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Re-examining the Role of Financial Constraints in Business Cycles: Is Something Wrong with the Credit Multiplier?*

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Abstract: Motivated by the apparent failure of the credit multiplier mechanism (CM) to deliver amplification in DSGE models, we re-examine its role in business cycles to address the question: is something wrong with the CM? Our answer is no. In coming to this answer we construct a model with reproducible capital and collateral constraints within two setups, a closed and a small open economy. Our results from the first model do not differ from the ones of previous papers. However, our main finding is that it is not the CM what fails in this type of models, but rather their ability to produce sufficient variability in prices. In particular, in this model, general equilibrium dynamics counteract the logic of price fluctuations described by theoretical models thus preventing the CM from being triggered. The second model allows us to confirm our previous claim: absent general equilibrium effects, when feeding the model with exogenous asset price dynamics, the CM is indeed an effective amplifying mechanism of shocks into the economy.
Keywords: Collateral constraints, Credit multiplier, Asset prices.
JEL Classification: E21, E22, E32, E44.

Resumen: Dada su aparente incapacidad para producir amplificación en modelos de tipo DSGE, en este documento se reexamina el papel del multiplicador crediticio (MC) en el ciclo económico para determinar si existe algún problema con él. La respuesta es no. Para llegar a esta aseveración se desarrolla un modelo con capital reproducible y restricciones de colateral en dos contextos, uno de economía cerrada y otro de economía pequeña y abierta. Los resultados del primer modelo no difieren de otros resultados encontrados en la literatura. Sin embargo, la principal conclusión es que lo que falla en este tipo de modelos no es el MC sino su inhabilidad para generar suficiente variabilidad de precios. En particular, en este modelo, la dinámica de equilibrio general contrarresta la lógica detrás de las fluctuaciones de precios descrita por los modelos teóricos, lo que evita que el MC se detone. El segundo modelo permite confirmar que en ausencia de efectos de equilibrio general, cuando la dinámica del precio de los activos es exógena, el MC es un mecanismo amplificador de choques efectivo.
Palabras Clave: Restricciones de colateral, Multiplicador crediticio, Precio de activos.

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1 Introduction

"Business cycles appear to be large, persistent and asymmetric relative to the shocks hitting the economy".[1] One of the explanations that have been offered as to what lies behind this observation, states that there is some underlying mechanism in the economy that transforms small, temporary shocks into large and persistent aggregate output fluctuations. In this line, many theoretical papers suggest that financial frictions provide this mechanism, and thus play a key role in amplifying and propagating macroeconomic shocks (see Bernanke and Gertler (1989) and Kiyotaki and Moore (1997)). These papers model financial frictions as endogenous borrowing constraints that depend on the degree of agents' solvency and limit the extent to which productive projects can be externally financed. In particular, Kiyotaki and Moore (1997), henceforth KM, consider an economy where assets serve both as factors of production and collateral for loans. The fact that assets have two roles is key, since it determines that not only will agents' borrowing constraint limits depend on the value of their assets, but also, the price of these assets will be affected by the size of the credit limits. The dynamic interaction between asset prices and credit limits that is triggered when the economy is hit by a shock is thus capable of generating large and persistent fluctuations in output and asset prices. This mechanism is usually referred to as the credit multiplier. Despite theoretical consensus on the key role of financial frictions in amplifying and propagating macroeconomic shocks, quantitative papers that embed the credit multiplier into fully fledged DSGE models conclude that although credit constraints delay the velocity at which productivity shocks propagate into the economy, they have no significant amplification effects, with the exception of special cases.[2] All in all, the size of the multiplier is still an open question, and it is unclear why in some model economies it is quantitatively important, and why in some others it is not.

Motivated by these results, in this paper we re-examine the quantitative role of financial frictions in business cycles to address the following question: is there something wrong with the credit multiplier? Our answer is no. In arriving to this conclusion, we work with a model with reproducible capital and collateral constraints within two setups, a closed and a small open economy. Our results from the

[1] This is how Kocherlakota (2000) describes output fluctuations over the years. See Kocherlakota (2000), p. 2.

[2] See, for instance, Kocherlakota (2000) and Cordoba and Ripoll (2004a) for models with a fixed factor in which amplification only arises under specific combinations of parameters. Chen (2001), Krishnamurthy (2003), Cordoba and Ripoll (2004b), Aoki, Benigno and Kiyotaki (2009) and Liu, Wang and Zha (2009) are other examples of models in which amplification may occur; however, their setups also include fixed assets and/or constitute major departures from simple DSGE models of credit constraints, making the source of amplification difficult to disentangle. Liu, Wang and Zha (2009), for example, consider land together with capital as collateral for loans and analyze demand shocks to housing as opposed to TFP shocks. Cordoba and Ripoll (2004b) and Aoki, Benigno and Kiyotaki (2009) also consider fixed assets as collateral for loans while Krishnamurthy (2003) proposes a theory of incomplete hesging in which the supply of hedging available in the economy is constrained by the aggregate value of collateral. Finally, Chen (2001) considers a model in which not only entrepreneurs but also banks are constrained, and includes bank capital and durable assets as collateral.

first model in terms of propagation and amplification do not differ from previous papers. However, we find that it is not the credit multiplier what fails in this type of models, but rather their ability to produce sufficient variability in prices. In a closed economy model with reproducible capital, this happens because the general equilibrium dynamics dampen the response of asset prices to a productivity shock, thus reducing their effect on borrowing constraints and preventing the credit multiplier from being triggered. Moreover, potential fixes such as adding adjustment costs to capital accumulation or an asset in fixed supply do not solve this problem. Our small open economy setup, allowing for exogenous asset price dynamics, confirms the previous claim: absent general equilibrium effects, the credit multiplier is indeed effective in amplifying shocks, generating large investment and output fluctuations.

We begin our analysis by introducing collateral constraints in the production of capital goods in an otherwise standard RBC model. The fact that capital is reproducible and that it is the only asset that can be used as collateral in the economy is one of the main distinctions of the model with respect to other papers that have tested the propagation and amplification of shocks in models with collateral constraints (see, for example, Kocherlakota (2000), Cordoba and Ripoll (2004a) and Liu, Wang and Zha (2010)). In our setup, collateralized debt arises from a limited commitment problem on the borrower's side and collateral is given by the value of total production of the constrained agent at the end of each period. A key feature then is that collateral is not fixed and thus its value may vary not only because of price changes but also due to quantity changes.

We find that a model with these features is capable of delivering more than 25% more propagation relative to its frictionless counterpart; however, in terms of amplification, not only does the model not display amplification of the magnitude predicted by the theory, but it also performs worse than a model with the same characteristics but without frictions (roughly 20% less amplification). The main reason underlying the last result is that when we allow capital to be reproducible, the general equilibrium effects that arise counteract the logic of asset price fluctuations described in theoretical models. The generated volatility is not only not enough to generate the necessary increase in the price of capital so as to obtain quantitatively significant amplification but is also substantially smaller than that observed in the data (0.56% versus 10.35%, respectively).[3] The intuition behind this is the following: when the economy is hit by a negative productivity shock, the relative surplus of capital generated is partially offset by the decrease in investment that takes place immediately after the shock, which in turn dampens the variability of asset prices. One could argue that the small decrease in prices could potentially be offset by the decrease in investment, however, in our model this decrease is much lower than the one that would be needed to offset the small price effect on credit limits. Thus, the countervailing effect observed prevents the credit multiplier mechanism from being triggered and hence is key to understand the lack

[3] The price of capital is approximated by the S&P 500 market price deflated by the price of non-durable goods and services. All volatilities are computed as the standard deviation of the HP-filtered data from 1952:Q1 to 2009:Q3.

of amplification under our closed economy setup.[4]

This motivates our second exercise, a small open economy analysis in which we isolate the credit multiplier from general equilibrium dynamics to test whether, when being fed with empirically plausible changes in asset prices, it delivers a higher degree of output amplification. Specifically, we abstract from household behavior and focus on the lending relationship and investment decisions of entrepreneurs, taking the volatility of the price of capital as given. As mentioned before, the results from this exercise confirm our claim that, absent the general equilibrium effects, the credit multiplier is an effective amplifying mechanism of shocks into the economy. Furthermore, when calibrated to match realistic price movements, our small open economy model generates investment volatility of the same order of magnitude as those obtained in the closed economy model and in the RBC (4.85%, 4.06% and 7.27%, respectively).

Our model is closely related to that of Carlstrom and Fuerst (1997), henceforth CF, who develop a computable general equilibrium model where physical capital producers face endogenous agency costs that limit their access to credit. Their main findings suggest that although agency costs cause a delay in the change of aggregate investment, enhancing the persistence of productivity shocks which in turn help replicate the hump-shaped response of output found in the data, they fail to produce an amplified response of output to shocks. We depart from CF's framework in that borrowing constraints arise from limited enforceability of contracts, instead of from endogenous agency costs. In this way, we are able to test the quantitative significance of the credit multiplier as described by KM and revise the role that asset prices play in generating persistence and amplification within a setup that, if financial frictions were removed, collapses to a standard RBC model. Our paper contributes to the literature on financial frictions by showing that the lack of amplification in these models should not be attributed to the failure of the credit multiplier mechanism but rather to the general equilibrium dynamics that dampen the variability of asset prices and do not allow the credit multiplier to come to be.

The rest of the paper is organized as follows. Section 2 presents the benchmark closed economy model. Section 3 describes its calibration and main results, as well as some robustness checks. Section 4 introduces the small open economy version of our model and comments on its results. Finally, Section 5 concludes.

[4] Our results are robust when changing relevant parameter values.

2 The benchmark model

2.1 General features of the economy

Consider an economy populated by a continuum of infinitely lived agents of two types, households and entrepreneurs. Both types of agents have unit mass. The entrepreneurs produce capital goods from consumption goods using a linear technology, for which they need external financing as well as their own income. The economy is also populated with a firm producing a single consumption good, and a risk neutral capital mutual fund (CMF) that acts as intermediary between the households' resources and entrepreneurials' financing needs.

A productivity shock to the consumption goods sector is realized at the beginning of the period. The sequence of events within a given time period following the realization of this shock is the following:

1. The consumption goods producing firm hires labor and rents capital from households and entrepreneurs and production takes place.

2. Households decide how much to consume and invest. For each unit of capital that a household wishes to purchase, she gives q_t units of consumption goods to the CMF, where q_t is the price of capital.

3. The CMF uses the resources obtained from households to provide loans to the entrepreneurs.

4. Entrepreneurs invest the resources borrowed, together with their own net worth, into their capital production technology.

5. Finally, entrepreneurs repay their loans and make consumption and investment decisions.

An important feature of this economy is that if a household wishes to purchase capital she will do so by lending funds to the entrepreneurs through the CMF. The CMF will then lend the resources to the entrepreneur and a loan contract will be established. In this contract debt is collateralized, thus making credit limits endogenous. This arises because entrepreneurs cannot commit to repay their loans, and therefore must provide a collateral as a way of securing their debts. The financial contract will be explained in detail when we talk about the problem of the entrepreneur. Having described briefly the general features of the economy, we go on now to describe the problem of each agent.

2.2 Households

The representative household's problem is given by:

$$\max_{\{c_t^H,\, k_{t+1}^H,\, l_t^H\}_{t=0}^{\infty}} E_t \sum_{t=0}^{\infty} \beta^t U(c_t^H, 1 - l_t^H)$$

$$s.t. \qquad c_t^H + q_t(k_{t+1}^H - (1-\delta)k_t^H) \leq w_t^H l_t^H + r_t k_t^H$$

where E_t denotes the expectational operator conditional on time t information, $\beta \in (0,1)$ is the time discount factor, c_t^H, k_t^H and l_t^H are household's consumption, stock of capital and labor supply, respectively, all in period t. Leisure endowment is normalized to one. Every period, the household sells her labor and rents last period's accumulated capital to the consumption good producing firm at a wage rate w_t^H and rental rate r_t, respectively. They also purchase consumption goods at a price of 1, and capital goods, with the assistance of the CMF, at price q_t.

Household's choices are summarized in the Euler equation:

$$q_t = \beta E_t[\frac{U_c(c_{t+1}^H, 1 - l_{t+1}^H)}{U_c(c_t^H, 1 - l_t^H)}(r_{t+1} + (1 - \delta)q_{t+1})] \quad (1)$$

and the labor leisure condition:

$$U_l(c_t^H, 1 - l_t^H) = U_c(c_t^H, 1 - l_t^H)w_t^H \quad (2)$$

where δ is the rate of depreciation on capital.

2.3 Consumption good producing firm

Consumption goods are produced using a standard constant returns to scale production function. The firm's problem is given by:

$$\max_{\{k_t^d,\, l_t^{Hd},\, l_t^{Ed}\}} F(k_t, l_t^H, l_t^E) - r_t k_t - w_t^H l_t^H - w_t^E l_t^E$$

$$\text{where} \qquad F(k_t, l_t^H, l_t^E) = \theta_t (k_t)^{\alpha_k} (l_t^H)^{\alpha_h} (l_t^E)^{\alpha_E} \quad (3)$$

$F(k_t, l_t^H, l_t^E)$ denotes aggregate output, k_t, l_t^H and l_t^E are the firm's demand for capital, household and entrepreneurial labor, respectively. α_k, α_h and α_E are their respective shares in output and w_t^E is the wage rate for entrepreneurial labor. Finally, θ_t is the productivity shock. Competition in the factor markets implies that wages and the rental rate are equal to their marginal products:

$$r_t = \alpha_k F_t / k_t \quad (4)$$

$$w_t^E = \alpha_E F_t / l_t^E \quad (5)$$

$$w_t^H = \alpha_H F_t / l_t^H \quad (6)$$

2.4 Entrepreneurs

It is useful to define the representative entrepreneur's problem as consisting of 5 steps:1. The entrepreneur rents his capital and inelastically supplies his labor to the consumption goods producing firm. After the production of consumption goods takes place, he sells his undepreciated capital to the CMF for consumption goods to build up net worth (expressed in consumption units):

$$n_t = w_t^E + k_t^E[q_t(1 - \delta) + r_t] \quad (7)$$

where n_t is net worth and k_t^E denotes capital holdings of the entrepreneur at the beginning of the period.

2. He borrows resources from the households, through the CMF, using his net worth as the basis of the loan contract:

$$i_t - n_t$$

where i_t is investment at time t.

Two key assumptions about the entrepreneur are implicit in the contract. First, the entrepreneur's technology is idiosyncratic in the sense that, once his production has started, only he has the skill necessary to finish it and second, the entrepreneur cannot precommit to repay his loan.[5] This makes the creditors want to secure themselves by not allowing the value of debts to exceed the value of the entrepreneur's collateral, which in turn makes borrowing constraints endogenous in this contract. More specifically, through the contract, the entrepreneur agrees to borrow $i_t - n_t$ and to repay d_t to the lender at the end of the period, after all production has taken place. He will choose to default if the value of his production net of repayment is lower than the value he obtains when defaulting, given by a fraction χ of the value of his production.[6] That is, the entrepreneur will choose to maximize the following expression:

$$\max\{\underbrace{q_t z i_t - d_t}_{\text{if no default}};\ \underbrace{\chi q_t z i_t}_{\text{if default}}\}$$

where $z i_t$ is the entrepreneur's capital goods production technology with z representing his exogenous productivity. Thus, for the contract to be self-enforcing, d_t must be set such that the entrepreneur will always choose not to default in equilibrium. This condition is given by:

$$d_t \leq (1-\chi) q_t z i_t$$

which ensures that:

$$\max\{q_t z i_t - d_t; \chi q_t z i_t\} = q_t z i_t - d_t$$

Hence, the optimal contract is given by the solution to:

$$\max_{\{i_t\}} q_t z i_t - d_t$$

$$\begin{aligned} s.t \qquad i_t - n_t &= d_t \\ (1-\chi) q_t z i_t &\geq d_t \\ q_t z i_t - d_t &\geq n_t \end{aligned}$$

[5] To make his commitment problem relevant, we assume that the entrepreneur will always want to invest more than his net worth. This implies assuming that net worth is sufficiently small which is achieved by making the entrepreneur more impatient than the household.

[6] Note that there is no penalty from defaulting, if the entrepreneur defaults one period, he is not banned from participating in the loan market in the next. Thus, the contract is based solely on entrepreneurial net worth and not on past outcomes.

where the first constraint represents the break-even condition for the lender, and the second and third represent the borrowing constraint and the participation constraint for the entrepreneur, respectively. Two key things are worth noting here. First, the participation constraint will never bind, which will ensure that the return to internal funds is greater than the return to external funds (which is one, given the intra-period nature of the loans), thus providing incentives for the entrepreneur to accumulate as much net worth as possible and invest it all in his project.[7] Second, the borrowing constraint will always bind. This is due to the linear nature of the capital goods production technology as well as to the return to internal funds being greater than one, both of which make the entrepreneur want to invest as much as possible to maximize his income.

Finally, from the break-even condition and the borrowing constraint, we can solve for the amount of loans and investment:

$$d_t = \frac{(1-\chi)q_t z}{1-(1-\chi)q_t z} n_t$$

and

$$i_t = \frac{1}{1-(1-\chi)q_t z} n_t \tag{8}$$

From these equations we can see that investment, and thus capital production, as well the total amount of loans, are increasing functions of the entrepreneur's net worth n_t and the price of capital q_t. This is what lies at the heart of the credit multiplier described in theoretical papers on collateral constraints, that is, the mechanisms capable of amplifying and propagating macroeconomic shocks.

3. He invests i_t in his capital goods production technology.

4. The entrepreneur repays his loan:

$$d_t = (1-\chi)q_t z i_t \tag{9}$$

5. Finally, he consumes and accumulates capital. His maximizing problem at the end of the period is given by:

$$\begin{aligned} \max_{\{c_t^E,\, k_{t+1}^E\}_{t=0}^{\infty}} \quad & E_t \sum_{t=0}^{\infty} (\beta\gamma)^t U(c_t^E) \\ s.t. \quad & c_t^E + q_t k_{t+1}^E \leq R_t n_t \\ \text{where} \quad & R_t = \frac{(q_t z i_t - d_t)}{n_t} = \frac{\chi q_t z i_t}{n_t} \end{aligned} \tag{10}$$

where c_t^E is entrepreneurial consumption, k_{t+1}^E is his demand for new capital, R_t is the return to internal funds and $\beta\gamma$ is the time discount factor. We assume here that entrepreneurs discount the future more heavily than households and thus $\gamma \in (0,1)$. As mentioned before, this is to ensure that entrepreneurial consumption is always positive and self-financing never occurs. Without this assumption, and given the high return to internal funds, entrepreneurs would postpone consumption and accumulate as much

[7] The model will be calibrated so as to ensure this is true.

capital as possible so that they are completely self-financed, thus making the commitment problem and credit constraints irrelevant.

The Euler equation for the entrepreneur is given by:

$$q_t = \beta\gamma E_t[\frac{U_c(c^E_{t+1})}{U_c(c^E_t)}(r_{t+1} + (1-\delta)q_{t+1})]R_{t+1} \tag{11}$$

2.5 CMF

The key role of the CMF is to act as an intermediary between households, who want to purchase capital and are ultimately the lenders in this economy, and entrepreneurs, who produce the capital. It thus acts as a cooperative, by which capital can be efficiently purchased. Note that the capital the household buys comes from three different sources: *i*) undepreciated capital sold by entrepreneurs to the CMF after consumption goods production has taken place, *ii*) new capital goods the CMF receives as repayment for their loans and *iii*) new capital that entrepreneurs must sell off to finance their end of period consumption.

2.6 Equilibrium

A competitive equilibrium are sequences of prices $\{r_t, w^H_t, w^E_t, q_t\}^\infty_{t=0}$, and allocations for households and entrepreneurs $\{c^H_t, k^H_{t+1}, l^H_t, c^E_t, k^E_{t+1}, l^E_t, i_t, n_t, d_t\}^\infty_{t=0}$ such that, given prices and k_0, allocations solve the household's, the consumption goods firm's and the entrepreneur's problems (equations (1) to (11) hold) and markets clear:

$$F_t = c^H_t + c^E_t + i_t \tag{12}$$

$$G_t = zi_t = k_{t+1} - (1-\delta)k_t \tag{13}$$

$$k^H_t + k^E_t = k_t \tag{14}$$

$$l^{H,d}_t = l^{H,s}_t \tag{15}$$

$$l^E_t = 1 \tag{16}$$

3 Calibration and results

In this section we first describe the calibration of the benchmark model, then we compare its impulse response functions to a productivity shock to its frictionless counterpart and comment on the results, and finally, we present some robustness checks.

3.1 Calibration

The model is calibrated on a quarterly basis. Households' discount factor, β, is set to 0.9913, thus implying a real annual interest rate of 4%. Following CF, we assume that $U(c_t^H, 1-l_t^H) = \ln c_t^H + \nu(1-l_t^H)$ where ν is set to 2.91 so as to match a steady state labor participation rate of households of 0.3.

The values of factor shares in the production of final goods, α^K, α^H and α^L, are set to 0.36, 0.6399 and 0.0001, respectively. Notice that entrepreneurial labor share is positive but very small to ensure that net worth is not driven by labor dynamics. The annual depreciation of capital is assumed to be 10%, hence δ is set to 0.025. The value of γ is set to 0.972 so as to match an annual steady state rate of return to internal funds of around 12.31%.[8] Overall, the entrepreneurial discount factor is thus roughly 0.96. We assume that $U(c_t^E) = \frac{(c_t^E)^{1-\phi}}{1-\phi}$ with ϕ equal to 0.01.[9] Finally, we set χ, the fraction of total value of production that the entrepreneur gets to keep in case of default, equal to 0.73 to match a leverage ratio of 38%.[10]

We take a standard stance and assume that the aggregate productivity shock, θ_t, follows an AR(1) process: $\theta_t = a + \rho\theta_{t-1} + \varepsilon_t$ with ρ and a equal to 0.95 and 0.05, respectively, so that the unconditional expected value of θ is 1. ε_t is a zero-mean *iid* innovation with a standard deviation of 0.007. We abstract the analysis from idiosyncratic differences and set the productivity parameter in the capital goods technology, z, to 1. Table 1 summarizes the values of the parameters used.

[8] The average ROE for the main U.S. sectors between 1998 and 2008 equals 12.31%. Data available at http://pages.stern.nyu.edu/~adamodar/.

[9] This assumption differs from CF's linear utility function for the entrepreneur, which implies an IES=∞. Adding a small degree of curvature to the utility function allows us to uniquely pin down entrepreneurial consumption. Notice that the IES in this case is still high (equal to 100) so the results derived from the two cases are quite similar.

[10] This is in line with data on average leverage (measured by debt over net worth) over the last 50 years published in the Flow of Funds Accounts of the U.S. by the Federal Reserve.

Table 1

Parameter values		
Households' discount factor	β	0.9913
Leisure term	ν	2.91
Capital share	α^K	0.36
Households' labor share	α^H	0.6399
Entrepreneurs' labor share	α^E	0.0001
Depreciation	δ	0.025
Entrepreneurs' additional discount factor	γ	0.9720
Entrepreneurs' coefficient of risk aversion	ϕ	0.01
Fraction of value of production going to entrepreneurs if default	χ	0.73
Productivity of capital production technology	z	1
Autorregresive coeff. productivity shock	ρ	0.95
Constant of autorregresive process	a	0.05
Std. deviation productivity shock	σ	0.007

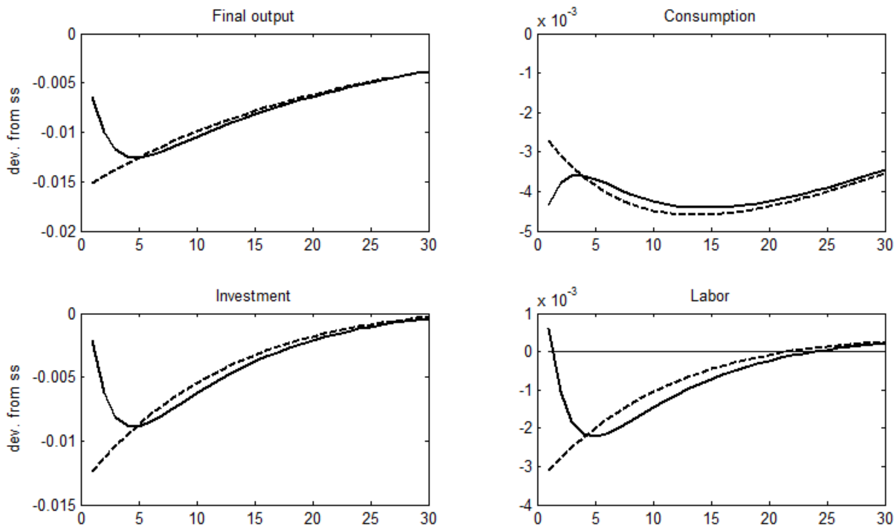
3.2 Results

3.2.1 Impulse response functions

In order to study the role that credit constraints play as an amplification and propagation mechanism of shocks into the economy, we analyze the behavior of our closed model economy when it is hit by a one standard deviation negative shock to aggregate productivity. From now on we will refer to our benchmark model as the CC model. Then, we contrast these results with the ones obtained from a model in which collateralized debt is not present; in this case, the economy collapses to a standard RBC model.[11] Figure 1 presents the impulse response functions of both models.

[11] Notice that when loan contracts are perfectly enforced, the price of capital and hence the return to internal funds, q_t and R_t, are 1 due to the linearity of the technology and the fact that entrepreneurs run their investment projects with zero profits. Given that entrepreneurs discount the future more heavily than households, in steady state they do not accumulate any capital and end up consuming all their income. Hence, the economy takes the form of a standard RBC model in which a small fraction of income flows to entrepreneurs.

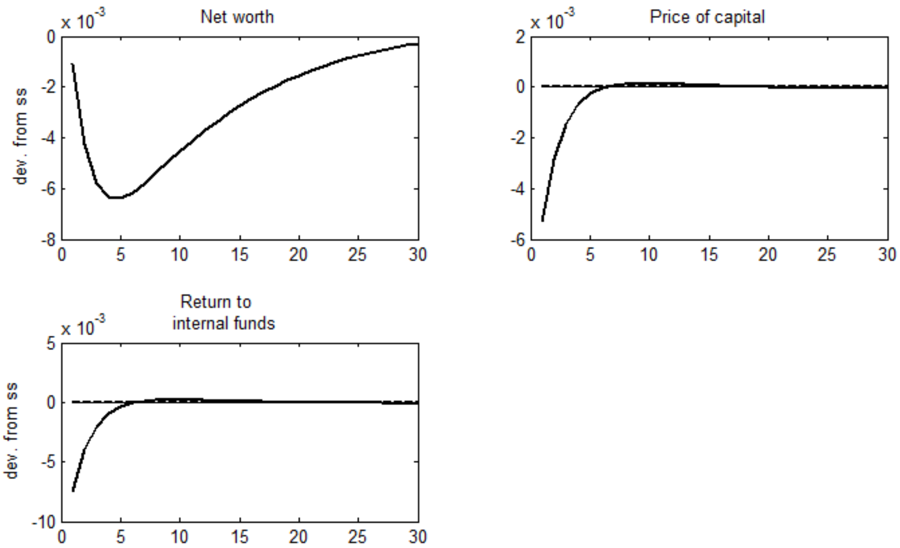
Figure 1a: Impulse response functions



Notes: The solid and dotted lines depict the CC and RBC models' dynamics, respectively.

Figure 1a illustrates the first striking result: with the exception of the first 5 periods, our model with frictions does not behave very differently form a standard RBC model. The reason behind this is the following. When a negative productivity shock hits an economy, wealth falls one-to-one with productivity, and consumption and investment also fall. In a frictionless model, physical wealth is constant and the value of capital does not move, so all the dynamics come from changes in marginal productivity. In our model with frictions, investment is a function of both price of capital and net worth (see equation (8)), and given that net worth is relatively fixed, if the price of capital does not move, there is little chance of getting investment to move much either.

Figure 1b: Impulse response functions



Notes: The solid and dotted lines depict the CC and RBC models' dynamics, respectively.

Figure 1b helps to illustrate this last point. We can see that not only do net worth and the return to internal funds display low volatility in the CC model, but also and most importantly the price of capital, which is almost 20 times less volatile in the model than what we observe in the data (0.56 vs 10.35 respectively).

3.2.2 Propagation and amplification

Table 2 presents some of the statistics derived from the model that help quantify the persistence and magnitude of the movements observed. Propagation is measured as the positive autocorrelation of a variable that is generated when the economy is subject to a shock. In this sense, the hump-shaped response of some of the variables commented above already predicts an increase in the propagation mechanism displayed by the CC model. We use the first order autocorrelation coefficient of the impulse response function to quantify the degree of propagation of a variable. The first row of Table 2 presents its magnitude for final output and investment in the CC model and contrasts them with their counterparts in the RBC model (in parenthesis). As expected, the CC economy displays more than 25% more propagation than the frictionless economy for both output and investment. It is important to highlight that this increased persistence arises solely due to the different reaction of the variables during the first periods after the shock and not due to the degree of persistence that all variables inherit from the dynamics of the productivity shock itself. Another indicative measure of the delayed response of the business cycle dynamics under financial frictions is given by the number of periods that it takes for the different variables to reach their trough after a shock occurs. While in the RBC model all variables respond immediately, reaching their lowest value in period one (the period of the shock) in the CC model variables reach their maximum value in period five. This is consistent with Cogley and Nason (1995) who show that output in the U.S. peaks four quarters after a shock occurs (their exercise is done for a positive shock).

Table 2

Amplification and persistence

	Output		Investment	
Persistence	0.90	(0.71)	0.92	(0.70)
Periods to trough	5	(1)	5	(1)
Max. dev. from ss level (%)	-1.25	(-1.52)	-0.89	(-1.24)

We say that a model displays an amplification mechanism if it succeeds in creating interactions such that the maximum deviation of output from steady state when the mechanism is at work exceeds the maximum deviation reached when the mechanism is not present. As the third row of Table 2 shows, output and investment percentage deviations from their respective steady state in the CC model are smaller (in absolute terms) relative to those in a model with no frictions (21% and 24% less deviation in each case). This is, our model lacks amplification of productivity shocks.

3.2.3 What lies behind the lack of amplification?

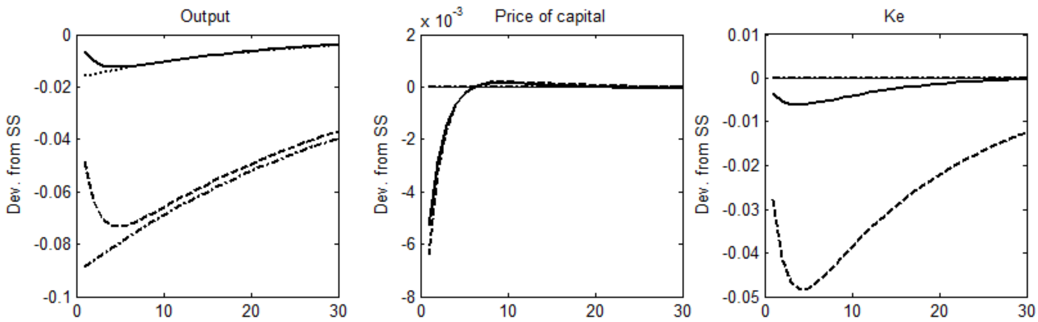
First of all, note that in our model the initial response of output to a productivity shock is smaller than in a model without frictions, and even though output continues to decrease in the period following the shock, this is not enough to generate amplification above that obtained by the RBC. This is different from what we observe in a model with a fixed factor, where the initial response of output to a shock is the same in a model with and without frictions. Thus, any further decrease in output that occurs in a model with frictions and a fixed factor, will deliver amplification above the one obtained by a frictionless model.

The fact that our model has reproducible capital has a strong implication for prices; this is the main reason behind our lack of amplification. When we allow for capital to be reproducible, the effect that a productivity shock has on its price is greatly reduced relative to when capital is fixed. Thus, its effect on the borrowing constraint is also diminished. One can argue that this could potentially be offset by the decrease in investment that takes place when productivity decreases, but in our calibration this decrease is much lower than the one that would be needed to offset the small price effect on credit limits. We would need then a much higher decrease in the price of capital to generate significant capital disaccumulation by entrepreneurs so as to improve upon a model without frictions.

In order to see what is the maximum decrease in price of capital and therefore the maximum amplification that the model is able to deliver, we varied the value of key parameters. Even though we improved relative to our benchmark model, we could never top the model without frictions. In particular, α_k, the share of capital in production, and χ, the parameter that determines the share of the value of total capital production that is used as collateral and hence the amount of loans in the economy, were varied.

Increasing the capital share at the expense of household's labor share greatly increases amplification. However, this is also true in a model without frictions. Figure 2 illustrates these results.

Figure 2: Varying factor shares

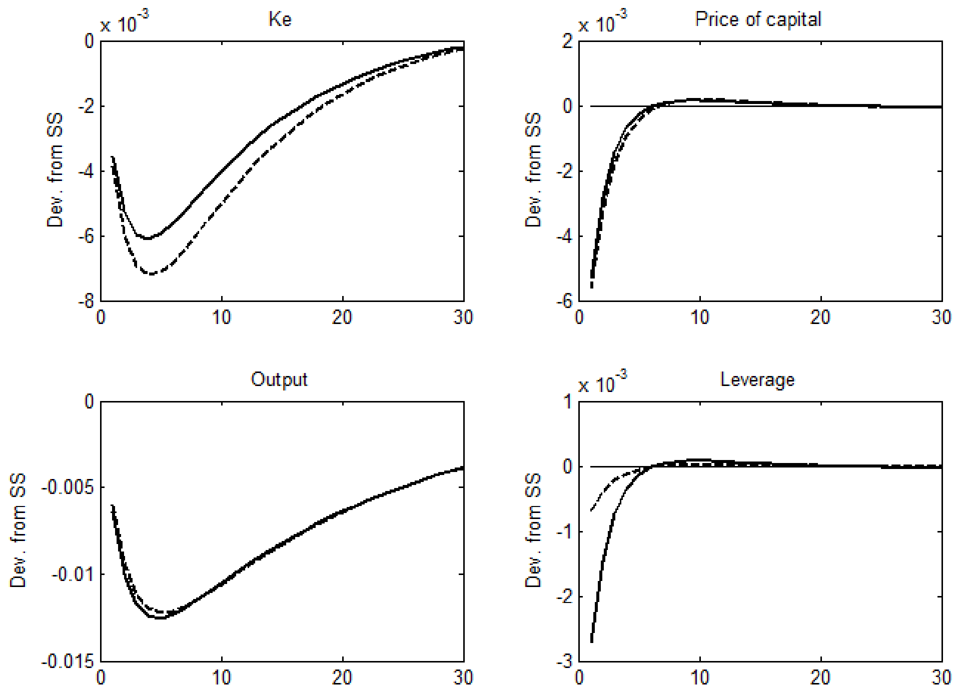


Notes: The solid and dotted lines depict the CC and RBC models' dynamics with $\alpha = 0.36$, respectively. The dashed and dash-dotted lines depict the CC and RBC models' dynamics with $\alpha = 0.55$, respectively.

Notice that when trying to get amplification, what matters in the CC model is the entrepreneur's response to the shock in terms of capital accumulation and not his size in the steady state, as measured by his capital holdings. This can be seen when we vary the factor share of capital. The size of the entrepreneur increases relative to the unconstrained model, and so does his capital accumulation response to the shock. However this is not enough to generate amplification to improve upon the model without frictions.

Changing χ does not affect the frictionless model's results, but its effect on the constrained model is not as straightforward as the one we get from changing the capital share. In particular, we observe that the larger χ is, the greater the decrease in the price of capital, but the smaller the decrease in the amount of loans, and leverage, as the borrowing constraint is tightened. However, given that the decrease in q_t helps relax the credit constraint, one could argue that if this was large enough it could offset the effect of the higher χ. All in all, this is a quantitative matter and our results suggest that the decrease in the price of capital is not large enough to offset the lower degree of deleveraging that is brought about by the larger χ, but is sufficient to generate some incentives for the entrepreneurs to disaccumulate more capital so that the decrease in investment and output is almost the same as in our benchmark model. What we have is a change in the composition of investment, in favor of entrepreneurs net worth, but not in its quantity. Even though the decrease in q_t is enough to maintain investment constant, it is not big enough to provide sufficient incentives for total capital disaccumulation to be below that in the benchmark model, and thus, amplification is not obtained. Figure 3 illustrates these results.

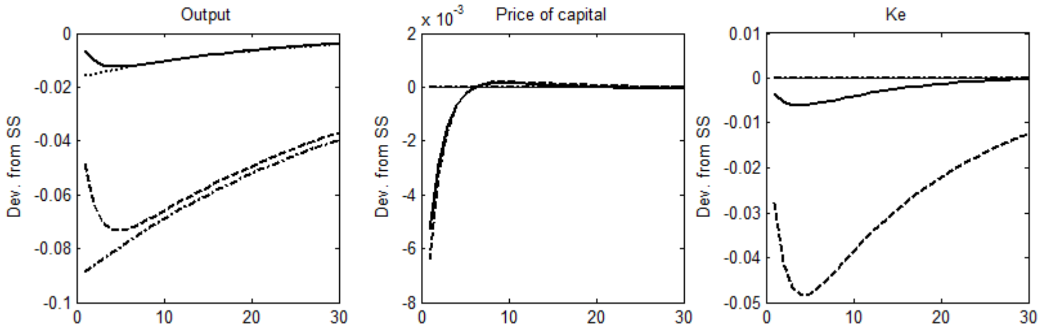
Figure 3: Varying χ



Notes: The solid and dotted lines depict the CC model's dynamics with $\chi = 0.73$ and $\chi = 0.90$, respectively.

Finally, we looked at the effect on amplification from combining changes in factor shares and changes in χ but the results do not change significantly relative to the effects of changing factor shares only, given the small overall effects generated by changing χ. This is shown in Figure 4.

Figure 4: Varying factor shares and χ



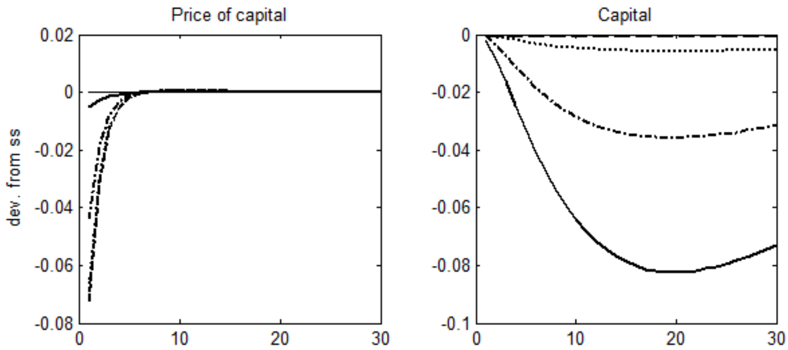
Notes: The solid and dotted lines depict the CC and RBC models' dynamics with $\alpha = 0.36$ and $\chi = 0.73$, respectively. The dashed and dash-dotted lines depict the CC and RBC models' dynamics with $\alpha = 0.55$ and $\chi = 0.90$, respectively.

Finally, another important reason behind the fact that we are not getting amplification relative to an unconstrained model and relative to what theoretical papers predict is that in our setup, the role of reallocation, which lies at the heart of the amplification mechanism in models with a fixed factor, is not the same. Models with a fixed factor rely on the efficient redistribution from less to more productive agents that is brought about when asset prices change after a productivity shock to generate amplification. In our model, where capital is reproducible, this role for reallocation does no longer exist and capital accumulation becomes the key mechanism through which amplification may occur. The intuition behind this is the following. When an economy with reproducible capital is hit by a negative productivity shock, the initial decrease in output is the result of both the shock and the optimal adjustment in labor. Thus, to get amplification in the model with frictions above that obtained in its frictionless counterpart, the effects of capital disaccumulation in the first should be greater than those in the latter. As stated above, in our model this is not the case, and even though output continues to decrease for some periods following the shock, the overall decrease is not enough.

3.2.4 Alternative specifications

Capital adjustment costs and land Two features that one might think could improve the model's results regarding its lack of amplification are adding capital adjustment costs or land to the benchmark setup. Intuitively, the former would offset, at least partially, the immediate response of investment to a shock which, in turn, would imply higher asset price volatility relative to the baseline case. On the other hand, the introduction of land as an additional factor of production that also serves as collateral would allow the credit multiplier mechanism to also work through movements in land prices. Despite these seemingly compelling arguments, neither case contributes to getting a significant improvement in the degree of amplification of shocks into the economy in our model. The reason why this is the case has been commented before: RBC-like models mostly rely on capital accumulation (and labor) to produce final output. Furthermore, the fact that there is only one final goods producer using capital as an input implies that the role for reallocation of capital from less to more productive agents, which is key in theoretical papers of fixed assets, is not present here. Note then, that the only way to get amplification in our model is through capital accumulation and not through capital reallocation.[12] As shown in Figure 5, even though adding adjustment costs increases the volatility of the price of capital, they also depress investment volatility and inhibit capital accumulation (or disaccumulation in the case of a negative shock) and thus amplification does not occur.

Figure 5: Adding capital adjustment costs



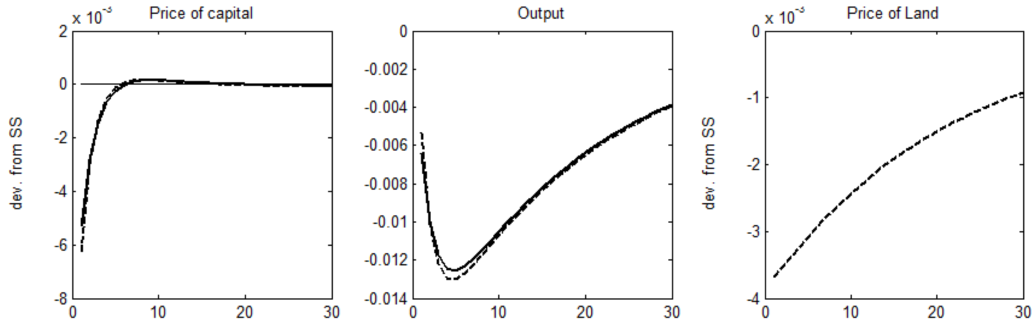
Notes: The solid, dashed and dotted lines depict the CC model's dynamics without and with small and large capital adjustment costs, respectively.

With respect to land, even though this provides an additional source through which the credit multiplier can be fed, its relative importance in the productive process is so small that output is hardly affected.[13] Figure 6 illustrates this result.

[12] In our model, what is "reallocated" when a shock hits the economy, are final goods from households to entrepreneurs. This is, reallocation occurs from consumption to capital production which represents a more productive use of the resources.

[13] The role that land plays as a factor of production for aggregate output is presumably small; hence, the value assigned to the land share in a constant returns to scale aggregate production function should not be too large.

Figure 6: Adding land



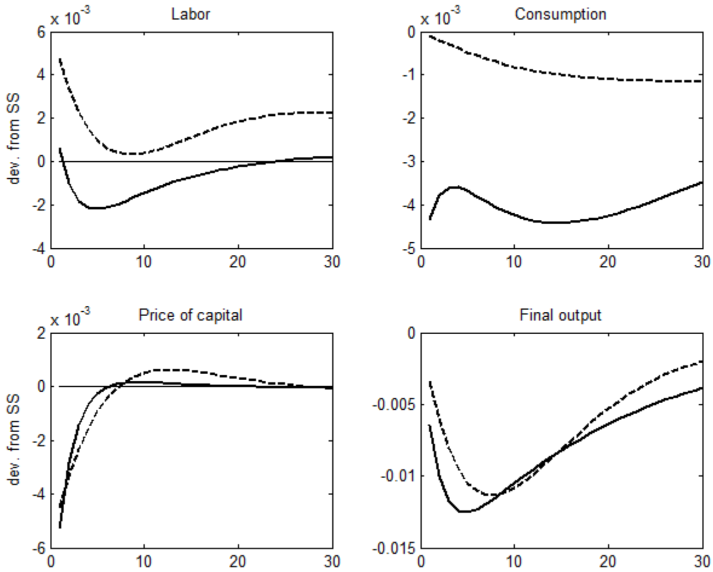
Notes: The solid and dashed lines depict the benchmark CC model's dynamics and the CC model with land as an additional factor of production, respectively.

Habit formation In recent years, models with habit formation have been quite successful in linking consumption with asset prices.[14] Thus, introducing a habit in our setup could potentially deliver the high asset price volatility that we are looking for. These models typically specify an exogenously given consumption process and use the first order conditions of a representative consumer to derive the implications for asset prices. However, Lettau and Uhlig (2000) show that in the presence of habit formation, when consumers can choose consumption and labor optimally in response to some more fundamental shock, the labor-leisure channel provides an avenue for adjusting to the aggregate shock, enabling the agent to smooth consumption drastically. The intuition behind this is that the habit formation makes the agent very risk averse, which implies a very low elasticity of substitution. Thus, the agents want to smooth consumption, making consumption very unresponsive to shocks.

We include a habit component in our model of credit constraints, and as expected, our results are in line with those of Lettau and Uhlig (2000). In particular, Figure 7 shows how, when a negative productivity shock hits the economy, labor increases slightly, consumption remains relatively unchanged and so does the price of capital. This is in line with what we previously mentioned; the low elasticity of substitution implied by the habit leads workers to increase their labor supply as they do not want to adjust consumption much, and this reflects ultimately in low volatility of asset prices. Finally, with respect to final output, its response to a productivity shock does not change much relative to our model without the habit, but its volatility is substantially dampened (in the model with habit formation, output is almost half as volatile as in the model without).

[14] See, for example, Constantinides (1990) and Campbell and Cochrane (1995).

Figure 7: Habit Formation



Notes: The solid and dashed lines depict the benchmark CC model's dynamics and the CC model with habit formation, respectively.

The key insight then is that habit formation generates a very strong income effect, agents use labor to smooth consumption extremely and thus asset prices do not move much. This leads not only to amplification not occurring, but also to levels of consumption and output volatility that are much lower than those observed in the data[15].

4 The small open economy model

As stated earlier, the most important reason behind the lack of amplification in our benchmark model is the fact that reproducible capital has a strong implication for price volatility. In particular, the general equilibrium dynamics that arise when capital is reproducible dampen the response of its price

[15] When considering models with Epstein-Zin preferences, which have also been used in the asset pricing literature to attain high asset price volatility, the same critique that early habit formation models receive, that is, the fact that these preferences rely on exogenous consumption processes to obtain high asset price volatility, applies (in particular, when using Epstein-Zin preferences, consumption must be modeled as containing a small persistent expected growth rate component, and fluctuating volatility, to capture time-varying economic uncertainty). Thus, when consumption is chosen optimally, it becomes relatively smoother, asset prices do not move much and amplification does not occur.

to a productivity shock, thus preventing the credit multiplier to be triggered. The first three columns of Table 3 illustrate this point by comparing the volatilities of output, investment, price of capital and leverage in the data with the ones obtained from our unconstrained and constrained models.[16]

Table 3

Standard deviations				
	Data	RBC	CC	SOE
$\sigma(Y)$	1.60	1.78	1.40	0.92
$\sigma(I)$	7.27	5.67	4.06	4.85
$\sigma(q^K)$	10.35	-	0.56	10.35
$\sigma(lev)$	3.52	-	0.76	14.21

The CC model fares relatively well with respect to output and investment volatility when comparing it to the RBC model, but fails dramatically when it comes to asset prices and leverage. With respect to prices, the volatility observed in our model is almost 20 times lower than the one observed in the data, and almost 5 times lower for leverage.

Thus, to prove our claim regarding the implications of reproducible capital, we isolate the credit multiplier mechanism from the general equilibrium dynamics that dampen the response of prices. In order to do this, we develop a small open economy model, where the only two agents are the firm producing consumption goods and the entrepreneur producing capital goods and where the price of capital is modeled as an exogenous stochastic process. As before, we analyze the response of output, investment, price of capital and leverage to a productivity shock in this setup, paying special attention to volatilities, and compare them to those obtained from the data and our original model.

4.1 Firm's problem and financial contract

The consumption goods firm's problem is given as before by:

$$\max_{\{k_t^d,\, l_t^{Ed}\}} F(k_t^d, l_t^{Ed}) - r_t k_t^d - w_t^E l_t^{Ed}$$

where

$$F(k_t^d, l_t^{Ed}) = \theta_t (k_t^d)^{\alpha_k} (l_t^{Ed})^{1-\alpha_k}$$

[16] The U.S. time series for output and investment are Real GNP and Gross Private Domestic Investment (in chained 2005 dollars) from the BEA. Capital price is approximated by the S&P 500 market price deflated by the price of non-durable goods and services. Leverage is measured as the liabilities to net worth ratio taken from the Flow of Funds Accounts of the U.S. All variables are detrended using a HP filter from 1952:Q1 to 2009:Q3.

With respect to the entrepreneur, his problem can now be described as follows. He will begin each period by renting his capital and inelastically supplying his labor to the consumption goods producing firm, and thus his net worth will be:

$$n_t = l_t^E w_t^E + k_t^E r_t$$

The entrepreneur will then engage in a financial contract, using his net worth as the basis of the loan, where he will obtain borrowing from outside the economy, which will again be limited by the value of his collateral. The optimal contract is then given by the solution to:

$$\max_{\{i_t\}} q_t z i_t - d_t$$

$$\begin{aligned} s.t \qquad i_t - n_t &= d_t \\ (1-\chi) q_t z i_t &\geq d_t \\ q_t z i_t - d_t &\geq n_t \end{aligned}$$

He will then invest i_t in his capital goods production technology, and finally, repay the loan. The difference between total capital production in every period and the amount needed to repay the loan will go on to increase the stock of capital in the economy, so that:

$$k_{t+1} = (1-\delta) k_t + \chi z i_t$$

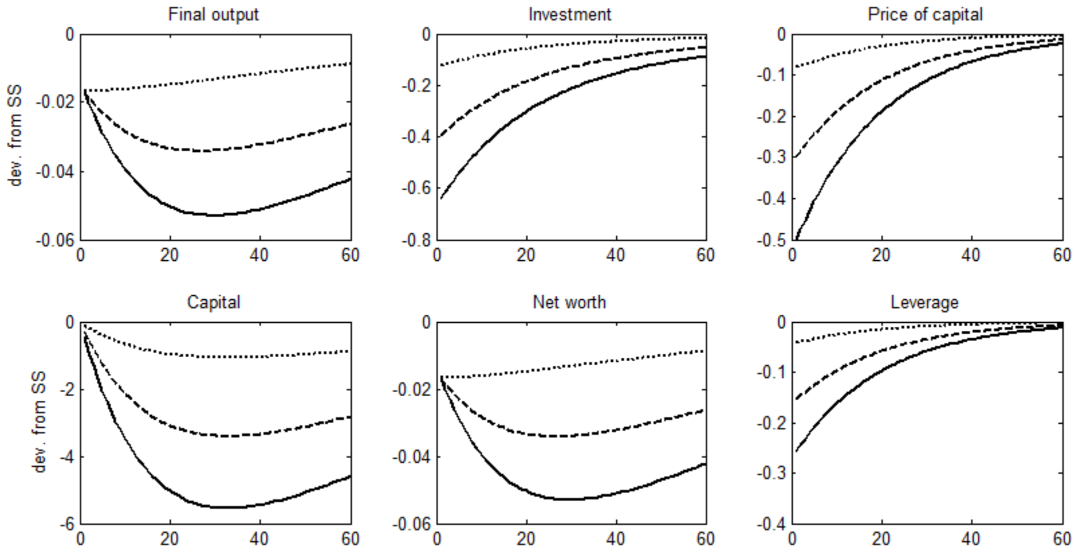
Finally, the price process is modeled as an AR(1):

$$q_t = a_q + \rho_q q_{t-1} + \varepsilon_t^q$$

with ρ_q and a_q equal to 0.95 and $(1-\rho_q) * q_{ss}$ respectively, where q_{ss} refers to the steady state value of the price of capital in our original model. To reproduce the fact that the price of capital decreases when a productivity shock hits the economy, we assume that these two are correlated, and for simplicity we set the correlation coefficient equal to 1. Finally, we set the standard deviation of the price process σ_q to be equal to 0.081, so as to match the volatility of prices observed in the data.[17] The rest of the parameters take the same values as before. Figure 8 shows the impulse response functions of our small open economy (SOE) when it is hit by a one standard deviation shock to prices, for different values of σ_q.

[17] This is one way of doing it. Alternatively, we could have chosen to match this volatility with the autocorrelation coeffcient as well as the standard deviation of the shock.

Figure 8: Impulse response functions



The solid, dashed and dotted lines depict the dynamics of the SOE model with $\sigma_q = 0.081, 0.3$ and 0.5, respectively.

What we take from this figure is simple: in this setup, the credit multiplier mechanism, when isolated from general equilibrium mechanisms, is effective in amplifying shocks and generating large investment, output, price and leverage fluctuations. The last column of Table 3 presents these variables' volatilities as obtained from the small open economy exercise. As mentioned before, the value of σ_q is set so as to match the volatility of the price of capital so this shouldn't be seen as an accomplishment of the model. What is interesting though, is that at the same time as we match price volatility, our model is able to generate investment volatility of the same magnitude as that obtained from the RBC. This poses an important improvement with respect to the latter, given that even though the RBC model performs well in terms of the real variables, it remains silent when it comes to prices and leverage. With respect to output, we are not able to match its volatility, mainly because we are not allowing for any volatility in labor. Finally, with respect to leverage, the small open economy exercise improves relative to our original model, but overstates volatility in the data quite significantly.

5 Conclusions

In this paper we re-examine the quantitative role of financial frictions, in the form of credit constraints, in business cycles. In particular, we assess whether they are able to generate quantitatively important amplification and propagation effects in a model where capital can be accumulated, relative to a model without frictions. We do this by introducing collateral constraints in the production of capital goods, first in an otherwise standard RBC closed economy model, and then in a small open economy setup.

Our results from the closed economy model in terms of propagation and amplification do not differ from previous quantitative papers who have embedded the credit multiplier mechanism into RBC models: even though credit constraints delay the velocity at which shocks propagate into the economy, they have no significant amplification effects. However, our main finding is that it is not the credit multiplier what fails in this type of models, but rather their ability to produce sufficient variability in prices. In particular, in a model with reproducible capital like ours, this happens because the general equilibrium effects counteract the logic of price fluctuations described by theoretical models, thus dampening the dynamic interaction between asset prices and credit limits that is necessary for amplification to occur. Moreover, potential fixes such as adding adjustment costs to capital accumulation or an asset in fixed supply do not solve this problem. The small open economy setup, allowing for exogenous asset price dynamics, confirms our previous claim: absent the general equilibrium effects, the credit multiplier is indeed an effective amplifying mechanism of shocks into the economy.

We conclude then that the credit multiplier will only play an important role in cases that are difficult to construct in actual model economies. For example, large changes in prices are required, which may arise in models with fixed assets or asset specificity, but these are cases in which investment by definition does not change much. This is a problem that is shared by the asset pricing literature, and a challenge for future research is finding a mechanism that delivers more volatility in asset prices in an environment that is empirically plausible. Potential candidates include incorporating economic disaster risk as in Guorio (forthcoming and 2012), allowing for different shocks such as uncertainty and financial shocks, or extending the model to include differential beliefs or "noisy" information, as in Albagli, Hellwig and Tsyvinski (2013). It is important though that, for our purposes, these mechanisms do not represent major departures from simple DSGE models of credit constraints, which could make the source of amplification, if any, difficult to disentangle.

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