

# International recessions

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## Abstract

The international synchronization of the 2008-2009 crisis has been one of the key features of the recent recession as most countries have experienced large macroeconomic contractions. Another feature of the 2008-2009 crisis has been the sharp fall in employment but not in productivity. These two features—international synchronization and absence of significant productivity fall—are not present in many of the previous contractions. We develop an explicit model of financial frictions to show that these changes are consistent with the view that ‘credit shocks’ have been playing a more prominent role as a source of business cycle fluctuations in an environment with international mobility of capital.

PRELIMINARY AND INCOMPLETE

## 1 Introduction and evidence

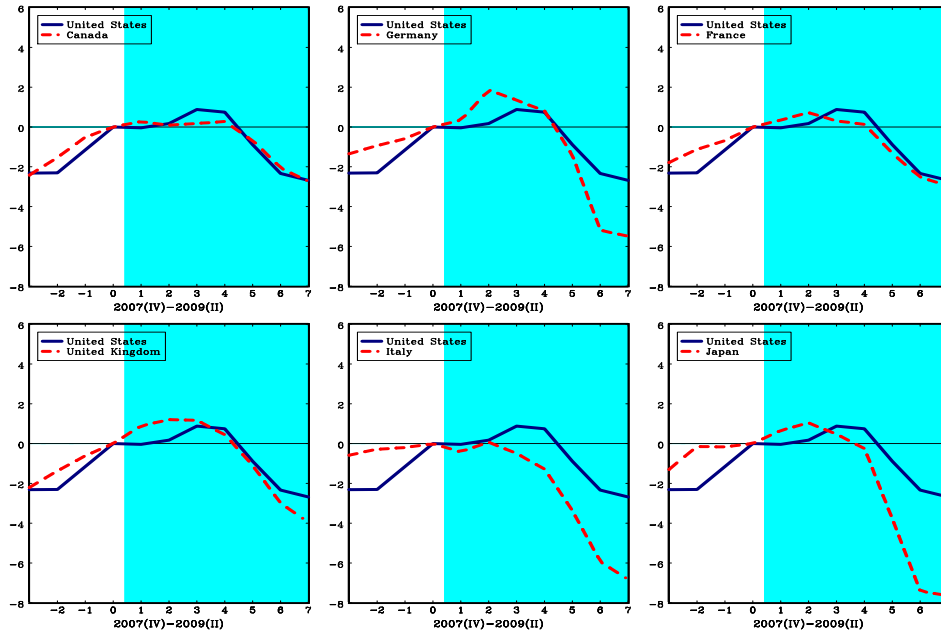
This paper is motivated by two observations about the 2008-2009 crisis. The first observation is the international synchronization of the recession as most countries have experienced large macroeconomic contractions. The second observation is that, although employment has fallen dramatically, productivity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

### 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

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 that has characterized the current crisis.

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 latest 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.

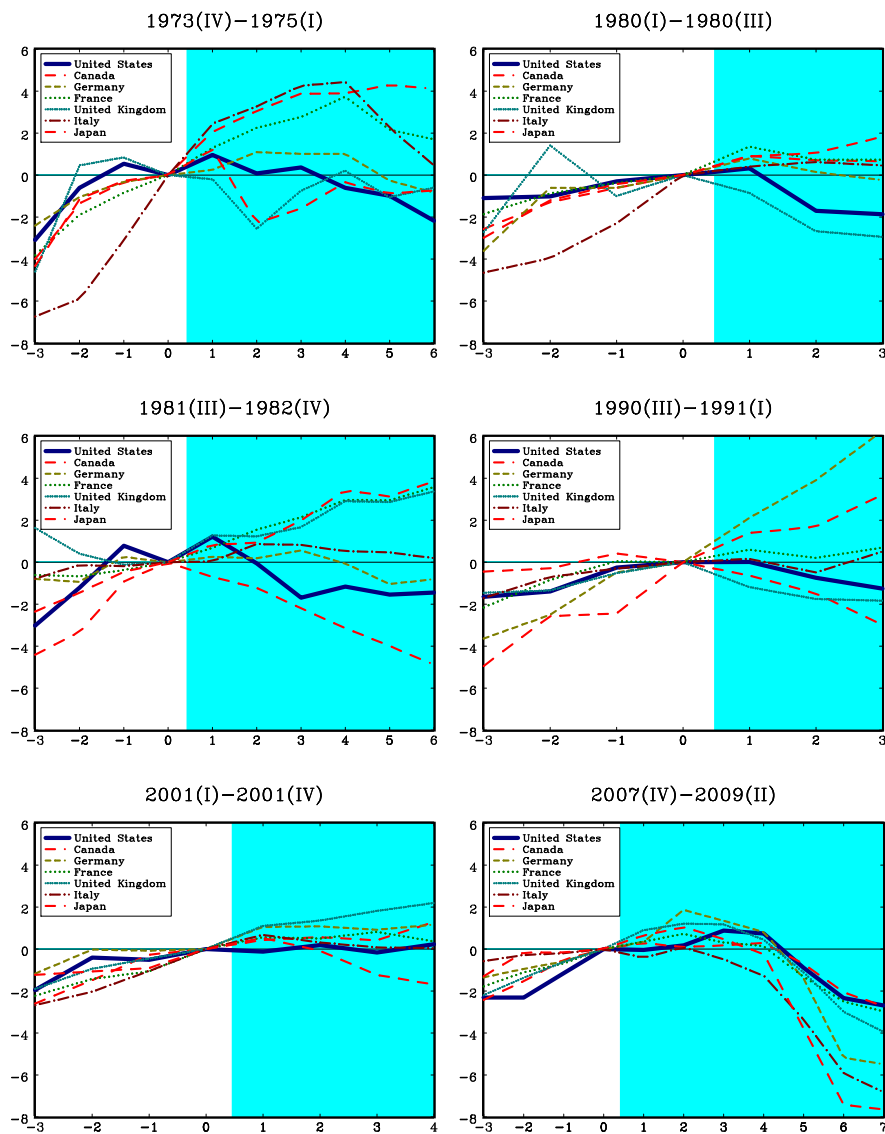
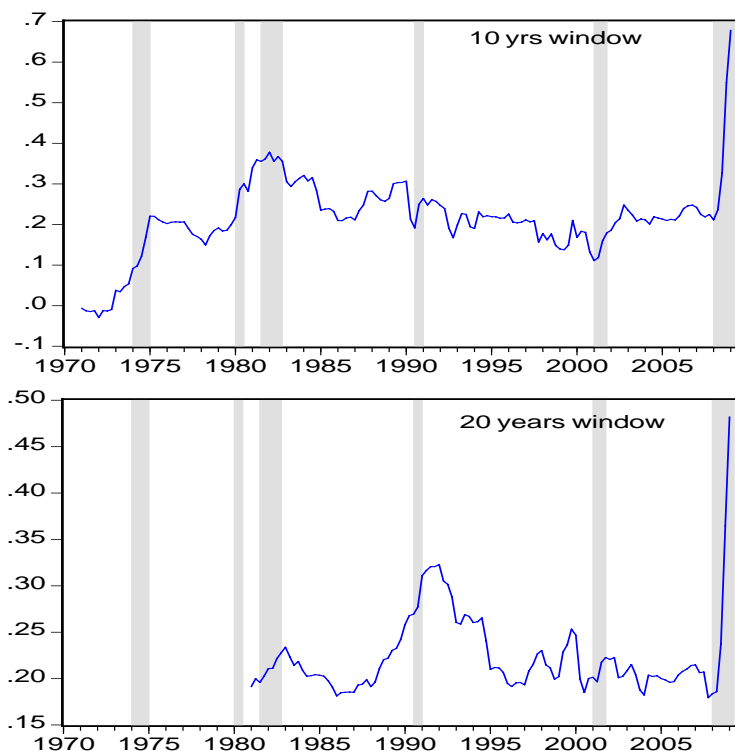


Figure 3: Average rolling correlations of US GDP v/s G7 countries.



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.

## 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. This pattern is in contrast to the dynamics of labor and output. As can be seen in Figure 5, all recessions 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 been declining on average in the group of the seven major industrialized economies.

### 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 recessions.
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. The observation that labor productivity has not slowed down during the more recent recession casts doubts on the relevance of productivity shocks as the major source of macroeconomic contraction.

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 main source of business cycle fluctuations, we should observe a higher correlation between

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

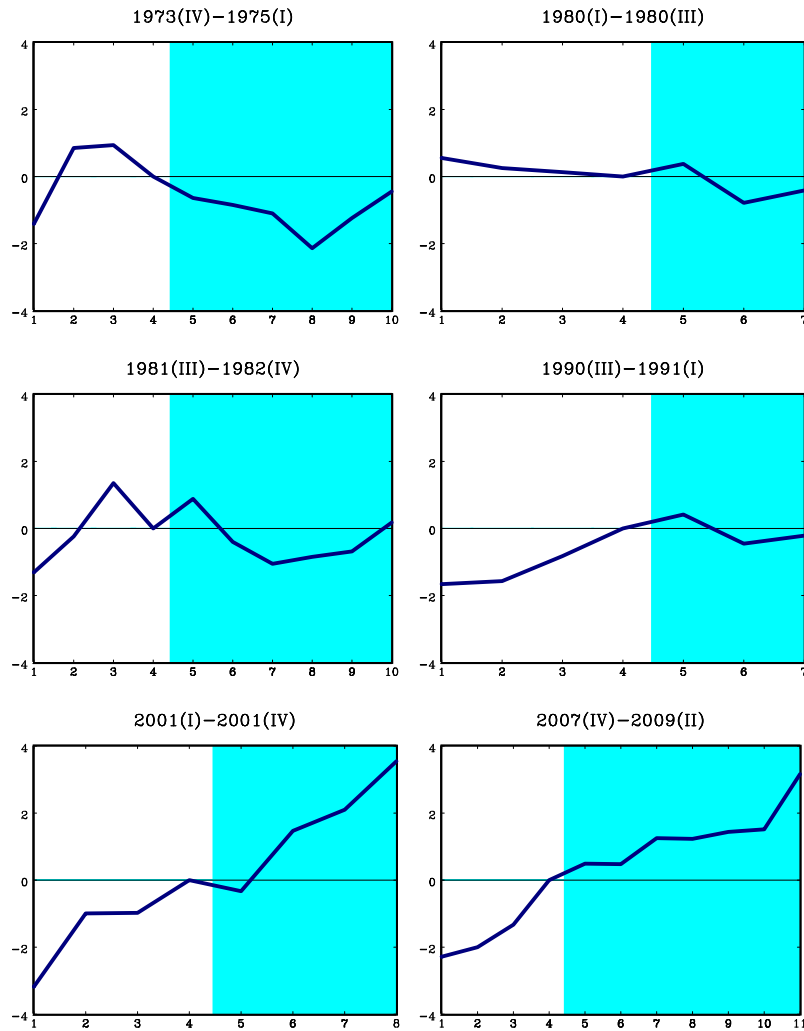


Figure 5: Hours and GDP in the private nonfarm sector.

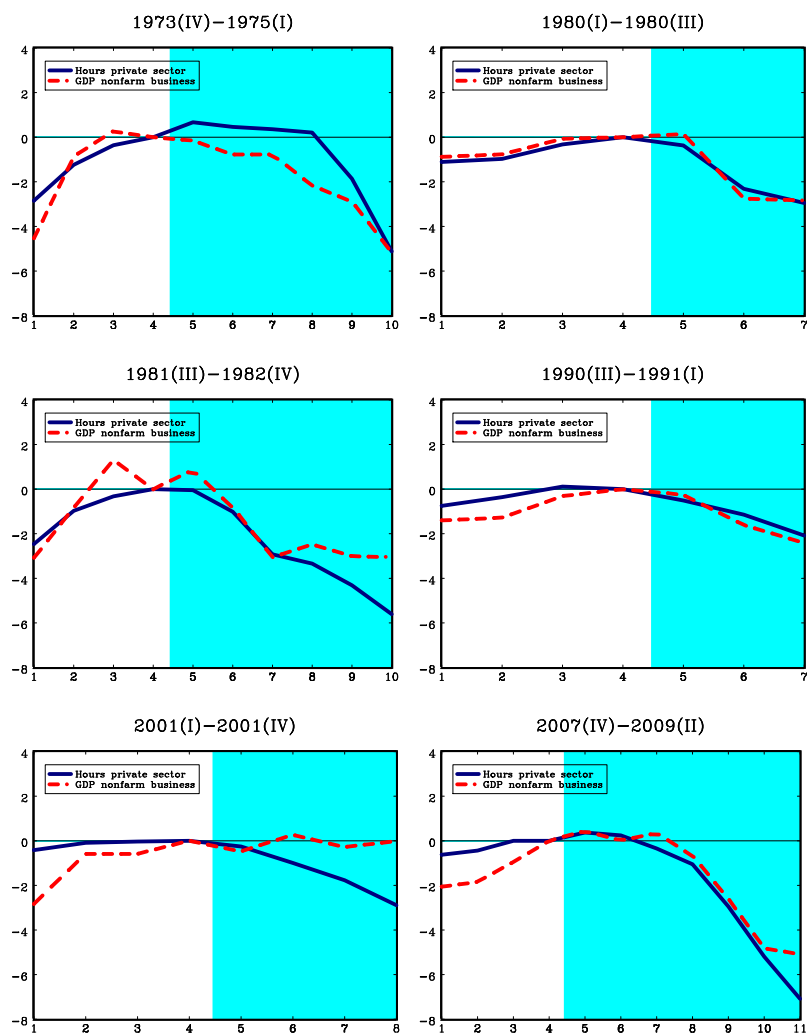
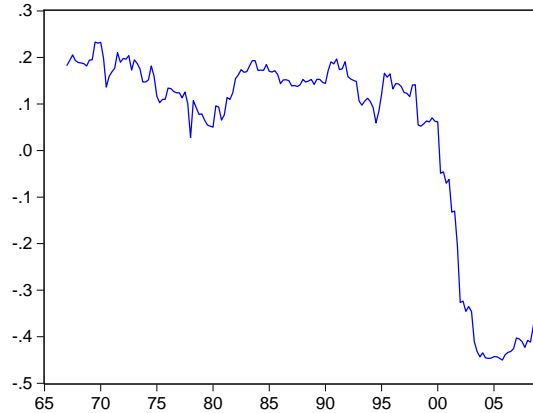


Figure 6: Rolling correlations of productivity growth and hours growth in the US.

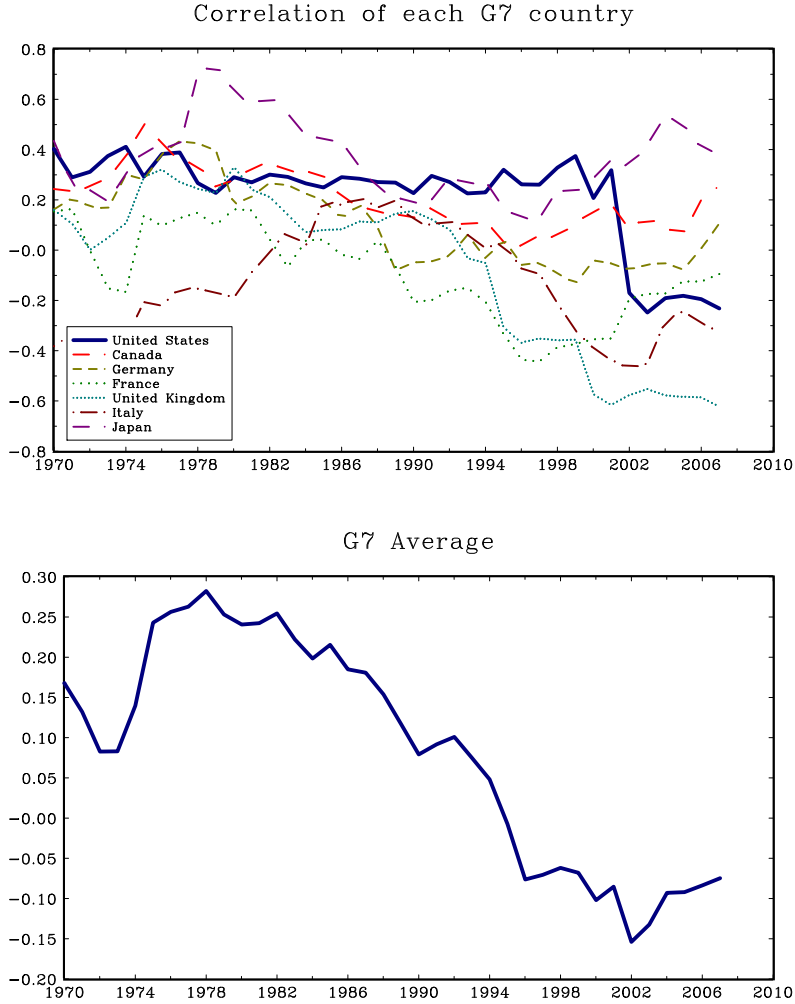


productivity and labor. It is then difficult to reconcile the hypothesis of productivity driven recessions with the fact that productivity kept growing during the most recent contractions.

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 outlined above. 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 Jerermann 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, instead, the incentive to default is higher and lenders cut on lending. Following a credit cut, borrowers are forced to restructure their financial position 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. Because the financial

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.



cost contributes to the whole cost of hiring workers and acquiring investments, the demands for labor and investment decline.

We can now describe how a credit contraction spills over other countries even if foreign borrowers do not face any credit contraction. Consider two countries that are financially integrated. For convenience let's think of 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 equity increase can only 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 a single country becomes more elastic. Although the increase in the cost of equity in country  $A$  is smaller, the higher cost also applies to firms operating in country  $B$  since now there is a single worldwide market (law of one price). This will have macroeconomic consequences for country  $B$ . Thus, the credit contraction in country  $A$  will affect 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 3.

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  $\beta$ . 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.

It will be convenient to describe first 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  $\nu$  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  $l_t = w_t l_t + d_t + b_t - b_{t+1}/R_t$ , which is then repaid at the end of the period, after the realization of revenues.<sup>1</sup>

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 more 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  $\xi_t$ ; (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,

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

Because default arises after choosing  $b_{t+1}$ , the liquidation value of the firm's equities is  $\phi \bar{V}_t(b_{t+1}) - \xi_t$ , which is smaller than the continuation value  $\bar{V}_t(b_{t+1})$ . 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  $(1-\phi)\bar{V}_t(b_{t+1}) + \xi_t$ . 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  $(1-\phi)\bar{V}_t(b_{t+1}) + \xi_t$ . Thus, the total value from defaulting is  $l_t + (1-\phi)\bar{V}_t(b_{t+1}) + \xi_t$ , 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  $\bar{V}_t(b_{t+1})$  is at least as big as the value of defaulting, that is,

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

Rearranging terms, the enforcement constraint can be rewritten as:

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

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<sup>1</sup>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 conditions.

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.<sup>2</sup>

To better illustrate the role played by the stochastic liquidation cost  $\xi_t$ , we can substitute  $\bar{V}(b_{t+1}) = V_t(b_t) - d_t$  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  $\xi_t$  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,  $\phi \bar{V}_t(b_{t+1}) - \xi_t$ .<sup>3</sup>

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

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

subject to:

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

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

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

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<sup>2</sup>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  $\xi_t$  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.

<sup>3</sup>We can also think of  $\xi_t$  as a liquidity shock along the lines of Kiyotaki and Moore (2008).

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

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

$$(1 + \phi\mu)REm' = 1, \quad (5)$$

where  $\mu$  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  $\mu$  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 with the interest rate and wage rate constant. These properties can be seen directly from the first order conditions. Condition (5) shows that  $\mu$  decreases with the expected discount factor,  $Em'$ . An increase in  $\xi$ , that is, a negative credit shock, makes the enforcement constraint tighter. Because firms are forced to reduce the dividends, the investors's consumption decreases. This induces a decline in the discount factor  $m' = \beta u_c(d')/u_c(d)$  and an increase in the multiplier  $\mu$  (condition (5)). Condition (4) then shows that the demand for labor declines.

Essentially, 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-term) it has to cut employment. We should notice that, if investors are risk-neutral, the discount factor is equal to  $Em' = \beta$  and the credit shock does 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 household-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  $\delta$  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:

$$U_h(c_t, h_t) + w_t U_c(c_t, h_t) = 0, \quad (6)$$

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

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,  $\xi$ , 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 (12); (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  $\xi$ .*

### 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  $\mu$  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  $\beta$  is sufficiently smaller than  $\delta$ , 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  $\xi$  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  $\xi$  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  $\xi$  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  $\mu$  changes which in turn affects the demand for labor (see condition (4)), changing employment and output. For a more general specification of workers' preferences,

there will be income effects on the supply of labor. We will study these general equilibrium effects quantitatively.

## 2.4 The economy with mobility of capital

We now consider the open economy version of the model with two symmetric countries. The model can be easily extended to any number of countries and with different degrees of heterogeneity. Each country has the same characteristics as those described in the previous section. The shocks  $z$  and  $\xi$  are country-specific and they follow a joint Markov process.

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 ownership of firms. Therefore, in a financially integrated economy, investors own the worldwide portfolio of shares. This 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.

Households/workers can engage in international borrowing and lending. Notice that, whether the international borrowing and/or lending is done by workers or firms is irrelevant. We are assuming international borrowing and lending from households/workers only for convenience. The equilibrium will be exactly the same if firms were allowed to borrow directly in international markets. Another way to think about our assumption is that there are risk neutral intermediaries who intermediates funds between households and firms, domestic and foreign.

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

$$w_t h_t + b_t + n_t = c_t + \frac{b_{t+1}}{R_t} + \frac{n_{t+1}}{\tilde{R}_t}$$

where  $\tilde{R}_t$  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, which reads:

$$\delta \tilde{R}_t E_t \left\{ \frac{U_c(c_{t+1}, h_{t+1})}{U_c(c_t, h_t)} \right\} = 1 \quad (8)$$

Combining (7) with (8) we get  $R_t = \tilde{R}_t$ , which implies the equalization of the interest rates

across countries.<sup>4</sup>

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 states  $z, \xi, \tilde{z}, \tilde{\xi}$ , the bond issued by the firms of both countries,  $B$  and  $\tilde{B}$ , and the foreign position of the domestic country  $N$  (or alternatively of the foreign country  $\tilde{N} = -N$ ).

**Definition 2.2 (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  $\tilde{V}(\mathbf{s}; b)$ ; (iv) aggregate prices  $w(\mathbf{s}), R(\mathbf{s}), \tilde{w}(\mathbf{s}), \tilde{R}(\mathbf{s}), m(\mathbf{s}, \mathbf{s}')$ ; (v) aggregates of domestic and foreign bonds held by workers,  $N, B^w, \tilde{N}, \tilde{B}^w$ , and firms,  $B^f, \tilde{B}^f$ ; (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 (12); (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  $z, \xi, \tilde{z}, \tilde{\xi}$ .*

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  $N + \tilde{N} = 0$ . This is in addition to the clearing conditions for the domestic markets, that is,  $B^w = B^f$  and  $\tilde{B}^w = \tilde{B}^f$ .

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

**Proposition 2.2** *Consider a negative credit shock only to country 1. In the autarky regime only the employment of country 1 changes. In the regime with capital mobility 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 and by the same magnitude. This can be easily seen from the first order

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<sup>4</sup>It is well known that with international borrowing and lending, the stock of debt is not stationary, posing some problems in the quantitative study of the dynamic system. To avoid this problem, in the quantitative section we assume that there is a very small cost of lending abroad which is proportional to the aggregate net foreign asset position of the domestic country. Denoting by  $N_t$  the net foreign position of the country, the cost per unit of foreign holding is  $\psi N_t$ . Here  $\psi$  is a parameter that is positive but very small. The first order condition for holding domestic and foreign bonds becomes  $R_t = \tilde{R}_t(1 - \psi \cdot N_t)$ . Therefore, the interest rate is always lower in the country with a positive foreign asset position. However, because  $\psi$  is very small, the interest rate differential is also small.

conditions of firms, equations (4) and (5). Because investors are globally diversified, domestic and foreign firms use the same discount factor. Furthermore, because the interest rate is equalized worldwide, we can then see from equation (5) that the change in  $\mu$  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 will be 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 the 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  $\mu$  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 2.3** *Consider a negative credit shock only to country 1. If country 1 is a small open economy, then 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 relative 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 of 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.

### 3 General model with capital accumulation

There are two production inputs, physical capital  $k_t$  and labor  $h_t$ . The production function of an individual firm takes the form  $y_t = z_t(k_t^\theta h_t^{1-\theta})^\nu = F(z_t, k_t, h_t)$ . Capital depreciates at rate  $\tau$  and there is a cost associated with changing the stock of capital. Given  $i_t$  the investment, the law of motion for the stock of capital is:

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

where the function  $\Upsilon(.,.)$  is strictly increasing and concave in both arguments.

With capital accumulation the budget constraint of the firm becomes:

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

and the enforcement constraint:

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

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

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

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,

$$Q = (1 + \phi\mu)Em' \left[ (1 - \mu')F_k(z', k', h') + (1 - \delta + \Upsilon_k(k', i'))Q' \right] \quad (13)$$

## 4 Parametrization

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 of investors, which we set to the quarterly value of  $\beta = 0.9825$ . This implies a yearly return of about 7%.

The utility function of workers takes the log form  $U(c, h) = \alpha \ln(c) + (1 - \alpha) \ln(1 - h)$ , with  $\alpha = 0.348$ . This implies a steady state value of hours equal to 1/3. For investors we also use the log specification  $u(c) = \ln(c)$ .

The parameter  $\phi$  affects the enforcement of contracts. Higher is the value of  $\phi$  and higher is the leverage. We choose  $\phi$  to have a steady state leverage of 0.5. The leverage is defined as  $b_t/k_t$ . The required value is  $\phi = 0.073$ .<sup>5</sup>

The return-to-scale parameter is set to  $\nu = 0.9$ . If we interpret the return to scale as deriving from market power, then  $1/\nu - 1$  is the markup over the average cost. Thus,  $\nu = 0.9$  implies a mark-up of 10 percent, which is the value usually used in macro studies.

Next we set  $\theta$  so that the steady state share of wages in output is 60 percent. In the model, the share of wages is equal to  $\nu(1 - \theta)[1 + (1 - \delta/\beta)/\phi]$ . Given  $\nu = 0.9$ ,  $\phi = 0.073$ ,  $\delta = 0.9925$  and  $\beta = 0.9825$ , the required value of  $\theta$  is 0.333. The depreciation rate for physical capital is set to  $\tau = 0.02$ .

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

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

---

<sup>5</sup>Notice that the leverage also depends on other parameters. Therefore, the required value of  $\phi$  is chosen through an iterative procedure: We choose  $\phi$ , pin down all the other parameters, solve for the steady state and verify that the leverage ratio is 0.5.

The parameter  $\varphi$  is set to generate a reasonable volatility of investment in the regime with capital mobility. The chosen value is  $\varphi = 0.0003$ .

We are now left with the parameters of the stochastic processes for the productivity and credit shocks,  $z$  and  $\xi$ . We assume that the two shocks are independent from each other and they both follow a first order autoregressive process, that is:

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

where  $\epsilon \sim N(0, \sigma_z)$  and  $\varepsilon \sim N(0, \sigma_\xi)$ .

Given the processes for the two shocks we have four parameters:  $\rho_z$ ,  $\sigma_z$ ,  $\rho_\xi$ ,  $\sigma_\xi$ . We start by setting  $\rho_z = \rho_\xi = 0.95$ ,  $\sigma_z = 0.01$ ,  $\sigma_\xi = 0.05$ . The whole set of parameter values are summarized in Table 1.

Table 1: List of parameters.

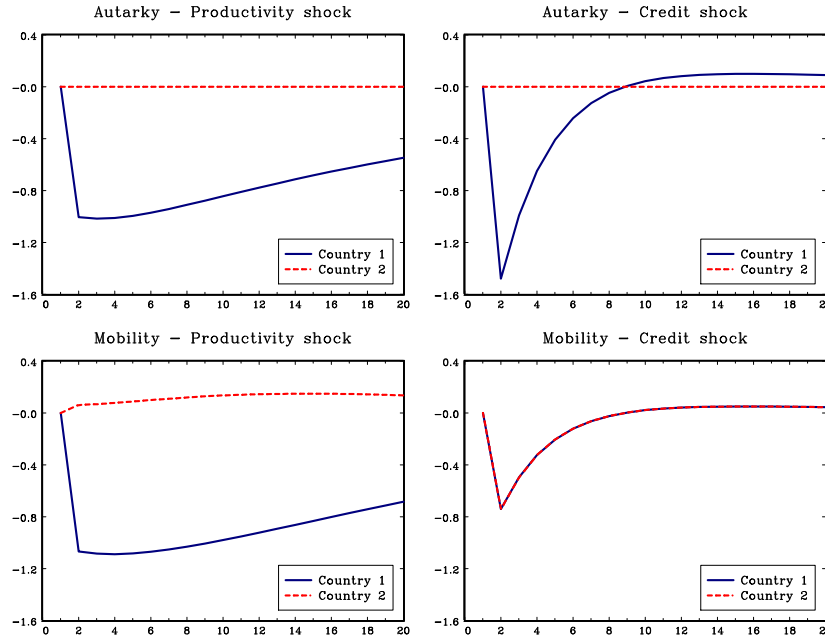
<i>Calibrated parameters</i>	
Discount factor for households/workers, $\delta$	0.9925
Discount factor for entrepreneurs, $\beta$	0.9825
Utility parameter, $\alpha$	0.3481
Production technology, $\theta$	0.3328
Depreciation rate, $\tau$	0.0200
Return to scale, $\nu$	0.9000
Enforcement parameter, $\phi$	0.0733
Adjustment cost parameter, $\varphi$	0.0003
Productivity persistence, $\rho_z$	0.9500
Productivity volatility, $\sigma_z$	0.0100
Credit shock persistence, $\rho_\xi$	0.9500
Credit shock volatility, $\sigma_\xi$	0.0400

## 4.1 Impulse responses

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 in country 1 only. 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:

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

$$Q = (1 + \phi\mu)Em' \left[ (1 - \mu')F_k(z', k', h') + (1 - \delta + \Upsilon_k(k', i'))Q' \right], \quad (15)$$

$$(1 + \phi\mu)REm' = 1. \quad (16)$$

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  $\mu$  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. With 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 because investors are perfectly diversified, thus investors' 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

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

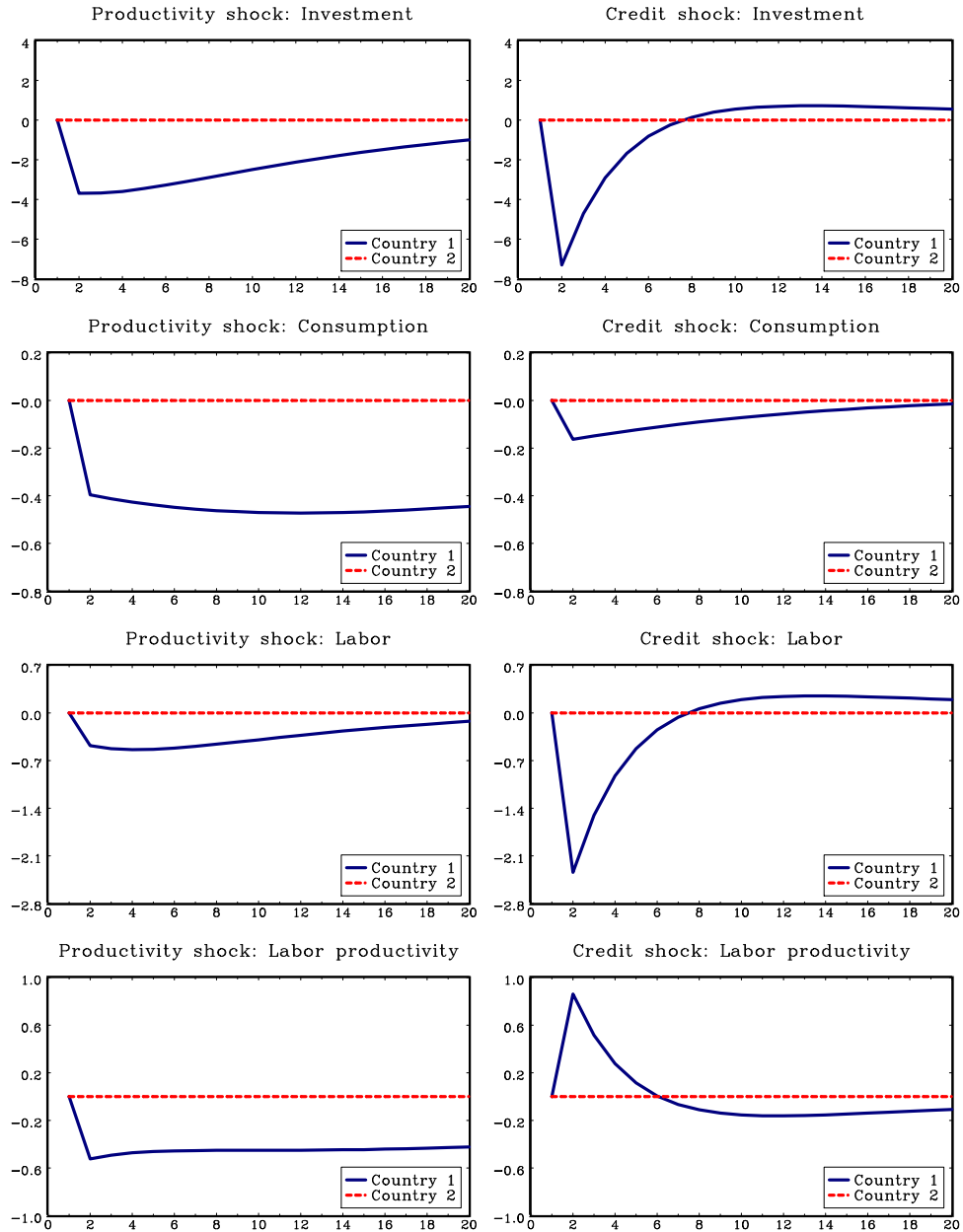
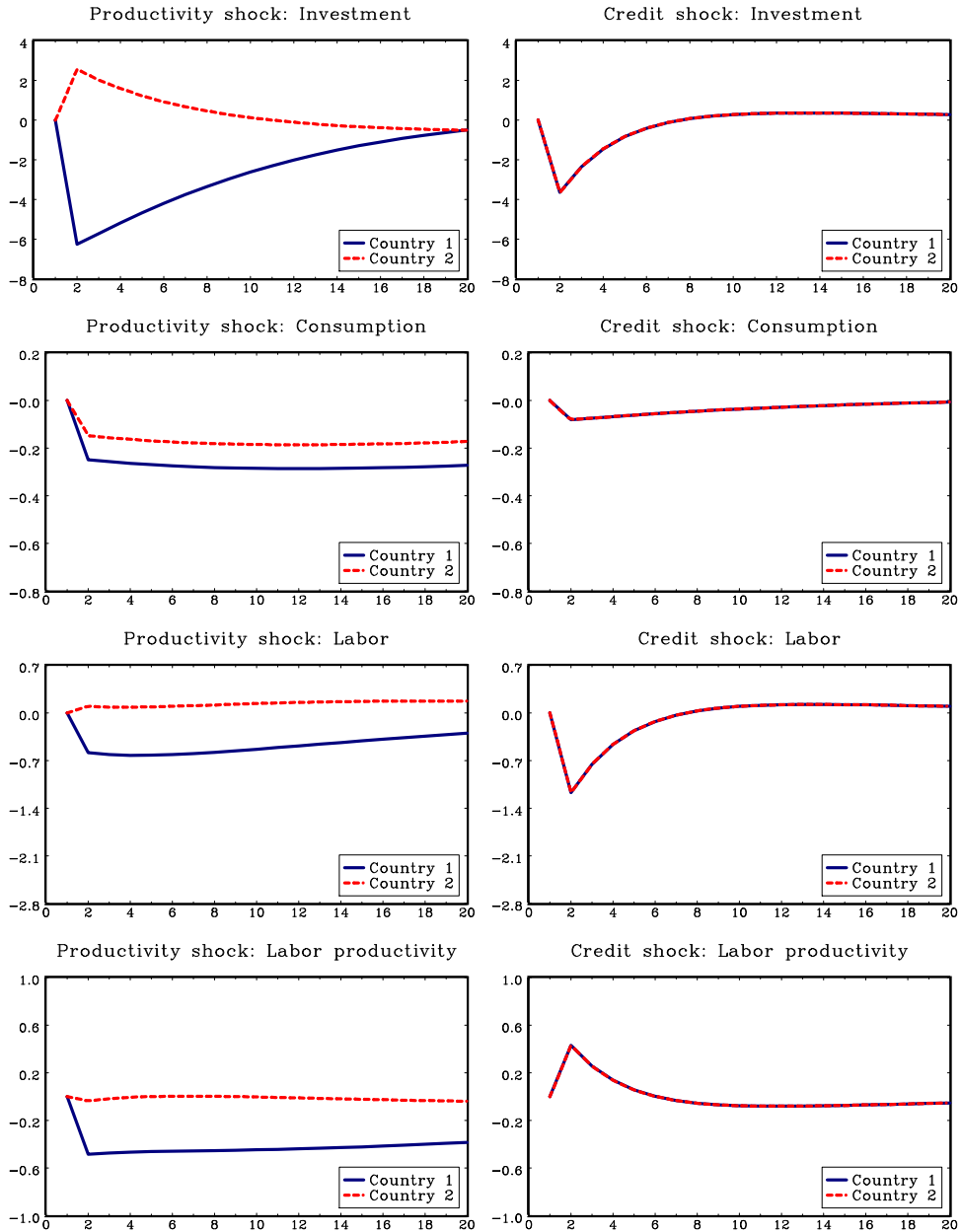


Figure 10: Financial integration (regime with perfect mobility of capital). Impulse responses to productivity and credit shocks in country 1 only.



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 Conclusion

This paper investigates one of the potential mechanisms underlying the international spillover of recessionary episodes and of the 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 the major 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. Credit 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. 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 output unless the shocks are internationally correlated. But if productivity shocks are correlated across countries and they have been the major source of business cycle fluctuations, it is difficult to reconcile the fact that the correlation of labor productivity with hours has declined in recent years.

We conclude that the current recession and its international transmission could be explained by a large credit shock. This shock, even if originates in only one country, could easily be

transmitted to other countries thanks to the high degree of capital markets integration. Thus credit shocks are important for understanding the international business cycle. Although the paper illustrates the macroeconomic importance of these shocks, it does not provide an explanation of what could cause a credit shock. More research is needed to identify the sources of these shocks.

## 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  $\xi_t$ . However, the price obtained through the sale is only a fraction  $\phi < 1$  of the original value of equity, that is,  $\phi\bar{V}_t(b_{t+1})$ .

If the parties reach an agreement, 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  $\bar{V}_t(b_{t+1}) - T_t$ . Without reaching an agreement the entrepreneur gets zero. For the lender, the value received under renegotiation is  $T_t$ . Without renegotiation it will get the liquidation value  $\phi\bar{V}_t(b_{t+1}) - \xi_t$ . Notice that, independently of whether the lender reaches an agreement or not, it will receive  $b_{t+1}$  in the next period.

The bargaining problem is:

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

where  $\chi$  is the bargaining power of the firm.

The first order conditions are:

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

Solving the first order condition for the transfer we get:

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

Therefore, the renegotiation value received by the firm is:

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

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

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

Collecting terms and re-arranging we get:

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

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  $\phi$ . 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 (12) and let  $\lambda$  and  $\mu$  be the Lagrange multipliers associate with the two constraints. Taking derivatives we get:

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

The envelope condition is:

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

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

## C Dynamic system

We have to solve for the variables  $k_{t+1}$ ,  $b_{t+1}$ ,  $n_{t+1}$ ,  $\mu_t$ ,  $w_t$ ,  $h_t$ ,  $c_t$ ,  $d_t$ ,  $i_t$ ,  $V_t$ ,  $R_t$ ,  $Q_t$  in country 1 and for the corresponding variables in country 2 as a function of the states,  $z_t$ ,  $\xi_t$ ,  $k_t$ ,  $b_t$ ,  $n_t$ , 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:

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

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,

$$\begin{aligned}
R_t - \tilde{R}_t &= 0 \\
n_t + \tilde{n}_t &= 0.
\end{aligned}$$

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