Credit Constraints and Macroeconomic Instability in a Small Open Economy*

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Abstract

This paper presents a dynamic model for a small open economy with imperfect financial market. It provides a framework to analyze the role of credit constraints and debt denomination in the generation and amplification of macroeconomic instability in an open economy context. As in Bernanke and Gertler (1989), the imperfection in the financial market results from the existence of a costly state of verification (CSV) problem. Entrepreneurs whose net worth is not enough to finance their desired physical investment have to pay a premium above the risk-free interest rate to obtain external funds. Other key ingredients of the model are that a foreign good is used as an input in the production of the capital good, and that the debt is denominated in terms of the foreign good. Real exchange rate depreciations generate an increase in the cost of producing capital and a reduction in the net worth of entrepreneurs due to the debt denomination. Therefore, recessionary effects can be deepened.

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1 Introduction

After the financial crises that took place in East Asia at the end of 1997, economists turned to the available financial crisis models, expecting to find a feasible explanation for those events. They discovered that no one model provided a good enough "fit" for the crisis at hand. The existing models for financial crises have at their roots either fiscal deficits or credibility problems associated with the trade-off between high unemployment and pegged exchange rates. Neither of these elements were present in the countries affected by the 1997 financial upheaval.

This lack of a satisfactory explanation to the crisis at hand has given rise to a need for new modes of thought in the study of financial crises. One of these new lines of research has started to take elements of the "closed economy" literature on credit constraints to be applied in an open economy context. Open economy considerations such as debt denomination, real exchange rate and foreign goods give a new dimension to the credit constraint problem faced by entrepreneurs with the potentiality of deepening its role in the propagation of economy instability. In this paper I attempt to construct a model to evaluate the role of credit constraints and debt denomination on the propagation of economic instability.

Initially two explanations were offered for the recent financial turmoil in East Asia.[1] The first focuses on moral hazard as a common source of over-investment, excessive external borrowing and significant current account deficits.[2] In this line of research, the implicit public guarantees of corporate investment stimulate investment projects which, under different conditions, simply would not be profitable. The crisis is triggered by a negative shock that generates inflationary expectations due to future fiscal deficits, associated with the bailout policy. A second possible explanation for the 1997 crisis places more emphasis on the problems which grow out of an upper end mismatch between a country's short-term obligations denominated in foreign currency and the actual amount of foreign currency to which that country has access on short notice.[3] In this scenario, the country in question is extremely vulnerable to a reversal of capital inflows. Chang and Velasco (1998)

[1]Additionally, these hypothesis have been presented as explanations to financial crises affecting Chile (1982) and Mexico (1994).

[2]See Diaz-Alejandro (1985), McKinnon, Pill (1996), Krugman (1998), Burnside, Eichenbaum, and Rebelo (1998), and Corsetti, Pesenti and Roubini (1999).

[3]See Chang and Velasco (1999), and Goldfajn and Valdés (1997).

describe it this way: "Bankruptcies, payments moratoria and asset price collapses proliferate. The panic feeds on itself, causing foreign creditors to call in loans and deposits to withdraw funds from banks -all of which magnified the illiquidity of domestic financial institutions and forced yet another round of costly asset liquidation and price deflation".

Without a doubt some elements of each of these two models were present in the East Asian economies at the time of the crisis. But no little skepticism has risen with regard to how viable the models are as complete explanations unto themselves. It is, arguably, hard to believe that these models can capture the full magnitude of the events in question or of their propagation. For example, based on Krugman's (1999) argument let us consider a key indicator of bad-lending: the non-performing loan indicator. A higher than normal level of this indicator (with respect to its usual trend) could represent a signal of potential problems in the allocation of loans. Although the level of this indicator did in fact rise after the East financial crisis was triggered, its magnitude prior to the crises was not, in fact, abnormal in most of the countries involved. It is, of course, the level before the crisis that is most relevant when examining the validity of the moral hazard-over-investment model. Regarding the model of international illiquidity even though it is capable of generating multiple equilibria and therefore it provides a framework for contagion, it seems to tell just a portion of the story. In this model financial distress comes from early and costly liquidation of investment. However, as Krugman (1999) has pointed out early liquidations account for just a small part of an economy's financial distress. Endogenous liquidation effects such as firms collapsing due to debt denomination better reflect the reality of financial crises.

Recently, a new line of research has begun paying attention to the role played by financial market imperfections in the "new variety of crises". Aghion, Bachetta and Banerjee (1999a,b) and Krugman (1999), among others, have argued that one source of financial instability can be found in the role played by credit constraints. Consider a situation in which the ability of a firm to borrow is limited by its net worth. Also assume that firms' debts are denominated in foreign currency, while their income is generated in the local currency. In this scenario, a devaluation could generate two different effects going in opposite directions. On the one hand, a devaluation stimulates aggregate demand by its effect on net exports. On the other hand, the same devaluation increases the interest rate through its effect on net worth, generating a decrease in aggregate demand through a decrease in investment.

One crucial and so far unsettled step for this line of research is to provide a model able to capture the main characteristics previously mentioned without resorting to oversimplified assumptions. In particular, lack of dynamics and ad-hoc assumptions about the nature of the financial imperfection has obfuscated the results obtained.

This paper presents a dynamic model for a small open economy with imperfect financial market that provides a framework to effects of external shocks in the generation and amplification of economic instability. The main elements of the model are:

Credit constraints: as in Bernanke and Gertler (1989), the imperfection in the financial market results from the existence of a costly state of verification (CSV) problem. Entrepreneurs whose net worth is not enough to finance their desired physical investment have to pay a premium above the risk-free interest rate to obtain external funds.

Foreign good requirement: a foreign good is used as input in the production of the capital good. In this context, external shocks that generate a real exchange rate depreciation generate an increase in the cost of producing capital, in turn, inducing to a reduction in investment and output. Moreover, the increase in the price of capital reduces entrepreneurs' net worth/investment expenditures ratio, increasing the risk premium that entrepreneurs have to pay for every level of capital. Thus, investment and subsequent output are affected negatively even more.

Debt denomination: debt is denominated in terms of the foreign good. In this context, negative shocks that generate a depreciation of the real exchange rate reduce the net worth of the economy due to debt denomination. Again, the fall in net worth limits the ability of entrepreneurs to obtain external funds, damaging investment.

In this context, recessionary effects of negative external shocks can be deepened. Therefore, more severe losses in output and investment are predicted by the model. This pattern can to some extent resemble the one observed in financial crisis episodes such as Chile (1982), Mexico (1994), and East Asia (1994).

The paper is structured as follows. Section 2 describes the main characteristics of the model. Section 3 discusses the financial contract problem. Section 4 studies the equilibrium conditions and the sources of instability in this model economy. Section 6 concludes.

2 The Model

In this section I develop a dynamic model for a small open economy with two kinds of final goods: home and foreign; and one intermediate good, capital. There are three different types of agents: households, entrepreneurs, and foreign lenders. Households have infinite horizons and their basic activities are working, consuming, and saving. Entrepreneurs have finite horizons and they only engage in investment and production activities. Each period a fraction (1-δ) of entrepreneurs goes out of business.[4] Those who go out of business at period t are replaced by new entrepreneurs, therefore the number of entrepreneurs is kept constant. Each period t, entrepreneurs who survive to the next period (t+1) supply one unit of labor inelastically.[5] Also entrepreneurs consume only in the period that they die. Additionally, entrepreneurs are assumed risk-neutral.

In each period t entrepreneurs produce capital using home and foreign goods as inputs. The capital produced in period t is combined with labor (supplied by households and entrepreneurs) to produce the home good in period t+1. Purchases of home and foreign goods in period t are financed by entrepreneurial net worth and borrowing from external intermediaries. The net worth of an entrepreneur is defined as the capital gains accumulated from previous capital investments plus the wage received in exchange for supplying labor.

The imperfection in the financial market is due to the existence of a costly state of verification (CSV) problem. Under this assumption, only the borrower (entrepreneur) can observe the outcome of any specific capital investment at no cost. In this context, the financial contract involves auditing strategies by lenders, which introduces agency costs into the process. Net worth is critical in this context. A higher level of self-financing investment mitigates the agency-cost problems, reducing the external finance premium that entrepreneurs face. Thereby, increasing potential investment.

I also assume that foreign debt is denominated in terms of the foreign good. This assumption introduces an additional source of fluctuation of net worth. Unexpected changes in relative prices (or real exchange rate) generate

[4] This implies that the expected lifetime for each entrepreneur is $\frac{1}{1-\delta}$.

[5] Then, each period entrepreneurs who supply labor are old entrepreneurs who survive to the next period and new born entrepreneurs. The assumption that new entrepreneurs work the first period they are born allows them to have a positive net worth (equals to their real wage) at the moment they ask for a loan in the financial market.

variations in entrepreneurs' net worth, affecting directly the external finance premium that they have to pay and, consequently, the investment that they can afford. Hence, this affects production and net worth the next period (and so on), generating a persistent pattern.

We analyze now the structure of the model in more detail.

2.1 Environment

Goods. There are three goods. A home good, a foreign good and a capital good. Capital is not consumed but used in production of the home good. For expository reasons, capital is assumed to depreciate fully.

Households. There is a continuum of households of length unity which obtain utility from real consumption of home and foreign goods. Also, each household supplies labor inelastically in every period and invests its savings in an external financial intermediary that pays the riskless rate of return. Let C_t^H and C_t^F denote household consumption of home and foreign goods respectively. W_t is the real wage for household labor, and B_t are the deposits held at external intermediaries (denominated in terms of the foreign good) yielding a risk-free world real interest rate R^*. The household's objective function is given by

$$\max E_t \sum_{t=0}^{\infty} \beta^t [\nu \ln(C_t^H) + (1-\nu)\ln(C_t^F)]. \tag{1}$$

The individual household budget constraint is given by

$$C_t^H + p_t C_t^F = W_t + p_t R_t^* B_t - p_t B_{t+1}, \tag{2}$$

where p_t is the relative price of the foreign good in terms of the home good or real exchange rate in this model. The household chooses C_t^H, C_t^F, and B_{t+1} to maximize (1) subject to (2).

Production Technology. The home good is produced by a constant-returns technology using capital good and labor. Labor is supplied inelastically by households and entrepreneurs (labor quantity is normalized to 1). The home production function is

$$Y_t = A_t K_t^{\alpha} L_t^{1-\alpha}, \tag{3}$$

where Y_t is aggregate amount of home good output, K_t is the aggregate amount of capital good produced by entrepreneurs in period t-1, L_t is the supply of labor, A_t is a productivity parameter and α is the capital share in the total output.

Investment Technology. Home and foreign goods are combined in period t and transformed into period-(t+1) capital through CES investment technology.

$$I_t = [\gamma^{\frac{1}{\theta}}(I_t^H)^{\frac{\theta-1}{\theta}} + (1-\gamma)^{\frac{1}{\theta}}(I_t^F)^{\frac{\theta-1}{\theta}}]^{\frac{\theta}{\theta-1}}, \tag{4}$$

where I_t^H (I_t^F) is the amount of home (foreign) good used to produce the capital good, and θ is the elasticity of substitution between home and foreign goods.

Now, we define the capital-based price index q. The capital-based price index q is the minimum expenditure, Z=I^H+pI^F such that I=1, given p. In other words, q measures the least expenditure of home goods that buys a unit of investment. We can prove that

$$q = (\gamma + (1-\gamma)p^{1-\theta})^{\frac{1}{1-\theta}}. \tag{5}$$

Note that the capital-based index q is an increasing function of p. Now, we can define the amount of home and foreign goods used in the production of the capital good for a given I and p

$$I_t^H = \gamma q_t^\theta I_t \tag{6}$$
$$I_t^F = (1-\gamma)(\frac{q_t}{p_t})^\theta I_t. \tag{7}$$

These equations state that the demand for the home (foreign) good is proportional to real investment with a proportional coefficient that is an isoelastic function of the ratio of the home good's price (foreign good's price) to the capital-based index.

Finally, the amount of capital available to production at period (t+1) is equal to

$$K_{t+1}^j = \omega^j I_t, \tag{8}$$

where ω^j is a disturbance affecting entrepreneur j's production of capital good. This disturbance satisfies $E(\omega^j)$=1 and c.d.f. $F(\omega)$. The imperfection in the capital market stems from the existence of asymmetric information. The outcome of the investment technology (the realization of shock ω^j) can only be observed without cost by the entrepreneur. Other agents in the economy (lenders) have to pay a fraction μ of capital good in order to learn the effective outcome. Random auditing is not feasible; that is, lenders can pre-commit to auditing in pre-determined states only with probability one.

Outputs of projects undertaken in period t are mutually independent, so there is no aggregate uncertainty about the aggregate quantity of capital available for production at $t{+}1$ given a level of investment in period t, $K_{t+1}{=}I_t$.

3 Financial Contract

An entrepreneur j whose net worth is lower than its desired amount of investment has to borrow from the capital market. At the end of period t entrepreneur j's net worth is equal to N^j_{t+1}. Then, the amount of resources that he has to obtain from external funds to finance his expenditures in the production of the capital good is given by

$$D^j_{t+1} = \frac{q_t I_t}{p_t} - \frac{N^j_{t+1}}{p_t}, \tag{9}$$

where D^j_{t+1} is the entrepreneur j's foreign debt denominated in terms of the foreign good, $q_t I_t$ is the expenditure required to produce I_t units of capital, and N^j_{t+1} is the net worth of entrepreneur j in terms of home good.

Note that entrepreneurs borrow from an intermediary abroad and households save abroad, so we rule out the existence of local intermediaries. Doing this we eliminate the possibility that households lend to entrepreneurs through a local intermediary. All contracts are denominated in foreign currency. Again, this eliminates the possibility of *intra-country* contract denominated in local currency.[6] At period t foreign intermediaries face an alternative cost equal to the risk-free world interest rate R^*_{t+1}.

The financial structure plays a role given the costly state of verification problem. In this scenario, only the borrower (entrepreneur) can observe the outcome of any specific capital investment at no cost. This financial contract involves auditing strategies by lenders, which introduce agency costs into the

[6] Again, I do this for expository reasons.

process. The auditing cost is assumed to be a proportion μ of the capital good produced. Following Gale and Hellwit (1986) it is possible to show that the incentive compatible loan contract will specify a set $A^j = [0, \overline{\omega}^j)$ of realizations of the shock in which verification of the return will occur. In the rest of the events, $F^j = [\overline{\omega}^j, \infty]$, no verification occurs. The payment to the lender if $\omega \in A^j$ equal to the project return. If $\omega \in F^j$ the repayment is not contingent on the return but a fixed repayment X^j_{t+1}. The threshold value, $\overline{\omega}^j$, such that the entrepreneur will be able to repay the loan for $\omega^j \geqslant \overline{\omega}^j$ at contractual rate X^j_{t+1} is given by

$$\frac{\overline{\omega}^j R^K_{t+1} q_t I_t}{p_{t+1}} = X^j_{t+1} D^j_{t+1}, \tag{10}$$

where R^K_{t+1} is the expected price of capital in terms of home good, and p_{t+1} is the expected relative price of the foreign good in terms of the home good. For $\omega^j \leq \overline{\omega}^j$, the entrepreneur cannot repay the loan to the rate X^j_{t+1} and must declare default. At this moment the lender pays the auditing cost and keeps what is found. Thus, the intermediary gets $(1-\mu)\frac{\omega^j R^K_{t+1} q_t I_t}{p_{t+1}}$ units of foreign good and the entrepreneur gets nothing. When $\omega^j \geq \overline{\omega}^j$, the entrepreneur can repay the loan at rate X^j_{t+1}. In this case, the intermediary receives $X^j_{t+1} D^j_{t+1}$ and the entrepreneur keeps $\frac{\omega^j R^K_{t+1} q_t I_t}{p_{t+1}} - X^j_{t+1} D^j_{t+1}$. No agency costs are incurred in this case.

A loan contract specifies the cutoff value $\overline{\omega}^j$ and a contractual rate X^j_{t+1}. The intermediary accepts these terms if the expected return of this operation is at least equal to its alternative cost. Therefore, loan contract offers must satisfy the constraint

$$[1 - F(\overline{\omega}^j)] X^j_{t+1} D^j_{t+1} + (1-\mu) \int_0^{\overline{\omega}^j} \frac{\omega R^K_{t+1} q_t I_t}{p_{t+1}} dF(\omega) \geq R^*_{t+1} D^j_{t+1}. \tag{11}$$

This equation states that expected repayments net of expected monitoring costs must at least be equal to the intermediary's opportunity cost.

On the other hand, entrepreneur type j expected return is given by

$$E_t \left\{ \int_{\overline{\omega}^j}^{\infty} \frac{\omega R^K_{t+1} q_t I_t}{p_{t+1}} dF(\omega) - [1 - F(\overline{\omega}^j)] X^j_{t+1} D^j_{t+1} \right\}, \tag{12}$$

where expectations reflect the fact that R^K_{t+1} is a random variable that the entrepreneur assumes as given. Using equations (9) and (10) we can substitute X_{t+1}^j and D_{t+1}^j into equations (11) and (12) to express the contract problem just in terms of $\overline{\omega}^j$ and I_t. The incentive-compatible loan contract and the level of investment in this economy is obtained from the solution to the maximization problem

$$\max_{\overline{\omega}^j, I_t} E_t \left\{ \int_{\overline{\omega}^j}^{\infty} \frac{\omega R_{t+1}^K q_t I_t}{p_{t+1}} dF(\omega) - [1 - F(\overline{\omega}^j)] \frac{\overline{\omega}^j R_{t+1}^K q_t I_t}{p_{t+1}} \right\}, \tag{13}$$

subject to

$$[1 - F(\overline{\omega}^j)] \frac{\overline{\omega}^j R_{t+1}^K q_t I_t}{p_{t+1}} + (1-\mu) \int_0^{\overline{\omega}^j} \frac{\omega R_{t+1}^K q_t I_t}{p_{t+1}} dF(\omega) \geq R_{t+1}^* \left(\frac{q_t I_t}{p_t} - \frac{N_{t+1}^j}{p_t}\right), \tag{14}$$

where the return to capital in period $t+1$, the relative price of home goods in period t and $t+1$, and the net worth of entrepreneur j are taken as given in the maximization problem.

Following Bernanke, Gertler, and Gilchrist (1998) it is possible to show that the solution to the previous problem will satisfy

$$\frac{q_t I_t^j}{N_{t+1}^j} = \Psi \left(E_t \left\{ \frac{R_{t+1}^K p_t}{R_{t+1}^* p_{t+1}} \right\} \right) \textit{ with } \Psi'(\cdot) > 0 \text{ and } \Psi(1) = 1. \tag{15}$$

The term $E_t \left\{ \frac{R_{t+1}^K p_t}{R_{t+1}^* p_{t+1}} \right\}$ represents the expected discounted return on capital. So in equilibrium this term has to be greater or equal to 1. This equation is the key relationship in the financial-accelerator literature. It shows that capital expenditure of entrepreneur j is proportional to his net worth, with a proportionality factor increasing in the external fund premium that entrepreneurs have to pay above the risk-free rate. Inverting this equation we can express it conveniently as

$$E_t\{R_{t+1}^K\} = \phi \left(\frac{N_{t+1}^j}{q_t I_t^j} \right) E_t\{\frac{R_{t+1}^* p_{t+1}}{p_t}\} \textit{ with } \partial\phi(\cdot)/\partial I_t > 0. \tag{16}$$

This relation shows that the external finance premium depends inversely on the contribution of entrepreneur j's own funds (net worth) as a proportion of the total investment cost.

4 The General Equilibrium Model

4.1 The Financial Contract

The previous section presented the solution to the partial equilibrium contracting problem between the lender and the entrepreneur. The relations obtained are now introduced in a dynamic general equilibrium model which allows us to endogenize the return to capital, and the relative price of capital. In order to obtain the aggregate supply curve for investment we must aggregate equation (15) over all entrepreneurs. The aggregate supply curve of funds is given by

$$\frac{q_t I_t}{N_{t+1}} = \Psi\left(E_t\left\{\frac{R^K_{t+1} p_t}{R^*_{t+1} p_{t+1}}\right\}\right). \tag{17}$$

Inverting this relation we obtain,

$$E_t\{\frac{R^K_{t+1} p_t}{R^*_{t+1} p_{t+1}}\} = \phi\left(\frac{N_{t+1}}{q_t I_t}\right). \tag{18}$$

If entrepreneurs' net worth is lower than investment expenditures, entrepreneurs must pay a positive risk premium over the risk-free interest rate. Moreover, entrepreneurs face an external finance premium decreasing on their own net worth. At this point it is appropriate to emphasize a characteristic of this model. The risk premium that entrepreneurs must pay is a function (among other things) of the real exchange rate.[7] Thus, changes in the real exchange rate will affect the cost of new investment and, through this channel, will affect the cost of external capital that entrepreneurs face. As it will become clear later, this is not the only channel through which changes in the real exchange rate affects the external cost of capital. Specifically, changes in the real exchange rate also will affect net worth.

The expected gross return to producing capital in period t can be written

$$E_t\{R^k_{t+1}\} = E\left\{\frac{\alpha Y_{t+1}}{q_t K_{t+1}}\right\}. \tag{19}$$

As it was mentioned before, I assume that in each period a constant fraction (1-δ) of entrepreneurs die. This assumption implies that entrepreneurs have finite horizons precluding entrepreneurs of accumulating enough funds

[7] Remember that the price of capital (q) is a function the real exchange rate (p).

to become self-financed. New generations of entrepreneurs replace the ones who die. Entrepreneurs inelastically supply labor receiving a wage W^e for their services.[8] Entrepreneurs who die at period t are not allowed to work or to invest just to consume home goods.[9]

The evolution of aggregate net worth is given by

$$N_{t+1} = \delta \left\{ R_t^K q_{t-1} K_t - \frac{p_t}{p_{t-1}} R_t^* (q_{t-1} K_t - N_t) - \mu \int_0^{\overline{\omega}} \omega R_t^K q_{t-1} K_t dF(\omega) \right\} + W_t^e. \tag{20}$$

Aggregate net worth is equal to the gross earnings on capital holdings less the repayment of borrowing and the monitoring costs plus the real wage earnings. Note that if the debt is denominated in terms of the foreign good, debt repayments are conditional on the actual real exchange rate, p_t. If debt were denominated in terms of the home good, the repayment would be fixed in terms of the home good. In this case the term $\frac{p_t}{p_{t-1}} R_t^*$ would be replaced by $E_{t-1} \left\{ \frac{p_t}{p_{t-1}} R_t^* \right\}$. Therefore, unanticipated real exchange rate depreciations (rises in p) increase debt repayments, lowering net worth, which will in turn decrease investment.[10]

4.2 Equilibrium Relations

Equilibrium in the capital market is given by the demand and supply for capital. Supply of capital is given by equation (18) while the demand for capital is given by the marginal product of capital obtained from equation (19). Then,

$$\phi \left(\frac{N_{t+1}}{q_t K_{t+1}} \right) \frac{R_{t+1}^* p_{t+1}}{p_t} = \frac{\alpha A_t}{q_t K_{t+1}^{1-\alpha}}. \tag{21}$$

The evolution of the entrepreneurs' budget constraint is given by

$$q_t K_{t+1} = p_t D_{t+1} + N_{t+1}, \tag{22}$$

[8] This assumption is introduced in order to assure that new entrepreneurs born at period t to have some positive net worth at the moment they try to obtain external funds.

[9] The total labor input L_t is a composite of household labor, H_t, and entrepreneur labor H_t^e. In particular, $L_t = H_t^{-} H_t^{e(1--)}$. Both components are assumed to be supplied inelastically in an amount equals to 1.

[10] The role of unanticipated changes in p will be discussed in details later on.

where D_{t+1} corresponds to the total amount of loans that entrepreneurs obtain from lenders. Combining this last equation with equation (20), we obtain the resource constraint for those entrepreneurs that survive from period t to period $t+1$.

$$q_t K_{t+1} = p_t D_{t+1} + \delta \left\{ R_t^K q_{t-1} K_t - p_t R_t^* D_t - \mu \int_0^{\overline{\omega}} \omega R_t^K q_{t-1} I_{t-1} dF(\omega) \right\} + W_t^e, \tag{23}$$

where

$$W_t^e = (1-\alpha)(1- - \ )Y_t.$$

Entrepreneurs who die at period t are assumed to consume all their income in the home good. The budget constraint for these entrepreneurs is given by

$$C_t^e = (1-\delta) \left\{ R_t^K q_{t-1} K_t - p_t R_t^* D_t - \mu \int_0^{\overline{\omega}} \omega R_t^K q_{t-1} I_{t-1} dF(\omega) \right\}, \tag{24}$$

where C_t^e is the entrepreneur consumption of the home good. Now, aggregating the resources constraints of households, and entrepreneurs (equations (2), (23), and (24)), we obtain the current account equation for the economy,

$$C_t^H + p_t C_t^F + q_t K_{t+1} + C_t^e = Y_t + p_t R_t^* (B_t - D_t) - p_t (B_{t+1} - D_{t+1}) - \mu \int_0^{\overline{\omega}} \omega R_t^K q_{t-1} I_{t-1} dF(\omega). \tag{25}$$

I assume that the rest of the world is much larger than the domestic economy and that its spending in the home good is a negligible fraction of its income. Also, the elasticity of substitution is assumed to be 1. In this case the value of domestic exports in terms of the foreign good is fixed. Therefore, the foreign demand for the home good is given by

$$C_t^{H^*} = p_t X. \tag{26}$$

where X is the fixed value of domestic exports in terms of the foreign good. By defining net exports (in units of the home good) as,

$$NX_t = C_t^{H^*} - p_t C_t^F - p_t I_t^F, \tag{27}$$

the current account equation rewrites

$$p_t(B_{t+1} - D_{t+1}) - p_t R_t^*(B_t - D_t) = C_t^{H^*} - p_t C_t^F - p_t I_t^F. \tag{28}$$

Combining (25) and (27) we obtained the resource constraint for the economy.

$$C_t^H + C_t^e + I_t^H + C_t^{H^*} = Y_t - \mu \int_0^{\overline{\omega}} \omega R_t^K q_{t-1} I_{t-1} dF(\omega), \tag{29}$$

where C_t^H is the household consumption of the home good, and I_t^H is the entrepreneurs' demand of the home good for investment purposes. These elements are equal to the total output of the home good net of monitoring costs.

Finally, the solution to the maximization problem of the representative household yields standard first-order conditions for consumption of home and foreign goods and savings

$$\beta E_t \left\{ \frac{C_t^H}{C_{t+1}^H} R_{t+1}^* \frac{p_{t+1}}{p_t} \right\} = 1 \tag{30}$$

$$C_t^F = \frac{(1-\nu)}{\nu} \frac{C_t^H}{p_t}. \tag{31}$$

The complete set of equations that defines the model has been presented. In the next section I will describe the non-stochastic steady state of the model.

5 Steady-State and Dynamics

5.1 The steady-state

The steady state is characterized by constant levels of consumption, stocks of capital and debt, and by constant value of the real exchange rate.[11] From equation (20) and using the steady-state relation for R^K (equation (19)), we can obtain the steady-state relation for the net-worth

[11] The complete set of equationts is presented in the appendix A where I assume that the idiosyncratic shock to the production of the capital good, ω, is distributed uniformly in the support $[0, 2]$.

$$N = \frac{\delta}{(1-\delta R^{*})}\left\{\alpha A K^{\alpha} - R^{*} q K - \mu \int_{0}^{\overline{\omega}} \omega \alpha A K^{\alpha} dF(\omega)\right\} + \frac{(1-\alpha)(1- - \ )}{(1-\delta R^{*})} A K^{\alpha}. \tag{32}$$

Note that the real exchange rate depreciation term is not present in the steady-state. Thus, one key channel in order to generate multiplicity of equilibria has disappeared. Only unanticipated changes in the real exchange rate makes the debt denomination issue become relevant in this model.

The second relation is given by the supply of capital and the demand for capital. From equations (18) and (19) we can express this relation by

$$\phi(\frac{N}{qK})R^{*} = \frac{\alpha A}{qK^{1-\alpha}}. \tag{33}$$

By combining this last equation together with the net worth relation for the steady state, we obtain the equilibrium in the capital market as a relation between q, the cost of one unit of capital in terms of the home good, and K, the equilibrium level of capital. One feature of this relation is that the level of capital and the real exchange rate are negatively correlated across steady states. The intuition is simple, a lower q reduces the cost of investment expenditures as a proportion of the net-worth. This increases the supply of funds for any given level of external finance premium. On the other hand, a reduction of q increases the marginal productivity of capital production increasing its demand. These two effects combined increase the level of capital in equilibrium.

Finally, the third relation necessary to determine the steady-state is the equilibrium in the home good market. Using equations (22) to (30) we can obtain the next equilibrium relation[12]

$$\begin{aligned} AK^{\alpha} &= \nu(1-\alpha)\text{-}\ AK^{\alpha} + \frac{(1-\delta)}{(1-(1-\delta)R^{*})}\left\{\alpha A K^{\alpha} - R^{*} q K - \mu \int_{0}^{\overline{\omega}} \omega \alpha A K^{\alpha} dF(\omega)\right\} \\ &\quad + \left(\frac{q^{1-\theta}-\gamma}{1-\gamma}\right)^{\frac{1}{1-\theta}} X + \gamma q^{\theta} K + \mu \int_{0}^{\overline{\omega}} \omega \alpha A K^{\alpha} dF(\omega), \end{aligned} \tag{34}$$

where θ is the elasticity of substitution between home and foreign inputs in the production of capital. Combining equation (32), (33) and (34) we obtain a unique steady state equilibrium for the system.

[12] I assume that the steady state holdings of bonds by households are zero.

5.2 The log-linearized system

In this section I present the log-linearized version of the model. Lower case represents deviation of the variable with respect to its steady state value. The set of equations here presented are obtained from equations in appendix A.

$$y_t = \frac{C^H}{Y} c_t^H + \frac{C^e}{Y} c_t^e + \frac{I^H}{Y} i_t^H + \frac{C^{H^*}}{Y} c_t^{H^*} + \phi_t^y \tag{35}$$

$$c_{t+1}^H = c_t^H + r_{t+1}^* + \pi_{t+1} \tag{36}$$

$$\begin{aligned} n_{t+1} \quad = \quad & \lambda_0 r_t^K + \{\lambda_0 - \lambda_1\} q_{t-1} - \{\lambda_1 - \delta R^*\} (r_t^* + \pi_t) + \delta R^* n_t + \\ & \{\lambda_0 - \lambda_1 + \lambda_2 \alpha\} k_t + \lambda_2 a_t - \phi_t^n \end{aligned} \tag{37}$$

$$r_{t+1}^K - r_{t+1}^* - \pi_{t+1} = -\chi(n_{t+1} - q_t - k_{t+1}) \tag{38}$$

$$r_t^K = y_t - q_{t-1} - k_t \tag{39}$$

$$q_t = \varphi p_t \tag{40}$$

$$y_t = a_t + \alpha k_t \tag{41}$$

$$\pi_t = p_t - p_{t-1} \tag{42}$$

$$i_t^H = \theta q_t + k_{t+1} \tag{43}$$

$$c_t^{H^*} = p_t \tag{44}$$

$$r_t^* = \rho_r r_{t-1}^* + \varepsilon_t^r \tag{45}$$

$$a_t = \rho_a a_{t-1} + \varepsilon_t^a, \tag{46}$$

where $\lambda_0 = \frac{\delta R^K qK}{N}$, $\lambda_1 = \frac{\delta R^* qK}{N}$, and $\lambda_2 = \frac{(1-\alpha)(1-- \ )AK^\alpha}{N}$.

Equations (35) and (36) represent the familiar log-linearized versions of the resource constraint of the economy and the Euler equation. The term ϕ_t^y reflects the deviation of the aggregate monitory cost with respect to its steady state level.

Equation (37) represents the log-linearized version of the net worth evolution. An unanticipated depreciation of the real exchange rate reduces net worth by a term that is proportional to the steady state level of leverage. A higher level of debt with respect to the total investment expenditure, increases the effect of unanticipated devaluations in the evolution of the net worth.[13]

Equation (38) represents the log-linearized version of the supply of capital (18). This equation reflects the importance of the net worth relative to the investment purchases. A negative deviation of this ratio from its steady state value, temporarily increases the risk premium that firms have to pay in order to obtain loans from intermediaries. Without capital market frictions the term $\chi(n_{t+1} - q_t - k_{t+1})$ becomes zero. Note also that in this open economy version, the real exchange rate influences the behavior of the risk premium through two different channels. First, a real exchange rate higher than its steady state level (depreciated) increases the cost of producing capital inducing to a high external finance premium for given values of n and k. Second, a depreciation of the real exchange rate with respect to its steady state value, reduces net worth due to debt denomination.

The equation (39) represents the linearized version of the demand for capital or the marginal productivity of capital. Note that given the assumption of complete depreciation, this term is completely predetermined in absence of productivity shocks.

Equation (40) relates the evolution of the price of capital and the price of the real exchange rate. The term φ represents the elasticity of the capital price to changes in the real exchange rate. For the Leontieff case this elasticity is equal to $\frac{(1-\gamma)p}{\gamma+(1-\gamma)p}$. It can be shown that this value is decreasing in γ for given values of p. This can be considered a potential source of instability for economies with more dependence on the foreign good. For the same level of volatility of the real exchange rate, the volatility of the capital price is higher when γ is higher, inducing to larger changes in investment response.

Equation (41) is the linearized version of the home good production tech-

[13]See appendix B for a formal derivation of this effect.

nology. In my model only changes in productivity, represented by a_t, affect present output given that capital is predetermined from the previous period and labor supply is fixed.

Equation (42) is the definition of the change in the real exchange rate. The evolution of home good requirements in the production of capital is represented by equation (43). A depreciation of the real exchange rate increases q, which induces entrepreneurs to substitute foreign for home goods. The reaction of the demand for the home good by entrepreneurs is weighted by the elasticity of substitution between these two inputs. Also, the demand for the home good reacts to changes in the aggregate level of investment of the firm, k_{t+1}. Equation (44) represents the external demand for the home good.

Finally, equations (45) and (46) describe international real interest rate and productivity process. Process ε_t^i (i=r, a) is assumed to be serially uncorrelated.

6 Calibration

The discount rate β is assumed to be equal to $\frac{1}{R^*}$. This condition ensures that we have a well defined steady state. The quarterly international real interest rate is set to 1%. For the production of capital technology I set the elasticity of substitution, θ, to be either 0 or 1. The former implies the Leontieff technology and the second one, the Cobb-Douglas technology. The home good share in the production of capital, γ, is set to either 0.5 or 0.8. These numbers are consistent with the evidence of the importance of the imported capital goods in trade volumes. The consumption production technology is assumed to be Cobb-Douglas with a capital share of 0.35, a household labor share of 0.6435, and an entrepreneurial labor share of 0.0065. This last value is sufficiently small to assure that the model collapses to a standard RBC model in absence of capital market frictions.

The remaining parameters in the model are chosen to imply a steady state risk premium of four hundred basis point and a ratio of net worth to investment expenditures in steady state equal to 0.7. This last value is fairly high, in special for the values observed in small open economies. One additional step must be done in order to close this value to the one observed in the data. However, any success in this direction will tend to ratify the results obtained because it will stress the role of the debt in the amplification of the shocks. The monitoring costs are assumed to be 25% of the total assets of the firm in case of bankruptcy. Then, μ is set to be 0.25. The survival probability δ is set to 0.92 while the idiosyncratic productivity variable ω is assumed to be distributed uniformly in the support [0,2].

The persistence of the world interest rate and productivity shocks are assumed to be 0.8 and 0.5 respectively.

7 Simulation

I consider two types of shocks hitting the economy, a world interest rate shock, and a productivity shock. The economy response under imperfect capital markets is contrasted with the reaction of an economy with perfect capital market, i.e. an economy where μ is equal to zero. In the case of perfect capital market the model collapses to an standard RBC model where the ownership of capital is irrelevant. I also study impulse responses of the variables in the model for different requirements of the foreign good in the production of capital. In this case, γ, represents how important the home good is relative to the foreign good in the production of the capital good. Finally, I present results that account for the importance of the degree of substitution between inputs in the production of capital. In this case, I report the economy reaction for elasticities of substitution for the Leontieff case (θ=0) and Cobb-Douglas (θ=1).

7.1 World Interest Rate Shock

Figure 1 shows the response of the economy to a temporary 2% increase in the world interest rate, r^*, for both the perfect and imperfect capital market cases. Given that labor supply is fixed and capital is predetermined in the previous period, the initial output response is the same for both cases. However, after the initial period the response of output in the imperfect capital market case is more than twice the response of output for the perfect capital markets case. The answer to this amplifying effect can be found in the behavior of the investment. On impact, investment in the capital market friction case decreases almost 75% more than under perfect capital markets. The unanticipated increase in the world interest rate decreases the demand for capital. The decrease in the demand for capital reduces both the demand for home and foreign goods. The decrease in the demand for the home good by investors generates a decrease in the relative price of the home good or a depreciation of the real exchange rate. But now, the depreciation of the real exchange rate increases debt repayments that entrepreneurs face due to the debt denomination. In this scenario, net worth is decreased exacerbating the credit constraint faced by entrepreneurs, therefore, deepening the decrease in the demand for capital and amplifying the reaction of the economy.

Another dimension that can be analyzed is the role played by the foreign good in the production of capital. Figure 2 shows the reaction of the economy to the same 2% increase in the world interest rate for different values of γ, the requirement of the foreign good in the production of capital. A higher value of γ implies a lower use of the foreign good in the production of capital. As can be seen, a higher requirement of the foreign good tends to amplify recessionary effects of the increase in r^*. In fact, the reaction of the output and investment more than double the case with lower foreign good requirements. It is worth noting that the reaction of the real exchange rate is similar in both cases. Which implies that the effect of the debt denomination should not be very different in both cases. However, the effect on the price of capital is significantly different. A higher γ implies a higher elasticity of the capital price q to changes in p, reducing the demand for capital in a more strongly manner. It is important to stress this last result. Small open economies are likely to be dependent to imports of capital good in order to produce goods. This dependence in the foreign good is clearly a source of instability and amplification of the shock.

Finally, figure 3 shows the economy reaction to the interest rate shock for different elasticities of substitution between home and foreign goods in the production of capital. As can be seen both patterns seem to be similar for output and investment. However, the reduction in demand for home goods by entrepreneurs is less strong in the case where entrepreneurs can substitute the foreign good for the home good. This is what is happening in this case. The depreciation of the exchange rate or the increase in the price of the foreign good in terms of the home good stimulates the substitution effect between home and foreign goods. Entrepreneurs that can substitute factors would like to do it in a more aggressive way. However, output of the home good is fixed in the initial period which limits their ability to obtain more of that factor. This element determines the hump-shaped pattern of the demand for the home good for investment purposes. Output loses tend to be higher for the case of more substitution because of the price of capital effect. The increase in the price of capital is higher when θ is higher, generating a higher fall in investment and by this mean on output.

7.2 Productivity Shock

The second experiment I address is a shock to productivity in the production of the home good. In particular, I consider the reaction of the economy to a 1% fall in the productivity level with respect to its steady state level. Figure 4 shows the reaction of two economies, one with capital market frictions and the other one without imperfections in the capital market. The fall in output for both economies is almost the same. The question that arises is that capital market frictions do not seem to amplify the productivity shock in this case. In this model that is the case because of the debt denomination. Unexpected changes in the relative prices have redistributive effects from lenders to borrowers or vice versa. In this case, the fact that production is affected negatively by the productivity shock generates an increase in the prices of the home good in terms of the foreign good. This unanticipated appreciation of the real exchange rate redistribute wealth from lenders to borrowers which obligations are denominated in terms of the foreign good. This last effect tends to compensate the fall in net worth due to the lower rent of capital.

Figure 5 presents impulse responses of the variable in the model for two different level of home good requirement, γ, in the production of capital. As it is was stressed for the case of the interest rate shock, what it makes the difference here is the lower elasticity of the price of capital to changes in the real exchange rate. The fall in production and the consequent fall in the price of the home good, has a lower impact in the cost of investment when γ is higher or the home good is more important in the production of capital. This last effect tends to generate a more pronounced pattern for the fall in investment and a slightly more contractionary effect on output.

Finally, figure 6 presents the economy reaction when we introduce the "elasticity of substitution dimension". The dynamics differ basically in those related to the consumption of the home and foreign good by the entrepreneurs (for investment purposes). In this case, the higher price of the home good leads entrepreneurs to substitute this factor for the cheaper one, the foreign good. To the extent that the elasticity of substitution is positive they can do it. The patterns for the home and foreign goods used in investment activities confirm this last effect. When θ is equal to 1, the fall in the home good investment is more pronounced while for the foreign good is almost unchanged with respect to its initial level. This substitution effect mitigates the effects of the negative shock in productivity over investment and to some extent over the output evolution.

8 Conclusions

This paper presents a dynamic model for a small open economy with imperfect financial market that provides a framework to analyze the role of credit constraints in the generation and amplification of economic instability. As in Bernanke and Gertler (1989), the imperfection in the financial market results from the existence of a costly state of verification (CSV) problem. Entrepreneurs whose net worth is not enough to finance their desired physical investment have to pay a premium above the risk-free interest rate to obtain external funds. The effects of negative external shocks are amplified by credit constraints. Another key ingredient of the model is that a foreign good is used in domestic investment. In this context, a real depreciation generates an increase in the cost of producing capital inducing to a reduction in investment and output. Moreover, the increase in the price of capital reduces entrepreneurs' net worth/investment expenditures ratio, increasing the risk premium that entrepreneurs have to pay for every level of capital. Thus, investment and subsequent output are affected negatively even more. I also assume that the debt is denominated in terms of the foreign good. In this context, negative shocks that generate depreciation of the real exchange rate reduce the net worth of the economy due to debt denomination.

The model was calibrated and simulated in order to analyze the quantitative reaction of the economy to world interest rate and productivity shocks. The main conclusions obtained are that credit constraints play a role in the amplification and transmission of external shocks. Second, to the extend that debt is denominated in terms of the foreign good, the effects of increases in the world interest rate or loss of confidence by foreign investors are magnified. Output and investment present more recessionary patterns in this case. Finally, the fact that a foreign good is used as an input in the production of the capital good is also an important source of dynamic in the model. Indeed, shocks that tend to depreciate the real exchange rate are deepened when the foreign good component is more important. More severe losses in output and investment are predicted by the model. This pattern resembles, to some extent, the one observed in financial crisis episodes such as Chile (1982), Mexico (1994), and East Asia (1994).

9 Appendix

9.1 Appendix A

Assuming that $\omega \sim U[0,2]$ we can obtain the next analytical solutions to the steady-state.

$$I^H = \gamma q^\theta I \tag{47}$$

$$I^F = (1-\gamma)\left(\frac{q}{p}\right)^\theta I \tag{48}$$

$$q = \left\{\gamma + (1-\gamma)p^{1-\theta}\right\}^{\frac{1}{1-\theta}} \tag{49}$$

$$K = I \tag{50}$$

$$Y = AK^\alpha \tag{51}$$

$$N = \delta\left\{R^K qK - R^*(qI - N) - \mu\int_0^{\overline{\omega}} \omega R^K qIdF(\omega)\right\} + W^e \tag{52}$$

$$\overline{\omega} = \frac{2}{\mu}(1 - \frac{R^*}{R^K}) \tag{53}$$

$$W^e = (1-\alpha)(1 - -)AK^\alpha \tag{54}$$

$$\frac{N}{qK} = \frac{\mu^2 - 2}{\mu^2} + \frac{1-\mu}{\mu^2}\frac{R^K}{R^*} + \frac{1+\mu}{\mu^2}\frac{R^*}{R^K} \tag{55}$$

$$R^K = \frac{\alpha A}{qK^{1-\alpha}} \tag{56}$$

$$pC^F = \frac{(1-\nu)}{\nu}C^H \tag{57}$$

$$C^e = (1-\delta)\left\{R^K qK - R^*(qI - N) - \mu\int_0^{\overline{\omega}} \omega R^K qIdF(\omega)\right\} \tag{58}$$

$$C^H + pC^F + qK + C^e = Y + p(R^* - 1)(B - D) - \mu \int_0^{\overline{\omega}} \omega R^K qIdF(\omega) \quad (59)$$

$$p(R^* - 1)(B - D) = C^{H^*} - pC^F - pI^F \quad (60)$$

$$D = \frac{qK - N}{p} \quad (61)$$

$$C^{H^*} = pC^* \quad (62)$$

9.2 Appendix B

In this appendix I show the asymmetric effects of unanticipated changes in relatives prices on net worth depending on the degree of leverage that the firm exhibits. Given that capital is fixed in period t, net worth, N_{t+1}, is determined by the relative price of foreign goods in terms of home good (equation (20)). This dependence stems from the debt denomination in terms of the foreign good. An increase in p_t (a devaluation of the real exchange rate) raises debt payments in terms of the home good, lowering the net worth. If the debt were denominated in terms of the domestic good, the expression $\frac{p_t}{p_{t-1}} R_t^*$ would become $E_{t-1}\left\{\frac{p_t}{p_{t-1}} R_t^*\right\}$. In this case, the payment in period t would be fixed in terms of the home good. In such a case, unexpected changes in the real exchange rate will not affect the net worth but will redistribute wealth from lenders to borrowers.

At this point it is important to mention that the effect of unexpected changes in p_t will depend on the degree of leverage of firms. To illustrate this point let us define the next relations

$$U_t^{\Delta p} \equiv \frac{p_t}{p_{t-1}} - E_{t-1}\left\{\frac{p_t}{p_{t-1}}\right\}. \quad (63)$$

and

$$V_t = R_t^K q_{t-1} K_t - \frac{p_t}{p_{t-1}} R_t^* (q_{t-1} K_t - N_t) - \mu \int_0^{\overline{\omega}^j} \omega R_t^K q_{t-1} K_t dF(\omega) \quad (64)$$

where $U_t^{\Delta p}$ is the unexpected shift in $\frac{p_t}{p_{t-1}}$. We can express V_t as

$$V_t = E_{t-1}\left\{V_t\right\} - U_t^{\Delta p} R_t^*(q_{t-1}K_t - N_t) \tag{65}$$

Now, differentiating equation (36) with respect to the unanticipated movement in the rate of depreciation, $U_t^{\Delta p}$, we can obtain the next expression

$$\frac{\partial V_t / E_{t-1}\left\{V_t\right\}}{\partial U_t^{\Delta p} / E_{t-1}\left\{\frac{p_t}{p_{t-1}}\right\}} = \frac{-E_{t-1}\left\{\frac{p_t}{p_{t-1}}\right\} R_t^*(q_{t-1}K_t - N_t)}{E_{t-1}\left\{V_t\right\}} \tag{66}$$

This last expression represents the elasticity of entrepreneurial equity with respect to an unanticipated movement in the rate of real depreciation. This elasticity lies in the range $(-\infty, 0]$, depending on the entrepreneur's degree of leverage. The higher the ratio of net worth to investment expenditure, the lower this elasticity. In particular, if this ratio is lower than 0.5 then this elasticity is higher than 1 in absolute value. Now, we can see why sudden depreciations when the debt is denominated in terms of the foreign good have an asymmetric effect depending on the degree of leverage. As we saw, countries with higher financial development exhibit higher ratios of debt to net worth, which increases their exposure to external shocks when debt is denominated in terms of the foreign good.

Depreciations of the real exchange rate, p_t, also affect the entrepreneurs' demand for home good. The effect of p_t on I_t^H operates through two channels working in opposite directions. Let us consider an increase in p_t, the relative price of the foreign good in terms of the home good. Increases in p_t in turn increase q_t, the capital price index, which generates a rise in the demand for home goods for investment purposes. Entrepreneurs using both goods (foreign and home goods) in the production of capital will substitute for the relatively more expensive foreign good, a less expensive home good. We call this the substitution effect. On the other hand, increases in p_t raise the external finance premium that entrepreneurs face reducing investment in equilibrium. An increase in p_t raises investment expenditure ($q_t I_t$) reducing the contribution of entrepreneur j's own funds (net worth) as a proportion of total investment cost. We called these the income effect. The income and substitution effects have opposite influences. If the income effect dominates the substitution effect, an increase in p_t decreases entrepreneurs' demand for home good.

Figure 1
Impulse Responses to a World Interest Rate Shock

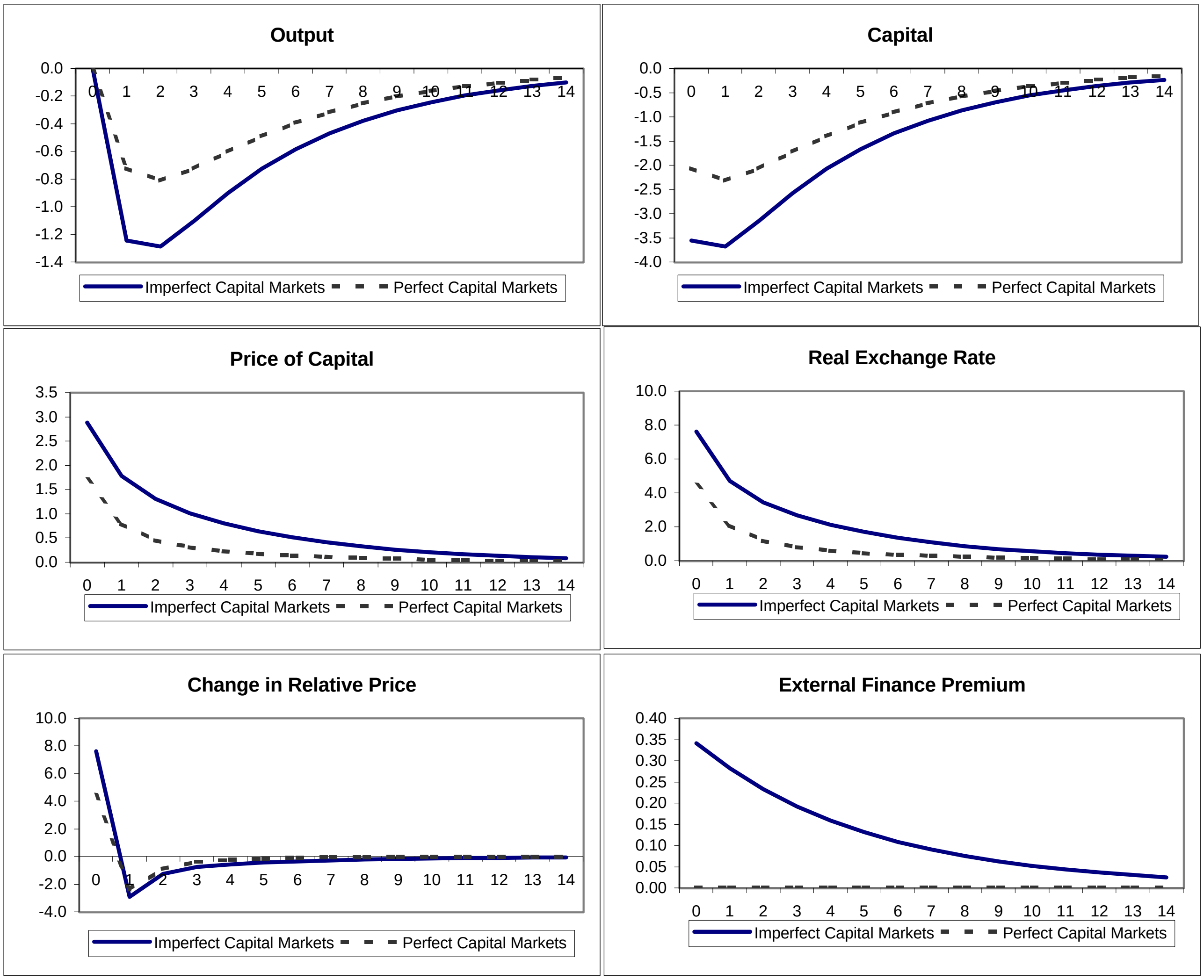


Figure 2
Impulse Responses to a World Interest Rate Shock

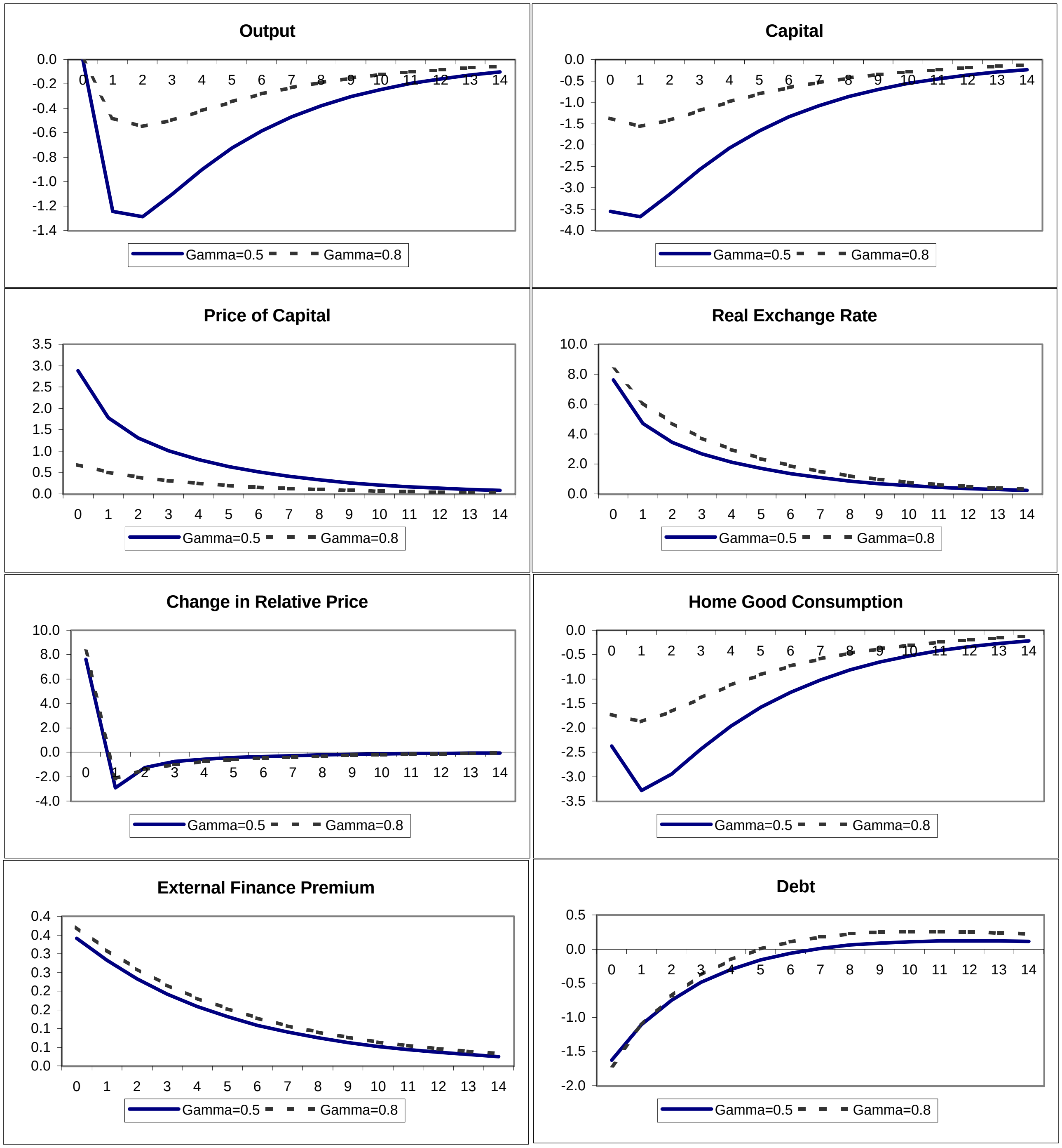


Figure 3
Impulse Responses to a World Interest Rate Shock

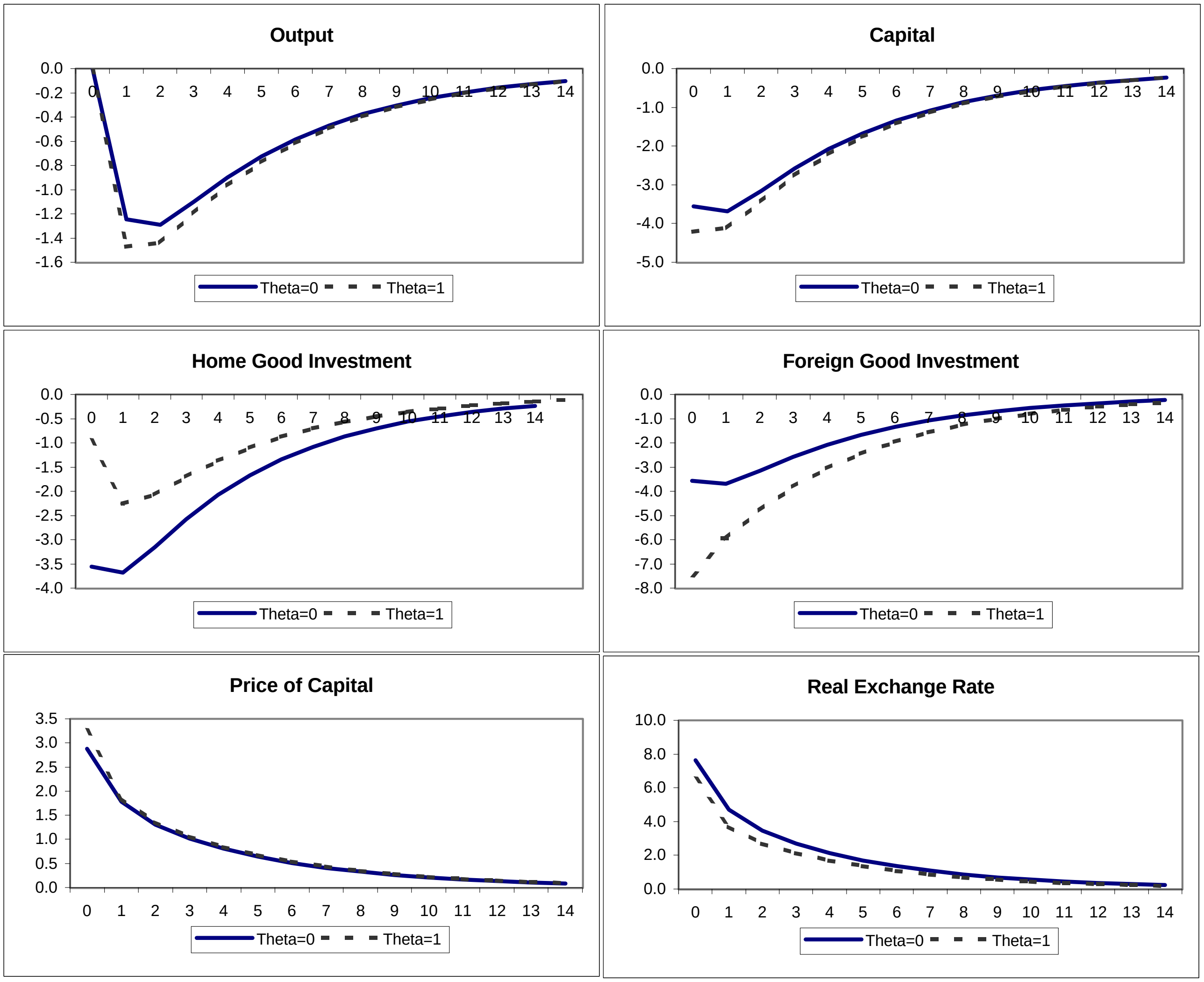


Figure 4
Impulse Responses to a Productivity Shock

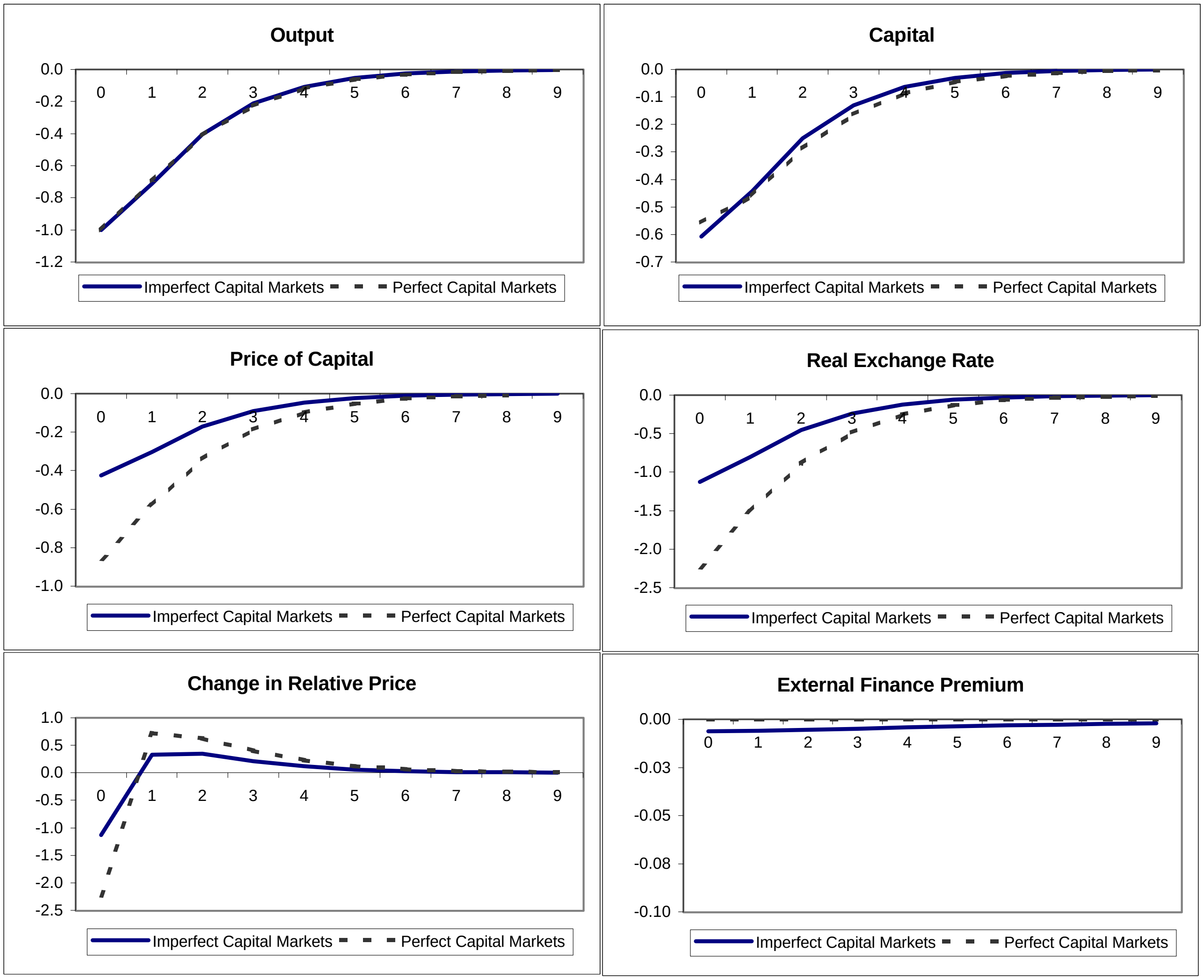


Figure 5
Impulse Responses to a Productivity Shock

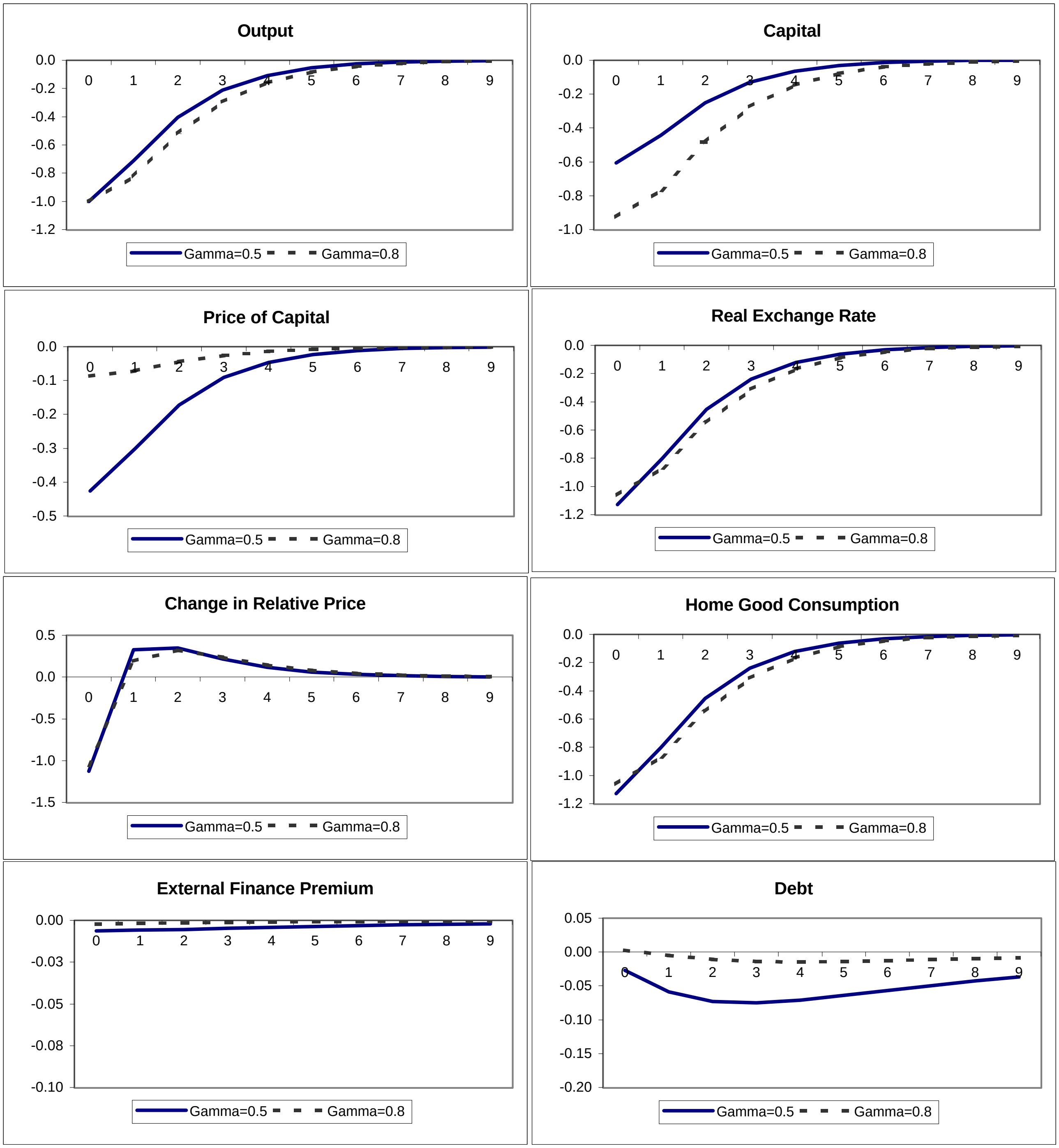
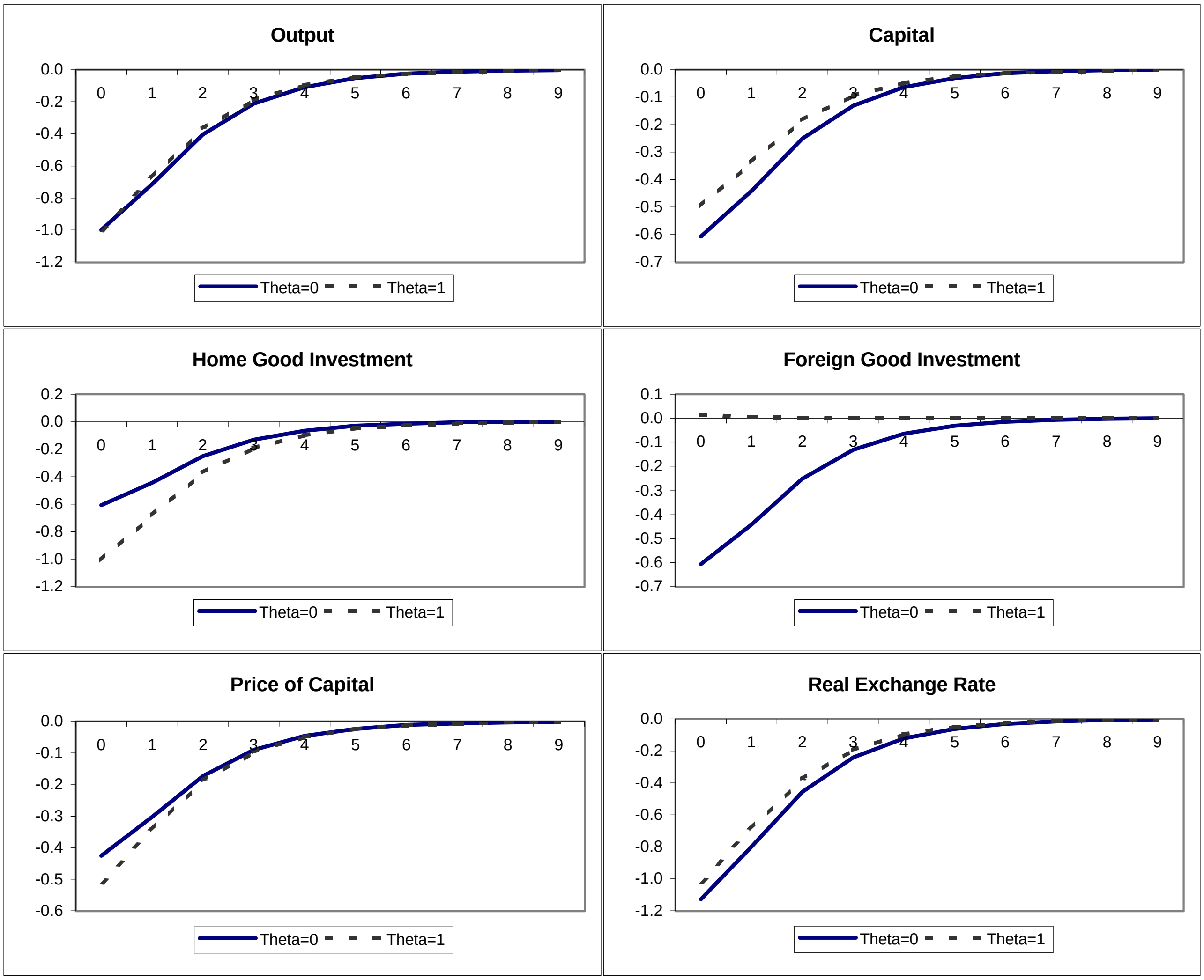


Figure 6
Impulse Responses to a Productivity Shock



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