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Enrique G. Mendoza
Vincenzo Quadrini

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ABSTRACT

Two observations suggest that financial globalization played an important role in the recent financial crisis. First, more than half of the rise in net borrowing of the U.S. nonfinancial sectors since the mid 1980s has been financed by foreign lending. Second, the collapse of the U.S. housing and mortgage-backed-securities markets had worldwide effects on financial institutions and asset markets. Using an open-economy model where financial intermediaries play a central role, we show that financial integration leads to a sharp rise in net credit in the most financially developed country and leads to large asset price spillovers of country-specific shocks to bank capital. The impact of these shocks on asset prices are amplified by bank capital requirements based on mark-to-market.

Enrique G. Mendoza
Department of Economics
University of Maryland
College Park, MD 20742
and NBER
mendozae@econ.umd.edu

Vincenzo Quadrini
Department of Finance and Business Economics
Marshall School of Business
University of Southern California
701 Exposition Boulevard
Los Angeles, CA 90089
and NBER
quadrini@usc.edu

1 Introduction

The global financial crisis that started with the meltdown of the U.S. sub-prime mortgage market in 2007 was preceded by a twenty-year period of substantial growth in debt and leverages, in an environment of increasing world financial integration, low real interest rates and growing U.S. external deficits. During this period of widening “global imbalances” we also observed several financial crises in emerging economies with cross-country contagion that in some cases did not appear driven by fundamentals. Some of these crises affected the capital markets of the industrial world (particularly the LTCM crisis in the aftermath of the 1998 Russian crash).

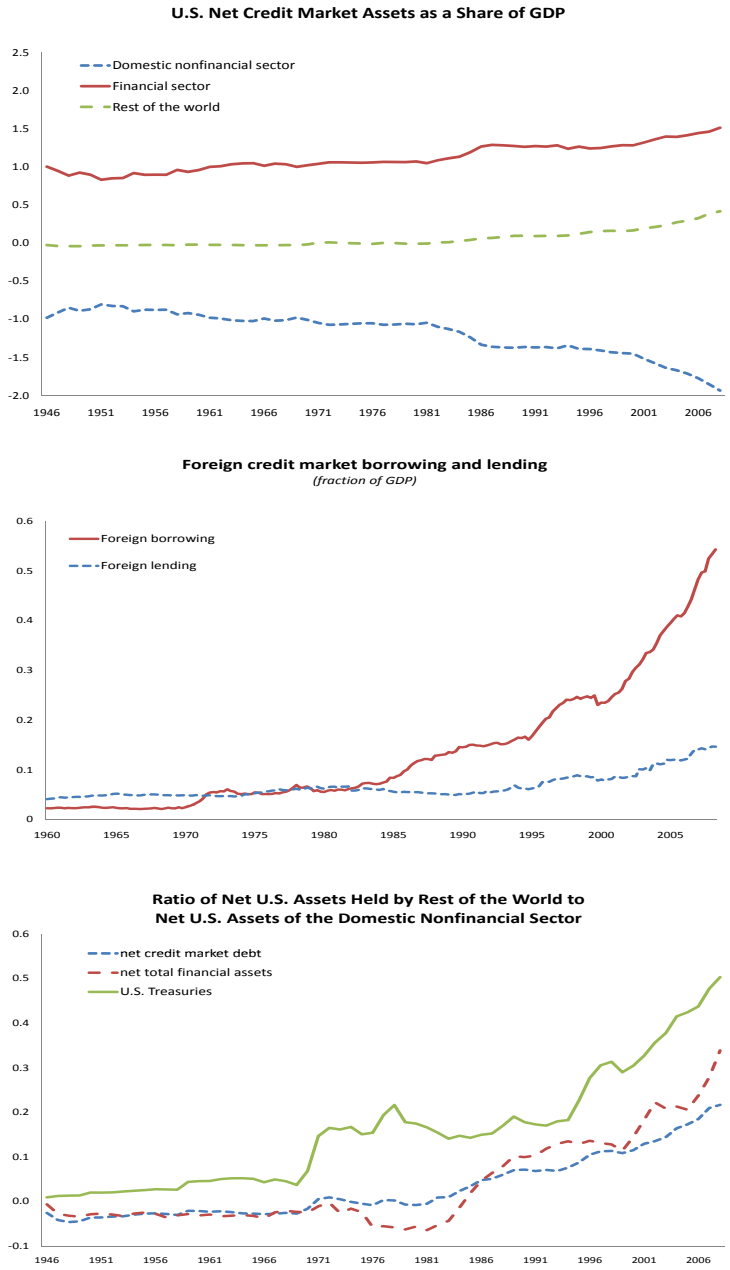
These events have generated a large body of research with well-established contributions. Until now, however, the study of global imbalances and the study of financial crises and contagion have remained somewhat separate subjects. In contrast, this paper addresses the question of whether the ongoing global financial crisis and the process of financial globalization are related. In particular, we study two issues. First, whether financial globalization contributed to the buildup of high leverages in some industrialized countries, especially the U.S. Second, whether credit frictions amplify the effects of shocks to the balance sheet of banks and how these effects are transmitted across countries.

The motivation for this paper derives from the evidence provided in Figure 1 according to which the U.S. credit boom was largely fueled by foreign lending.

1. The first panel of Figure 1 shows that the net debt-income ratio of the U.S. nonfinancial sectors doubled between 1982 and 2008 (net credit market assets as a ratio of GDP of these sectors fell from -1 to about -2). A surge in net debt of this magnitude, which affected all three nonfinancial sectors (households, nonfinancial businesses, and the government), is unprecedented in the data available since 1946.¹
2. Starting in the mid 1980s, the integration of world capital markets that resulted from the removal of capital controls and innovations in financial markets produced significant changes in gross and net foreign asset

¹Data is from the Flow of Funds of the Federal Reserve Board. Net credit is defined as credit market assets minus credit market liabilities. Credit market assets and liabilities exclude all non-debt financial instruments, particularly equity holdings.

Figure 1: Net credit before and after financial integration.



positions worldwide (see Lane & Milesi-Ferretti (2006)). In the United States, both gross and net foreign borrowing rose sharply. Regarding net foreign credit, about half of the increase in the net debt-income ratio of the nonfinancial sectors mentioned above was financed by a rise in net credit assets held by the rest of the world (see again the top panel of Figure 1), and this was also an unprecedented phenomenon in the post-war period. Before the mid 1980s, the U.S. fitted well the definition of financial autarky: The net debt of the domestic nonfinancial sectors was almost identical to the net credit assets of the financial sector, with a zero net credit position for the rest of the world.² In terms of gross positions, the second panel of Figure 1 shows that the foreign credit claims on U.S. nonfinancial sectors grew sharply since 1985, while U.S. lending to foreigners (i.e. claims of the U.S. nonfinancial sectors on foreign agents) experienced a relatively modest increase. As a result, net credit assets held by the rest of the world vis-a-vis the United States grew by 50 percentage points of U.S. GDP since 1982.

3. The above trends identified in net credit assets are even more pronounced for net total financial assets and net Treasury securities, as shown in the bottom panel of Figure 1. The plot shows the net asset positions of the U.S. vis-a-vis the rest of the world as a ratio of the corresponding net asset positions held by the domestic nonfinancial sectors for three asset categories: credit market assets (as in the top two panels), total financial assets (which include non-credit assets like equity), and U.S. Treasury bills. The ratios for credit assets and total financial assets hover near zero before the mid 1980s, reflecting again the fact that before financial globalization the U.S. was effectively in financial autarky. By the end of 2008, however, net credit assets held by the rest of the world amounted to 1/5 of U.S. net credit liabilities of the nonfinancial sectors, and for total financial assets the ratio was even higher at about 1/3. For T-bills, the rest of the world increased its positive net position sharply with the collapse of the Bretton Woods system in the early 1970s, but even that increase dwarfs in comparison

²Note that the data for financial sectors combines domestic and international components, and hence it is not accurate to associate the financial sectors data with domestic financial sectors. Before financial integration, the international components were negligible, so the association was valid. After the mid 1980s, however, part of the rise in net credit of financial sectors reflects also the effects of financial globalization.

with the surge observed since the mid 1980s. By 2008, the rest of the world was a net holder of about one in every two T-bills held outside of the U.S. financial sectors.

The fact that a large fraction of the credit expansion experienced by the U.S. economy was financed by foreign borrowing raises several questions. First, was the surge in debt in the United States a consequence of financial globalization? Second, if globalization led to higher U.S. leverages, did the higher leverages make the current crisis worse for asset prices? Third, did globalization strengthen the spillover effects of the crisis to other countries?

In order to address these issues, we start with a model that can rationalize both the expansion in domestic credit within the United States and the growth of its liabilities, vis-a-vis the rest of the world, following financial integration. The model extends the framework of Mendoza, Quadrini, & Ríos-Rull (2009) which has proven useful for explaining these two features of the data. This new setup, however, differs in two important dimensions. The first difference is that the model features three sets of economic agents within each country: savers (or wage earners), producers (or capital owners), and financial intermediaries. In Mendoza et al. (2009) savers and producers were merged in a single agent and financial intermediaries were not explicitly modeled. As we will see, the intermediation sector plays a central role in the analysis of the current paper. The second difference is that the analysis conducted in Mendoza et al. (2009) is limited to steady states and transitions from a steady state with financial autarky to one with full financial integration. In this paper, instead, we focus on the effects of unanticipated (and hence non-diversifiable) shocks that hit the net worth of financial intermediaries.

In our model, savers receive endowment incomes that are subject to idiosyncratic shocks. They can trade state-contingent claims with financial intermediaries but there are constraints to the set of feasible claims. These constraints derive from incentive-compatibility conditions imposed by limited enforceability of financial contracts, which differs across countries. Countries with higher enforcement systems allow for better insurance of the idiosyncratic risks and lower propensity to save. As a result, these countries tend to accumulate negative net foreign asset positions.

Producers do not face idiosyncratic uncertainty, so effectively we assume a representative producer. They also trade with financial intermediaries

and face limited enforcement of contracts, which takes the form of a collateral constraint. Financial intermediaries raise funds from savers with state-contingent deposits and make loans to producers. They own a fixed amount of physical capital and face a capital requirement that affects their ability to intermediate funds from savers to producers. The capital requirement is linked to the equity of the intermediaries valued at market prices (as in mark-to-market accounting). The structure of the intermediation sector has some similarities with Van-denHeuvel (2008).

The main simulation exercise we conduct in the paper consists in a ‘small’ unanticipated shock that reduces the value of banks’ equity (by about 0.5 percent the value of world wide loans). This unanticipated shock induces a large reduction in asset prices (almost 13 percent on impact). Moreover, it takes a long period of time for asset prices to fully recover (about 12 years). Since in a financially integrated economy asset prices are global, this price decline is the vehicle for international contagion of the financial crisis. Asset price declines are smaller than they would be in the presence of the same shock under financial autarky. This is precisely because the shock affects the asset prices worldwide, and not just the country where the shock originated.

We then examine the quantitative effects of shifting from a capital requirement based on mark-to-market to a system based on historical prices. The role played by mark-to-market accounting in the recent financial crisis has been widely debated. Because of this accounting principle, the recent asset price drop has caused a large decline in the equity value of banks, impairing their ability to make loans. This has led many academics and practitioners to propose the suspension or adjustment of this principle given the widespread financial difficulties (see, for example, the interviews with Robert Shiller and James Chanos in the March 30, 2009 Wall Street Journal). Our results indicate that, if the mark-to-market accounting was replaced with a system based on historical prices, the response of asset prices to shocks affecting the balance sheet of banks would be significantly smaller.

The financial mechanisms at work in our model are related to several mechanisms studied in the literature on ‘credit channels’ and ‘financial accelerators’. Classic references include Fisher (1933), Bernanke & Gertler (1989) and Kiyotaki & Moore (1997). Meh & Moran (2008) extended this class of models to an environment where bank capital plays a central role in the transmission of monetary shocks. Gertler & Karadi (2009) examined the effects of government credit provision to distressed banks. Aguiar & Drumond (2007), Drumond & Jorge (2008), Van-denHeuvel (2008) and

Zhu (2007) also use models where the behavior of financial intermediaries is important for macroeconomic fluctuations. Similar mechanisms, although without an explicit modeling of the banking sector, have been used to study Sudden Stops and financial contagion in emerging economies during the 1990s (see, for example, Caballero & Krishnamurthy (2001), Calvo (1998), Cook & Devereux (2006), Gertler, Gilchrist, & Natalucci (2007), Mendoza & Smith (2006), Mendoza (2008) and Paasche (2001)). Our work is also related to the recent studies examining the implications of financial integration among countries that are heterogenous in the degree of domestic financial development (see Aoki, Benigno, & Kiyotaki (2007), Caballero, Farhi, & Gourinchas (2008), Mendoza, Quadrini, & Ríos-Rull (2008), Mendoza et al. (2009) and Prades & Rabitsch (2007)).

The rest of the paper is organized as follows. Section 2 describes the structure of the model. Section 3 explores the properties of the model numerically. Section 4 examines the implications of changing the mark-to-market rule and Section 5 conducts a sensitivity analysis. The final Section 6 concludes.

2 Analytical Framework

We extend the model studied in Mendoza et al. (2009) by adding a more structured financial intermediation sector. The goal is to study how the behavior of financial intermediaries in response to shocks to their balance sheet propagate these shocks to the rest of the economy.

There are two countries, indexed by $i \in \{1, 2\}$, each inhabited by a continuum of agents of total mass μ^i . Agents are of two types: producers and savers, each of mass $\mu_i/2$. They all have the same preferences and maximize the lifetime utility $E \sum_{t=0}^{\infty} \beta^t U(c_t)$, where c_t is consumption at time t and β is the intertemporal discount factor. The utility function is strictly increasing and concave with $U(0) = -\infty$ and $U'''(c) > 0$.

Each country is endowed with a fixed per-capita supply \bar{k} of a non-reproducible, internationally immobile asset, traded at price P_t^i . This asset is used in production as specified below. We now describe the specific aspects of the two types of agents.

2.1 Savers

Savers are very similar to the agents described in Mendoza et al. (2009) except that they do not have the managerial ability to generate income through

the use of the productive asset. They receive income in the form of an *idiosyncratic* stochastic endowment w_t , with a Markov conditional probability distribution denoted by $g(w_t, w_{t+1})$. We also assume that the savers are the shareholders of the financial intermediaries from which they receive non-negative dividends d_t .

Savers can buy contingent claims, $b(w_{t+1})$, that depend on the next period's realizations of the endowment. In absence of aggregate uncertainty, the price of one unit of consumption goods contingent on the realization of w_{t+1} is $q_t^i(w_t, w_{t+1}) = g(w_t, w_{t+1}) / (1 + r_t^i)$, where r_t^i is the equilibrium interest rate.³ The budget constraint for an individual saver is:

$$d_t + w_t + b(w_t) = c_t + \sum_{w_{t+1}} b(w_{t+1}) q_t^i(w_t, w_{t+1}). \quad (1)$$

Market incompleteness on the side of savers is modeled by assuming limited enforcement. Contracts are not perfectly enforceable due to the limited (legal) verifiability of shocks. Because of this, savers can divert part of their endowment but they lose a fraction ϕ^i of the diverted income. The parameter ϕ^i characterizes the degree of enforcement of financial contracts in country i . Appendix A shows that, under the assumptions that agents cannot be excluded from financial markets and there is limited liability, incentive compatibility imposes the following two constraints:

$$b(w_1) - b(w_j) \leq \phi^i \cdot (w_j - w_1) \quad (2)$$

$$w_j + b(w_j) \geq 0 \quad (3)$$

for all $j \in \{1, \dots, J\}$. Here J denotes the number of all possible realizations of the endowment and w_1 is the lowest (worst) realization.

The first condition requires that insurance received through contingent claims, $b(w_1) - b(w_j)$, cannot be bigger than the variation in income, scaled by ϕ^i . When ϕ^i is sufficiently large, savers are able to get full insurance of idiosyncratic risk and maintain constant consumption. When $\phi^i = 0$, only non-state-contingent claims are feasible. A key assumption is that ϕ^i pertains to the country of residency of the savers. Cross-country differences in financial development are captured by differences in ϕ^i . The second constraint derives from limited liability. The assumption is that a saver can

³The contingent claims are sold by competitive intermediaries as described below.

always default on a contract at the beginning of next period. At this point the intermediary can only recover the endowment w_j .

Let $\{q_\tau^i(w_\tau, w_{\tau+1})\}_{\tau=t}^\infty$ be a (deterministic) sequence of prices in country i . The optimization problem of an individual saver can be written as:

$$V_t^i(w, b) = \max_{c, b(w')} \left\{ U(c) + \beta \sum_{w'} V_{t+1}^i(w', b(w')) g(w, w') \right\} \quad (4)$$

subject to

$$(1), (2) \text{ and } (3)$$

The solution to the saver's problem yields decision rules for consumption, $c_t^i(w, b)$, and contingent claims, $b_t^i(w, b, w')$. The decision rules determine the evolution of the distribution of savers over w and b . The distribution is denoted by $M_t^i(w, b)$.

We show in Appendix B that, by properly redefining the stochastic process for the endowments, the problem can be reformulated as if each saver chooses non-contingent claims, that is,

$$V_t^i(\tilde{w}, \bar{b}) = \max_{c, b' \geq -\tilde{w}_1} \left\{ U(c) + \beta \sum_{w'} V_{t+1}^i(\tilde{w}', \bar{b}') g(\tilde{w}, \tilde{w}') \right\} \quad (5)$$

subject to

$$d + \tilde{w} + \bar{b} = c + \frac{\bar{b}'}{1 + r_t^i}$$

where \tilde{w} is a transformation of w derived in the appendix and \bar{b} is the expected value of the contingent claims. The solution can then be characterized by the first order condition:

$$U'(c_t) \geq \beta(1 + r_t^i)EU'(c_{t+1}) \quad (6)$$

which is satisfied with equality if $\bar{b}' > -\tilde{w}_1$.

2.2 Producers

Differently from Mendoza et al. (2009), we assume that the owners and users of the productive asset—the producers—are different from other agents

(savers). This separation makes the model more tractable when we consider unanticipated financial shocks.

Producers receive a constant flow of endowment w^p and generate income $y_{t+1} = F(k_{t+1}) = Ak_{t+1}^\nu$, where k_{t+1} is the quantity of the productive asset purchased at time t . The parameter ν is smaller than 1 because of limited managerial capital that each producer has. Managerial capital is internationally mobile. Therefore, with capital mobility producers can choose to operate at home, buying the domestic productive asset, or abroad, buying the foreign productive asset. But they cannot do both. To keep the problem simple we have deliberately assumed that producers do not face idiosyncratic uncertainty neither in the endowment w^p nor in production. Therefore, we can focus on the representative producer.

As in the case of savers, producers can enter in contractual arrangements with financial intermediaries. Because producers do not face idiosyncratic uncertainty, their financial contracts are not state contingent. Denote by $l_{t+1}/(1+r_t^i)$ the loan contracted with a financial intermediary. In addition to the interest rate, the bank also charges a financial cost $\varphi_t^i(l_{t+1})$ which is nonnegative, increasing and convex in the loan size. Therefore, the producer receives the funds $[l_{t+1} - \varphi_t^i(l_{t+1})]/(1+r_t^i)$ at time t and promises to repay l_{t+1} at $t+1$. The precise nature of this cost will be specified later in the description of the banking sector. We anticipate here that this cost will be zero at steady state and it plays a role only in equilibria in which the equities of the financial intermediaries are low.

Limited enforcement constrains the amount that the intermediary is willing to lend as follows:

$$l_{t+1} \leq \psi^i \cdot [k_{t+1}P_{t+1}^i + F(k_{t+1})] \quad (7)$$

This constraint derives from the assumption that the producer can always default on a contract at the beginning of next period. At this point the intermediary can only recover a fraction ψ^i of the producer's assets, that is, the market value of productive capital plus production. The parameter ψ^i could differ across countries which justifies the superscript i .⁴

The producer starts the period with capital k_t and liabilities l_t and solves

⁴As we will see, the equilibrium interest rate is usually lower than the intertemporal discount rate due to the precautionary motive of savers. Because of this, producers have an incentive to borrow as much as possible. The above enforcement constraint makes sure that borrowing is bounded.

the following problem:

$$W_t^i(k, l) = \max_{c, k', l'} \left\{ U(c) + \beta W_{t+1}^i(k', l') \right\} \quad (8)$$

subject to

$$w^p + kP_t^i + F(k) + \frac{l' - \varphi_t^i(l')}{1 + r_t^i} = c + l + k'$$

$$l' \leq \psi^i [k'P_{t+1}^i + F(k')]$$

which is subject to the budget and enforcement constraints.

Given a deterministic sequence of prices $\{r_\tau^i, P_\tau^i, \varphi_\tau^i(\cdot)\}_{\tau=t}^\infty$, the solution is characterized by the following first order conditions:

$$U'(c_t) = [\beta U'(c_{t+1}) + \mu_t] \left(\frac{1 + r_t^i}{1 - \varphi_{t,d}^i(l_{t+1})} \right) \quad (9)$$

$$U'(c_t) = [\beta U'(c_{t+1}) + \mu_t \psi^i] \left(\frac{P_{t+1}^i + F_k(k_{t+1})}{P_t^i} \right) \quad (10)$$

where μ_t is the Lagrange multiplier associated with the collateral constraint (7). The multiplier is positive if the constraint is binding.

Assuming that all producers in each country start with the same initial states, k and l , they all choose the same productive asset, k' , and next period liabilities, l' , and they enter the next period with the same states. Conditions (9) and (10), together with the budget and enforcement constraints, determine the whole sequence of consumption for a given sequence of prices. Of course, prices must satisfy the general equilibrium conditions that we will describe below.

It is interesting to notice that conditions (9) and (10) imply that there is an equity premium in the accumulation of productive assets. Because the term $\varphi_{t,d}^i(\cdot)$ is nonnegative, the parameter restriction $\psi^i < 1$ implies that the return from the productive asset is bigger than the interest rate. Thus, asset prices are lower than in the absence of the enforcement constraint.⁵ As we will see, this feature will play an important role in characterizing the composition

⁵Mendoza (2008) derives a similar result in a small open economy model with a collateral constraint on foreign borrowing.

of the net asset positions of different countries when the international capital markets are liberalized.

2.3 Financial intermediaries

Financial intermediaries are profit maximizing firms owned by savers. They sign financial contracts with savers and producers. We assume that financial intermediaries own a fixed quantity \bar{k}^f of the economy's productive capital. We think of \bar{k}^f as the physical capital that is necessary to run the intermediation activity. For simplicity, this capital is assumed to be in the balance sheet of the intermediary but it does not generate any income directly. What is important for our analysis is that the balance sheet of financial intermediaries depends on the market price of the asset.⁶

Financial intermediaries start the period with real assets \bar{k}^f , a stock of loans made in the previous period to producers, L_t , and deposits from savers, B_t . The deposits are given by the value of all contingent claims purchased by savers in the previous period, that is,

$$B_t = \int_{w_{-1}, b_{-1}, w} \sum_w b_{t-1}^i(w_{-1}, b_{-1}, w) g(w_{-1}, w) M_{t-1}(w_{-1}, b_{-1}).$$

where the subscript -1 denotes variables known in the previous period. In writing this expression we are assuming that each intermediary diversifies perfectly the claims purchased by workers. The beginning-of-period equity of the financial intermediaries is equal to:

$$e_t = \bar{k}^f P_t^i + L_t - B_t \quad (11)$$

Given the beginning of period equity, the financial intermediary raises new deposits, makes new loans and pay dividends to shareholders (savers). Therefore, the consolidated (per-capita) budget constraint of the intermediation sector is:

$$e_t + \frac{B_{t+1}}{1 + r_t^i} = \bar{k}^f P_t^i + \frac{L_{t+1}}{1 + r_t^i} + d_t \quad (12)$$

⁶The assumption that financial intermediaries choose to keep the productive asset even if it does not generate income is ad hoc. In fact, because the productive asset has a market value, intermediaries would be better off selling them and closing down operations. Of course, there are ways to enrich the model to make the holding of \bar{k}^f from intermediaries fully rational. However, we decided to impose this by assumption to keep the analysis as simple as possible. All we want to get is that the market price of the productive asset is going to affect the equity of the bank.

The left-hand-side includes the source of funds, equity plus deposits. The right-hand-side is the use of funds, productive asset plus loans and dividends.

So far, the description of the intermediation sector is standard, except for the assumption that intermediaries own \bar{k}^f . We now introduce some frictions that will make the intermediation sector central to the analysis.

The first assumption is that intermediaries cannot issue new shares. This simply means that dividends cannot be negative, that is, $d_t \geq 0$.

The second assumption is that banks can issue two types of loans. The first type of loans are subject to a capital requirement, that is, they must be backed by bank equities. The second type of loans are not subject to this requirement but imply an extra cost.

Denote by \bar{L}_{t+1} the stock of loans that are subject to the capital requirement. On this stock the bank faces the following constraint:

$$\bar{L}_{t+1} \leq \alpha(e_t - d_t) \tag{13}$$

where $\alpha > 1$. The constraint imposes that this type of loans cannot be bigger than a multiple of the bank equity after the payment of dividends. Next we have to specify how \bar{L}_{t+1} is determined.

Denote by l_{t+1} the total loan made to an individual producer. Part of this loan, \bar{l}_{t+1} , is of the first type, and therefore, it is subject to capital requirement. The remaining part of the loan, $l_{t+1} - \bar{l}_{t+1}$, is of the second type and it is not subject to the capital requirement. However, in order to exempt the loan from the capital requirement the intermediary has to incur the cost $\kappa(l_{t+1} - \bar{l}_{t+1})^2$. This cost can be interpreted as resources used by the bank to improve the risk standard of the loan (so that it is exempted from capital requirement) and/or to sell part of the loan directly to savers through securitization. Notice that the quadratic cost has to be incurrent on each individual loan.

The banking sector is competitive. Therefore, in a symmetric equilibrium, each bank offers loans by charging a fee that depends on the size of the loan:

$$\varphi_t(l_{t+1}) = \begin{cases} \kappa(l_{t+1} - \chi_t^i)^2 & \text{if } l_{t+1} \geq \chi_t^i \\ 0 & \text{otherwise} \end{cases}$$

Up to χ_t^i , the cost of the loan for a producer is the interest rate. Above χ_t^i , the bank also charges a convex cost on top of the interest rate.

Because of competition, banks minimize the cost charged to each customer. This is obtained by choosing the largest χ_t^i compatible with the owned equity. Compatibility here means that, in equilibrium, the total stock of loans made by banks subject to the capital requirement does not violate constraint (13). The largest χ_t^i is obtained when banks pay no dividend. In equilibrium, all banks choose the same $\chi_t^i = \alpha(\bar{k}^f P_t + L_t - B_t) = \alpha e_t$. In other words, banks choose the threshold that in equilibrium is equal to the capital requirement if they pay no dividend. Therefore, if the demand for loans does not exceed the maximum capacity of the banking sector for capital-backed loans (that is, the loans that the banking sector can make without incurring the extra cost when it pays zero dividends), the borrowing cost for producers is only the interest rate r_t^i . However, if the demand exceeds the maximum loans that can be backed by bank capital, banks will charge the additional financial cost.

The threshold χ_t^i is essentially an equilibrium price which, together with the interest rate r_t^i , define the terms of the loan contract offered to producers in country i . Both χ_t^i and r_t^i are determined in equilibrium to clear the market. Given symmetry, the total per-capita loans made by banks are equal to the individual demand, that is, $L_{t+1} = l_{t+1}$. Furthermore, we have:

$$\begin{cases} L_{t+1} = \bar{L}_{t+1} & \text{if } l_{t+1} \leq \chi_t^i \\ L_{t+1} > \bar{L}_{t+1} & \text{if } l_{t+1} > \chi_t^i \end{cases}$$

Banks take as given the pricing schedule for loans, that is, they take as given χ_t^i and r_t^i since they are determined by competitive forces. Because the net return on loans is simply the interest rate r_t^i , the problem solved by the intermediary can be written as follows:

$$\Upsilon_t^i(B, L) = \max_{d \geq 0, B', L'} \left\{ d + \left(\frac{1}{1 + r_t^i} \right) \Upsilon_{t+1}^i(B', L') \right\} \quad (14)$$

subject to

$$L - B = \frac{L'}{1 + r_t} - \frac{B'}{1 + r_t} + d$$

where the constraint is obtained by eliminating e_t in equation (12) using equation (11).

Notice that the cost $\varphi_t^i(\cdot)$ does not enter the budget constraint because it is ultimately paid by the borrower. The capital requirement is implicit in the pricing variable χ_t^i . The discount rate for a financial intermediary is the relevant discount rate for its shareholders, that is, the savers. Under the assumption that there is no aggregate uncertainty, this is the interest rate.

It is easy to see that the dividend policy of an individual intermediary is undetermined. Because the discount rate is the interest rate, the intermediary is indifferent at the margin in the use of equity or deposits in the financing of loans. Given the indeterminacy, we assume that when the capital requirement is not binding, that is, banks can satisfy the total demand of loans without paying any financial cost, they distribute with dividends all the equities in excess of the capital requirement. The relevance of this assumption will be discussed below.

2.4 Unexpected shock to the balance sheet of banks

Starting from a steady state equilibrium, we consider a one-time, unanticipated shock that reduces the equity of the financial intermediaries. This could be caused by an unexpected loss in some of the loans made to producers (because, for instance, some producers default on their debt). Alternatively we can think of this shock as an unexpected physical depreciation in \bar{k}^f . It is important to stress that the shock is unanticipated and arises only once. Thus, the economy will experience transition dynamics that are fully deterministic and will converge back to the initial steady state. The exact nature of the experiment will be described in the quantitative section.

The assumed dividend policy of the financial intermediaries plays a crucial role in characterizing the transition dynamics. Before the arrival of the unanticipated shock, intermediaries have minimized their stock of equity up to the point in which the capital requirement is satisfied with equality. This has been imposed by assumption given the indeterminacy of the dividend policy. Therefore, if the shock is sufficiently large, intermediaries become unable to fulfil the capital requirement. The inability to issue new shares (non-negative dividends) implies that banks cannot rebuild their equity quickly by cutting dividends. Thus, they are forced to lower χ_t^i and charge a positive financial cost $\varphi_t^i(\cdot)$.

It is helpful to provide a graphical illustration of the market for loans and how it is affected by this shock. Figure 2 plots the demand for loans from producers (which is downward sloping in the cost of borrowing) and the

supply from banks (which is horizontal until the capital requirement binds given the bank's equity). The supply is plotted for a given interest rate, before and after the shock. Before the shock, the economy is at the steady state, with the equilibrium marginal cost of borrowing equal to the interest rate because loan demand intersects the supply in the horizontal segment.

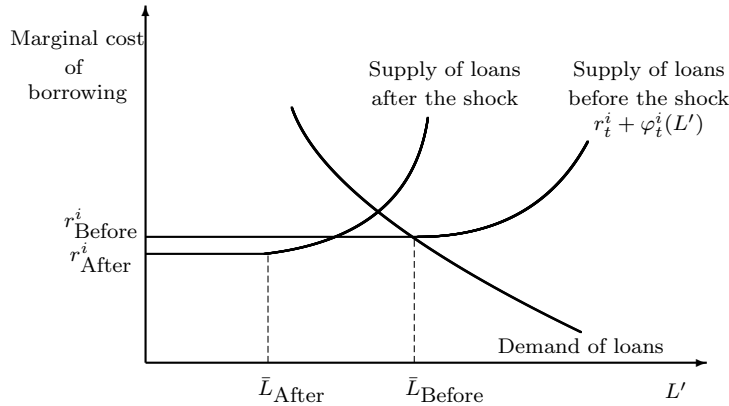


Figure 2: Equilibrium in the market for loans for a given interest rate.

After the shock, the maximum amount of loans that can be backed by bank equity shrinks to \bar{L}_{After} . Even if banks pay zero dividends, this is the maximum volume of loans that banks can make without incurring a cost. Anything above is offered at an increasing price. As a result of the new intersection between loan demand and supply, the equilibrium cost of borrowing *increases* and the volume of loans declines. Because banks cut lending, however, they demand less deposits from savers and the interest rate *declines* from r_{Before}^i to r_{After}^i . Thus, the spread between the marginal cost of borrowing and the interest rate on deposits widens. Even if the interest rate declines, the marginal cost of borrowing is higher than in the pre-shock equilibrium. The marginal cost of borrowing is what matters for asset prices as can be seen from equations (9)-(10). It is the increase in this cost that generates an asset price crash.⁷

The fall in the price of assets generates a further deterioration in the balance sheet of banks. As a result, in the general equilibrium of the model

⁷In the final equilibrium the demand for loans from producers also shifts, generating a further declines in borrowing. We have ignored this shift to simplify the discussion.

\bar{L}_{After} shifts even further to the left inducing a larger credit contraction and a larger drop in prices. This is the driving force of the amplification generated by the banking sector. This mechanism is akin to the Fisherian debt-deflation mechanism and the financial accelerator emphasized in models without an explicit financial intermediation sector. With the explicit modeling of the intermediation sector, the mechanism becomes more powerful because banks are much more leveraged than non-financial businesses.

2.5 General equilibrium

We have already provided an informal description of the equilibrium. Here we provide a formal definition. We start with the environment without mobility of capital (financial autarky). We will then describe how the definition can be adjusted for the case with capital mobility.

The sufficient aggregate states are given by the distribution of savers, $M_t^i(w, b)$, the liabilities of producers, L_t^i , and the stock of productive capital owned by producers, K_t^i . Knowing the distribution of savers and the loans made by banks, we can determine the net worth of producers and the equities of banks (once the equilibrium price of the productive asset is determined). We have the following definition:

Definition 1 (Financial autarky) *Given the financial development parameters, ϕ^i and ψ^i , initial distributions of savers, $M_t^i(w, b)$, banks' loans, L_t^i , productive capital owned by producers, K_t^i , for $i \in \{1, 2\}$, an equilibrium without international mobility of capital is defined by sequences of: (i) savers' policies, $\{b_\tau^i(w, b, w')\}_{\tau=t}^\infty$; (ii) producers' policies, $\{l_\tau^i(k, l)\}_{\tau=t}^\infty$ and $\{k_\tau^i(k, l)\}_{\tau=t}^\infty$; (iii) intermediaries' policies, $\{d_\tau^i(B, L)\}_{\tau=t}^\infty$, $\{L_\tau^i(B, L)\}_{\tau=t}^\infty$ and $\{B_\tau^i(B, L)\}_{\tau=t}^\infty$; (iv) prices $\{P_\tau^i, r_\tau^i, \chi_\tau^i, q_\tau^i(w, w')\}_{\tau=t}^\infty$; (v) distributions $\{M_\tau^i(w, k, b)\}_{\tau=t+1}^\infty$. Such that: (i) the policy rules solve problems (4), (8) and (14); (ii) prices are competitive and satisfy $\chi_\tau^i = \alpha(\bar{k}^f P_t^i + L_t - B_t)$ and $q_\tau^i = g(w, w')/(1 + r_t^i)$; (iii) asset markets clear, $\int_{w, b, w'} b_\tau^i(w, b, w') M_\tau^i(w, b) g(w, w') = B_\tau^i(B, L)$ and $k_\tau^i(K, L)/2 = \bar{k} - \bar{k}^f$ for each $i \in \{1, 2\}$ and $\tau \geq t$; (iv) the sequence of distributions of savers is consistent with the initial distributions, the individual policies and the stochastic processes for the idiosyncratic shocks.*

The definition of the equilibrium with globally integrated capital markets is similar, except for the prices and market clearing conditions (ii) and (iii). With financial integration there is a global market for assets and asset prices

are equalized across countries. Therefore, condition (ii) becomes $\chi_\tau^1 = \chi_\tau^2$, $q_\tau^1 = g(w, w')/(1 + r_t^1) = g(w, w')/(1 + r_t^2) = q_\tau^2$ and $P_\tau^1 = P_\tau^2$. Furthermore, asset markets clear globally instead of country by country. Hence, the market clearing condition for the productive assets becomes $\sum_{i=1}^2 k_\tau^i \mu^i = \bar{k} - \bar{k}^f$ and the market clearing condition for contingent claims becomes $\sum_{i=1}^2 \int_{w,b,w'} b_\tau^i(w, b, w') M_\tau^i \mu^i(w, b) g(w, w') = \sum_{i=1}^2 B_\tau^i(B, L) \mu^i$.

3 Quantitative application

In this section we study the model's quantitative predictions regarding the effects of financial integration and shocks to the balance sheet of banks. The parameter values are set as follows. We interpret the first country as the United States and the second country as the rest of the world. Therefore, we calibrate the model so that the economic size of the US is 30 percent the size of the world economy. This is obtained by assuming that the population size of the first country is $\mu^1 = 0.3$.⁸

Preferences take the logarithmic form $U(c) = \log(c)$. The intertemporal discount rate is set to $\beta = 0.94$.

We interpret the endowments as labor income and the returns from productive assets as capital income. Based on this interpretation we set average per-capita endowment, $\bar{w} + w^p$, to 0.8 and the income generated with productive assets to $y = Ak^\nu = 0.2$. Given the normalization $k = 1$ this is obtained by setting $A = 0.2$. Notice that the capital income is only 20 percent (and correspondingly the labor income is 80 percent) because this is net of depreciation. The return-to-scale parameter is set to 0.75. The total endowment is split equally between producers and savers, that is, $\bar{w} = w^p = 0.4$.

The stochastic endowment of savers takes two values, $w = \bar{w}(1 \pm \Delta_w)$, with symmetric transition probability matrix. We follow recent estimates of the U.S. earnings process and set the persistence probability to 0.95 and $\Delta_w = 0.6$.

Next we choose the parameters of the financial structure. These are the parameters ϕ^1, ϕ^2, ψ^1 and ψ^2 , where the superscript denotes the country. For the parameters ϕ^1 and ϕ^2 , what matters is the difference not the absolute

⁸There are two ways to impose different economic sizes of the two countries: by differentiating the population size and/or the per-capita quantities (endowment and productive asset). However, what matters for the quantitative results is the total economic size of the country, not the sources of the size differences. Therefore, to simplify the presentation we have assumed that countries only differ in population size.

values. Therefore, we set $\phi^2 = 0$. We are then left with three parameters. Their values are chosen to replicate the following targets in the steady state equilibrium with capital mobility:

1. Domestic credit in country 1 (the US) is 195 percent the value of domestic output.
2. Domestic credit in country 2 (the Rest of the World) is 119 percent the value of domestic output.
3. The net foreign asset position of country 1 (the US) is 30 percent the value of domestic output.

These numbers come from the 2005 World Development Indicators. The Rest of the World includes OECD countries (except the US) and emerging economies. The parameters that generate these targets are: $\phi_1 = 0.21$, $\psi_1 = 0.62$ and $\psi_2 = 0.45$.

At this point we are left with the parameters characterizing the intermediation sector. These parameters do not affect the steady state targets imposed above, and therefore, they can be set independently. The parameter determining the cost of loans κ is not important for the equilibrium outside the steady state and its value will be specified below. The per-capita endowment of the productive asset is set to $\bar{k} = 1.05$ and the one held by financial intermediaries is $k^f = 0.05$. Therefore, the stock of productive assets owned by financial intermediaries is only 5 percent of the stock owned by the rest of the economy. The capital requirement for loans is set to $\alpha = 10$. This implies that loans must be backed by 10 percent of equity.⁹

We should emphasize that the parameters of the intermediation sector (κ , \bar{k}^f and α) are not pinned down using precise calibration targets since it is difficult to identify these targets empirically. Therefore, although the results we show in the next sections provide helpful information about the quantitative potential of the model, they should be taken with caution.

3.1 Steady state properties and long-term effects of capital liberalization

In this section we show that the model generates an increase in leverages in the most financially developed country (country 1) as a result of financial

⁹For comparison, the Basle II accord sets a risk-weighted capital requirement on commercial banks equal to 8 percent of their assets.

liberalization. This provides an answer to the first question asked in the Introduction: did the globalization of financial markets lead to higher US borrowing? The key statistics showing the result are reported in Table 1.

Table 1: Statistics for financial variables in steady states with and without mobility of capital.

	<i>Country 1</i>		<i>Country 2</i>	
	<i>Autarky</i>	<i>Mobility</i>	<i>Autarky</i>	<i>Mobility</i>
Interest rate	4.31	3.92	3.67	3.92
Price productive asset	3.21	3.28	3.30	3.28
Total domestic credit	169	195	126	119
Foreign position in productive assets	-	34	-	-15
Foreign borrowing	-	64	-	-27
Net Foreign asset position	-	-30	-	12

Note: Financial variables are in percentage of domestic output.

Before looking at the various asset positions with and without financial integration, let's look at the equilibrium interest rates. In both countries and in both financial regimes, the interest rates are smaller than the intertemporal discount rate $1/\beta - 1 \approx 0.06$. This is the consequence of precautionary savings from savers who face uninsurable idiosyncratic risks. Because producers do not face any uncertainty (absence of precautionary motives), the low interest rate implies that they will borrow as much as possible. Therefore, the borrowing limit (7) is binding.

We can now look at the stock positions of the two countries. In the steady state without capital mobility (autarky), the domestic credit of country 1 is 169 percent the value of domestic output while in the steady state with financial integration this is 195 percent.¹⁰ Therefore, the model predicts that capital markets liberalization has contributed to an increase in domestic credit of 26 percentage points the value of domestic output. In country 2, instead, capital liberalization has generated a decline in domestic credit of 7 percentage points.

¹⁰Domestic credit is the sum of loans taken by producers plus the net worth of savers if this is negative. Because the value of the contingent claims can be negative, some savers are actually borrowing. However, the debt of savers is small in aggregate.

Capital liberalization has also induced country 1 to accumulate a positive net position in the productive asset of 34 percent the value of domestic output. This is associated to an increase in foreign borrowing of 64 percent.¹¹ Therefore, after capital markets liberalization, the net foreign asset position of country 1 reaches the long-term value of minus 30 percent.

The mechanism leading to these changes can be explained as follows. As can be seen from Table 1, in the pre-liberalization equilibrium country 1 has a higher interest rate and a lower price of the productive asset than country 2. Prices equalize after liberalization. Therefore, in country 1 the interest rate declines and the price of the productive asset increases. This allows producers in country 1 to increase borrowing since the higher price of the productive asset increases the value of the collateral. At the same time, because producers in country 1 face enforcement constraints that are less tight than in country 2, that is, $\psi^1 > \psi^2$, we can see from condition (10) that they require a lower return on the productive asset compared with the return required by producers in country 2. The concavity of the production function then implies that producers in country 1 operate larger scales. This contributes to the positive position of country 1 in the productive asset.

To understand the negative net foreign asset position, we have to consider the role played by savers. Because the interest rate in country 1 declines while in country 2 increases (compared to the autarky equilibrium), savers decrease their savings in country 1 and save more in country 2. As a result, a large fraction of borrowing from producers is financed by foreign savers through the banking system.

To summarize, the model captures the fact that capital liberalization has contributed to generating a significant amount of foreign borrowing for country 1, the US. The increase in borrowing induced by capital markets liberalization is in the order of 64 percent the value of domestic income.

¹¹The net foreign position in the productive asset is the difference between the total productive assets owned by domestic producers and the domestic endowment of the asset, \bar{k} , multiplied by the market price P_t^i . Foreign borrowing is the difference between domestic credit, defined in the previous footnote, and the total loans made by domestic banks, that is, loans financed by the ‘positive’ claims of domestic savers and the equities of domestic banks.

3.2 Shock to bank equity and the short-term effects of capital liberalization

In this section we address the second and third questions asked in the Introduction: Did the higher US leverages induced by globalization make the current crisis worse? Did globalization allow the crisis to spread to other countries?

In order to address these two questions we have to specify the driving force behind the recent crisis. Although the events leading to the crisis are complex and connecting the causes of these events to only one factor provides an incomplete picture, there is no doubt that the balance sheet deterioration of financial intermediaries played an important role. Therefore, we consider a shock that decreases the equities of banks by a certain percentage of outstanding loans. This can be interpreted as unexpected losses due to unrecoverable loans made to producers. The goal of the paper is to understand the consequences of these losses.

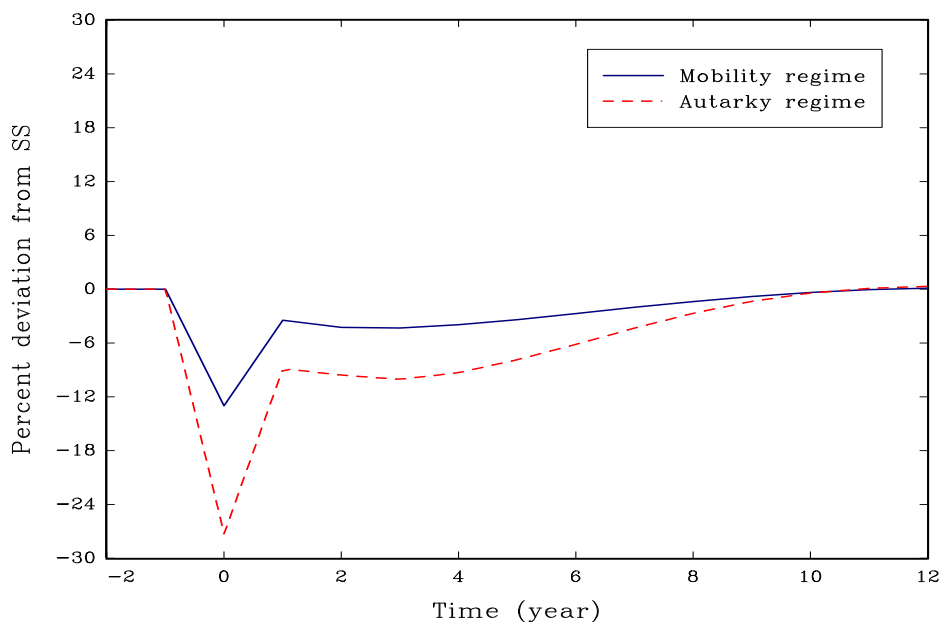
We consider a shock that generates a loss of bank equity in country 1 of 0.5 percent the value of worldwide loans. This is equivalent to about 1.5 percent the value of loans made in country 1. We start by studying the impulse responses of asset prices which are reported in Figure 3 for the economies with and without international mobility of capital.

Consider first the regime with capital mobility. As shown by the continuous line, the shock generates an initial drop in the price of assets of about 13 percent. In considering the transition dynamics, the cost of avoiding bank capital requirement plays an important role. This is captured by the parameter κ , which in the simulation is set to 0.1. As banks become unable to fulfil the whole demand of loans without violating the capital requirement, they start charging the additional financial cost. Higher values of κ increase this cost more rapidly and induce a larger drop in the demand for loans. This, in turn, generates a larger drop in asset prices.¹²

Figure 4 plots the impulse responses for other variables (in levels) but only in the case with capital mobility. The interest rate drops as banks demand less deposits from savers in response to the reduction in the demand of loans. The demand of loans decreases because of the higher marginal cost of loans for producers, the ratio $(1 + r_t^i)/(1 - \varphi_{t,l}^i(l_{t+1}))$. The total volume of loans made by banks contracts significantly and, as a result, producers cut

¹²As we increase κ , the response of asset prices becomes larger. However, for very large values of κ we are unable to solve for the transition dynamics.

Figure 3: Impulse response of asset prices to an unanticipated shock to bank equities. Economy with and without mobility of capital.

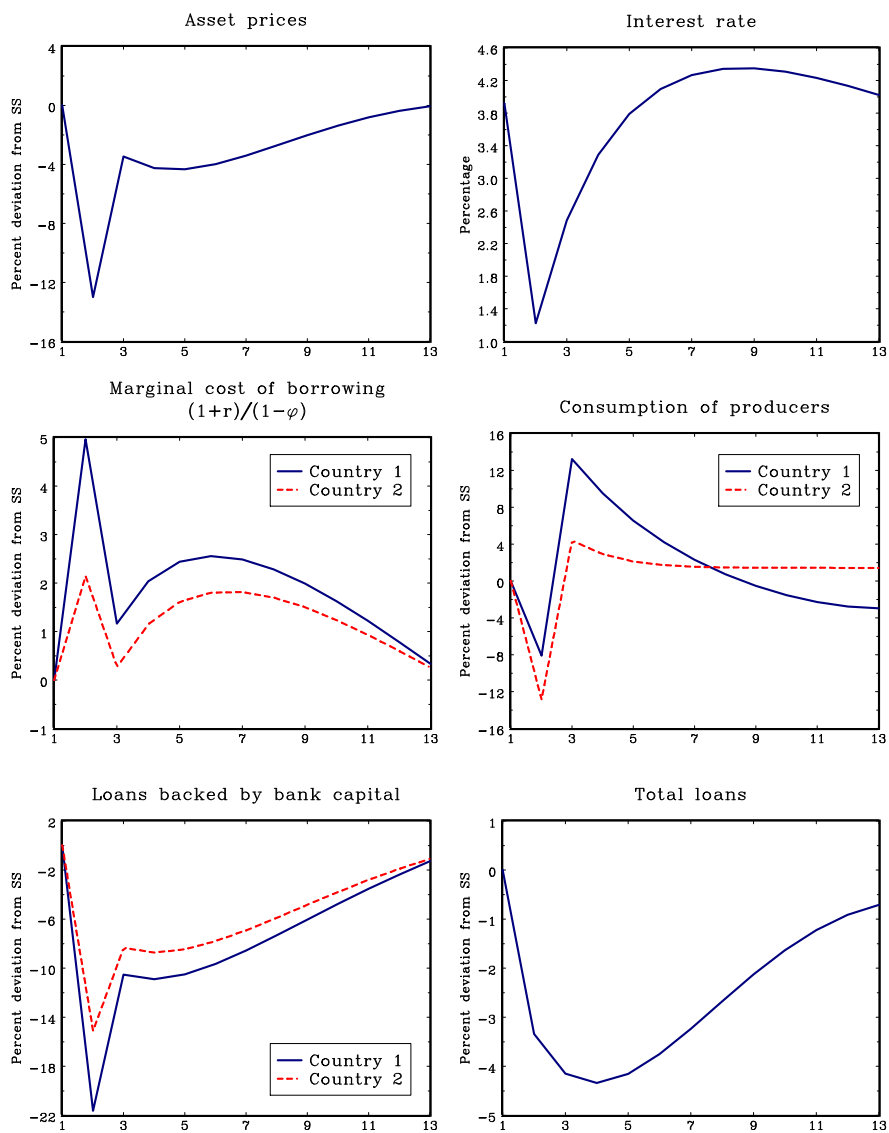


their consumption initially.

Next we consider the asset price response to the same shock but in the regime without mobility of capital. As before, the shock derives from losses made on country 1 loans. In the environment with mobility of capital it does not matter whether the losses come from loans made in country 1 or country 2. With capital mobility, in fact, firms can borrow indistinguishably from domestic and foreign banks. Therefore, what matters is the worldwide lending capacity of the whole banking sector. In the regime without capital mobility, however, whether the losses are in country 1 or 2 matters. Only the country in which the losses are materialized faces the type of consequences shown in Figure 3 by the dashed line. Comparing the economies with and without mobility of capital, we observe that the response of asset prices is much bigger in the autarky regime.

Why is the asset price drop bigger in the autarky regime? The key to the answer is the fact that globalization creates larger financial markets. While in a closed economy borrowing is limited to the funds supplied by

Figure 4: Impulse response of asset prices to an unanticipated shock to bank equities. Economy with mobility of capital.



domestic intermediaries, in a globalized economy producers can also borrow from foreign intermediaries. As a result, in a globalized world the credit contraction and the impact on aggregate prices are spread among all countries that are financially integrated. The effect on country 1 is then smaller.

This finding seems to provide a negative answer to the question of whether globalization made the crisis worse for the United States. More specifically, the simulation exercise suggests that the crisis could have been much worse if the US economy was not financially integrated in the world financial market. However, this is an incomplete thought because it misses the fact (which is consistent with the model) that leverage in the U.S. economy rose sharply because of financial integration. Without financial integration, the economy would have been less leveraged (as shown in the previous section), and hence the aggregate volume of loans would have been smaller. Consequently, it would have been possible that the losses incurred by financial institutions and/or their likelihood were smaller. If we assume that the losses for the banking sector are proportional to the stock of loans, then it is true that the initial losses for banks in country 1 are smaller given the lower leverage. However, the response of asset prices would still be higher than in the regime with capital mobility. We will come back to this point in Section 5.

The results shown in Figures 3 and 4 also provide an answer to the question of whether globalization allowed the crisis to spill over other countries. Here the model provides a clear answer: Although the impact on the originating country is smaller (as discussed above), other countries will be affected by the shock even if the shock originated abroad. Therefore, with globalized markets, country-specific shocks propagate to other economies inducing a worldwide drop in asset prices.

4 Mark-to-market accounting

In this Section we explore how changes in the accounting principle used to value assets in the banks' balance sheet modifies the response of the model to the initial financial shock. In the previous simulations we assumed that the 'equity' of financial intermediaries relevant for the capital requirement was determined by valuing assets at market prices. More specifically, capital was valued at price P_t . Therefore, we assumed a mark-to-market approach.

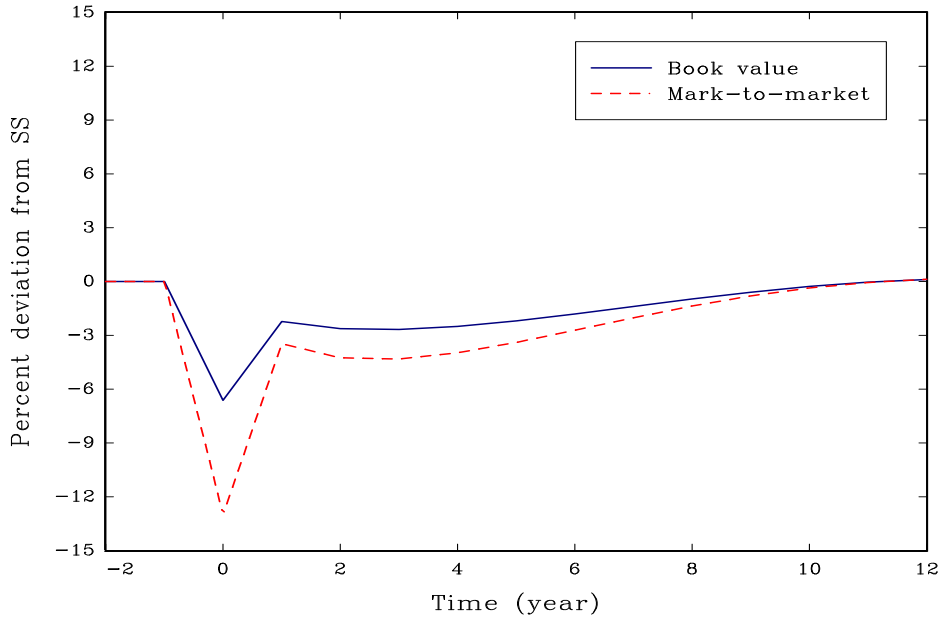
We now consider an alternative scenario in which the banks' assets are valued at historical prices for the purpose of capital requirement, that is, for the application of the constraint $\bar{L}_{t+1} \leq \alpha(e_t - d_t)$. In our context this means

that in order to calculate the value of bank equities, the asset \bar{k}^f continues to be valued at the steady state price \bar{P} even if the market price changes. Using (12), the capital requirement can also be expressed as:

$$\bar{L}_{t+1} \leq \alpha \left(\bar{k}^f \bar{P} + \frac{L_{t+1}}{1 + r_t^i} - \frac{B_{t+1}}{1 + r_t^i} \right)$$

The impulse responses of asset prices under mark-to-market and mark-to-historical-price are shown in Figure 5. The initial drop in the market price of assets is now about 7 percent, which is significantly smaller than the 13 drop generated in the previous case. The changes in all the remaining variables plotted in Figure 4 are also smaller when the capital requirement is assessed using historical prices.

Figure 5: Impulse response of asset prices to an unanticipated shock to bank equities. Economy with mobility of capital under mark-to-market and historical prices.



The intuition for this result is simple. Even if there is a drop in the market price of assets, the ‘book value’ of equities does not fall and this allows financial intermediaries to maintain higher levels of loans without incurring

an additional financial cost. On the other hand, when the bank equities are valued at market prices, a drop in P_t generates a drop in e_t which reduces the banks' ability to make loans subject to capital requirement. If the drop in P_t is small, banks may not be forced to cut lending because they can reduce dividends. If the drop is large, the non-negativity of dividends binds and banks are forced to charge high lending costs.

5 Sensitivity

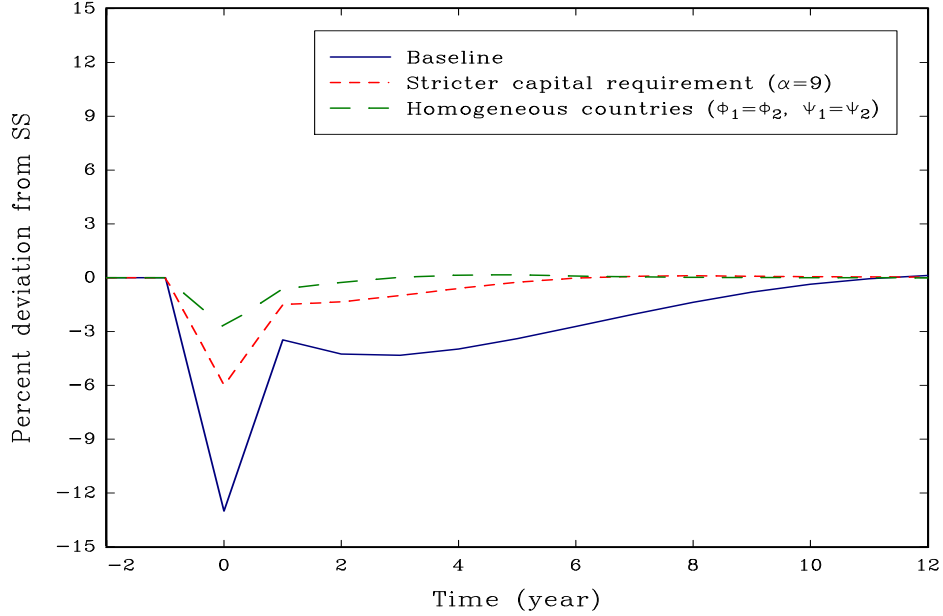
What is the incidence of the capital requirement for banks? In our model this is captured by the parameter α . To show the sensitivity of the results to this parameter, Figure 6 plots the impulse response of asset prices when $\alpha = 9$, which implies a capital requirement of 11.1 percent of equity (compared with $\alpha = 10$, or 10 percent of equity, in the baseline calibration). As can be seen, a lower value of α , that is, a stricter capital requirement for banks, reduces the impact of the shock on asset prices. This is because with a higher capital requirement, the fall in bank equity induces a smaller reduction in the supply of loans that need to be backed by bank capital. Because of this, the marginal cost of borrowing increases less and the impact on prices is lower.

Figure 6 also plots the impulse response when country 2 has the same characteristics of country 1. More specifically, the financial parameters ϕ and ψ of country 2 are set to the same values assigned to country 1 in the baseline calibration. This implies that, financial liberalization does not induce an increase in leverage in neither of the two countries. Therefore, comparing this impulse response to the response for the baseline model allows us to decompose in two factors the importance of capital markets liberalization for country 1 (the US): the ability to access a larger market and the formation of higher leverages.

As can be seen from the figure, the impact of the shock on asset prices is smaller when country 2 is as financially developed as country 1. This is because country 1 is now less leveraged (thus, the initial losses for banks are smaller) and the bank capital in country 2 is larger (since producers in the second country can borrow more). This effect, however, is more than compensated by the fact that country 1 can now access a larger market. Comparing the impulse response with that plotted in Figure 3, we observe that the asset price drop is much bigger in autarky even if the leverage of country 1 does not change in response to capital markets integration.

Another important observation that follows from these results is that

Figure 6: Impulse response of asset prices to an unanticipated shock to bank equities in the economy with mobility of capital. Sensitivity to α and cross-country heterogeneity.



financial globalization in the presence of differences in domestic financial development not only accounts for the surge in debt in country 1, it also implies much larger amplification and global transmission in the response of asset prices to small, unanticipated shocks to banks' capital. Hence, this finding suggests that financial globalization among countries with heterogeneous financial markets has made the crisis worse.

6 Conclusion

Financial integration among countries that differ in domestic financial development produces a significant increase in net credit for the most financially developed country. In this paper we examined the connection between this phenomenon, the effects of shocks to bank equities on asset prices, and the cross-country contagion of financial turbulence.

We proposed a setup in which financial constraints induced by limited

enforcement affect the financial positions of savers, producers and financial intermediaries. The model also captures the mark-to-market rules for financial intermediaries that have been at play in the recent crisis.

Cross-country differences in enforcement create the conditions for financial integration to generate a surge in debt in the most financially developed country. Thus, the model captures the fact that the United States have experienced a large increase in leverage during the last two decades, largely financed by foreign lending. Moreover, the model predicts that relatively small shocks to the equity of one country's financial intermediaries produce large responses in equilibrium asset prices world wide. Thus, the model can explain large asset price declines and global contagion in asset prices.

Replacing the accounting principle of mark-to-market for bank capital valuation based on historical prices reduces the magnitude of the asset price declines induced by shocks to the balance sheet of banks. Hence, our model lends support to the view that the mark-to-market principle should be replaced with a more flexible rule or at least discontinued in times of financial turbulence. Of course, the same outcome can also be reached by keeping the mark-to-market principle but relaxing the constraint on capital requirement. This conclusion should be taken with caution since our model abstracts from frictions that are often used to defend mark-to-market accounting, such as moral hazard problems on the part of bank managers.

A Appendix: Set of feasible contingent claims

Suppose that agents have the ability to divert part of their income. Diversion is observable but not verifiable in a legal sense. If an agent diverts x , he or she retains $(1 - \phi)x$ while the remaining part, ϕx , is lost. We allow ϕ to be greater than 1. This can be interpreted as a fine or additional punishment. A similar assumption is made in Castro, Clementi, & MacDonald (2004) but in an environment with information asymmetry.

Contracts are signed with financial intermediaries in a competitive environment. Financial contracts are not exclusive, meaning that agents can always switch to another intermediary from one period to the other. The set of state-contingent claims that an intermediary is willing to offer must be incentive-compatible.

Let $V_t(w, b)$ be the value function for an agent with current realization of endowment w and non-endowment wealth b . After choosing the contingent claims $b(w_j)$, the next period value is $V_t(w_j, b(w_j))$. In case of diversion, the agent would claim that the realizations of the endowment was the lowest level w_1 and divert the difference $w_j - w_1$. In this process the agent retains $(1 - \phi)(w_j - w_1)$ and receives $b(w_1)$. The non-endowment wealth would be $\tilde{b}(w_j) = b(w_1) - \phi(w_j - w_1)$ and the value of diversion is:

$$V_t\left(w_j, b(w_1) - \phi \cdot (w_j - w_1)\right)$$

Incentive-compatibility requires:

$$V_t\left(w_j, b(w_j)\right) \geq V_t\left(w_j, b(w_1) - \phi \cdot (w_j - w_1)\right)$$

which must hold for all $j = 1, \dots, N$.

It is important to emphasize that the financial intermediary can tell whether the agent is diverting but there is no court that can verify this and force the repayment of the diverted funds. Compared to the standard model with information asymmetries, this assumption is convenient because it simplifies the contracting problem when shocks are persistent. Also convenient is the assumption that financial contracts are not exclusive and agents can switch to other intermediaries without a cost. This further limits the punishments available to the current intermediary. Also notice that, although the new level of wealth after diversion is verifiable when a new contract is

signed, this does not allow the verification of diversion because the additional resources could derive from lower consumption in previous periods, which is not observable and verifiable. Again, the intermediary knows that the additional resources come from diversion but it cannot legally prove it.

The last assumption is limited liability for which agents renegotiate negative values of net worth, and therefore, $w_j + b(w_j) \geq 0$. The agent's problem can be written as:

$$V_t(w, b) = \max_{c, b(w')} \left\{ U(c) + \beta \sum_{w'} V_{t+1}(w', b(w')) g(w, w') \right\}$$

subject to

$$a = c + \sum_{w'} b(w') q(w, w')$$

$$V_t(w_j, b(w_j)) \geq V_t(w_j, b(w_1) - \phi \cdot (w_j - w_1))$$

$$w_j + b(w_j) \geq 0$$

Using standard arguments for recursive problems, we can prove that there is a unique solution and the function $V_t(w, b)$ is strictly increasing and concave in b . The strict monotonicity of the value function implies that the incentive-compatibility constraint can be written as:

$$b(w_j) \geq b(w_1) - \phi \cdot (w_j - w_1)$$

for all $j = 1, \dots, N$. This is the constraint we imposed on the original problem.

B Appendix: Equivalent economy

Let \bar{b}_t be the expected next period value of contingent claims, that is, $\bar{b}_t = \sum_{w_{t+1}} b(w_{t+1}) g(w_t, w_{t+1})$. Then a contingent claim can be rewritten as $b(w_{t+1}) = \bar{b}_t + x(w_{t+1})$ where, by definition, $\sum_{w_{t+1}} x(w_{t+1}) g(w_t, w_{t+1}) = 0$. The variable \bar{b}_t can be interpreted as a non-contingent bond and the variable $x(w_{t+1})$ is the pure insurance component of contingent claims.

Because agents choose as much insurance as possible, the constraint for incentive-compatibility will be satisfied with equality, that is,

$$b(w_1) - b(w_j) = \phi \cdot (w_j - w_1)$$

Using $b(w_{t+1}) = \bar{b}_t + x(w_{t+1})$, the constraint can be rewritten as:

$$x(w_1) - x(w_j) = \phi \cdot (w_j - w_1)$$

which must hold for all $j > 1$. The variables $x(s_j)$ must also satisfy the zero-profit condition, that is,

$$\sum_j x(s_j)g(w_t, w_j) = 0$$

Therefore, we have N conditions and N unknowns. We can then solve for all the N values of x . The solution can be written as:

$$x(w_j) = -\phi \cdot W_j(w_t)$$

where $W_j(w_t)$ is an exogenous variable defined as $W_j(w_t) = w_j - \sum_i g(w_t, w_i)w_i$. Notice that this variable depends on the current shock which affects the probability distribution of next period shock.

Define the following variable:

$$\tilde{w}_j(w_t) = w_j - \phi \cdot W_j(w_t)$$

This is a transformation of the shock. Using this new shock, the budget constraint can be written as:

$$d_t + \tilde{w}_j(w_t) + \bar{b}_{tx} = c_t + \frac{\bar{b}_{t+1}}{1 + r_t}$$

By redefining the endowment to be $\tilde{w}_j(w_t)$, it is as if agents choose non contingent claims \bar{b}_t . Differences in financial deepness are captured by difference in the stochastic properties of the transformed shock. So, for example, if $\phi = 0$, we go back to the original shock because contingent claims are not feasible. If $\phi = 1$ and shocks are iid, the transformed shock becomes a constant. We are in the case of full insurance. Any intermediate values allow only for partial insurance.

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