International recessions*

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Abstract

The 2008-2009 US crisis is characterized by un unprecedent degree of international synchronization as all other G7 countries have experienced large contractions at almost exactly the same time as the US. Another feature of the crisis is the sharp fall in US employment but not in US productivity. These two features—international synchronization and absence of significant productivity fall—are not present in many of the previous US contractions. We develop an explicit model of financial frictions to show that these changes are consistent with the view that 'credit shocks' have played a more prominent role as a source of business cycle fluctuations in an environment with international mobility of capital.

1 Introduction and evidence

This paper is motivated by two observations about the 2008-2009 crisis. The first observation is that the recent recession has been characterized by a high degree of international synchronization as most developed countries have experienced large macroeconomic contractions. The second observation is that, although employment has fallen dramatically, productivity has not contracted. As we will document below, these two features of the recent crisis differentiate the recent recession from many of the previous recessions experienced by the US economy.

1.1 International comovement

Figure 1 plots the US GDP against the GDP of the other G7 countries during the recent recession, up to the second quarter of 2009. The numbers are percent deviations from the level

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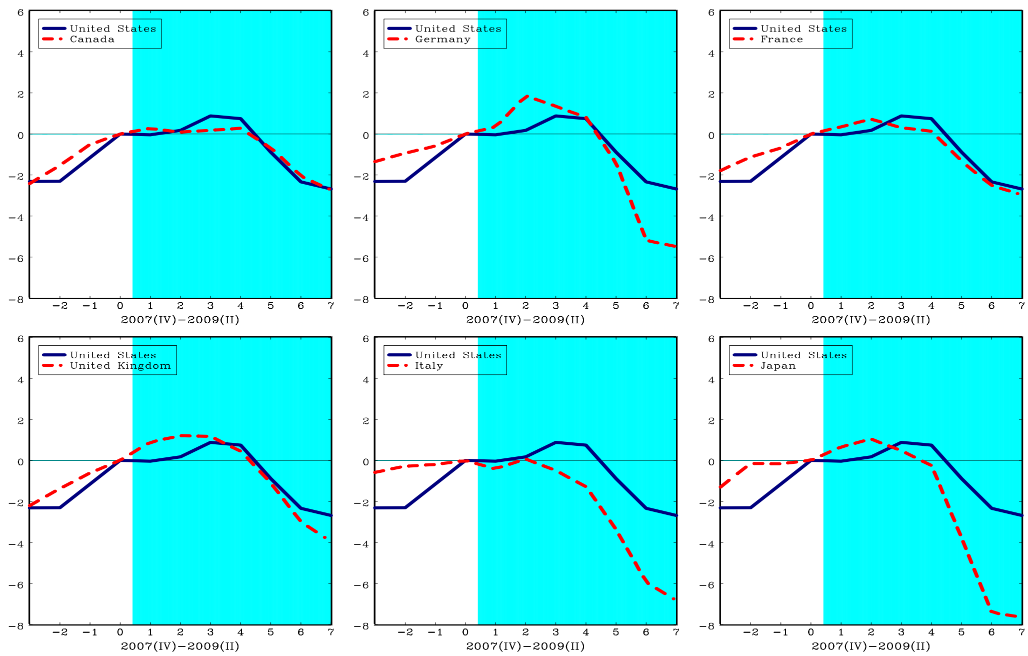
of GDP in the quarter preceding the first recessionary period identified by the NBER Business Cycle Dating Committee (fourth quarter of 2007). Fourth quarters before the official recession are also plotted. The figure reveals the strong co-movement in macroeconomic activity among the G7 countries.

Figure 1: The dynamics of GDP during the 2008 recession: US v/s other G7 countries.



To examine whether the international synchronization of the recent recession differs from previous contractions, Figure 2 plots the GDP dynamics for the G7 countries in six of the most recent US recessionary episodes: one recession experienced in the first half of the 1970s, two in the first half of 1980s, one in the early 1990s and two in the 2000s. A quick glance at the figure shows that the synchronization of the US GDP with other G7 countries has been significantly stronger in the recent recession. While the G7 countries experienced very different GDP dynamics during the previous US recessionary periods, in the most recent contraction the GDP of all countries have moved in the same direction.

The higher cross-country synchronization of most recent recession can also be seen in Figure 3 which plots the average correlation of US GDP with the GDP of each of the other G7 countries. The correlations are computed on rolling windows of 10 and 20 years. The dates in the graph correspond to the end points of the window used to compute the correlation.

Figure 2: The dynamics of GDP during the six most recent recessions in the G7 countries.

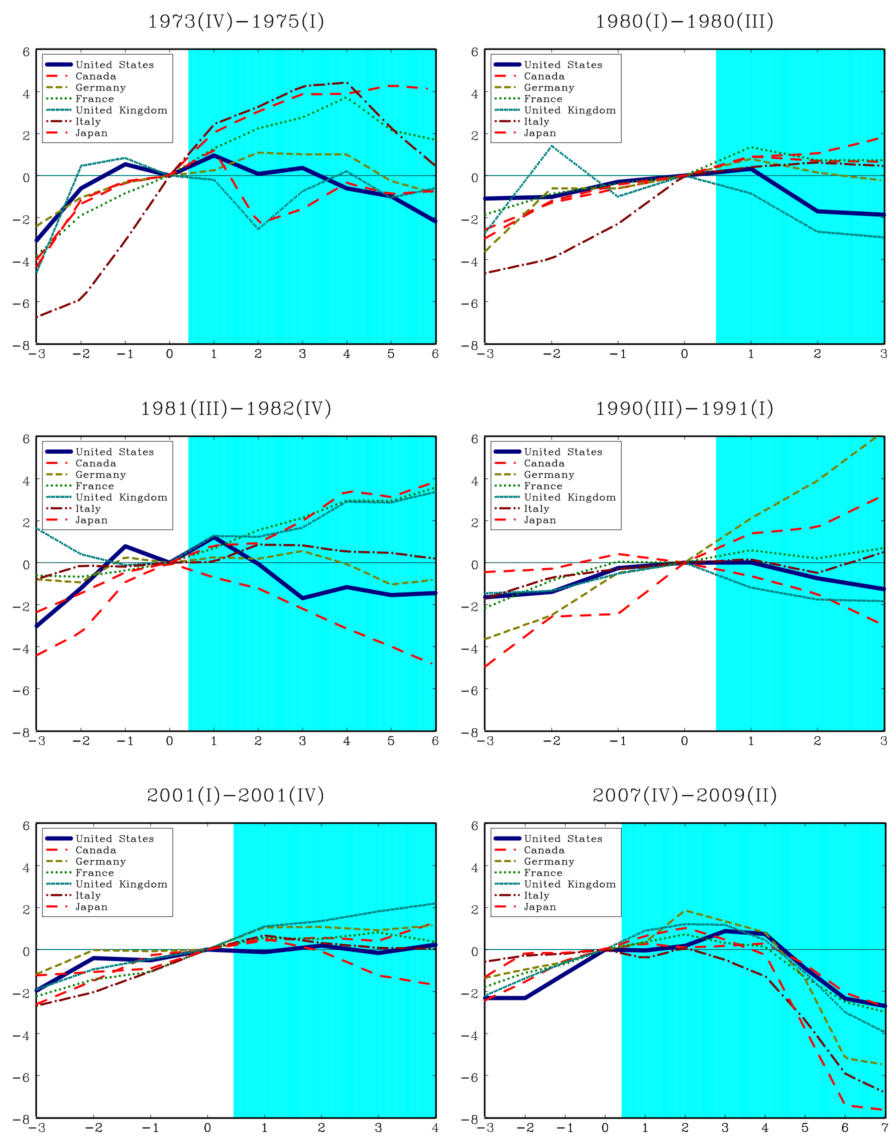
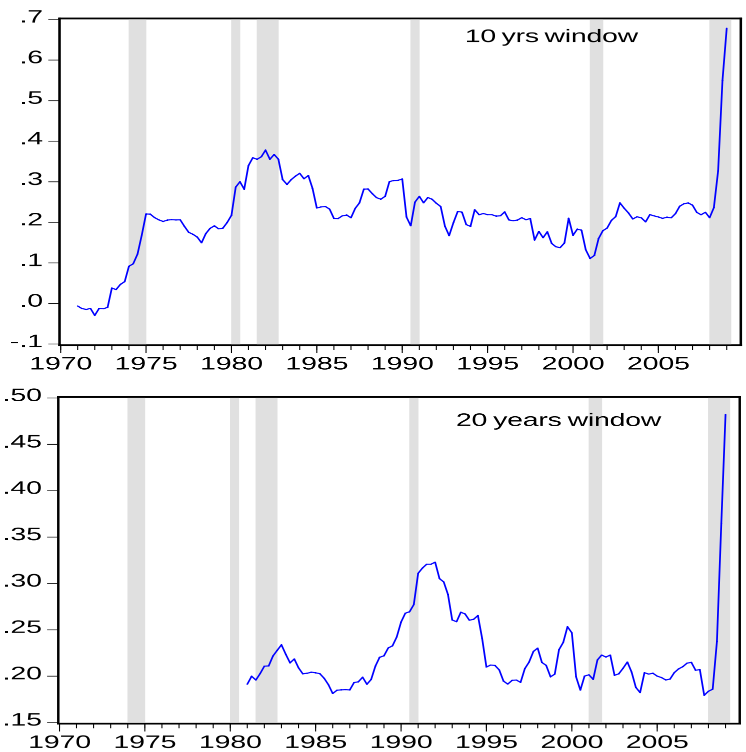


Figure 3: Average rolling correlations of US GDP v/s G7 countries.



Although the figure shows that during previous recessions there is an increase in correlation, the current recession stands out as the one that marks an increase in correlation larger than the increases observed in previous recessions (for a similar point see also Imbs, 2010)

1.2 Productivity and economic activity

Figure 4 plots labor productivity (output per hour) in the nonfarm business sector of the US economy for the six most recent recessions. As shown in the last panel, in the recent recession labor productivity has continued to grow for most of the period. This pattern can also be seen in the 2001 recession. By contrast, in the first four recessions, labor productivity has declined and its level at the end of the recession was not higher than before the recession. Therefore, while earlier recessionary episodes have been associated with significant falls in productivity, there is not much of a productivity slow down in the last two recessions. The differential pattern of productivity between recent and earlier recessions cannot be seen in the dynamics of labor and output. As shown in Figure 5, all recessions experienced by the US economy during the last 40 years are characterized by sizable contractions in working hours and GDP.

The different behavior of productivity and labor during the two most recent recessions reflect a more general pattern for which the correlation between productivity and labor has declined sharply in the US economy. Figure 6 plots rolling correlations of productivity (output per hour in the private nonfarm business sector) and labor (hours worked in the private nonfarm business sector) computed on 20 years windows. The Figure shows a drastic drop in the correlation between productivity and labor starting at the beginning of the 2000s. This pattern is also documented in Gali and Gambetti (2009) for the US economy.

Is the declining correlation between labor productivity and hours also a feature of other countries? Figure 7 plots rolling correlations of output per hour and working hours for each of the G7 countries. Because of comparability issues, these correlations are computed only for the manufacturing sector and at an annual frequency. Although there are some divergences among the G7 countries, the average plotted in the bottom panel clearly shows that the correlation has declined on average for these group of countries.

1.3 Hints from the data and theoretical approach

To summarize, the graphs shown above point out two major changes:

1. Higher international synchronization of the recent recession.
2. Lower correlation between productivity and labor.

Both findings suggest that in more recent periods shocks different from technological disturbances may have played a more prominent role in generating business cycle fluctuations. In particular, the observation that labor productivity is negatively correlated with working hours casts doubts on the relevance of productivity shocks as the major source of macroeconomic contraction. This is especially true in the most recent recession.

The higher cross-country synchronization also casts doubts on the relevance of technology shocks. Even if countries were financially integrated, the standard international RBC model predicts that country-specific technology shocks generate divergent macroeconomic responses unless the productivity shocks are internationally correlated. See, for example, Heathcote and Perri (2004). However, if productivity shocks that are internationally correlated were the

Figure 4: Productivity of labor (output per hour) in the private nonfarm sector.

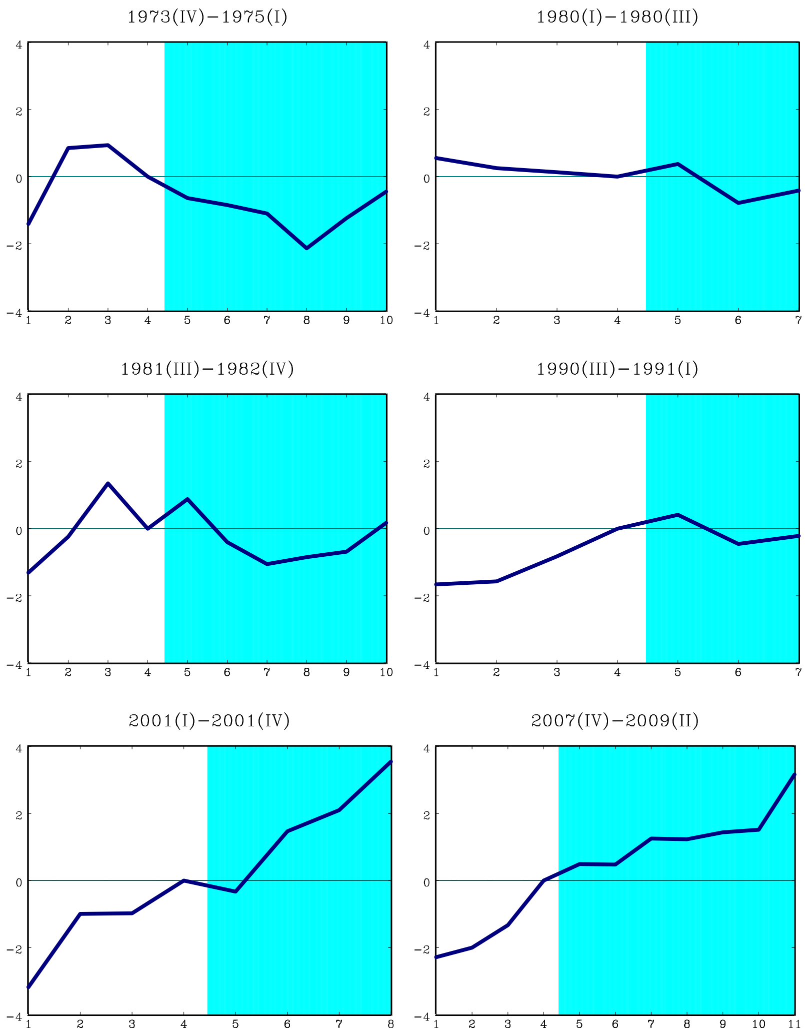


Figure 5: Hours and GDP in the private nonfarm sector.

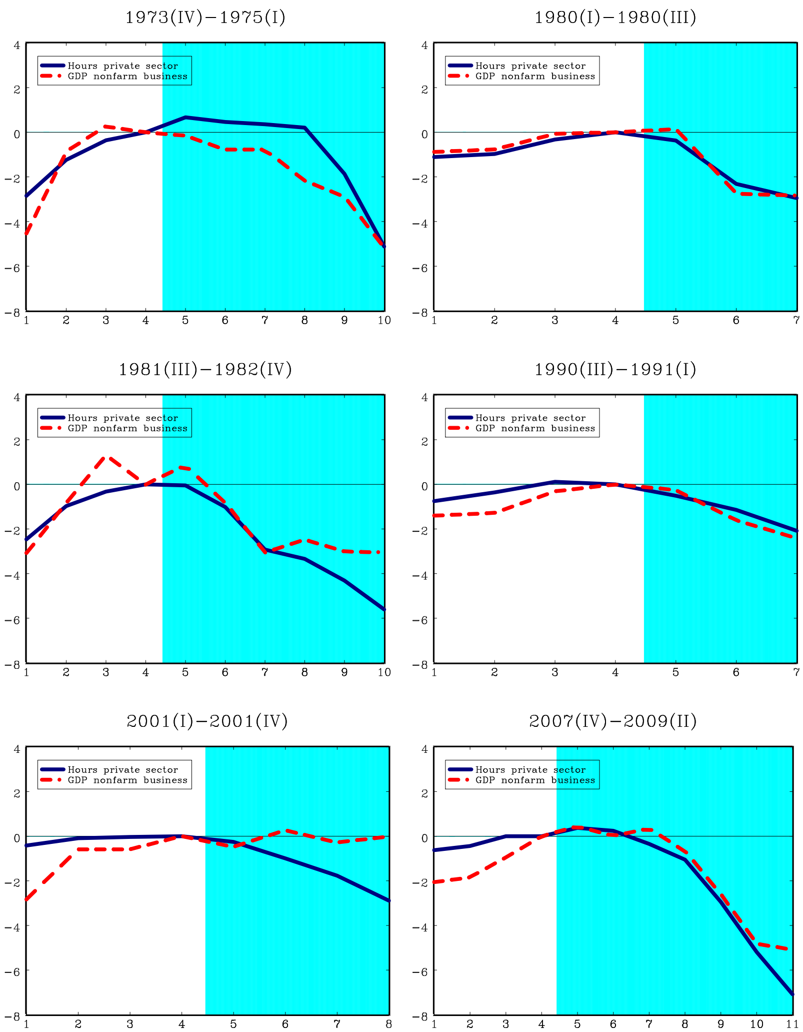
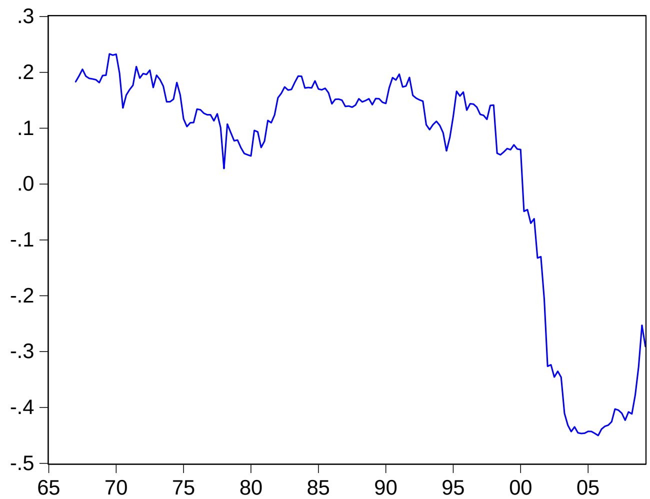


Figure 6: Rolling correlations of productivity growth and hours growth in the US.

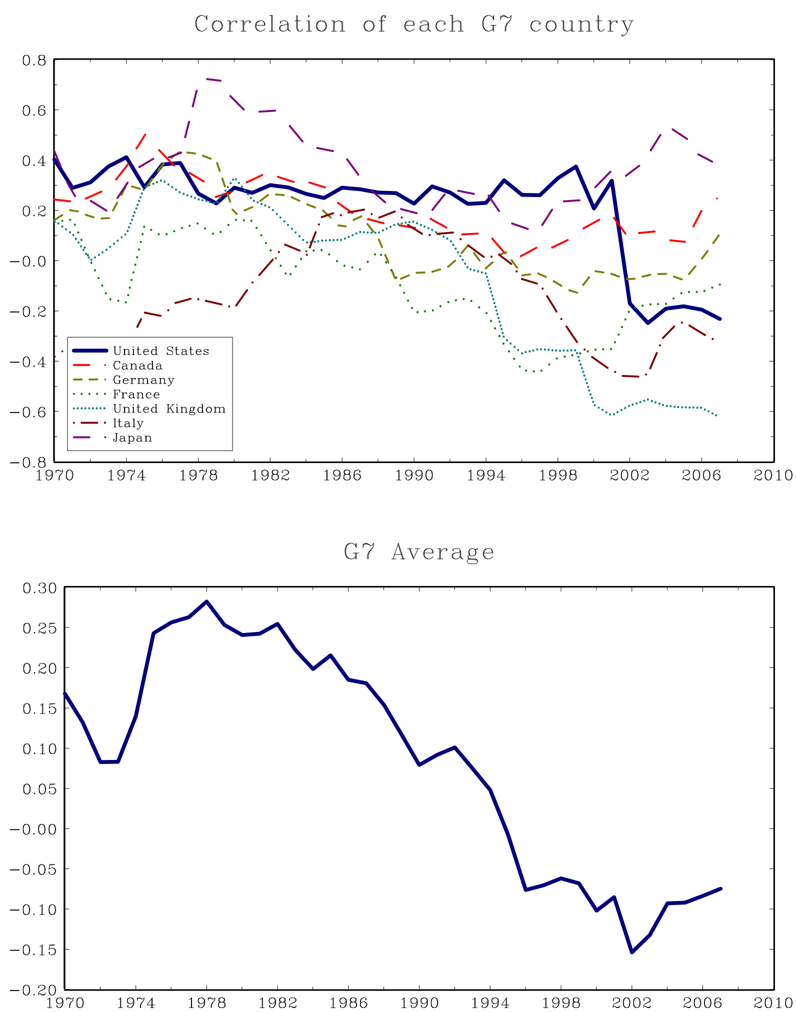


main source of business cycle fluctuations, we should observe a higher correlation between productivity and labor. It is then difficult to reconcile the hypothesis of productivity driven recessions with the fact that productivity kept growing during the most recent contractions.

If we accept the view that productivity shocks cannot be the major force underlying the recent crisis, what other shocks can account for the two facts outlined above? In this paper we show that 'credit shocks' are a plausible candidate for reconciling the two facts. In particular, we show that credit shocks can generate greater international synchronization and lower correlation between productivity and labor in an environment with international mobility of capital. The empirical relevance of credit shocks has also been explored in Jermann and Quadrini (2009) but in closed economies. In this paper we show that these shocks are also important for understanding the macroeconomic dynamics of economies that are financially globalized as these shocks can generate significant cross-country comovements in macroeconomic variables and asset prices.

We consider a model in which firms have an incentive to borrow but the debt is constrained by credit frictions resulting from the limited enforcement of debt contracts. The ability to borrow is subject to random disturbances referred to as 'credit shocks'. Good (credit) times are periods in which borrowers have lower incentives to default and, as a result, lenders are willing to provide more credit. In bad (credit) times the incentive to default is higher and lenders cut on lending. Following a credit cut, borrowers are forced to restructure their financial position

Figure 7: Rolling correlations on a 20 years window of productivity growth with hours growth in the manufacturing sector. Annual data for the G7 countries.



by increasing equity. Because raising equity is costly, that is, the equity holders ask for a higher return, the financial cost for the firm increases. Since the financial cost contributes is part of the cost of hiring workers and acquiring investments, the demands for labor and investment decline.

In this environment a credit contraction in one country spills over other countries even if foreign borrowers do not face any credit contraction. To better illustrate the mechanism, consider a world composed of two countries: country A and country B. A credit contraction in country A requires a substitution between debt and equity for firms operating in this country. In a closed economy, the increase in equity must be provided by investors of country A. At the same time, the market for loans clears locally without any spillover to country B. Thus, when economies are not financially integrated, a credit contraction in country A does not affect country B.

Let's now consider the case in which the two countries are financially integrated. In this case firms located in country A can raise equity not only from investors in country A but also from investors in country B. Having access to a larger pool of suppliers, the cost of raising funds increases less, and therefore, the macroeconomic impact on country A will be smaller. Essentially, the supply of funds to the producers of one country becomes more elastic. Although the increase in the cost of equity in country A is smaller, the financing cost increases also for firms located in country B since now there is a single worldwide market (law of one price). Through the higher worldwide cost of financing, the credit contraction in country A affects also country B.

The above description clarifies why a credit shock to country A spills to country B, generating a recession in both countries. What happens to the productivity of labor? Because TFP does not change and the share of labor in production is smaller than one, a reduction in employment increases the productivity of labor. Thus, the model can generate a negative correlation between productivity and hours.

2 The model without capital accumulation

It will be convenient to present first a simple version of the model without capital accumulation. This allows us to derive some results analytically providing simple intuitions for the quantitative results we will derive with the more general model in Section 4.

The basic structure of the economy has some similarities with the model studied in Kiyotaki and Moore (1997) in the sense that there are two sectors populated by agents with different discount factors and different investment opportunities. In the first sector there is a continuum of risk-averse investors who discount the future at rate β. Investors are the shareholders of firms. In the second sector there is a continuum of risk-averse workers with discount factor $\delta > \beta$. The different discounting between the owners of firms (investors) and workers implies that firms borrow from workers subject to the enforcement constraints we will describe below. This result also requires that the market for the ownership of firms is segmented, that is, only investors have access to this market while workers can only save in the form of bonds.

Differently from Kiyotaki and Moore (1997), both agents are risk-averse. An important implication of this assumption is that the effective discount rates for investors and workers are not constant in equilibrium but fluctuate in response to aggregate shocks. As we will see, fluctuations in the effective discount rates play a central role in the analysis of this paper.

To facilitate the presentation, we first describe the closed-economy version of the model. Once we have characterized the key properties of the economy in autarky, it will be trivial to extend it to the environment with international mobility of capital.

2.1 Investors and firms

There is a continuum of investors with lifetime utility $E_0 \sum_{t=0}^{\infty} \beta^t u(c_t)$. They are the owners of firms and derive income only from dividends. Therefore, $c_t = d_t$. Denote by $m_{t+1} = \beta u_c(d_{t+1})/u_c(d_t)$ the effective discount factor for investors. This is also the discount factor used by firms since they maximize shareholders' wealth.

Firms operate the production function $F(z_t, h_t) = z_t h_t^{\nu}$, where h_t is the input of labor and z_t is a stochastic variable affecting the productivity of all firms (aggregate productivity). The parameter ν is smaller than 1 implying decreasing returns to scale.

Firms start the period with debt b_t. Before producing they choose the labor input h_t, the dividends d_t, and the next period debt b_{t+1}. The budget constraint is:

$$b_t + w_t h_t + d_t = F(z_t, h_t) + \frac{b_{t+1}}{R_t}$$

where R_t is the gross interest rate.

The payments of wages, $w_t h_t$, dividends, d_t, and current debt net of the new issue, $b_t - b_{t+1}/R_t$, need to be made before the realization of revenues. This implies that the firm faces a cash flow mismatch during the period. The cash needed at the beginning of the period is

$w_t h_t + d_t + b_t - b_{t+1}/R_t$. Using the budget constraint this is equal to the cash revenue $F(z_t, h_t)$, which is realized at the end of the period. To cover the cash flow mismatch, the firm contracts the intra-period loan $l_t = w_t h_t + d_t + b_t - b_{t+1}/R_t$, which is then repaid at the end of the period, after the realization of revenues.[1]

Debt contracts are not perfectly enforceable. After raising cash with the intra-period loan, the firm can distribute the cash and default (that is, the firm can distribute l_t which is bigger than the planned dividend d_t). In case of default, the lender can sell the firm and use the net revenue from the sale to partially recover the debt. However, there is some loss of value in selling the firm. In particular, we make the following assumptions: (i) The sale of the firm involves a cost ξ_t; (ii) Only a fraction $\phi < 1$ of the equity value of the firm is recovered through the sale.

Let $V_t(b_t)$ be the value of the firm's equity at the beginning of the period. This is defined as the discounted value of dividends, that is,

$$V_t(b_t) \equiv d_t + E_t \sum_{j=1}^{\infty} \left(\prod_{s=1}^{j} m_{t+s} \right) d_{t+j} = d_t + \overline{V}_t(b_{t+1})$$

Because default arises after choosing b_{t+1}, the liquidation value of the firm's equities is $\phi \overline{V}_t(b_{t+1}) - \xi_t$, which is smaller than the continuation value $\overline{V}_t(b_{t+1})$. Therefore, it is in the interest of the lender to renegotiate the loan.

The renegotiation outcome is determined as follows. The net surplus from renegotiating is $(1-\phi)\overline{V}_t(b_{t+1}) + \xi_t$. Without loss of generality (see Appendix A) we assume that the firm has all the bargaining power, and therefore, the value retained in the renegotiation stage is the whole surplus $(1-\phi)\overline{V}_t(b_{t+1}) + \xi_t$. Thus, the total value from defaulting is $l_t + (1-\phi)\overline{V}_t(b_{t+1}) + \xi_t$, that is, the cash raised with the intra-period loan and distributed before defaulting, plus the renegotiation value.

Enforcement requires that the market value of the firm $\overline{V}_t(b_{t+1})$ is at least as big as the value of defaulting, that is,

$$\overline{V}_t(b_{t+1}) \geq l_t + (1-\phi)\overline{V}_t(b_{t+1}) + \xi_t.$$

[1] The assumption that the dividends are paid at the beginning of the period, as opposed to the end of the period, is not crucial for the results but it simplifies the analytical expressions.

Rearranging terms, the enforcement constraint can be rewritten as:

$$\phi \cdot \overline{V}_t(b_{t+1}) \geq l_t + \xi_t.$$

Appendix A provides the detailed description of the renegotiation process leading to this condition and the generalization to the case in which the bargaining power is split between the firm and the lender.

The modeling of the renegotiation process follows Jermann and Quadrini (2009). The only difference is that here the shock ξ_t enters the enforcement constraint additively while Jermann and Quadrini assume that ξ_t multiplies the value of equity $\overline{V}_t(b_{t+1})$. Although this does not change the basic properties of the model, we have chosen the additive formulation because it allows us to derive some of the properties analytically.[2]

To better illustrate the role played by the stochastic liquidation cost ξ_t, we can substitute $\overline{V}(b_{t+1}) = V_t(b_t) - d_t$ and $l_t = w_t h_t + d_t + b_t - b_{t+1}/R_t = F(z_t, h_t)$ in the enforcement constraint to get:

$$\phi V_t(b_t) \geq \phi d_t + F(z_t, h_t) + \xi_t.$$

Consider a pre-shock equilibrium in which the enforcement constraint is binding. An increase in the liquidation cost of the firm ξ_t leads to a tighter constraint. This requires either a reduction in dividends and/or in the input of labor. Because the shock affects the ability to borrow, we will refer to it as 'credit shock'. It can also be interpreted as an asset price shock because it affects the net value of selling the firm, $\phi\overline{V}_t(b_{t+1}) - \xi_t$.[3]

[2] It is important to point out that the concavity of the revenue function is essential for maintaining an atomistic structure of production. Because the term ξ_t does not depend on the production scale, there are increasing returns in financing. Thus, the firm could increase the leverage by choosing a larger production scale. Decreasing returns in production, however, prevents the firm from becoming too big.

[3] We can also think of ξ_t as a liquidity shock along the lines of Kiyotaki and Moore (2008).

Firm's problem: The optimization problem of the firm can be written recursively as follows:

$$V(\mathbf{s};b) \quad = \quad \max_{d,h,b'}\left\{d + Em'V(\mathbf{s}';b')\right\} \tag{1}$$

subject to:

$$b + d = F(z,h) - wh + \frac{b'}{R} \tag{2}$$

$$\phi Em'V(\mathbf{s}';b') \geq F(z,h) + \xi \tag{3}$$

where $\mathbf{s}$ are the aggregate states, including the shocks z and ξ, and the prime denotes the next period variable.

In solving this problem the firm takes as given all prices and the first order conditions are:

$$F_l(z,h) = \frac{w}{1-\mu} \tag{4}$$

$$(1 + \phi\mu)REm' = 1, \tag{5}$$

where μ is the lagrange multiplier for the enforcement constraint. These conditions are derived under the assumption that dividends are always positive, which usually holds in the neighborhood of the steady state. The detailed derivation is in Appendix B.

We can see from condition (4) that limited enforcement imposes a wedge in the demand for labor. This wedge is strictly increasing in μ and disappears when $\mu = 0$, that is, when the enforcement constraint is not binding.

Some (partial equilibrium) properties The characterization of the firm's problem in partial equilibrium provides helpful insights about the property of the model once extended to a general equilibrium set-up. For partial equilibrium we mean the equilibrium in which the interest rate and wage rate are both exogenously given and constant.

Under these conditions, equation (5) shows that μ decreases with the expected discount factor, Em'. An increase in ξ, that is, a negative credit shock, makes the enforcement constraint tighter. Because firms reduce the payment of dividends, the investors's consumption has to decrease. This induces a decline in the discount factor $m' = \beta u_c(d')/u_c(d)$ and an increase in the multiplier μ (condition (5)). Condition (4) then shows that the demand for labor declines.

Intuitively, when the credit conditions become tighter, firms need to rely more on equity financing and less on debt. However, it is costly to increase equity in the short run since investors demand a higher return. Because the firm does not find optimal to raise enough equity to sustain the same production scale (at least in the short-run) it has to cut employment. Notice that, if investors were risk-neutral, the discount factor would be equal to $Em' = \beta$ and the credit shock would not affect employment, as long as the interest rate does not change (which is the case in the partial equilibrium considered here).

In the general equilibrium, of course, prices would also change. In particular, changes in the demand of credit and labor will affect the interest rate R and the wage rate w. To derive the aggregate effects we need to close the model and characterize the general equilibrium.

2.2 Closing the model and general equilibrium

There is a representative worker with lifetime utility $E_0 \sum_{t=0}^{\infty} \delta^t U(c_t, h_t)$, where c_t is consumption, h_t is labor and δ is the intertemporal discount factor. Workers have a higher discount factor than entrepreneurs, that is, $\delta > \beta$. This is the key condition for the enforcement constraint to bind. Workers hold bonds issued by firms but they cannot buy shares of firms (market segmentation). The budget constraint is:

$$w_t h_t + b_t = c_t + \frac{b_{t+1}}{R_t}$$

and the first order conditions for labor, h_t, and next period bonds, b_{t+1}, are:

$$U_h(c_t, h_t) + w_t U_c(c_t, h_t) = 0, \tag{6}$$

$$\delta R_t E_t \left\{ \frac{U_c(c_{t+1}, h_{t+1})}{U_c(c_t, h_t)} \right\} = 1. \tag{7}$$

These are standard optimizing conditions for the typical consumer's problem. The first condition defines the supply of labor as an increasing function of the wage rate. The second condition defines the interest rate on bonds.

General equilibrium: We can now define a competitive equilibrium. The sufficient set of aggregate states, $\mathbf{s}$, are given by the productivity shock, z, the credit shock, ξ, and the aggregate stock of bonds, B.

Definition 2.1 (Recursive equilibrium) *A recursive competitive equilibrium is defined by a set of functions for (i) workers' policies $h(\mathbf{s})$, $c(\mathbf{s})$, $b(\mathbf{s})$; (ii) firms' policies $h(\mathbf{s}; b)$, $d(\mathbf{s}; b)$ and $b(\mathbf{s}; b)$; (iii) firms' value $V(\mathbf{s}; b)$; (iv) aggregate prices $w(\mathbf{s})$, $R(\mathbf{s})$ and $m(\mathbf{s}')$; (v) law of motion for the aggregate states $\mathbf{s}' = \Psi(\mathbf{s})$. Such that: (i) household's policies satisfy the optimality conditions (6)-(7); (ii) firms' policies are optimal and $V(\mathbf{s}; b)$ satisfies the Bellman's equation (1); (iii) the wage and the interest rate are the equilibrium clearing prices in the markets for labor and bonds, and the discount factor for firms is $m(\mathbf{s}') = \beta u_c(d_{t+1})/u_c(d_t)$; (iv) the law of motion $\Psi(\mathbf{s})$ is consistent with the aggregation of individual decisions and the stochastic processes for z and ξ.*

2.3 Characterization of the equilibrium

To illustrate the main properties of the model, we look at some special cases in which the equilibrium can be characterized analytically. Consider first the economy without shocks. We can show that in a steady state the no-default constraint binds.

To see this, consider the first order condition for the bond, equation (7), which in a steady state becomes $\delta R = 1$. Using this condition to eliminate R in (5) and taking into account that in a steady state $Em' = \beta$, we get $1 + \phi\mu = \delta/\beta$. Because $\delta > \beta$ by assumption, the lagrange multiplier μ is greater than zero, implying that the enforcement constraint is binding. Firms want to borrow as much as possible because the cost of borrowing—the interest rate—is smaller than their discount rate.

In a model with uncertainty, however, the constraint may not be always binding. For this to be the case, we further need to impose that β is sufficiently smaller than δ, so that the interest rate is always smaller than the discount rate of entrepreneurs.

Let's consider now the case with shocks and the utility function for workers takes the special form $U(c_t, h_t) = (c_t - \alpha h_t^\gamma)^{1-\sigma}/(1-\sigma)$. This particular specification eliminates wealth effects on leisure so that the supply of labor depends only on the wage rate, that is, $h_t = (\alpha\gamma/w_t)^{\frac{1}{1-\gamma}}$. If the firms cannot divert the intra-period loan $l_t = F(z_t, h_t)$, the enforcement constraint becomes $\phi V_t(b_{t+1}) \geq \xi_t$ and credit shocks do not affect labor and production. This is stated formally in the next proposition.

Proposition 2.1 *Suppose that there are not wealth effects on the supply of labor. If the firm cannot diverted cash, changes in ξ have no effects on employment and output.*

If firms cannot divert cash, the demand for labor defined by condition (4) becomes $F_h(z,h) = w$, and therefore, it depends only on the wage rate. Changes in ξ affect the interest rate and the allocation of consumption between workers and investors but, without wealth effects on the supply of labor, they do not affect employment and output.

This result no longer holds when cash can be diverted. In this case the demand for labor depends on the tightness of the enforcement constraint. An increase in ξ tightens the enforcement constraint restricting the amount of borrowing. The change in dividends affects Em' and the change in the demand for credit impacts on the interest rate. Using condition (5) we can see that the multiplier μ changes which in turn affects the demand for labor (see condition (4)), changing employment and output.

For a more general specification of workers' preferences, the credit shock is not completely neutral because the change in workers' consumption induces an income effect on the supply of labor. From a quantitative point of view, however, the income effects are in general small. We will study the general equilibrium effects later in the quantitatively section of the paper.

3 Capital mobility

After characterizing the properties of the simple version of the model without mobility of capital, we are now ready to extend it to the environment with mobility.

Let's assume that there are two countries with the same size, preferences and technology as described in the previous section. Although we consider the case with only two symmetric countries, the model can be easily extended to any number of countries and with different degrees of heterogeneity. The shocks z and ξ are country-specific and they follow a joint Markov process. Therefore, each country may experience different realizations of productivity and credit shocks.

In an integrated capital market, investors can hold shares of domestic and foreign firms. Because firms are subject to country specific shocks, investors would gain from diversifying the cross-country ownership. Therefore, in a financially integrated economy, investors own the worldwide portfolio of shares and we have a representative 'worldwide' investor. This also implies that firms in different countries use the same discount factor $m_{t+1} = \beta u_c(\bar{d}_{t+1})/u_c(\bar{d}_t)$

where $\bar{d}_t$ denotes worldwide dividends.[4]

We keep the assumption that financial markets are segmented and households/workers have access only to the bond market. With capital mobility, however, they can also engage in international borrowing and lending. Whether the international borrowing and/or lending is done by workers or firms is irrelevant. For expositional simplicity we assume that international borrowing and lending is done by households/workers. But this is without loss of generality and the equilibrium allocation in the real sector of the economy will be the same if firms were allowed to borrow directly in international markets. We can also think that the intermediation of funds between households and firms in domestic and foreign markets is done by risk neutral and competitive financial intermediaries.

With international borrowing and lending, the stock of bonds held by workers of one country is not stationary. Although this is not an issue from a theoretical point of view, it creates some problem when the model is solved numerically. To make it stationary we assume that there is a cost of lending abroad which is proportional to the aggregate net foreign asset position of the domestic country. Denoting by N_t the net bond position of the country, the cost per unit of foreign holding is ψN_t. In the quantitative section of the paper we will set this parameter to a very small number so that the approximated model is stationary but the real macroeconomic variables will be affected only marginally by this cost.

Denote by n_t the foreign financial position of an individual household and b_t the domestic holding. The household's budget constraint is:

$$w_t h_t + b_t + n_t(1 - \psi N_t) = c_t + \frac{b_{t+1}}{R_t} + \frac{n_{t+1}}{\widetilde{R}_t}$$

where $\widetilde{R}_t$ is the foreign interest rate.

Compared to the closed economy, workers have an additional choice variable, that is, the foreign lending n_t (or borrowing if negative). Therefore, in addition to the first order conditions (6) and (7), we also have the optimality condition for the choice of foreign bonds:

$$\delta \widetilde{R}_t \Big(1 - \psi N_{t+1}\Big) E_t \left\{ \frac{U_c(c_{t+1}, h_{t+1})}{U_c(c_t, h_t)} \right\} \quad = \quad 1 \tag{8}$$

[4]Notice that this follows from the assumption that investors' utility depends only on consumption. If investors were also deriving utility from leisure, a perfect diversification of portfolio would not be necessarily optimal.

Combining (7) with (8) we get

$$R_t = \widetilde{R}_t(1 - \psi \cdot N_t),$$

which implies that the interest rate is always lower in the country with a positive foreign asset position. Of course, when the parameter ψ is set to a very small number, the interest rate differential is very small.

We can now define the equilibrium for the open-economy version of the economy. The aggregate states, denoted by $\mathbf{s}$, are given by the exogenous variables z, ξ, $\tilde{z}$, $\tilde{\xi}$, the bond issued by the firms of both countries, B and $\widetilde{B}$, and the foreign bond position of the domestic country N (or alternatively of the foreign country $\widetilde{N} = -N$). The foreign position is the net lending (if positive) or borrowing (if negative) of workers in country 1 to workers in country 2.

Definition 3.1 (Recursive equilibrium) *A recursive competitive equilibrium is defined by a set of functions for: (i) households' policies $h(\mathbf{s})$, $c(\mathbf{s})$, $b(\mathbf{s})$, $n(\mathbf{s})$, $\tilde{h}(\mathbf{s})$, $\tilde{c}(\mathbf{s})$, $\tilde{b}(\mathbf{s})$, $\tilde{n}(\mathbf{s})$; (ii) firms' policies $h(\mathbf{s}; b)$, $d(\mathbf{s}; b)$, $b(\mathbf{s}; b)$, $\tilde{h}(\mathbf{s}; b)$, $\tilde{d}(\mathbf{s}; b)$, $\tilde{b}(\mathbf{s}; b)$; (iii) firms' values $V(\mathbf{s}; b)$ and $\widetilde{V}(\mathbf{s}; b)$; (iv) aggregate prices $w(\mathbf{s})$, $\tilde{w}(\mathbf{s})$, $R(\mathbf{s})$, $\widetilde{R}(\mathbf{s})$, $m(\mathbf{s}, \mathbf{s}')$; (v) aggregates of domestic and foreign bonds held by workers, N, B^w, $\widetilde{N}$, $\widetilde{B}^w$, and firms, B^f, $\widetilde{B}^f$; (vi) law of motion for the aggregate states $\mathbf{s}' = \Psi(\mathbf{s})$. Such that: (i) household's policies satisfy the optimality conditions (6)-(8); (ii) firms' policies are optimal and satisfy the Bellman's equation (1) for both countries; (iii) the wages clear the labor markets; the interest rates clear the bond markets; the discount rate used by firms satisfies $m(\mathbf{s}, \mathbf{s}') = \beta u_c(\bar{d}_{t+1})/u_c(\bar{d}_t)$; (iv) the law of motion $\Psi(\mathbf{s})$ is consistent with the aggregation of individual decisions and the stochastic process for z, ξ, $\tilde{z}$, $\tilde{\xi}$.*

The only difference with respect to the equilibrium in the closed economy is that there is the additional market for foreign bonds and the discount factor for firms is given by the worldwide representative investor. The clearing condition is $N + \widetilde{N} = 0$. This is in addition to the clearing conditions for the domestic markets, that is, $B^w = B^f$ and $\widetilde{B}^w = \widetilde{B}^f$.

We are now ready to differentiate the response of the economy to credit shocks in the regime with and without capital mobility.

Proposition 3.1 *Consider a credit shock only to country 1 (change in ξ_t). In the autarky regime only the employment of country 1 changes. In the regime with capital mobility and $\psi = 0$, the employment in country 2 follows the same dynamics of country 1.*

When capital is mobile, a credit shock that hits only country 1 affects the employment of all countries by the same magnitude. This can be easily seen from the first order conditions of firms, equations (4) and (5). Because investors are globally diversified, domestic and foreign firms use the same discount factor. Furthermore, when $\psi = 0$ the interest rate is equalized worldwide. We can then see from equation (5) that the change in μ must be the same for all firms. Thus, the change in the demand for labor will be the same in both countries independently of whether the credit contraction is only for firms in country 1 or for firms in country 2.

To complete the proof we have to show that the change in wages is the same across countries. Since households face the world financial markets, whether the decline in the demand of credit comes from firms in country 1 or firms in country 2 does not matter. They will lead to the same change in the interest rate. Thus, the change in wealth would be the same for domestic and foreign households. This implies that the change in the supply of labor is the same in the two countries with the same effect on wages. Therefore, with capital mobility there is a strong cross-country co-movement in employment and output. We will see in the next section that the co-movement induced by credit shocks also applies to investment once we extend the model with capital accumulation.

Before turning to capital accumulation, there is another feature of the model that should be emphasized. As we have seen, the credit shock of one country spills over other countries if countries are financially integrated. However, the impact on the originating country is smaller when capital markets are integrated.

To see this, consider the channel through which a credit shock affects employment. After a credit contraction the firm is forced to pay less dividends and this decreases the discount factor $m' = \beta u_c(d')/u_c(d)$. From condition (5) we can see that this increases μ which in turn decreases the demand for labor (see condition (4)). The bigger the reduction in dividends, relatively to investors' consumption, the bigger the impact on the discount factor, and therefore, on the demand of labor. In an economy that is financially integrated, the change in dividends induced by the credit contraction in one country leads to a lower reduction in the consumption of investors since they are diversified. As a result, the decrease in the discount factor is smaller and the impact on the demand of labor is smaller. This can be proved analytically for the limiting case of a small open economy.

Proposition 3.2 *Consider a credit shock only to country 1. If country 1 is a small open economy and $\psi = 0$, the credit shock has not effect on employment.*

In the case of a small open economy, investors are perfectly diversified internationally and the reduction in the dividends paid in country 1 is negligible relatively to investors' consumption. Therefore, the discount factor does not change, which implies that the demand for labor in country 1 and elsewhere remains unchanged. At the same time, the reduction in the demand for debt is also negligible relative to the size of the international market. Thus, the interest rate does not change. This implies that there are not wealth effect on the supply of labor leaving the wage rate unaltered.

4 General model with capital accumulation

The production function takes the form $y_t = z_t(k_t^\theta h_t^{1-\theta})^\nu = F(z_t, k_t, h_t)$, where k_t is the input of capital and h_t is the input of labor.

Given i_t the flow of investment, the stock of capital evolves according to:

$$k_{t+1} = (1-\tau)k_t + \Upsilon(k_t, i_t) \tag{9}$$

where τ is the depreciation rate and the function $\Upsilon(.,.)$ is strictly increasing and concave in both arguments, capturing adjustment costs in investment. The reason to assume investment adjustment costs is to prevent excessive volatility of investment when the economy is open. This is a common practice in models with international mobility of capital since, in absence of these costs, capital would be reallocated across countries in response to productivity changes, generating an excessive volatility of investment.

With capital accumulation the budget constraint of the firm becomes:

$$b_t + d_t + i_t = F(z_t, k_t, h_t) - w_t h_t + \frac{b_{t+1}}{R_t}, \tag{10}$$

and the enforcement constraint:

$$\overline{V}_t(k_{t+1}, b_{t+1}) \geq \phi \cdot F(z_t, k_t, h_t) + \xi_t, \tag{11}$$

Notice that the value function now depends also on capital. The optimization problem solved by the firm is:

$$V(\mathbf{s}; k, b) = \max_{d,h,i,b'} \left\{ d + Em'V(\mathbf{s}'; k', b') \right\} \tag{12}$$

$$\text{subject to (9), (10), (11)}$$

The optimality conditions for the choices of labor, h, and debt, b', remain (4) and (5), and the first order condition for investment is:

$$\frac{1}{\Upsilon_i(k,i)} = (1+\phi\mu)Em'\left[(1-\mu')F_k(z',k',h') + \left(\frac{1-\delta+\Upsilon_k(k',i')}{I_i(k',i')}\right)\right]$$

This condition can also be expressed as a function of Tobin's $Q = 1/\Upsilon_i(k,i)$, that is,

$$Q = (1+\phi\mu)Em'\Big[(1-\mu')F_k(z',k',h') + (1-\delta+\Upsilon_k(k',i'))Q'\Big] \tag{13}$$

4.1 Some properties of the general model

In this section we show the impulse responses for some of the key macroeconomic variables for a parameterized version of the model. The impulses responses shown here are only meant to illustrate some of the properties of the model. A full quantitative analysis will be conducted in the next section. In that section we will describe in details the calibration and estimation of the parameters (see Table 1).

The functional forms that were not specified in previous sections are as follows. The utility function of workers takes the log form $U(c,h) = \alpha\ln(c) + (1-\alpha)\ln(1-h)$. For investors we also use the log specification $u(c) = \ln(c)$.

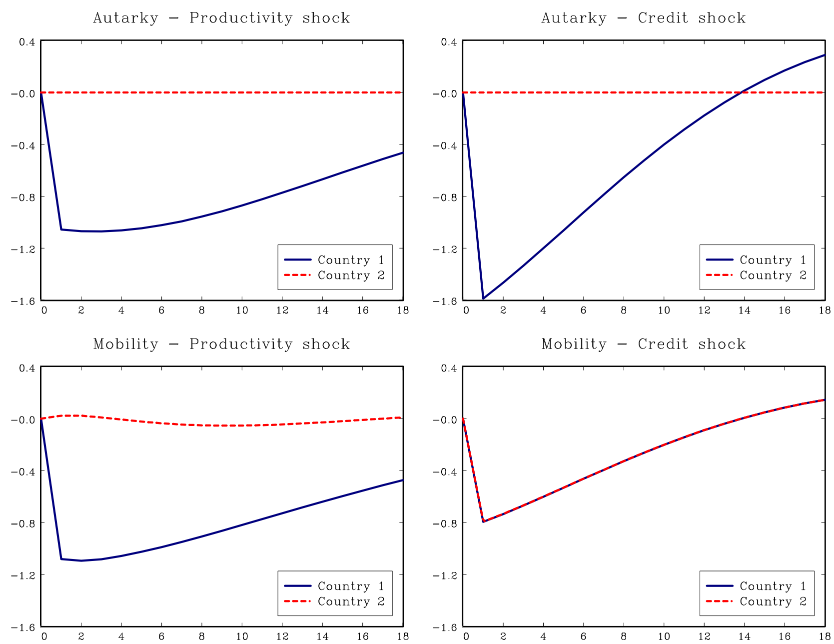
The adjustment cost for investment is determined by the function $\Upsilon(k,i)$ which takes the form:

$$\Upsilon(k,i) = \left[1 - \varphi\left(\frac{i}{k}\right)^2\right] i$$

The productivity and financial shocks are assumed to be independent from each other and they follow first order autoregressive processes that are highly persistent. In constructing the impulse responses reported here we further assume that shocks are also independent across countries. The model is solved after log-linearizing the dynamic system around the steady state. The full list of dynamic equations is reported in Appendix C.

Figure 8 plots the impulse responses of output to a productivity shock (left panels) and to a credit shock (right panels). The shocks are only in country 1. The top panels are for the regime without mobility of capital. The bottom panels are for the economy with capital mobility.

Figure 8: Output response to productivity and credit shocks realized only in country 1. Regimes with and without capital mobility.



In the case of a productivity shock, the international mobility of capital affects only marginally the dynamics of output. In autarky there are no spillovers to country 2 since the productivity shocks are uncorrelated across countries. With capital mobility the output of country 2 increases but only slightly due to the reallocation of capital from country 1 to country 2. Therefore, if technology shocks are the main source of business cycle fluctuations and they are uncorrelated across countries, the model does not generate comovement. This result is also obtained with a more standard open economy RBC model. See Heathcote and Perri (2004).

When we look at credit shocks (right panels), we get a very different picture. In the autarky regime it is still the case that the output of country 2 is not affected by the shock in country 1. However, when financial markets are integrated, the shock in country 1 has the same effect on the output of the two countries.

This result can be easily understood by looking at the first order conditions of firms, equations (4), (5) and (13), which for simplicity we rewrite here:

$$F_l(z, k, l) = \frac{w}{1-\mu}, \tag{14}$$

$$Q = (1+\phi\mu)Em'\Big[(1-\mu')F_k(z', k', h') + (1-\delta+\Upsilon_k(k', i'))Q'\Big], \tag{15}$$

$$(1+\phi\mu)REm' = 1. \tag{16}$$

Because investors diversify their portfolio internationally (they hold the same shares of firms across all countries), domestic and foreign firms face the same discount factor m'. The international mobility of capital also means that there is a unique worldwide interest rate R. Thus, from condition (16) we can see that the lagrange multiplier μ must be the same for all firms. Equations (14) and (15) then show that the change in the demand for labor, investment and Tobin's Q must be the same in the two countries. Notice that for households/workers it is irrelevant whether the credit contraction is for firms of country 1 or firms of country 2. Given the mobility of capital, what matters is the worldwide demand of credit. Another implication is that cross-country wages move in the same direction.

The last two figures plot the impulse responses of additional variables. Figure 9 for the economy without mobility of capital and Figure 10 for the economy with capital mobility.

Again, we find that in autarky a productivity or credit shock in country 1 does not affect country 2. With capital mobility, the productivity shock generates higher investment in country 2 but the spillover on employment is relatively small. Consumption also spills to country 2. One of the reason is that investors are perfectly diversified, and therefore, their consumption follows the same dynamics in the two countries. For credit shocks, instead, the spillover to country 2 is perfect: investment, consumption, labor and productivity follow exactly the same patterns in the two countries.

Let's look now at the dynamics of labor productivity. While a negative productivity shock reduces the productivity of labor, a negative credit shock has the opposite effect, that is, it generates an increase in the productivity of labor. In part this is the consequence of the assumption that the production function displays decreasing returns to scale. However, even with constant returns, labor productivity would increase since the response of capital is relatively small (investment is only a small fraction of capital).

The final feature of the model we would like to emphasize is the dynamics of the value of equity V_t. This can be interpreted as the value of shares. As can be seen from the last two panels of Figures 9 and 10, both shocks affect the stock market only locally when there is financial autarky. Instead, when capital is mobile, both shocks induce a cross country spillover or contagion in asset prices. The contagion is especially strong in response to a credit shock. In this case the impact on the asset prices of country 2 is even larger than in country 1 where the shock hits.

5 Quantitative analysis

In this section we conduct a quantitative analysis of the model. In particular, we are interested in quantifying the relative importance of productivity and credit shocks. This is done by performing a structural estimation of the parameters that govern the stochastic properties of the shocks. All other parameters are calibrated.

We think of country 1 as the US and country 2 as the other countries in the group of the seven largest industrialized economies, that is, Canada, Japan, France, Germany, Italy, UK. We refer to this group as G6 countries. To be consistent with the model, the ideal measure of labor should be total working hours. Unfortunately, while data on employment is available for all the G7 countries, data on working hours is only available for the US and three of the G6 countries: Canada, Germany, Japan. We will refer to this subgroup as G3 countries. The estimation will be performed twice: with data for the G3 countries (using working hours productivity) and the G6 countries (using employment productivity).

The quarterly data is from the OECD National Accounts Statistics over the period 1984.1-2009.3. The use of data starting in 1984 is motivated by two considerations. By starting in 1984 we do not deal with potential structural breaks associated with the so called 'Great Moderation'. More importantly, before the mid-1980s, there were significant capital account controls even among the industrialized countries. However, starting in the 1980s, many controls have been lifted and the international economy has become closer to a regime with cross-country mobility of capital. Since our model features two countries that are financially integrated, the model is a better representation of the post-1980s regime.[5]

[5]We could use the autarky version of the model to capture the pre-1980s period. However, the assumption that the earlier period was characterized by the autarky regime would be an over-characterization, especially for the G7 countries. Although the capital controls were widespread, they did not erase all the international

Figure 9: Financial autarky (regime without mobility of capital). Impulse response to productivity and credit shocks in country 1 only.

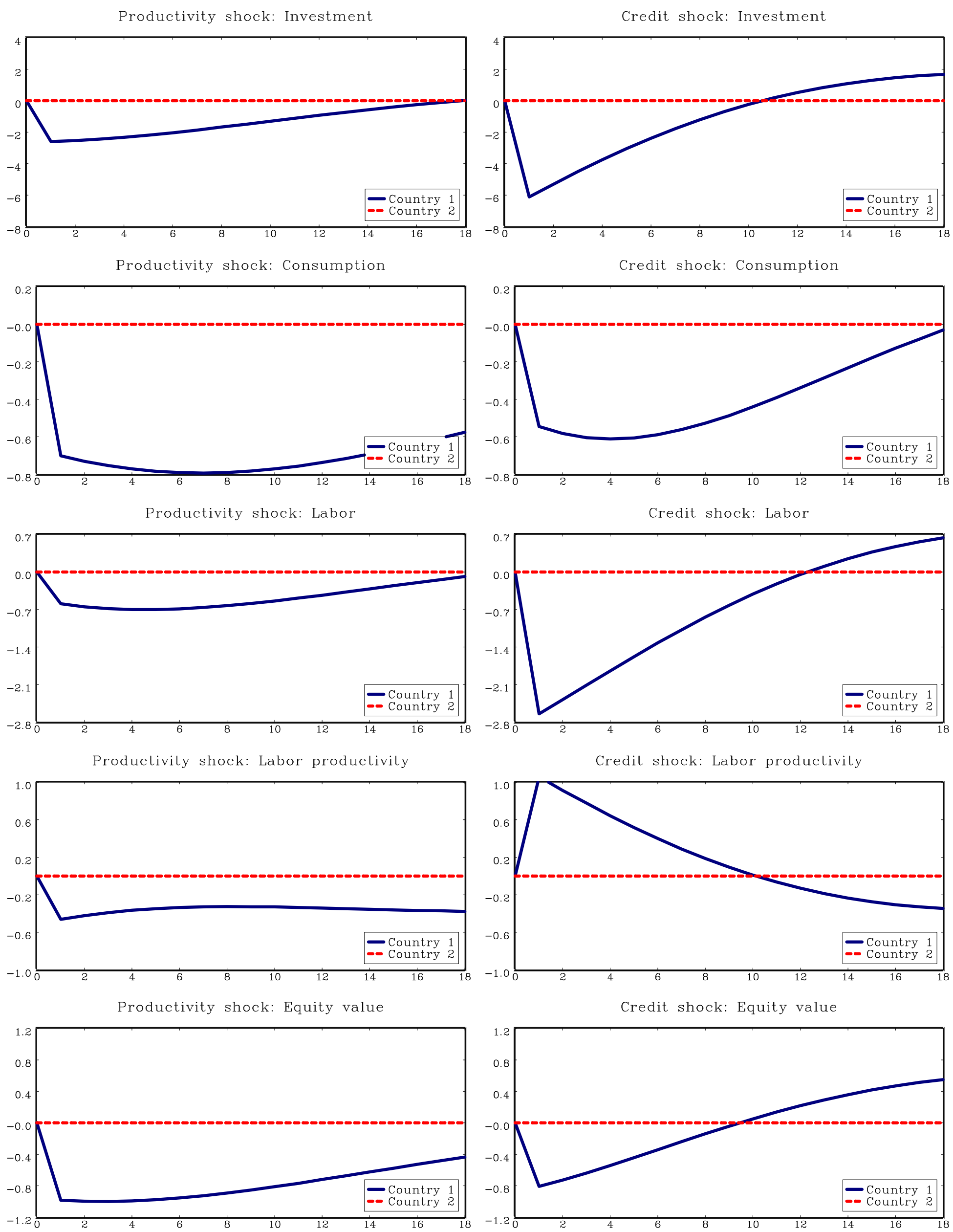
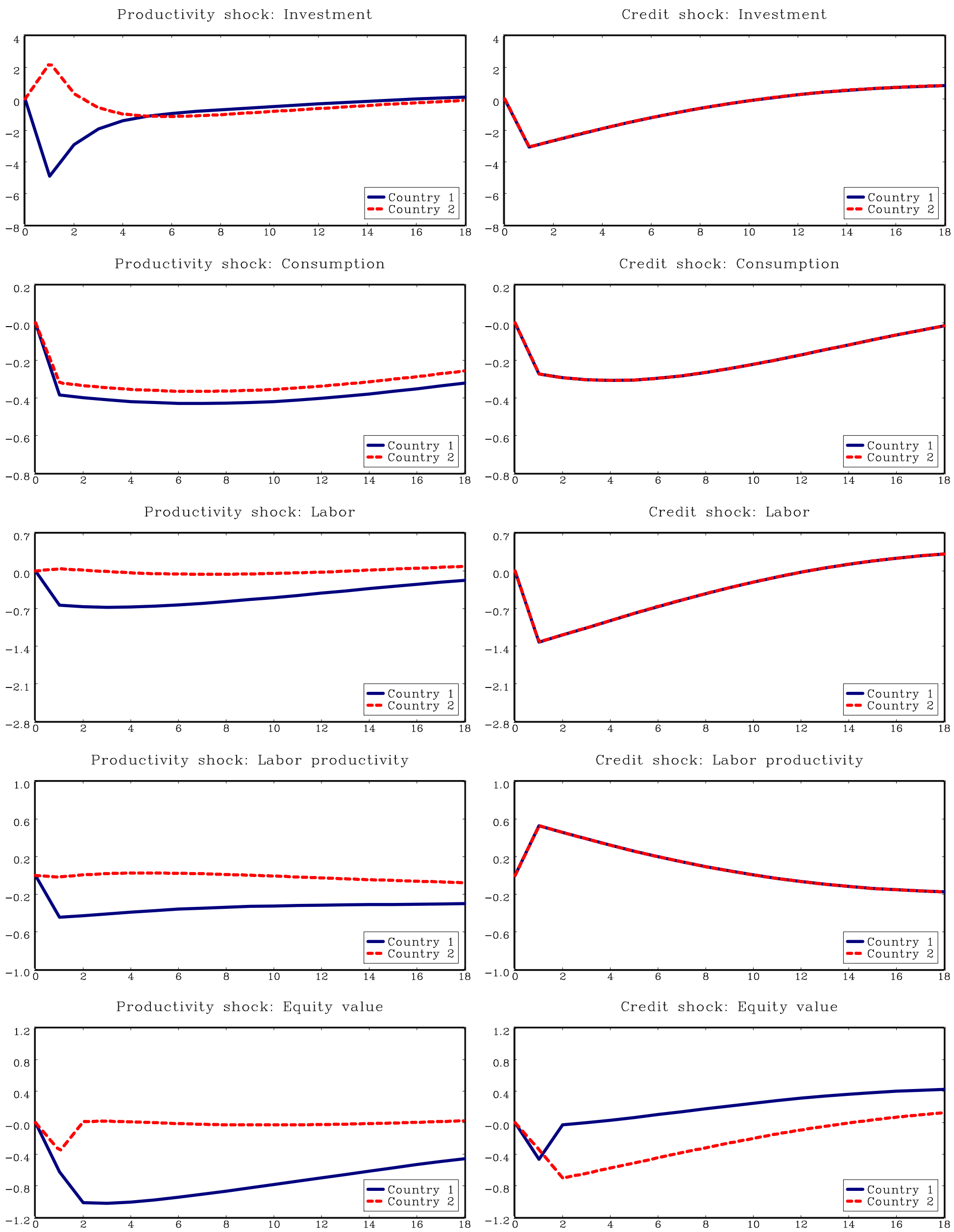


Figure 10: Financial integration (regime with perfect mobility of capital). Impulse responses to productivity and credit shocks in country 1 only.



Calibrated parameters: The discount factor of workers determines the average return on bonds. We set it to the quarterly value of $\delta = 0.9925$ which implies a yearly return of about 3%. The real return for stocks is determined by the discount factor for investors, which we set to the quarterly value of $\beta = 0.9825$. This implies a yearly return of about 7%.

The utility function takes the log form $U(c, h) = \ln(c) + \alpha \ln(1 - h)$, with $\alpha = 1.4$. This implies a steady state value of hours equal to 0.4.

The parameter ϕ affects the enforcement of contracts. Higher is the value of ϕ and lower is the leverage. We choose ϕ to have a steady state ratio of debt over physical capital of 0.5. The required value is $\phi = 9.18$.

The return to scale parameter is set to $\nu = 0.95$ and the parameter θ is chosen to have a labor income share of 0.6. The labor income share, that is, the steady state fraction of output going to workers in the form of wages is equal to $\nu(1 - theta)[1 + (1 - delta/beta)/\phi]$. Given the values of δ, β, ν and ϕ already chosen, the resulting value of θ is 0.3677.[6]

The depreciation rate for physical capital is set to $\tau = 0.025$ and the adjustment cost parameter for investments is set to $\varphi = 0.025$. This guarantees a reasonable volatility of investment relatively to output.

Estimated parameters The parameters that have not been calibrated are those determining the stochastic properties of the two shocks, z and ξ.

The productivity and credit shocks are assumed to be independent from each other and follow first order autoregressive processes, that is:

$$\begin{aligned}
\log(z_{t+1}) &= \rho_z \log(z_t) + \epsilon_{t+1}, \\
\log(\tilde{z}_{t+1}) &= \rho_z \log(\tilde{z}_t) + \tilde{\epsilon}_{t+1}, \\
\log(\xi_{t+1}) &= \rho_\xi \log(\xi_t) + \varepsilon_{t+1} \\
\log(\tilde{\xi}_{t+1}) &= \rho_\xi \log(\tilde{\xi}_t) + \tilde{\varepsilon}_{t+1},
\end{aligned}$$

flows of capital. Therefore, the pre-1980s is probably characterized by an intermediate regime in the intersection between full mobility and autarky. Since our model does not easily allow for intermediate regimes, we decided to focus on the most recent period.

[6]The parameters ϕ and θ need to be chosen jointly and not sequentially so that the leverage is 0.5 and the labor share 0.6.

where

$$\begin{pmatrix} \epsilon \\ \tilde{\epsilon} \end{pmatrix} \sim N\left(\begin{matrix} 0, \\ 0, \end{matrix} \begin{bmatrix} 1-\varrho_z & \varrho_z \\ \varrho_z & 1-\varrho_z \end{bmatrix} \sigma_z \right), \qquad \begin{pmatrix} \varepsilon \\ \tilde{\varepsilon} \end{pmatrix} \sim N\left(\begin{matrix} 0, \\ 0, \end{matrix} \begin{bmatrix} 1-\varrho_\xi & \varrho_\xi \\ \varrho_\xi & 1-\varrho_\xi \end{bmatrix} \sigma_\xi \right)$$

The parameters σ_z and σ_ξ determine the volatility of the shocks while the parameters ϱ_z and ϱ_ξ determine the cross country spillovers. If ϱ_z is zero then the productivity shock is uncorrelated across countries. If ϱ_z is equal to 0.5, productivity shocks are perfectly correlated. The same is true for the parameter ϱ_ξ governing the cross-country spillovers in credit shocks.

With capital mobility, the two credit shocks ξ and $\tilde{\xi}$ are not easily identifiable using real macroeconomic data since these shocks have almost identical effects on the real macroeconomic variables of the two countries. Therefore, we can only identify three shocks: two productivity shocks and one 'global' credit shock.[7] Because of this, in the estimation we assume that there is only one worldwide variable $\bar{\xi}_t$ affecting both countries. This variable follows the autoregressive process

$$\log(\bar{\xi}_{t+1}) = \rho_\xi \log(\bar{\xi}_t) + \bar{\varepsilon}_{t+1},$$

where $\bar{\varepsilon} \sim N(0, \sigma_\xi)$.

Given the specifications of the stochastic processes for the shocks, we have five unknown parameters: ρ_z, ϱ_z, σ_z, ρ_ξ, σ_ξ. The parameters are estimated structurally using Bayesian methods. The prior distributions for the parameters ρ_z and ρ_ξ we assume a Beta distribution with mean 0.5 and standard deviation 0.2. The parameter ϱ_ϵ has also a Beta distribution with mean 0.2 and standard deviation 0.1. For σ_z and σ_ξ we assume Inverse Gamma distributions with mean 0.01 and standard deviation 0.05. The use of these functional forms is standard in the literature. See Smets and Wouters (2007).

The estimation uses three macroeconomic variables: i) Growth rate of GDP for the US; ii) Growth rate of labor productivity (GDP divided by hours) for the US; iii) Growth rate of labor productivity (GDP divided by hours) for the G3 countries. We then repeat the estimation using data for all the G7 countries but measuring labor productivity as the ratio of GDP over employment since working hours are not available for all the G7 countries.

[7] Credit shocks that are country specific could be identified using variables related to financial stocks or flows of debt. For example, for the US we could use data from the Flows of Funds. Unfortunately, equivalent and comparable data for all of the other G7 countries is not available.

5.1 Results

The statistics for the estimated parameters are reported at the bottom of Table 1. For each parameter we report the prior density, the mode and the threshold values for the 5 and 95 percentiles of the posterior distribution.

Table 1: List of parameters

Calibrated parameters				
Discount factor for households/workers, δ	0.9925			
Discount factor for entrepreneurs, β	0.9825			
Utility parameter, α	1.4058			
Production technology, θ	0.3677			
Depreciation rate, τ	0.0250			
Return to scale, ν	0.9500			
Enforcement parameter, ϕ	9.1853			
Cost foreign bonds, ψ	0.0010*			
Estimated parameters	*Prior*	*Mode*	*Percentile*	
			5%	*95%*
A) US and G3 - Working hours productivity				
Productivity persistence, ρ_z	Beta[0.5,0.2]	0.9049	0.8935	0.9178
Productivity volatility, σ_z	IGamma[0.01,0.05]	0.0094	0.0090	0.0097
Productivity spillover, ϱ_z	Beta[0.25,0.1]	-0.0369	-0.0524	-0.0350
Credit persistence, ρ_ξ	Beta[0.01,0.01]	0.9774	0.9673	0.9841
Credit volatility, σ_ξ	IGamma[0.01,0.05]	0.0688	0.0627	0.0794
B) Us and G6 - Employment productivity				
Productivity persistence, ρ_z	Beta[0.5,0.2]	0.8848	0.8730	0.8928
Productivity volatility, σ_z	IGamma[0.01,0.05]	0.0086	0.0077	0.0097
Productivity spillover, ϱ_z	IGamma[0.01,0.05]	0.0700	-0.0067	0.1063
Credit persistence, ρ_ξ	Beta[0.01,0.01]	0.9760	0.9623	0.9836
Credit volatility, σ_ξ	IGamma[0.01,0.05]	0.0325	0.0325	0.0447

Notes: The cost of holding foreign bonds is very small and does not affect the quantitative properties of the real macroeconomic variables. The reason it is not zero is because with $\psi = 0$ the linearized model would not be stationary.

The estimated parameters show that both shocks are highly persistent. As far as the cross-country spillover in productivity is concerned, we see that ϱ_z is not very different from zero. Therefore, there is not much international spillovers in TFP.

Table 2 reports the standard deviations of the growth rate of key macroeconomic variables relative to output. The numbers are averages of the standard deviations from the posterior distribution. To compute these averages, we make 10,000 draws of parameters from the posterior distribution using the Random-Walk Metropolis algorithm and compute the standard deviation of the relevant macroeconomic variables for each draw. The goal of this table is to show that the model generates reasonable business cycle statistics. Worth noticing is that the model can generate volatility in hours of similar magnitude as output. This property, also shown in Jermann and Quadrini (2009), is a distinguished feature of this model when compared to the typical real business cycle model.

Table 2: Standard deviation of growth for major macroeconomic variables (relative to standard deviation of output).

	Standard deviations
A) US and G3 - Working hours productivity	
Labor	0.94
Investment	3.40
Consumption	0.39
Labor productivity	0.46
Net exports	0.33
B) US and G6 - Employment productivity	
Labor	0.79
Investment	3.21
Consumption	0.43
Labor productivity	0.45
Net exports	0.29

Notes: The statistics are generated by averaging the standard deviations associated with 10,000 draws of parameters from the posterior distribution.

Once we have shown that the model generates reasonable business cycle statistics, we can now focus on the contribution of productivity and financial shocks to generate these statistics. Table 3 reports the variance decomposition numbers. As for the standard deviations, the statistics are computed by averaging the numbers obtained for each of the 10,000 draws from the posterior distribution of the estimated parameters.

Financial shocks contribute to about half of the volatility of working hours. The contribution to output, investment and labor productivity is also significant, although smaller than the contribution to the volatility of labor. Consumption and net exports, instead, are mostly driven by productivity.[8]

[8]The result for net export is obvious once we think about the property of financial shocks with full capital markets integration. Abstracting from the possible income effects on the supply of labor, which are very small, a financial shock has exactly the same effect on production, investment and consumption of the two

Table 3: Decomposition of variance for the growth rates of major macroeconomic variables.

	Domestic z	Foreign z	Dom-For ξ
A) US and G3 - Working hours productivity			
Output	0.79	0.01	0.20
Labor	0.37	0.04	0.60
Investment	0.76	0.07	0.16
Total consumption	0.63	0.28	0.09
Labor productivity	0.49	0.05	0.46
Net exports	0.50	0.49	0.01
B) US and G6 - Employment productivity			
Output	0.88	0.02	0.10
Labor	0.51	0.04	0.45
Investment	0.83	0.08	0.09
Total consumption	0.63	0.33	0.04
Labor productivity	0.76	0.01	0.23
Net exports	0.50	0.49	0.01

Notes: The statistics are generated by averaging the variance decomposition associated with 10,000 draws of parameters from the posterior distribution.

We move now to the correlations statistics reported in Table 4. The first statistic we would like to focus is the correlation within one country between labor productivity and working hours. When we use working hours this correlation is -016. Therefore, the model is capable of generating a negative correlation between labor and productivity, which is consistent with the unconditional empirical moments shown earlier (based on working hours productivity). The negative correlation derives from the importance of credit shocks in generating labor movement. While productivity shocks generate a positive correlation, financial shocks lead to a negative correlation. Greater is the importance of credit shocks and lower is the unconditional correlation. When we use employment productivity, the correlation is positive by quite low.

The second property we would like to emphasize is the high cross-country correlation of output, labor and investment. Also this property derives from the significant contribution of credit shocks to business cycle fluctuations. Since credit shocks generate very high cross-country comovement while the comovement generated by productivity shocks is negligible (given the weak cross-country correlation of productivity shocks), the comovement increases

countries. This is the reason why we could not identify the financial shocks separately for each country. If these variables experience the same change in the two countries, net exports will not change. The weak impact on consumption is less straightforward. In general, movements in consumption are driven by shocks that move income persistently. Even though financial shocks are persistent, the impact on output is not very persistent. Consequently, consumption move significantly less than other variables.

Table 4: Within and between country correlations of major macroeconomic variables.

A) US and G3 - Working hours productivity

	Country 1						**Country 2**					
	Out	Lab	Inv	Con	Pro	Nex	Out	Lab	Inv	Con	Pro	Nex
Country 1												
Output	1.00	0.90	0.90	0.86	0.29	0.03	0.35	0.58	0.17	0.68	-0.43	-0.03
Labor	0.90	1.00	0.78	0.77	-0.16	0.10	0.55	0.84	0.42	0.71	-0.51	-0.10
Investment	0.90	0.78	1.00	0.68	0.32	-0.36	0.14	0.41	-0.15	0.47	-0.53	0.36
Consumption	0.86	0.77	0.68	1.00	0.26	0.03	0.66	0.69	0.44	0.94	0.03	-0.03
Productivity	0.29	-0.16	0.32	0.26	1.00	-0.15	-0.41	-0.50	-0.54	-0.01	0.14	0.15
Net exports	0.03	0.10	-0.36	0.03	-0.15	1.00	0.11	0.14	0.49	0.06	-0.05	-1.00

B) US and G6 - Employment productivity

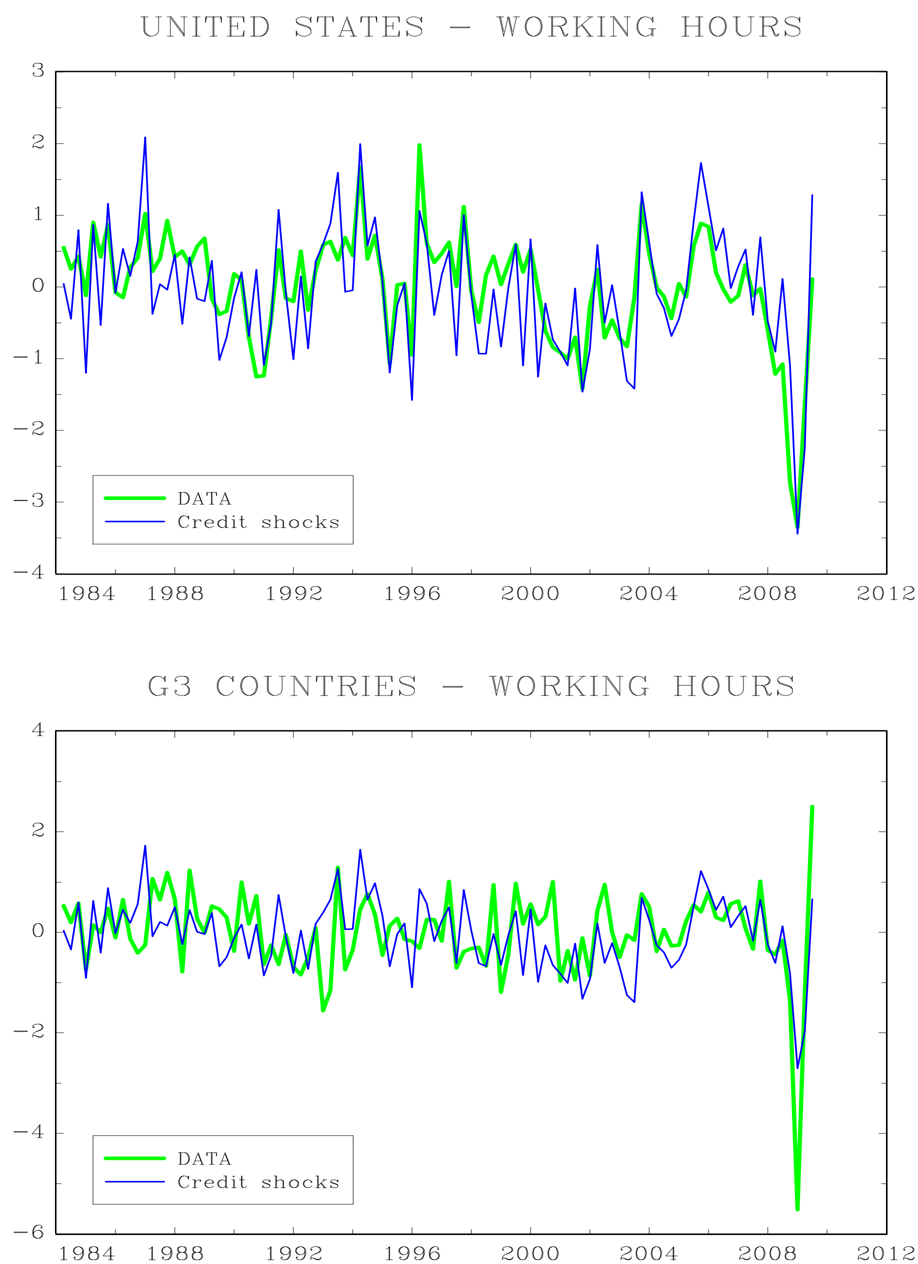
	Country 1						**Country 2**					
	Out	Lab	Inv	Con	Pro	Nex	Out	Lab	Inv	Con	Pro	Nex
Country 1												
Output	1.00	0.90	0.90	0.86	0.64	0.04	0.35	0.50	0.15	0.71	-0.08	-0.04
Labor	0.90	1.00	0.79	0.77	0.24	0.10	0.47	0.74	0.32	0.69	-0.21	-0.10
Investment	0.90	0.79	1.00	0.67	0.61	-0.33	0.13	0.31	-0.17	0.50	-0.24	0.33
Consumption	0.86	0.77	0.67	1.00	0.56	0.03	0.70	0.69	0.48	0.96	0.37	-0.03
Productivity	0.64	0.24	0.61	0.56	1.00	-0.08	-0.05	-0.18	-0.25	0.36	0.19	0.08
Net exports	0.10	0.10	-0.33	0.03	-0.08	1.00	0.06	0.12	0.43	0.03	-0.06	-1.00

with the contribution of credit shocks to business cycle fluctuations. This is consistent with the high synchronization of the recent crisis.

Finally, Figure 11 plots the series of working hours for the US and the G3 countries. Two series are plotted: the data series and the series generated by credit shocks. Let's focus on the last recessionary episode where working hours experienced a large drop in the US and in other industrialized countries (in the graph the G3 countries). As can be seen from the top graph, the dynamics of US labor in the recent recession is almost entirely captured by the dynamics of credit shocks. Credit shocks have also played an important role for the dynamics of labor in the G3 countries. However, it captures only half of the drop in hours experienced by the G3 countries during the recent crisis.[9]

[9] Since in the estimation we use empirical growth series for GDP in the US, productivity in the US and productivity in the G3 countries, the model replicates exactly the series for labor in the US but not for the G3 countries. Therefore, the difference between the two lines in the bottom graph is not exactly equal to the contribution of productivity shocks. However, according to our estimation, productivity did contribute significantly to the fall of labor in the G3 countries, differently from the US case.

Figure 11: Contribution of credit shocks to the dynamics of labor.



6 Conclusion

This paper investigates one of the potential mechanisms underlying the international spillover of recessionary episodes and international business cycle more generally. We showed that the 2008-2009 crisis has been characterized by an exceptionally high degree of international synchronization. Second, this episode has taken place in an environment where the correlation between labor productivity and working hours has declined significantly in the US and, on average, in other industrialized countries. These changes support the view that 'credit shocks' have played a more prominent role as a source of business cycle fluctuations given the increasing internationalization of capital markets.

We have considered an economic environment in which shocks to credit is one of the driving forces of the business cycle. These shocks affect the real sector of the economy through a credit channel: booms enhance the borrowing capacity of firms and in the general equilibrium they lead to higher employment, production but lower productivity of labor. The opposite arises after a credit contraction.

Within this framework we have shown that, when countries are financially integrated, credit shocks that are specific to one country affect the employment and production of other countries, with significant macroeconomic spillovers. At the same time, these shocks generate a negative correlation between labor productivity and working hours. On the contrary, country-specific productivity shocks do not generate large cross-country co-movement in real macroeconomic variables unless the shocks are internationally correlated. But if productivity shocks are correlated across countries and they are the major source of business cycle fluctuations, it is difficult to reconcile the fact that the correlation of labor productivity with hours is low and it has further declined in recent years.

Of course, there could be other shocks besides the ones considered here that could also generate cross-country comovement and weak correlation between productivity and labor. Since in the analysis we have abstracted from these other possible sources of business cycle, it is always possible that credit shocks are simply capturing the dynamics of these other shocks. However, it is not obvious how the most common shocks studied in the literature (for example the seven shocks considered by Smets and Wouters (2007)) can generate international comovement unless the shocks are internationally correlated.

We conclude that the current recession and its international transmission could be captured by a large credit shock. This shock, even if originates in one single country, could easily spill to other countries thanks to the international integration of capital markets. Therefore, credit shocks could be important for understanding the properties of the international business cycle. Although the paper illustrates the macroeconomic importance of these shocks, it does not provide an explanation for the causes of the shocks. Indeed, more research along these lines is needed.

Appendix

A Debt renegotiation

Suppose that, in case of renegotiation, the lender can confiscate the firm and sell to investors the firm's equity at a cost ξ_t. However, the price obtained through the sale is only a fraction $\phi < 1$ of the original value of equity, that is, $\phi \overline{V}_t(b_{t+1})$.

If the parties reach an agrement, the lender receives a payment T_t from the firm and leaves the debt b_{t+1} for the next period. The value received by the firm from the renegotiation is $\overline{V}_t(b_{t+1}) - T_t$. Without reaching an agrement the entrepreneur gets zero. For the lender, the value received under renegotiation is T_t. Without renegotiation it will get the liquidation value $\phi \overline{V}_t(b_{t+1}) - \xi_t$. Notice that, independently of whether the lender reaches an agrement or not, it will receive b_{t+1} in the next period.

The bargaining problem is:

$$\max_{T_t} \Big[\overline{V}_t(b_{t+1}) - T_t\Big]^{\chi} \Big[T_t - \phi \overline{V}_t(b_{t+1}) + \xi_t\Big]^{1-\chi},$$

where χ is the bargaining power of the firm.

The first order conditions are:

$$-\chi\Big[T_t - \phi \overline{V}_t(b_{t+1}) + \xi_t\Big] + (1-\chi)\Big[\overline{V}_t(b_{t+1}) - T_t\Big] = 0$$

Solving the first order condition for the transfer we get:

$$T_t = (1 - \chi + \chi\phi)\overline{V}_t(b_{t+1}) - \chi\xi_t$$

Therefore, the renegotiation value received by the firm is:

$$\overline{V}_t(b_{t+1}) - T_t = (1-\phi)\chi\overline{V}_t(b_{t+1}) + \chi\xi_t.$$

This is in addition to the diverted revenue that the entrepreneur receives independently of the renegotiation outcome. Therefore, the total value from defaulting is $F(z_t, l_t) + (1 - \phi)\chi\overline{V}_t(b_{t+1}) + \chi\xi_t$. This cannot be bigger than the value of not defaulting, that is,

$$\overline{V}_t(b_{t+1}) \geq F(z_t, l_t) + (1-\phi)\chi\overline{V}_t(b_{t+1}) + \chi\xi_t$$

Collecting terms and re-arranging we get:

$$[1 - \chi(1-\phi)] \cdot \overline{V}_t(b_{t+1}) \geq F(z_t, l_t) + \xi_t$$

In the main body of the paper we have considered the special case in which the firm has all the bargaining power, that is, $\chi = 1$. In this case the term $[1 - \chi(1-\phi)]$ becomes ϕ. However, this is without loss of generality: as long as $\chi > 0$, the enforcement constraint has exactly the same functional form.

B First order conditions

Consider the optimization problem (1) and let λ and μ be the Lagrange multipliers associate with the two constraints. Taking derivatives we get:

$$\begin{aligned}
d: &\quad 1 - \lambda = 0 \\
h: &\quad \lambda[F_h(z,h) - w] - \mu F_h(z,h) = 0 \\
b': &\quad (1 + \phi\mu) E m' V_{b'}(\mathbf{s}'; b') + \frac{\lambda}{R} = 0
\end{aligned}$$

The envelope condition is:

$$V_b(\mathbf{s}; b) \quad = \quad -\lambda$$

The above conditions can be re-arranged as in (4) and (5).

C Dynamic system

We have to solve for the variables k_{t+1}, b_{t+1}, n_{t+1}, μ_t, w_t, h_t, c_t, d_t, i_t, V_t, R_t, Q_t in country 1 and for the corresponding variables in country 2 as a function of the states, z_t, ξ_t, k_t, b_t, n_t, in country 1 and for the corresponding states in country 2. Therefore, we have 24 unknowns. To find a solution we linearize a system composed of 24 dynamic equations. First we have the following 11 equations from country 1:

$$
\begin{aligned}
& U_c(c_t,h_t)w_t + U_h(c_t,h_t) = 0 \\
& U_c(c_t,h_t) - \delta R_t E U_c(c_{t+1},h_{t+1}) = 0 \\
& w_t h_t + b_t + n_t(1-\psi n_t) - c_t - \frac{b_{t+1}}{R_t} - \frac{n_{t+1}}{\widetilde{R}_t} = 0 \\
& F_l(z_t,k_t,h_t) - \frac{w_t}{1-\mu_t} = 0 \\
& (1-\tau)k_t + \Upsilon(k_t,i_t) - k_{t+1} = 0 \\
& (1+\phi\mu_t)Em_{t+1}\Big[(1-\mu_{t+1})F_k(z_{t+1},k_{t+1},h_{t+1}) + (1-\delta+\Upsilon_k(k_{t+1},i_{t+1}))Q_{t+1}\Big] - Q_t = 0 \\
& \frac{1}{\Upsilon_i}(k_t,i_t) - Q_t = 0 \\
& (1+\phi\mu_t)R_t E m_{t+1} - 1 = 0 \\
& b_t + d_t + i_t - \frac{b_{t+1}}{R_t} - F(z_t,k_t,h_t) + w_t h_t = 0 \\
& \phi E m' V_{t+1} - F(z_t,k_t,h_t) - \xi_t = 0 \\
& d_t + E m_{t+1} V_{t+1} - V_t = 0.
\end{aligned}
$$

We also have 11 corresponding equations from country 2, bringing the total number of equations to 22. The last two equations, closing the system, are the conditions for the equilibrium in the international market, that is,

$$
\begin{aligned}
& R_t - \widetilde{R}_t(1-\psi\cdot N_t) = 0 \\
& N_t + \tilde{N}_t = 0,
\end{aligned}
$$

where the individual foreign asset positions of households/workers is equal to the aggregate positions, that is, $n_t = N_t$ and $\tilde{n}_t = \tilde{N}_t$.

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