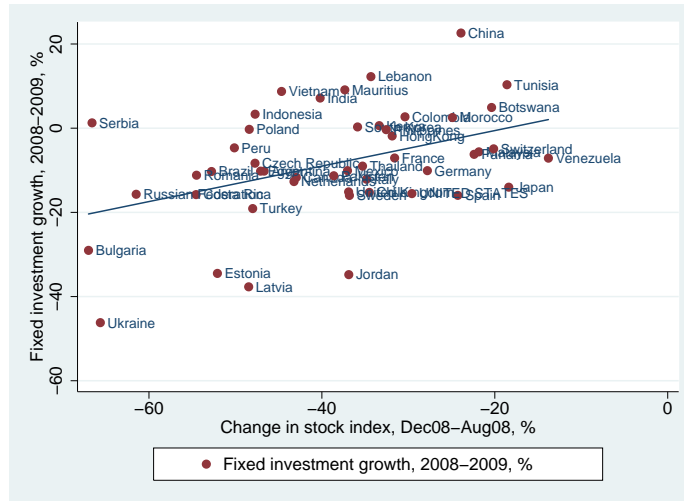


Figure A1: Changes in stock indices and investment growth during crisis

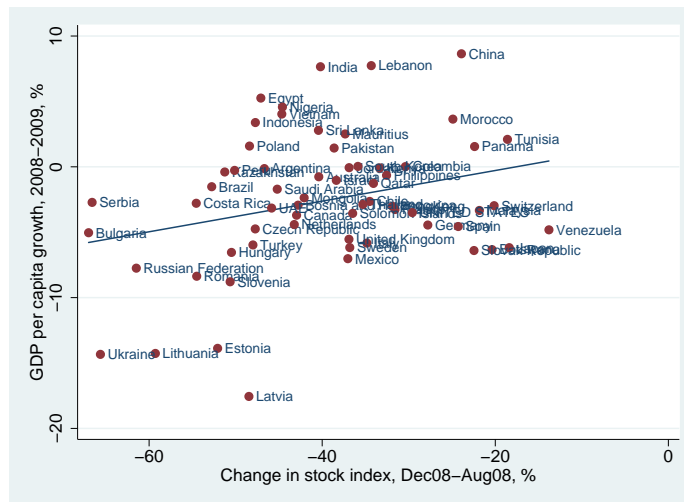


Figure A2: Changes in stock indices and output growth during crisis

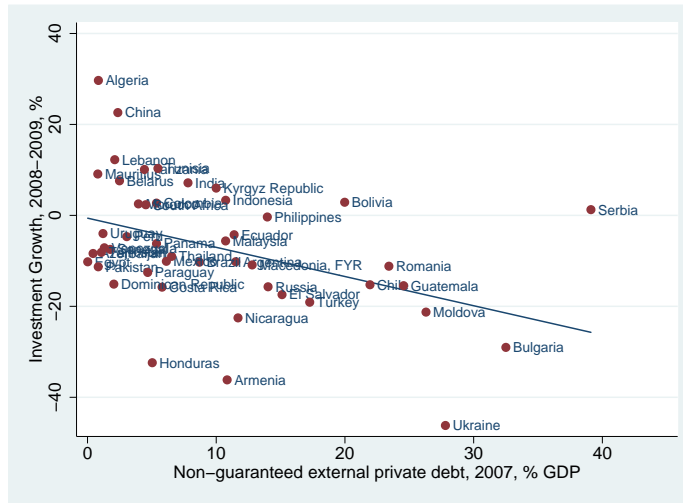


Figure A3: Pre-crisis external debt and investment growth during the crisis

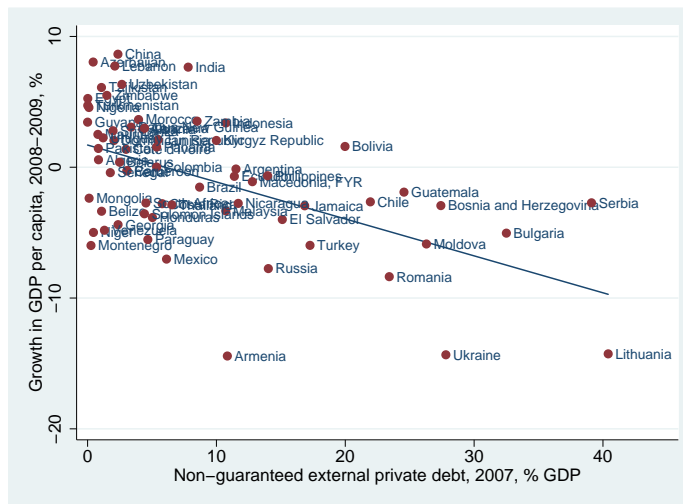


Figure A4: Pre-crisis external debt and output growth during the crisis

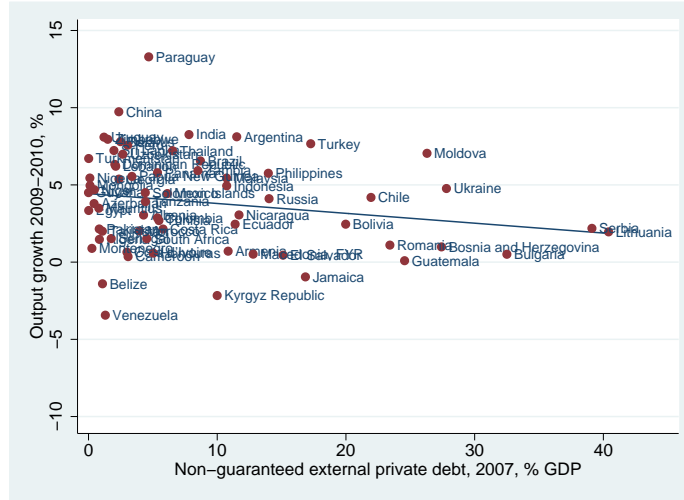


Figure A5: Pre-crisis external debt and output growth after the crisis

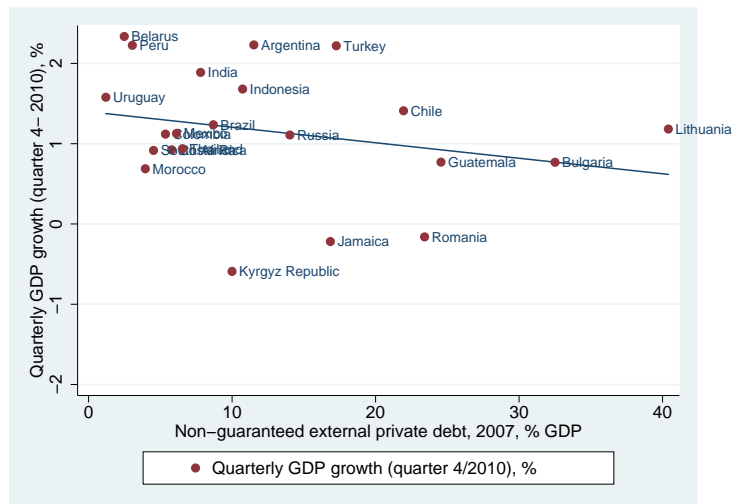


Figure A6: Pre-crisis external debt and output growth after the crisis

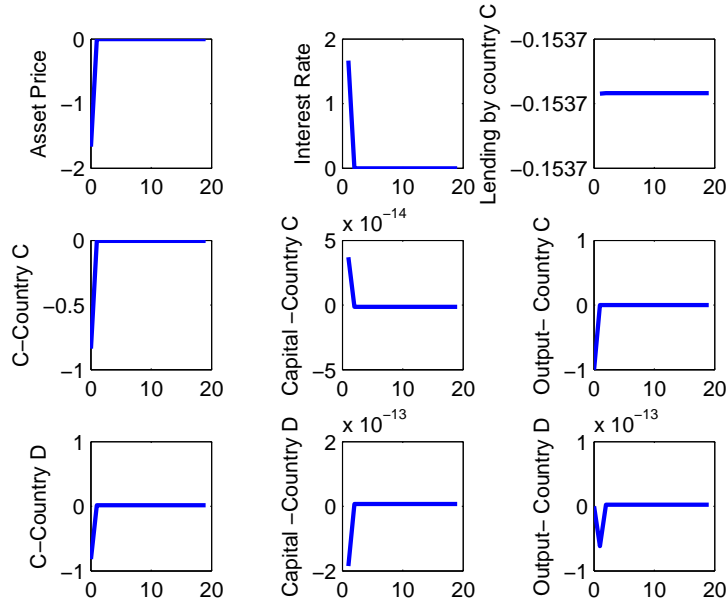


Figure A7: Impulse Responses to a -1% negative productivity shock to the Creditor economy- No collateral constraint- *iid* shocks

VARIABLES	(1) Debt flows 2009 v.s 2007	(2) Debt flows 2009 v.s 2007	(3) Debt flows 2009 v.s 2007	(4) Debt flows 2009 v.s 2007
Stock index change (Aug08-Dec08, %)	0.230*** (0.0533)			0.122** (0.0451)
Private debt 2007 (% GDP)		-0.116** (0.0546)	-0.131** (0.0573)	-0.00464 (0.0837)
Financial openness 2007			0.534 (0.409)	0.498 (0.345)
Reserve 2007 (% GDP)			-0.0342 (0.0786)	-0.0953 (0.0976)
Contract 2007			-0.00628 (0.0145)	-0.0288* (0.0142)
Observations	33	66	59	31
R-squared	0.417	0.050	0.093	0.356

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table A1: Pre-crisis debt, change in stock indices and 2009 change in debt inflows

VARIABLES	(1)	(2)	(3)	(4)	(5)
	Investment growth 2008-2009	Investment growth 2008-2009	Investment growth 2008-2009	Investment growth 2008-2009	Investment growth 2008-2009
Stock index change (Aug08-Dec08, %)	0.422*** (0.154)				0.337 (0.279)
Private debt 2007 (% GDP)		-0.642** (0.276)	-0.875*** (0.215)	-0.925*** (0.226)	-0.569** (0.216)
Growth TFP 2008			0.990* (0.585)		1.894** (0.698)
Financial openness 2007				-0.938 (1.157)	-0.915 (2.175)
Contract 2007				-0.107 (0.0756)	-0.0678 (0.0808)
Reserve 2007 (% GDP)				0.948*** (0.211)	0.228 (0.530)
Past inv. growth (average 00-07)					-0.0552 (0.727)
Observations	48	47	39	45	23
R-squared	0.178	0.176	0.343	0.445	0.693

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table A2: Pre-crisis debt, change in stock indices and 2008-2009 Investment growth

VARIABLES	(1)	(2)	(3)	(4)	(5)
	GDP growth 2008-2009	GDP growth 2008-2009	GDP growth 2008-2009	GDP growth 2008-2009	GDP growth 2008-2009
Stock index change (Aug08-Dec08, %)	0.122** (0.0542)				0.0259 (0.116)
Private debt 2007 (% GDP)		-0.282*** (0.0592)	-0.336*** (0.0574)	-0.329*** (0.0571)	-0.360*** (0.101)
Growth TFP 2008			0.191 (0.148)		0.332 (0.454)
Financial openness 2007				0.190 (0.370)	-0.261 (1.056)
Contract 2007				-0.0159 (0.0248)	-0.0418 (0.0276)
Reserve 2007 (% GDP)				0.162 (0.102)	0.167 (0.248)
Past growth (average 00-07)					0.194 (0.629)
Observations	62	67	53	60	27
R-squared	0.086	0.297	0.414	0.371	0.586

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table A3: Pre-crisis debt, change in stock indices and 2008-2009 output growth

VARIABLES	(1) GDP growth 2009-2010	(2) GDP growth 2009-2010	(3) GDP growth 2009-2010	(4) GDP growth 2009-2010
Stock index change (Aug08-Dec08, %)	0.000806 (0.0310)			-0.0584 (0.0628)
Private debt 2007 (% GDP)		-0.0638** (0.0292)	-0.0768* (0.0404)	-0.128** (0.0546)
Financial openness 2007			0.0407 (0.275)	-0.423 (0.340)
Contract 2007			-0.000454 (0.0148)	0.00509 (0.0162)
Reserve 2007 (% GDP)			0.0389 (0.0761)	0.0651 (0.102)
Past growth			0.163 (0.144)	0.255 (0.295)
Observations	58	67	60	31
R-squared	0.000	0.040	0.062	0.195

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table A4: Pre-crisis debt, change in stock indices and 2009-2010 output growth