Essays on International Macroeconomics

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Introduction

This thesis deals with different topics on international macroeconomics, in particular on business cycles in small open economies, the motives for net foreign asset accumulation and the transmission of shocks in an international framework. The three chapters deal with very different issues and different degrees of modeling complexity. There is an eternal discussion between the trade-off between simple models that target to understand a little piece of the macroeconomic mechanism and more complex models that are closer to reality. The first two chapters are more simple and their main contribution relies on the analysis of very particular issues, such as the role of expectations and the role of risk aversion. The last chapter tackles with a sophisticated 2-country model with vertically integrated firms to analyze the transmission of shocks.

The first chapter analyzes and quantifies the role of ‘news shocks’ in a small open economy real business cycle. Changes in expectations play an additional role to explain booms and busts in small open economies. These changes are modeled as ‘News shocks’, which are noisy signals that announce future productivity developments. As agents expect that the rate of growth of the economy will deviate from its steady state, they react by increasing their consumption and investment by running a current account deficit. If the expected favorable changes are not followed by actual increases in the fundamentals, investment and borrowing requires ex-post adjustment leading to an abrupt sudden stop in capital inflows. As in Beaudry and Portier (2004a) and Jaimovich and Rebelo (2006b) a positive comovement between consumption and investment is attained as agents have access to international financial markets. The numerical analysis shows that an open economy with “news shocks” is more volatile depending on the reliability of the signals and the frequency at which positive technology shocks take place, and is able to replicate the observed booms and bust pattern.

In the second chapter ‘Capital liberalization and the U.S. external imbalance’ written jointly with Katrin Rabistch we try to rationalize the observed US net foreign asset position. Differences in financial systems are often named as prime candidates for being responsible for
the current state of world global imbalances. This paper argues that the process of capital liberalization and, in particular, the catching up relative to the US of other advanced and emerging market economies in terms of financial account openness can explain a substantial fraction of the current US external deficit. We assess this link in a simple two country one good model with an internationally traded bond. Capital controls are reflected in the presence of borrowing and lending constraints on that bond. A reduction in the foreign country’s (RoW) constraint on capital outflows enables the domestic economy (US) to better insure against consumption risk and therefore decreases its motives for precautionary asset holdings relative to the rest of the world. As a result, the US runs a long run external deficit.

The last chapter develops a quantitative, dynamic open-economy model where low exchange rate pass-through results endogenously due to the need of distribution firms to bring goods to the final consumer and from nominal rigidities faced by wholesalers and retail firms in a vertically integrated open economy. The presence of nominal rigidities at different levels of this vertically integrated economy affects mark-ups volatility.
Chapter 1

‘News shocks’ in the small open economy
1.1 Introduction

The role of expectations in business cycles have been neglected in the literature given the counterfactual predictions they deliver in a standard dynamic general equilibrium framework. Real business cycles models predict that in the face of positive news about the future leads to a recession today. However, economists and observers argue that expectations played an important role on the investment boom in the US during the 90s and its subsequent correction. Similarly, emerging markets have suffered in the last decades recurrent crises. Experts have pointed out that the optimism by foreign investors and domestic agents together with other factors, is one of the explanations of the observed large corrections. How to introduce this intuitive idea formally in theoretical models is an open issue.

Many economies have experienced substantial capital inflows leading to an increase in economic activity. However, sometimes after some time of ‘bonanza’ these economies needed to adjust abruptly, suffering the so called ‘sudden stops’ in capital flows. The usual suspects are financial frictions, a negative shocks either in productivity, adverse terms of trade among others. It is also usually claimed that by commentators and experts that an excess of confidence by economic agents was one of the main factors driving the ‘booms’. As said by Dornbush in (1983) and by McKinnon and Pill (1993):

“The history of investment in South America throughout the last century has been one of confidence followed by disillusionment, of borrowing cycles followed by widespread default.”

In this paper I capture the idea of the role of expectations by extending the real business cycle framework to be subject to ‘News shocks’. This idea has been exploited in a closed economy by Beaudry and Portier (2004a) and Jaimovich and Rebelo (2006b) where cycles are driven, in addition to the usual contemporary unanticipated shocks, by the anticipation of shocks and the reception of signals. I extend the model to a small open economy framework and quantify the role of this type of shocks. Allowing agents to trade in international financial markets allows to analyze the role of borrowing and lending in the in the presence of noisy anticipated shocks. Access to international financial markets slacks the borrowing constraint and raise an additional concern if signals are not fully reliable. ‘News shocks’ are incorporated in the information set of the agents to capture the role of information and agents confidence. The question is whether ‘news shocks’, as determinants of business cycles fluctuations, are able to generate booms and busts in a small open emerging market economies.
The economy is subject to shocks to expectations modeled in the following manner: agents receive signals about the future that can take place or not in the future. Agents are rational and they convey the information available to make their forecasts about the future.\textsuperscript{1} ‘News shocks’ are defined as information that is useful to predict future fundamentals, but are unrelated to changes in current fundamentals but correlated with future fundamentals. These ‘news shocks’ have similar effects as demand shocks, either taste or monetary shocks. When positive ‘news shocks’ about the future arrive, investment and consumption display swings that are not associated with changes in contemporaneous productivity. This ‘news’ about the future in emerging markets can encompass a wide range of possibilities, such as expectations about future technological opportunities, an imminent financial liberalization, signing a trade agreement or the announcement of credible market reforms that will expand the access of foreign markets in the future.\textsuperscript{2}

Using this set-up a quantitative analysis is carried out to assess the extent to which whether a change in expectations or wrong expectations can explain the ‘boom’ in consumption and investment and subsequent adjustment that leads to a drop in output, consumption and investment, as well as the large current account reversals often observed in emerging market economies. These are the features that characterize a sudden stop. Due to financial openness the budget constraint is slack and agents do not have to trade-off consumption and investment in the face of expected increases in productivity as it happens when the economy is closed. Agents can borrow from external sources, carry out their investment projects (increasing the installed level of capital) without sacrificing consumption today. However, if the increase in productivity does not occur and agents rely on the positive signals, the level of installed capital is higher than the optimal level leading to an abrupt adjustment on capital and debt repayment. The contribution of this paper is to analyze and quantify the role of news on future productivity increases in a small open economy where agents can borrow or lend abroad for smoothing consumption purposes or to finance investment.

For the quantitative evaluation of the model I focus on emerging market economies. These economies have experienced trade and financial openness processes that led to a surge in capital inflows and periods of strong economic growth. Business cycles in these economies are characterized by higher macroeconomic volatility and some specific relations between their macro aggregates compared to the observed pattern in small developed economies. Con-

\textsuperscript{1}Departures from rational expectations assumption is possible by including behavioral biases such as optimism and overconfidence as in Jaimovich and Rebelo (2006a).

\textsuperscript{2}For a reference of a study on the effect of new market opportunities in a closed economy with differentiated varieties in production see Beaudry, Collard and Portier (2006).
sumption is more volatile than income, the current account is more counter-cyclical than in developed economies and real interest rates are counter-cyclical and lead the cycle. In addition these countries also face dramatic sudden stops in capital inflows and output. Before a sudden stop takes place the country is characterized by high output growth, massive capital inflows, and a boom in asset markets. After, the country suffers a sudden loss of access to international capital markets accompanied by a large reversal of current account deficit, followed by a sharp collapse of domestic production and aggregate demand, sharp corrections in asset prices and prices of non-traded goods relative to traded goods.

Numerical results show that the model does quite well in the following dimensions. First, in spite of anticipation of shocks we obtain a positive correlation between consumption and investment. Second, although the smoothness properties that anticipation of shocks have, still the volatility of the macro aggregates is relatively high accounting for 30 percent of the data volatility in the most basic case, and increases when adding persistence to the shock. The volatility of the current account and trade balance increases. Third, this model is able to generate sudden stops although not the observed output drops. However, we do better than other models that introduce collateral constraints. Models with this kind of financial frictions predict that a sudden stop on capital flows, modeled as a sharp drop in the value of the collateral constraint, leads to output increases. Agents in this situation have the incentive to work harder so as to slack the collateral and be able to borrow more, see Chari and McGrattan (2005). A way to obtain output drops is by including other financial constraints such as working capital constraints as in Neumeyer and Perri (2005) and Mendoza (2005).

Departures from the usual assumption of perfect knowledge of the current and true fundamental where the economy stands can go into two directions. The one followed here is that agents receive signals about the future and these can get realized with some probability. Another possibility is that agents do not have perfect information about the current state of the economy but they learn about the true state of the economy over time. This is the strategy followed by Boz (2005) in a capital asset market framework she assumes that both domestic and foreign investors extract signals from dividends and learn over time about the true state of the economy. In this paper we do not distinguish between foreign and domestic investors, we just assume that they share the same (good or bad) information to make forecasts and that the country can borrow without any constraint. Most of the recent literature on emerging market economies rely on financial frictions such as collateral constraints as in Aiyagari and Gertler (1990), Calvo (1998), the financial accelerator mechanism from

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\(^3\)See Prades, Elvira (2008), Essays on International Macroeconomics, 10.2870/19235
Bernanke, Gertler and Gilchrist (1998) and Kiyotaki and Moore (1997), margin calls as in Mendoza and Smith (2006). These models are able to generate the some amplification of negative shocks to explain what happens after a sudden stop takes place, but neglects the role of possible overinvestment or overborrowing processes that takes place before the crises driven by investor sentiment.\footnote{For a survey on financial frictions to explain sudden stops in emerging markets see Arellano and Mendoza (2002); their conclusion is that these models have problems to match quantitatively the observed facts.}

The paper is organized as follows. The following section reviews the literature on business cycles and the role of anticipation of shocks. In section 1.3 the main features of emerging market economies in terms of business cycles and expansions and recessions are analyzed. In section 1.4 the model with ‘news shocks’ is presented. In section 1.5 the quantitative properties of the model are studied. Then we focus on the open economy case. First, in subsection 1.5.1 in terms of impulse the responses to a ‘news shock’. Second, in 1.5.2 the ability of the model in generating business cycles is analyzed. Section 1.6 concludes.

1.2 Literature review

The present paper merges two strands of the literature. On one hand the role of expectations in business cycles in a closed economy as in Beaudry and Portier (2004a) and Jaimovich and Rebelo (2006b). On the other, real business cycles in a small open economy, as Mendoza (1991), Correia, Neves and Rebelo (1995) and Aguiar and Gopinath (2007). In a standard neoclassical closed economy, positive news about the future translates into a recession today, not following a positive comovement between consumption, investment and output, what Beaudry and Portier (2004a) denominate a Pigovian business cycles. In figure (1.1) the response of a ‘news shocks’ about a permanent increase of total factor productivity in a one good closed economy is plotted. When the shock is expected to be permanent, consumption increases on impact and labor supply, capital investment and output declines. Due to these counterfactual result obtained in a one good economy, the role of expectations in business cycles has been neglected in the literature. The role of anticipation of shocks has been analyzed by Cochrane (1994) among others. Although he concludes that consumption shocks play an important role in business cycles, the standard rbc model predicts a recession in the face of ‘news shocks’.

Recently, there is a revived interest for this idea, and there are numerous papers that in-
roduce twists in the neoclassical model in such a way that they overcome some of the counterfactual predictions. Beaudry and Portier (2006b) have modified the simple neoclassical model by including three sectors in the economy, with some complementarities in production and costly adjustment costs in transferring resources from one sector to the other they are able to obtain a positive comovement between consumption and investment. Jaimovich and Rebelo (2006b) carry out a similar exercise by introducing variable capital utilization that increases the extent to which output can respond to news about the future and adjustment costs to investment or capital utilization, to give an incentive to react immediately to future technical progress in a one sector model. In an empirical paper Beaudry and Portier (2006a) explore the role of news in the business cycle. News affect the economy on impact, as a demand shock, but with the difference that these shocks do have an impact on productivity in the long-run, i.e. demand shocks and supply shocks are correlated with a lag. They show that this “news shock” accounts for 50 percent of US business cycles fluctuations.

The other strand of the literature on the cyclical fluctuations in small open economies relates to real business cycle models. Mendoza (1991) and Correia et al. (1995) analyze business cycles and the role of different shocks for a small open economy such as Canada and Portugal. However, certain characteristics of the fluctuations in emerging economies cannot be accounted by these models. The role of the terms of trade has been exhaustively studied by Mendoza (1995) in a three sector intertemporal model. The main result is that terms of trade shocks account for 1/2 of GDP variability. From the theoretical point of view the role of foreign interest rates seemed negligible. However, several empirical studies have stressed the role of movements in US interest rates and country spreads in driving business cycles in emerging market economies. Neumeyer and Perri (2005) present a model of a small open economy, where the real interest rate is decomposed into an international rate and a country risk component. Country risk is affected by fundamental shocks but the effects are amplified through the presence of working capital. The model generates business cycles consistent with Argentine data. Their main policy implication is that eliminating country risk lowers Argentine output volatility more than stabilizing international rates. In addition, Uribe and Yue (2004) analyzed the fact that country spreads have been found to respond to changes in both the US interest rate and domestic conditions in emerging markets. They analyze whether country spreads drive business cycles in emerging countries, vice versa, or both. Also, if US interest rates affect emerging countries directly or primarily through their effect on country spreads. The theoretical model includes gestation lags, habit formation and in order to create an interest-induced substitution effect on the supply side of input markets.
Recently, Aguiar and Gopinath (2007) showed that by introducing a stochastic trend in productivity in a standard dynamic stochastic small open economy, the model can account for the behavior of emerging markets. They match the empirical evidence that emerging markets are subject to substantial volatility in the trend growth relative to developed economies. They are able to replicate the observed stylized fact in emerging market economies that consumption is more volatile than output.

On the other hand, the role of noisy anticipated shocks and is becoming very popular in the real business cycle literature to explain the US investment boom in the 1990's. In a recent paper Jaimovich and Rebelo (2006) analyze the role of ‘news shocks’ in a real business cycle model with adjustment shocks and investment specific technology shocks. Den Haan and Kaltenbrunner (2007) and Andolfatto (2006) analyze the role of labor market frictions and growth expectations. Lorenzoni (2006) presents a model with heterogeneous agents that receive shocks to expectations regarding aggregate productivity. And Devereux and Engel (2005) analyze the role of exchange rate expectations in the small open economy. In Boz (2005) agents learn about the state of the economy, when a shock takes place agents do not know if the shock is permanent or transitory.

An alternative role for shocks to expectations arises in models with increasing returns and multiple equilibria, see Benhabib and Farmer (n.d.) and for a recent explanation of the US 90’s experience Caballero, Fahri and Hammour (2006). In the case of models with increasing returns the positive relation with a boom is associated to a contemporaneous increase in total factor productivity and the incentive to work more during booms is fully captured by the current increase in labor productivity.

1.3 Emerging markets stylized facts

Business cycles As previously mentioned, emerging market economies are characterized by higher volatility of macroeconomic variables, see table 1.3 where standard measures of business cycles are provided for Argentina, Mexico, Korea and Turkey. In order to have an idea of how these economies differ from developed economies, the business cycle properties of Canada are also reported, as a representative developed small open economy. The main business cycle stylized facts are the following. Consumption and investment show positive comovement with output. The current account and net exports are negatively correlated with output. Consumption and investment tend to be more volatile than output. For consumption
is at odds with theory predictions where due to consumption smoothing the relation between consumption and output volatility should be the opposite. Theoretical models on business cycles in small open emerging market economies have faced serious difficulties to explain some of the stylized facts observed in emerging market economies. These models have been able to explain some of the features of the small open economy fluctuations, but cannot account for the observed large collapse in output, consumption and investment and the large adjustment in relative prices. Nor for the previous ‘booms’ before a crises.

**On booms and busts** In figure 1.12 we analyze the behavior of emerging markets before a recession, defined as when output remains for two consecutive periods is below the trend, and the posterior recovery phase. The plots describe the average recession in a sample of emerging market economies: Argentina, Mexico, Korea and Turkey. To date the beginning of a recessions we compute trend output using the HP filter with a smoothing parameter of 1600.\(^5\) We identify periods in which output is below trend for at least two consecutive quarters, say, t and t + 1. Recessions are dated as starting at time t - 1. This definition of recession is broader than the standard that accounts for falls in output. In graphs 1.8 we compute the growth rate and deviations from trend, they differ slightly in size and timings, the use of deviations from trend using an hp-filter is a broader definition of recession. Once the recessions dates for these emerging markets data are identified we compute the behavior of other macro variables such as consumption, investment and current account as percentage of gdp for the same time window: one year prior the recession and 3 years after. The dashed lines represent the 95 percent confidence interval around the average. Time zero is the quarter were the first fall in output is registered, i.e. which the recession starts.

These economies were growing at a fast pace. Consumption and investment were also strong. In addition, the current account deficits were large.

Emerging market economies are also characterized with periods of high growth and some infrequent but abrupt output declines. In figure 1.7 we observe the histograms of growth rates for different emerging market economies compared to those from Canada a developed small open economy and the US. The size of the growth rates are smaller in developed economies. Taking Mexico as an example we can see that the distribution of growth is similar to the US. However, the size of growth rates are bigger and falls are less frequent and sharper. We identify the periods when there was a sharp decline in economic activity and mild recessions took

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\(^5\)The use of the HP filter in a paper that stresses the role of shocks in the trend can appear odd. However, in order to calculate unconditional moments of a non-stationary series some detrending or normalization is needed.

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Prades, Elvira (2008), Essays on International Macroeconomics
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place in these sample of emerging market economies and analyze the pre-crisis behavior. First we analyze in figures 1.8 and 1.11 the deviations from trend and growth rates for Argentina, Mexico, Turkey and Korea of the main macro aggregates, including the current account as a percentage of output. A ‘sudden stop’ is defined as an abrupt and major reduction in capital inflows to a country that has been receiving large volumes of foreign capital. In particular, a ‘sudden stop’ occurs when net capital inflows have declined by at least 5% of GDP in one year. A current account reversal is defined, following Edwards (2004), as a reduction in the current account deficit of at least 4% of GDP in one year. We consider that mild recessions are deviations below trend. In table 1.1 we can observe the behavior of the macro aggregates prior to a crisis.

A more general analysis of the behavior of expansion and recessions are reported in table ???. We compute growth rates and deviations from trend and we distinguish between positive and negative, and check the following: the average increase (fall), the maximum increase (fall), and the frequency of being above (below) the trend or growing positively (negative). We observe that almost all variables seem to go in the same direction the same number of quarters, except for investment that tends to be falling more often (40 percent of the times compared to the 30 percent of output and consumption). There is some symmetry on average increases and falls, but when it comes to the maximum increase and fall the downside is sharper.

1.4 ‘News shocks’ in the Small Open Economy

The model is a standard small open economy business cycle model where ‘news shocks’ allows for a richer information structure compared to the standard unanticipated shocks. The specification closely follows Beaudry and Portier (2006b), here, to explain possible overborrowing processes that might have taken place in emerging markets not being accompanied by an increase in the fundamentals and in consequence its subsequent collapse. Beaudry and Portier (2006b) analyze the role of expectations on real business cycles to explain recessions in closed and developed economies, as the US.

Expectations or news shocks play an important role in the dynamics of the economy. In order to gain some intuition on why it can be relevant for business cycle movements we first discuss some properties of the standard neoclassical model in a small open economy. From the Euler equation condition and for log-linear preferences, we obtain that capital tomorrow
will be determined by the expectations about future marginal productivity of capital. That is, the conditional expected level of productivity \( E_t(z_{t+1} | z_t) \) determines the value of next period capital. The expected value depends on all the available information available at time \( t \). So, if the expected return on next periods capital is higher then the agent will be willing to increase the stock on capital. This decision takes into account that the budget constraint needs to be satisfied. Contrary to the closed economy case where an increase in investment necessarily implies a reduction of consumption or viceversa. In an open economy, the economy has access to international financial markets and can increase the capital stock without reducing consumption.

In a closed economy, without access to international financial market this will imply a fall in consumption. However, in an open economy with access to international financial markets both consumption and investment can be increased. This is an important result as, contrary to the closed economy version, a Pigovian business cycles where consumption and investment are positively correlated. In the following section the fully blown model is explained.

### 1.4.1 One good small open economy model

The model is a standard one good small open economy model. There is a representative agent that produces output, decides how much to consume and invest, supplies labor for production and has access to international markets to borrow and lend for consumption smoothing purposes and to finance investment.

The agents problem can be written as a social planner recursive problem:

\[
V(K, D, z, x) = \max_{K', D'} \left[ u(C, h) + \beta E(V(K', D', z', x')) \right]
\]

subject to:

\[
C - D' + K' = F(K, h) - \Phi(\cdot) - (1 + r_t)D + (1 - \delta)K
\]

The utility of the agents is maximized subject to the budget constraint. Where \( \beta \) is the subjective discount factor, \( \delta \) is the rate of capital depreciation and \( \alpha \) the capital factor in the production function. Where \( r \) is the foreign interest rate paid on debt \( D \). Agents can only trade non-contingent bonds in the international financial market, that is, markets are incomplete. Investment is subject to quadratic adjustment costs \( \Phi \) and the interest rate \( r_t \) faced by agents in their borrowing is debt elastic to insure debt stationarity.\(^6\)

\(^6\)There are several ways for achieving debt stationarity without affecting the business cycle characteristics, for more details see Schmitt-Grohe and Uribe (2003)
Preferences The agents preferences are Greenwood, Hercowitz and Huffman (1988) (GHH), a standard specification in small open economy models.

\[
u(C_t, h_t) = \left( C_t - x_{t-1} \frac{h_t}{\omega} \right)^{(1-\sigma)} \frac{1}{1 - \sigma}
\]

As shown by Mendoza (1991) and Correia et al. (1995) this functional form leads to a higher counter cyclical behavior of the current account, one of the characteristics of the business cycle in small open economies. With this type of preferences hours worked only depend on the current real wage, which is equal to the marginal product of labor. With GHH specification the wealth effect channel is shut down. Whereas with Cobb-Douglas preferences there is an interaction between income and substitution effects. Wealth effects reinforces the increase in consumption today as output is going to be higher in the future. However, this preferences alone do not generate an expansion in response to news about higher future values of productivity. Hours supplied remain constant on impact and therefore output remains constant, but investment can increase instead of falling as agents can borrow in international markets.

Interest rates and stationarity In order to guarantee stationarity the international interest rate is debt elastic, that is, if the country borrows above (below) the steady state ratio debt to output, interest rate will be higher (lower) to assure that bonds do not jump to a new steady state after a shock takes place. We also assume that impatience is not a motive for external borrowing. 7

\[
1 + r_t = 1 + r^* + \psi \left( e^{\left( \frac{D_{t+1}}{r_t} - D_{ss} \right)} - 1 \right)
\]

Adjustment costs on capital As to control for investment volatility we introduce a

---

7 Usually when the discount factor is constant, then the relation \( \beta(1 + r)g_{x,s} = 1 \) will determine the path of normalized consumption to be constant over time.
First order conditions
For the normalized economy, the first order conditions are as follows:

\( h_t : \)
\[
\tau \omega h_t^{\alpha-1} = \frac{1}{x_{t-1}} (g_t)^{-\alpha} (1 - \alpha) \left( \frac{z_t k_t}{h_t} \right)^{\alpha}
\]

\( b_{t+1} : \)
\[
(c_t - \tau h_t^{\alpha})^{-\sigma} = \beta g_t^{-\sigma} (1 + r_t) \left( c_{t+1} - \tau h_{t+1}^{\alpha} \right)^{-\sigma}
\]

\( k_{t+1} : \)
\[
(c_t - \tau h_t^{\alpha})^{-\sigma} \left( 1 + \phi \left( g_t \frac{k_{t+1}}{k_t} - \mu_g \right) \right)
\]
\[
= \beta g_t^{-\sigma} (c_{t+1} - \tau h_{t+1}^{\alpha})^{-\sigma} \left( \frac{k_{t+1}}{h_{t+1}} \right)^{-\alpha-1} g_{t+1}^{-\alpha} 1 - \frac{\alpha - 1}{\alpha} + \phi \left( g_t \frac{k_{t+2}}{k_{t+1}} - \mu_g \right)
\]

\( \lambda_t : \)
\[
c_t + d_{t+1} \frac{x_t}{x_{t-1}} + k_{t+1} \frac{x_t}{x_{t-1}} = y_t - \frac{\phi}{2} \left( g_t \frac{k_{t+1}}{k_t} - \mu_g \right)^2 k_t + (1 + r_t) d_t + (1 - \delta) k_t
\]

\[8\] It is also considered the possibility of introducing quadratic adjustment costs on investment ...

\[9\] see ? for more details. But there is a problem with this specification as pointed out by Jaimovich and Rebelo (2006b). This trend can be justified by appealing to home production, that is, agents positive utility from goods produced at home. They find that in models with stochastic technical progress this formulation can generate large recessions through an implausible mechanism.
Now, the uncertainty in the growth rate of labor productivity is reflected also as uncertainty in the subjective discount factor of the agents.

The labor supply schedule equals the marginal benefit for working with the marginal disutility of working, the former includes the marginal product of labor. The response of labor supply in the case of GHH preferences is unmitigated by consumption’s response. Hours worked therefore display strong cyclicality. The ease of substitution between leisure and consumption in the GHH specification induces also procyclicality in consumption. That is, the incentive to forgo some consumption in response to a positive transitory shock is minimized by the sharp drop in leisure.

1.4.2 Technology process and information structure

The economy is subject to two types of shocks, transitory surprises in total factor productivity and permanent labor augmenting shocks. The production function is Cobb-Douglas:

\[ F(k, h) = z_t k_t^\alpha (x_t h_t)^{1-\alpha} \]

Where \( k_t \) is capital and \( h_t \) hours worked. The two exogenous process are \( z_t \) which is total factor productivity and \( x_t \) that is a labor augmenting productivity process. The specification of the model follows closely Aguiar and Gopinath (2007) where labor augmenting productivity \( x_t \) follows a growth process characterized by a volatile stochastic trend instead to transitory fluctuations around a stable trend that characterize \( z_t \).

The time series representations of the shocks are the following:

\[ \log(z_t) = (1 - \rho_z) \log(\mu_z) + \rho_z \log(z_{t-1}) + \eta_{1,t} \]

Equation (1.4.2) is the usual autoregressive process for unanticipated transitory shocks, where \( \rho_z \) is the persistence of the shock and \( \eta_{1,t} \) follows an i.i.d process with mean zero and variance \( \sigma_z \).

\[ \log(g_t) = (1 - \rho_g) \log(\mu_g) + \rho_g \log(g_{t-1}) + \eta_{2,t} + \varepsilon_{t-p} \]

Equation (1.4.2) represents the evolution of the labor augmenting technology process \( g_{x,t} = \log(x_t) - \log(x_{t-1}) \), this is increasing over time at a constant rate in steady state \( g_{x,ss} \) and is subject to shocks. In this model the information structure is richer than in traditional business cycles. Agents receive an i.i.d. zero mean signal that brings new information about future technological innovations. And \( \varepsilon_{t-p} \) is an anticipated shock, in \( p \) periods in advance
the economy receives a signal or ‘news shock’, that can be informative or uninformative, on whether the economy is going to grow above/below average or not at all at period $t$. The term $\epsilon_{t-p}$ is a signal received at period $t-p$ that indicates whether the economy is going to grow above or below average. Instead of being extracted from a normal distribution, for the sake of simplicity this process can take two values. With probability $s$, the signal takes a value that will cancel the growth rate of that quarter. And with probability $1-s$ it takes the value $s/(1-s)g_{x,ss}$, that is, the economy grows above average. Note that the expected value of the signal is zero and labor augmenting technology never regresses.

$$\epsilon_{t-p} = \begin{cases} -g_{x,ss} & \text{with prob. } (s) \\ \frac{s}{1-s}g_{x,ss} & \text{with prob. } (1-s) \end{cases}$$

In addition, these signals can be informative about the future or not. With probability $(q)$ the signal is going to be validated at time $t$ and with probability $(1-q)$ the signal will turn out to be uninformative.

$$\eta_{2,t} = \begin{cases} 0 & \text{with prob. } (q) \\ -\epsilon_{t-p} & \text{with prob. } (1-q) \end{cases}$$

The standard information structure used in the literature is a special case of this, where the signal $v_t$ is informative and all shocks are unexpected and unanticipated and come as surprises. By using this information structure the idea that signals may sometimes be entirely void of information and that the confidence of agents can be driving the economic activity is captured.

In order to get more intuition on the mechanism, first we compute the impulse responses of the model in a non-stochastic environment to illustrate how agents decisions with regard consumption, investment and output in the face of ‘news shocks’. First we compare the impulse responses in the closed economy and see how a recession takes place in the case of positive news about the future. Then, in an open economy two cases are analyzed. First, when the anticipated news take realize in the future and, second, when they signal turns to be wrong.

For the simulation of the economy, we return to the stochastic environment and the information structure that agents have is richer than in standard models. Agents observe an i.i.d mean zero signal $v_t$. This signal brings new information about what is going to be the
level of labor productivity $p$ periods forward. With certain probability this growth signal will be validated by a technological growth. With some probability the growth signal will not be followed by the technological growth. In addition the case where shocks occur in an unanticipated way is also analyzed. If expectations were wrong agents could have incurred in an overborrowing and overinvestment process, and in the face of a continuous sequence of bad shocks they might be unable to repay or they will face a big adjustment.

The recursive competitive equilibrium is characterized by:

- optimal decision rules for $c$ and $h$
- vector of endogenous states $k'$ and $b'$
- the initial state of the system is given by the observed realization of the technologies $z$ and $x$ and by current endogenous states $k$ $b$

The model is solved by log-linearizing around the steady state and computing the normalized policy functions with standard numerical techniques.

1.5 Quantitative analysis

In this section the quantitative properties of the model are evaluated, first the model is calibrated for Mexico, a prototype of emerging market and then two exercises are carried out. First, we analyze the business cycle properties of the model with this richer information structure. Then, the ability of the model to replicate observed booms and busts is tested.

Calibration of the model Most of the parameters are standard in the small open economy business cycle literature and represent quarterly data. The discount factor $\beta$ is equal to 0.98. This matches in steady state the international interest rate paid on debt securities. The parameter $\psi$ that induces bond stationarity is set to 0.000742 as in Schmitt-Grohe and Uribe (2003), computed so as to match current account volatility. The parameters associated with labor supply, both $\omega$ and $\tau$ are taken from Aguiar and Gopinath (2007), which are the values that gives a steady state labor supply of 0.28 and labor elasticity is not unicity. The coefficient of risk aversion $\sigma$ is set equal to 2. The capital share $\alpha$ and the rate of capital depreciation $\delta$ take standard values. The steady state quarterly growth rate is 0.6 percent, that is $\mu_g$ is 1.006, calculated from hp-filtered trend quarterly gdp of Mexico.
There are three parameters without empirical counterpart, these are the precision of signals $q$, the probability of receiving positive signal $s$ and the number of periods $p$ between the signal and its actual realization. These are calibrated using simulated method of moments (SMM), we find the values of these parameters that minimize the distance between the data moments and the simulated moments. For different time lags $p$ we estimate the following vector of moments $\pi = (s, q)$ such that the following vector of data moments is matched $M^o = (\sigma_y, \sigma_c, \sigma_i)$. The model is simulated $N = 20$ times and for a time series length of $T = 200$. The vector of estimated parameters is such that minimizes the following:

$$J = \frac{NT}{NT+1} (M^s(\pi) - M^o) W (M^s(\pi) - M^o)^t$$

Where $W$ is the weighting matrix based on the variance and covariance of the estimators as to achieve efficient estimates of the parameters and minimizes the value of the $J$ statistic.

The support values of the signal process are, as mentioned in a previous section, a value that cancels the growth of the $p$ periods ahead or a value that is positive and is set as to match the property of being on expectation equal to zero. The volatility of the signal depends on the probability $s$ of receiving a positive signal. On the other hand the volatility of the true fundamental will depend in addition to its reliability $q$. The same applies to the volatility on the perceived process by the agents.

We obtain the following values: the reliability of the signal $q$ equals 0.80 and the probability of receiving a positive signal $s$ is 0.20, which at the same time implies a high above average value growth rate as $\frac{1-s}{s} g_{ss}$ increases the smaller is $s$. This implies that the percent of the times that the economy is growing is quite small and when it happens is in big bits. Comparing these results with the estimates of Beaudry and Portier (2004a) that they calibrated for the US economy, they are quite similar. They differ mainly in the difference between the probability of receiving a positive signal, but in terms of reliability assigned to the information received is more or less the same.\footnote{This suggests that, given the volatility observed in emerging market economies it may be interesting to introduce behavioral biases. Departures from the rational expectations assumption can be a possibility in order to account for the misperception of agents, in particular in emerging markets where there are informational frictions. In a recent paper \cite{10.2870/19235} and introduce two psychological biases such as \textbf{Optimism}, where agents are biased towards good outcomes, or \textbf{Overconfidence}, where agents overestimate the precision of the signals. The latter is able to produce greater volatility when deviations from rationality are large and the first case just modifies the steady state of the economy.}
1.5.1 Impulse responses in ‘News’ driven business cycles in the small open economy

The reaction of macroeconomic aggregates to announced shocks is the following. Agents receive ‘news shocks’, that is a signal that anticipates whether the level of technology is going to increase in some periods ahead or not. Given this information, subject to some degrees of precision, agents use it to make their forecasts and they react in advance. In standard closed economy neoclassical set-up, good news today about the future translates in a recession today. Agents learn about future increases in technology decide to rise consumption today and postpone production until the moment where the marginal productivity of labor is higher. However, in reality we do not observe recessions in the face of positive ‘news shocks’. The business cycle literature in closed economies are incorporating some twists in order to overcome this counter intuitive result.

For simplicity we first analyze a non-stochastic framework as to evaluate the impulse response functions to the announcement of a future permanent shock that is not realized. This exercise is quite limited but later we allow the agents to receive the signals with perfect information about the reliability of the signals.

In figure 1.2 we can observe how a small open economy reacts to a ‘news shocks’. Consumption increases a bit on impact and increases further when the technology is actually available. In contrast to what happens in a closed economy, the ability to borrow allows to increase investment. When the increase of technology takes place, then the supply side of the economy reacts by increasing labor demand as the marginal productivity of labor is actually higher, capital investment raises and output too. These results are similar to those obtained by Beaudry and Portier (2004a) for a closed economy. Agents observe that the economy will jump to a new level of productivity, so they optimally increase consumption and investment. The fact that the shock to productivity is permanent implies a boost to future output, therefore consumption responds, savings are reduced and a current account deficit is generated.

However, there is some probability that the expected increase in productivity is not realized. As it can be seen in figure 1.3 if the announced increase in technology does not take place, then the economy needs to adjust to the true level of the fundamentals. Investment falls as the level of capital needs to be adjusted to the optimal level given productivity. And consumption falls in order to free resources so as to pay the accumulated debt. The size of the adjustment depends on the size of the shock. These impulse responses can mimic the
behavior of a ‘sudden stop’, an abrupt increase in net exports.

We do not obtain a sharp fall in output that is usually associated with sudden stops. As pointed out by Chari and McGrattan (2005), under a set-up of financial frictions, it is hard to obtain output drops. To do so, is necessary to introduce additional economic frictions which have negative effects on output large enough to overwhelm the positive effect of a sudden stop. During a sudden stop, agents have the incentive to work more as to relax the collateral. Some modeling devices need to be used in order to obtain output drops when a sudden stop takes place, such as working capital constraints. For example, in Neumeyer and Perri (2005), firms must borrow to pay a fraction of the wage bill or as in Christiano, Motto and Rostagno (2004) where firms must borrow to pay foreign intermediate inputs. This requirement introduces a wedge between marginal productivity of labor and the marginal rate of substitution between labor and consumption.

In figure 1.4 the impulse responses for different time lags between the signal and the realization are plotted, the shock is transitory. As expected, if agents anticipate that they will be more productive in the future and then they will be willing to build the necessary capital to fully benefit from this increase in productivity.

1.5.2 Simulation of the model

We carry two quantitative exercises to evaluate the ability of the model in generating business cycles and in replicating the observed pattern of ‘booms’ and ‘busts’ in emerging market economies. In order to get a clear picture on how much ‘news shocks’ contribute to business cycle volatility we abstract from other possible sources of shocks, such as transitory and unanticipated.

Once the model is solved for the normalized economy, the series are non-normalized, that is, set back to levels by multiplying by $x_{t-1}$. The results on business cycle characteristics obtained with ‘news shocks’ and with unanticipated shocks, maintaining the same volatility of the shocks are reported in (??). The initial response from agents depends on how trustful is the information they receive, the more trustful it is the higher is the impact on consumption, investment and therefore on the current account deficit. Agents are rational and they use all the available information to make forecasts and do not make systematic errors. The agents receive ‘news shocks’ that they include in their information set, they react accordingly and when the time of the real increase of productivity takes place they adjust, if the productivity...
is as high as expected, then they will jump to the optimal levels. If the rise in productivity does not take place then, they have to disinvest until they reach the optimal level of capital according the actual productivity level and decrease consumption as to pay the incurred debt obligations.

**Uninformative signal** We compare the business cycle statistics obtained when shocks can take two values, either it cancels the growth of technology of that quarter or it keeps growing at is pace. The volatility generated is quite smaller than in a standard exogenous process as the volatility of the fundamental is reduced. The relative volatilities remain unchanged and correlation with output follows similar pattern than in the standard small open economies business cycle models. The unanticipated shock can explain 27 percent of the observed output volatility of the Mexican economy.

**Perfect signals** When agents receive perfect signals about the future the volatility of output, consumption and investment increases. Is noticeable that the volatility of the trade balance and the current account increases much more than the other variables when the economy receives perfect signals about the future. The volatility is also affected by the time lag between the signal and actual realization of the shock. As agents anticipate a future increase in productivity, they are willing to borrow more from international markets. The volatility of the other macro aggregates increases if the persistence of the shock on the growth rate is higher. Agents observe that the are entering a higher growth path and they want to fully benefit. With anticipated shocks the volatility of output in the model accounts for 30 percent of the one observed in the data. One negative result is the positive correlation between the trade balance and output one of the main characteristics that dsge models targets to match. The explanation here is that contrary to the case where shocks are unanticipated, output on impact does not react so strongly and it does so when the technology is available. In our model, this is also the time when the economy starts running current account surpluses. These positive correlation reduces as the persistence of the shock increases, but never being negative. Nevertheless the response of the current account is stronger than in the standard model.

**Noisy signals** These signals can be subject to certain reliability which is perfectly known by the agents. Their reaction to these signals is going to be moderated and therefore the volatility in the economy declines. However, by introducing persistence in the shocks to growth rate the volatility increases. When we simulate the economy for the values of \(s\) and \(q\) calibrated in the previous section the model performs quite good in several dimensions.
1.5.3 Does the model produce sizable ‘booms’ and ‘busts’?

In the absence of technological regress we ask whether the model is able to generate expansions and recessions as the ones observed in the emerging markets. Following Beaudry and Portier (2006b) approach to measure recessions for the U.S. economy, a similar exercise is carried to analyze wether a small open economy with ‘news shocks’ can replicate de drops in output, consumption, and investment observed from a sample of emerging market countries. In table ?? the computation the average increases (declines), the frequency that the economy is growing (not growing) and the maximum increase (drop) of the main macro magnitudes for Argentina, Mexico, Korea and Turkey are reported. These drops are not solely due to ‘news shocks’ but by doing this exercise we want to analyze its possible role and if recessions can take place even in the absence of technology drops. Also we analyze similar statistics for the deviations from trend. Macro variables adjust more or less at the same time, except for investment that falls more frequently and with bigger magnitudes. Targeting the exceptional episodes of sudden stops is optimistic for a model of this kind, however we want to analyze whether it is able to replicate the behavior of mild recessions and expansion periods. In table 1.6 the result are reported and also compared with the predictions from other two benchmark models in the literature of business cycles in small open economies Mendoza (1991) and Aguiar and Gopinath (n.d.).

In table 1.11, the last columns reports the expansions-recession statistics for different degrees of precision of \( q \) and \( s \). We analyze what happens with growth rates and with the deviations from trend generated by the data. Then the results for different combinations of precision and probability of getting positive shocks are considered. Comparing these results with the data for emerging markets we obtain the following results.

**Uninformative signal** First we check what are the expansion recession statistics for an economy that receives unanticipated shocks in terms of volatility and probability of getting a positive shock. We observe that with \( s = 0.5 \), that is, with equal probability of obtaining a value of \( \varepsilon_t \) that cancels growth of that period or a value that allows for growth, the frequency of periods of the economy growing is higher than the percentage of times that the economy is not growing. In terms of the size of the growth rates are big either positive or negative are smaller than the observed data and what the other two models are able to generate. Investment is the macro variable that falls more frequently.

**Perfect signal** The main feature of an economy that receives signals is that consumption
is extremely smooth hardly falling and when it does, the fall is very small. But, the size of the increases and falls increases.

Noisy signal Introducing noisy signals gives intermediate results from the previous cases in terms of size in the increases of output. The size and frequency of positive growth is affected by the probability of getting a positive shock in growth, its reliability $q$ and the persistence of the shock on growth. We feed the estimates from the simulated method of moments that are the combinations of $s$, $q$ and $\rho$ that minimizes the distance between the model and the data. We can observe that the model does quite well in matching these moments for the Mexican economy. Note that the anticipated shocks are the only source of fluctuations, and that there are no falls in total factor productivity. The fact that the size of the falls is not so big compared to the data means that are other shocks that might be driving this.

The dashed line in Figure 1.12 shows the average recession that our model generates.

1.6 Conclusion

In this paper, the role of ‘news shocks’ has been analyzed in a small open economy. In the last decades emerging markets have faced recurrent episodes of financial crises and sudden stops. Numerous theoretical papers have focused on explaining what are the reasons that makes these countries so vulnerable to shocks. These economies face some financial frictions that makes that a small negative shock can be amplified. However, little focus has been given to explain what can be seeding the crunch or mild recessions. Prior to the crises economies have enjoyed an increase in consumption, output and received an important amount of capital inflows, sometimes not accompanied with sufficiently strong fundamentals. In this paper I analyze the role of expectations in building up the crises or recession by introducing ‘news shocks’ in a standard neoclassical small open economy.

We extensively analyze how the agents react when they receive noisy signals about future productivity increases. First we analyze how the agents react in terms of output, consumption and investment. When shocks are anticipated and agents receive a perfect signal, that is, they know the probability at which these signals realize ex-post, agents react in advance although the increase in technology is not available already. Agents react by increasing consumption and investment, financing these two by running a current account deficit. However, there is some probability that the anticipated shock is not realized. When this happens,
economy needs to adjust and return to the old steady state. These situation can replicate a ‘sudden stop’, as the fundamentals have not changed and the economy cannot benefit from the expected increases in productivity they have to adjust and repay the debt contracted previously. In addition we obtain a positive comovement between consumption and investment in an open small open economy, contrary to the prediction of the standard closed economy model and as well as some closed economy versions of the model that they have introduced some other twist in the model such as various sectors, see Beaudry and Portier (2006b) or a particular set of preferences and investment specific shocks such as Jaimovich and Rebelo (2006b). As in the previous literature on crises we are not able to replicate an output drop, but we avoid the counterfactual result that models with collateral constraints that predicts that there will be an increase in output as agents can increase their borrowing limit.

The capacity of the model to replicate the observed booms and busts is also analyzed. We checked wether the model, without relying on falls in total factor productivity, is capable to replicate and to what extent the no growth episodes of output, consumption and investment. In terms of average size and minimum, the model does not perform very well, although we have fed in the quantitative exercise a small shock. These bad result can be overturned by introducing a greater variance on the signal. In terms of frequency the model does much better than the standard model, being the no growth episodes less likely and and being investment the macro aggregate that corrects more often. We conclude that expectations play an additional role in explaining booms and busts in emerging market economies and the ability of matching these statistics improves when the feature of anticipation is introduced.

For future research there are many avenues to follow that seem promising. First, to gain in realism, it would be interesting to incorporate ‘learning’ as in Jaimovich and Rebelo (2006b) among others. Agents do not know about the true state of the economy and by doing signal extraction they learn about it, under the ‘news’ set-up agents learn over time wether their forecast are right or not. The set-up of the model misses some of the main characteristics of emerging market economies such as financial frictions, the purpose was to isolate the effect of new shocks. However, other features such as working capital constraints or collateral requirements could be introduced. Although, not treated explicitly, with this modeling device default can occur in bad states of nature not in the good ones, as models on sovereign debt tend to predict. Models on sovereign defaults assume that markets are complete and in case of being in a good state the incentive is to default, even when the economy is punished to remain in autarky for some periods. Under this set up the economy will have the incentive to default in bad times, which is in line with the evidence.
Appendix
A) The economy in steady state

The economy in steady state is represented by the following system of equations.

\[ h_{ss} : \]
\[ h_{ss}^{\omega - 1} = \left( \frac{1}{\tau \omega} \right) (1 - \alpha) (g_x)^{-\alpha} \left( \frac{k_{ss}}{h_{ss}} \right)^{\alpha} \]

\[ \hat{b}_{ss} : \]
\[ 1 = \beta g_x^{-\sigma} (1 + r^*) \]

\[ \hat{k}_{ss} : \]
\[ 1 = \beta g_x^{-\sigma} \left( \alpha (g_x)^{-\alpha} \left( \frac{k_{ss}}{h_{ss}} \right)^{\alpha - 1} + (1 - \delta) \right) \]

budget constraint:
\[ \tilde{c}_{ss} = (g_{x,s})^{-\alpha} \left( \frac{k_{ss}}{h_{ss}} \right)^{\alpha} (h_{ss})^{1 - \alpha} - (g_{x,s} - (1 - \delta)) k_{ss} - (g_{x,s} - (1 + r^*)) b_{ss} \]

B) Estimation of business cycles statistics with GMM

We impose the following orthogonality conditions for the data moments:

\[ E[y_{hp,t}^2 - \sigma^2_y] = 0 \]
\[ E[c_{hp,t}^2 - \sigma^2_c] = 0 \]
\[ E[i_{hp,t}^2 - \sigma^2_i] = 0 \]
\[ E[n_{xy}^2 - \sigma^2_{nxy}] = 0 \]
\[ E[cay^2 - \sigma^2_{cay}] = 0 \]
\[ E\left[ \frac{(y_{hp,t} - c_{hp,t})}{\sigma_y \sigma_c} - \rho_{cy} \right] = 0 \]
\[ E\left[ \frac{(y_{hp,t} - i_{hp,t})}{\sigma_y \sigma_i} - \rho_{iy} \right] = 0 \]
\[ E\left[ \frac{(n_{xy} - xy)}{\sigma_y \sigma_{nxy}} - \rho_{nxy,y} \right] = 0 \]
\[ E\left[ \frac{(cay - ay)}{\sigma_y \sigma_{cay}} - \rho_{cay,y} \right] = 0 \]
C) Data sources

The data used in the text for different computations such as business cycle statistics, measures of sudden stops and calibration are the following.

**Argentina** The series for output (Y), total consumption (TC), which is the sum of private consumption (PC) and government consumption (GC), and net exports are obtained from MECON, the time series span from 1993q1-2005q4. The sample has been complemented with the Neumeyer and Perri database so as to have a sample from 1980q1. Annual real output in us dollars is from the World Development Indicators (WDI) and interpolated into quarterly data.

**Mexico** The series for output (Y), total consumption (TC), which is the sum of private consumption (PC) and government consumption (GC), and net exports are obtained from the OECD Main Economic Indicators (MEI), the time series span from 1980q1-2005q4. Annual real output in us dollars is from the World Development Indicators (WDI) and interpolated into quarterly data.

**Korea** The series for output (Y), total consumption (TC), which is the sum of private consumption (PC) and government consumption (GC), and net exports are obtained from the OECD Main Economic Indicators (MEI), the time series span from 1980q1-2005q4. Annual real output in us dollars is from the World Development Indicators (WDI) and interpolated into quarterly data.

**Turkey** The series for output (Y), total consumption (TC), which is the sum of private consumption (PC) and government consumption (GC), and net exports are obtained from the OECD Main Economic Indicators (MEI), the time series span from 1987q1-2005q4. Annual real output in us dollars is from the World Development Indicators (WDI) and interpolated into quarterly data.

**Canada** The series for output (Y), total consumption (TC), which is the sum of private consumption (PC) and government consumption (GC), and net exports are obtained from the OECD Main Economic Indicators (MEI), the time series span from 1980q1-2005q4. Annual real output in us dollars is from the World Development Indicators (WDI) and interpolated into quarterly data.
Table 1.1: Macro Magnitudes of pre-crisis/pre-recessions

<table>
<thead>
<tr>
<th></th>
<th>GDP</th>
<th>consumption</th>
<th>investment</th>
<th>CA/GDP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Argentina 1994Q1-Q4</td>
<td>5.9</td>
<td>6.1</td>
<td>14</td>
<td>-4.33</td>
</tr>
<tr>
<td>Mexico 1994Q1-Q4</td>
<td>4.4</td>
<td>4.6</td>
<td>8.4</td>
<td>-7.05</td>
</tr>
<tr>
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<td>3.7</td>
<td>5.1</td>
<td>-</td>
<td>-3.6</td>
</tr>
<tr>
<td>Turkey 2000Q1-Q4</td>
<td>3.1</td>
<td>4.5</td>
<td>-</td>
<td>-5.12</td>
</tr>
</tbody>
</table>

Notes: Average year on year quarterly changes in real GDP, real private consumption, real investment and average quarterly current account-to-GDP in usd ratios.
Sources: International Financial Statistics and National Statistical Offices.

Table 1.2: Baseline Parameters Values

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<tr>
<th>Parameter</th>
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<td>Labor weight</td>
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<td>Adjustment cost parameter</td>
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<td>Depreciation rate</td>
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<tr>
<td>Debt to GDP ratio</td>
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<td>Debt elastic parameter</td>
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<td>Trend</td>
<td>$\mu_g$</td>
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Prades, Elvira (2008), Essays on International Macroeconomics
European University Institute
### Table 1.3: BUSINESS CYCLE STATISTICS

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<th>Argentina</th>
<th>Mexico</th>
<th>Turkey</th>
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<th>Canada</th>
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<td>2.22 (0.002)</td>
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<td>3.04 (0.000)</td>
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<td>3.77 (0.003)</td>
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<td>9.54 (0.000)</td>
<td>11.43 (0.008)</td>
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<td>3.90 (0.001)</td>
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<td>1.00 (0.000)</td>
<td>1.00 (0.000)</td>
<td>1.00 (0.000)</td>
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<td>0.93 (0.016)</td>
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<td>-0.31 (0.147)</td>
<td>-0.41 (0.079)</td>
<td>-0.07 (0.094)</td>
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Notes: Business cycle statistics computed using quarterly data and estimated with GMM numbers in parenthesis are standard errors. Series are logged and HP filtered with a smoothing parameter of 1600, and when a strong seasonal component is present series are de-seasonalized using TRAMO-Seats.

---

**Figure 1.1:** Impulse responses in the neoclassical closed economy model to 'news shocks' about permanent technology increases when capital is costly to adjust.
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Table 1.5: Analysis of expansions and recessions (data)

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Notes: Statistics are computed for seasonally adjusted data.
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Booms and busts statistics from different models and specifications of the probability of receiving a positive signal $s$, its reliability $q$, and persistence of the shock $\rho$.

10.2870/19235
Figure 1.2: Impulse responses in the small open economy to transitory shocks and news socks about a permanent technology increases

Figure 1.3: Impulse responses in the small open economy to ‘news socks’ about permanent technology increases when capital is costly to adjust and the shock is not realized
Figure 1.4: Impulse responses in the small open economy to ‘news socks’ about transitory technology shocks when capital is costly to adjust and the shock is realized.

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Chapter 2

Capital liberalization and the U.S. external imbalance
2.1 Introduction

Among the most debated topics in international macroeconomics in recent years is the US current account deficit over the past years and the ongoing accumulation of US’ net foreign debt since the mid eighties. At the end of 2006 the US net foreign asset position is standing at about minus 25% of its GDP, the current account deficit in 2006 stands at above 6% of GDP after being in the red for most of the last 25 years. The size and persistence of the US net external positions are challenging to the conventional wisdom of the standard theory of the current account and has led to a large debate -among academics and policy makers alike. Contents of this debate are the sustainability of these imbalances, whether and when adjustment needs to take place or how painful it is going to be for the world economy. A number of authors have argued that the current imbalances might create major financial turbulence, or at least that major policy actions need to be taken to avoid a painful worldwide rebalancing process (e.g. Obstfeld and Rogoff (2004), Roubini and Setser (2005), Blanchard, Giavazzi and Sa (2005)). On the other hand, a number of papers have emphasized that before policy advice can be given as to how adjustment of the current global imbalance should take place, it is important to understand how these imbalances have arrived in the first place. Recently, attention has been put on cross-country differences in financial factors as a potential driving force behind the imbalances (Mendoza, Quadrini and Rios-Rull (2006), Caballero, Farhi and Gourinchas (2006)). We propose a mechanism that is related to this view, yet different. While we also stress the importance of financial factors, we focus less on the financial development within a country, but instead more on the role of differences in financial openness across countries. Arguably, the US is the economy that has had the most liberalized financial account already in the 1980s. We suggest that the catching up of other advanced and emerging market economies in terms of financial account openness may be partly responsible for the current global imbalances.

Figure 2.1 presents an index of financial openness developed by Chinn and Ito (2005) that is based on measures such as a country’s controls on capital and current account transactions, the presence of multiple exchange rates within that country or requirements for the surrender of export proceeds. As it can be seen from this index, the US has always been financially open over the last three decades, and most other regions have been liberalizing gradually since the beginning of the 1980s. We can observe that the index for Asian countries starts picking up in the late 1970s or early 1980s, for the group of Latin American emerging markets it increases in the early 1990s. The index for European countries shows a first increase in the early 1980s but picks up substantially also only in the early 1990s. Figure 2.2 plots the development of the US
current account and its net foreign asset position. As can be seen the gradual decline in the US net external position begins somewhere in the mid 1980s, and was actually positive before.

A basic function of world capital markets is to allow countries with imperfectly correlated income risks to trade them. If world financial markets were complete, countries would be able to largely reduce the cross-sectional variability in their per capital consumption levels. The empirical stylized facts just presented, indicate that a quarter century ago, for most regions of the world other than the US the degree of financial openness was rather limited. At that time, because of controls on inflows and especially on outflows of capital in most emerging market countries as well as in many industrial countries world capital markets were far from complete. With international capital markets being only a limited means for involving in consumption smoothing in response to country specific shocks, a country’s agents have an incentive to have some buffer asset holdings to insure against bad times in which consumption would be very low otherwise - there is a precautionary savings motive. We argue that while the US has had a very liberalized financial account already in the mid 1980s, long before the rest of the world (RoW), it nevertheless could not access world financial markets unrestrictedly, because the RoW had high controls on capital outflows. Effectively, this ‘constrained’ the US in its ability to borrow in international financial markets in order to insure against any risk of fluctuations in their consumption. When capital controls in the rest of the world started to be dismantled, this allowed the US to effectively borrow more easily at any point and decreased the importance for them to have precautionary asset holdings. It is the drop in the relative importance of precautionary savings that links the accumulation of US net foreign debt to the process of capital liberalization.

We address this question in a two country one good model and consider two cases: 1) an endowment economy, where outputs arrive stochastically each period, and, 2) a model with production and capital accumulation similar to Backus, Kehoe and Kydland (1992), which is the standard workhorse model of international macroeconomics. The simple model is developed mainly to build intuition, whereas the model with capital accumulation allows for a more realistic description of actual economies. We assume that the representative agent in each country can trade a non-contingent bond to smooth consumption in response to country specific shocks, but that she cannot do so unrestrictedly. In particular, in each country agents have limited access to borrow and lend in international financial markets; there are limits beyond which they cannot borrow or lend. We think of the presence of capital controls as being reflected in the tightness of these borrowing and lending constraints. When the limits are set to zero, such that the bond holdings are not only constrained but cannot be used at
all, the economies are in financial autarky. As the constraints get more and more relaxed, it becomes increasingly easier to achieve smoother consumption. The presence of the borrowing and lending constraints creates a role for a precautionary savings. The catching up of the rest of the world’s (RoW) financial openness, that is, the financial account liberalization in the RoW is modeled as a one-time permanent relaxation of the upper limit of capital outflows of the foreign economy. Effectively, this improves also the domestic -US- ability to borrow. For any given level of risk it faces it can now better use the international bond for consumption smoothing purposes, and the implied drop in consumption volatility means that it has less of a motive to hold assets as a buffer for times of low consumption. It is this drop of the (relative) importance of the precautionary savings motive that endogenously makes the U.S. hold long run negative net foreign assets as it transitions to a new implied steady state.

There are several contributions in the literature that our paper connects to. As mentioned before, in recent work Mendoza et al. (2006) also refer to differences in financial factors as a potential explanation for the U.S. external imbalances. They emphasize the heterogeneity of financial systems within countries such as a country’s credit markets and differences in the ability to borrow from collateral.¹ They propose a model in which agents face idiosyncratic risk from both endowments and investment technology, which has to be to be managed differently. In such a setup, differences in financial development between countries matter when economies open up to trade in international financial markets. The accompanied process of factor equalization -less developed economies face an increase in the interest rate relative to its autarky interest rate, therefore an incentive to save- leads to capital flows from less developed financial markets into the US economy. Contrary to Mendoza et al. (2006) we focus on the effects of capital liberalization on cross-country risk sharing, and show that even in a model with aggregate risk only the implied imbalances of a change in financial openness can be substantial.

Caballero, Farhi and Gourinchas (2006) argue that for emerging market economies, among them most prominently China, the development of local financial markets has not kept pace with the growth experiences of their economies. They argue, that for these countries, this has led to an inability to supply high quality financial assets. The high demand for quality assets on world financial markets, together with the process of capital liberalization has allowed emerging market economies to hold their savings in U.S. assets, or equivalently has allowed

¹Their paper also provides empirical evidence of a negative relationship between the state of development of a country’s credit markets and its current account. The ratio of Private Credit to Domestic Sector as percentage of GDP from the World Development Indicators shows that the US is (and has been) world leader in terms of credit market development.
the U.S. to more easily hold foreign debt.

The explanation for what is driving the US external deficit that is suggested here, that is, the decrease in the US precautionary savings motive relative to the rest of the world is similar to the mechanism proposed by Fogli and Perri (2006). They claim that the ‘great moderation’ in business cycle volatility in the US (compared to the rest of the world) has led to a decrease in consumption volatility which is what is driving the US external imbalance. In our model it is the opening up of countries’ financial accounts which allows the US to better smooth its consumption and which endogenously leads to the external deficit.

The paper is organized as follows. In section 2.2 we present the model framework, a simple two country endowment model that allows for constraints on capital in- and outflows. Section 2.3 explains in detail how financial openness and capital liberalization is modeled. Subsection 2.3.1 briefly describes the solution technique and discusses parametrization. In subsection 2.3.2 we present the results of the quantitative exercise for the simple model together with some sensitivity analysis. Section 2.4 proceeds with the discussion and results of the model with capital that can be calibrated. Section 2.5 concludes.

2.2 Endowment Economy

2.2.1 The model

The world economy consists of two countries, Home and Foreign, each inhabited by a large number of infinitely lived agents with mass $n$ and $(1 - n)$ respectively. We will assume that all idiosyncratic risk is perfectly insured among residents of a country, i.e. within-country financial markets are complete. We can therefore think of a representative consumer in each country that maximizes the expected sum of future discounted utilities from consumption $c_t$:

$$
E_0 \sum_{t=0}^{\infty} \beta^t u(c_t) \tag{2.1}
$$

where $\beta$ is the rate of time preference. The utility function $u(c)$ is assumed to be constant relative risk aversion $u(c) = (1/(1 - \sigma)) \left[ c^{1-\sigma} - 1 \right]$, where $\sigma$ is the coefficient of relative risk aversion. The foreign representative agent faces an equivalent problem, where foreign variables are denoted with an asterisk. Agents of each country receive an exogenous endowment $y_t$ or $y^*_t$ respectively in every period $t$. Exogenous outputs are assumed to follow a bivariate
autoregressive process of order 1:

\[
\begin{pmatrix}
    \ln(y_t) - \ln(\bar{y}) \\
    \ln(y_t^*) - \ln(\bar{y}^*)
\end{pmatrix} = A \begin{pmatrix}
    \ln(y_{t-1}) - \ln(\bar{y}) \\
    \ln(y_{t-1}^*) - \ln(\bar{y}^*)
\end{pmatrix} + \begin{pmatrix}
    \varepsilon_t \\
    \varepsilon_t^*
\end{pmatrix}
\]

(2.2)

where \( \bar{y} \) is mean income, \( A \) is a 2x2 matrix of coefficients describing the autocorrelation properties of the process, and \( \varepsilon = (\varepsilon_t \ \varepsilon_t^*)' \) is a vector of shocks from a bivariate normal distribution with mean zero and variance-covariance matrix \( V(e) \), i.e. \( e_t \sim N(0, V(e)) \).

Asset markets are incomplete in the sense that countries are only allowed to trade in a one-period risk free bond \( b_t \) which promises one unit of consumption the next period and trades at price \( \frac{1}{r_t} \), where \( r \) is the gross real interest rate. We can then write the domestic country’s budget constraint as:

\[
\frac{b_{t+1}}{r_t} = b_t + y_t - c_t \quad \text{with } b_0 \text{ given}
\]

(2.3)

Even though agents are assumed to be able to trade a risk free bond in order to smooth their consumption, they cannot do so unrestrictedly. In particular, we assume that the domestic country’s debt level cannot exceed some fraction \( B \) of the level of its current output:

\[
\frac{b_{t+1}}{y_t} \geq -B
\]

(2.4)

Due to capital controls international asset holdings are also limited by an upper bound.

\[
\frac{b_{t+1}}{y_t} \leq B^*
\]

(2.5)

The foreign country’s budget constraint and the borrowing and lending constraints are equivalent versions of equations (2.3) and (2.4), replacing all variables with starred ones. The borrowing limit for the foreign country therefore is \( \frac{b_{t+1}^*}{y_t} \geq -B^* \) and the lending limit is \( \frac{b_{t+1}^*}{y_t} \leq B^* \).

Due to symmetry and the fact that bond holdings must be in zero net supply, only two

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2In addition, there is a ‘natural debt’ limit as in Ayagari (1994) in which both countries will not borrow more than the minimum value that the endowment can take at period \( t+1 \) discounted to period \( t \) prices, but on top of that countries face more restrictive debt limits. To compute the natural debt limit in a two country model, where the interest rate is endogenous, is more difficult than in a partial equilibrium model where the interest rate is exogenous. In addition if one the constraint binds for one of the economies the interest rate differs for each agent, for a detailed discussion see Anagnostopoulos (2006). However, the debt limits we impose are generally stricter than the natural debt limit.

3In equilibrium, since bonds are held in zero net supply, the foreign country’s borrowing constraint reads \( \frac{b_{t+1}}{y_t} \leq B^* \) and the lending constraint reads \( \frac{b_{t+1}}{y_t} \geq -B^* \).
of the four constraints on borrowing and lending effectively matter. More precisely, the limit that is imposed on up to how much one country can borrow is determined by either its own borrowing constraint or by the other country’s lending constraint - whichever of the two is stricter. Formally, the range over which the international bond can effectively be traded is given by the interval \( [B, B^*] \), where 
\[
B = \max\left(-B_y t, -B^* y_t^*\right)
\]
denotes the domestic country’s effective borrowing constraint. Similarly, 
\[
B^* = \min\left(B_y t, B^* y_t^*\right)
\]
denotes the foreign country’s effective borrowing constraint.

The equilibrium of this economy is defined as a path of interest rates 
\( r = \{r_t\}_{t=0}^\infty \) together with consumption plans 
\( c = \{c_t\}_{t=0}^\infty \) and \( c^* = \{c_t^*\}_{t=0}^\infty \) and debt plans 
\( b = \{b_t\}_{t=0}^\infty \) and \( b^* = \{b_t^*\}_{t=0}^\infty \) such that:

1. \( c_t \) and \( b_{t+1} \) maximize (2.1) subject to (2.3)-(2.4)-(2.5)

2. \( c_t^* \) and \( b_{t+1}^* \) maximize the foreign version of (2.1) s.t. the foreign versions of (2.3)-(2.4)-(2.5)

3. the real interest rate clears the bond market, \( b_t + b_t^* = 0 \), for all \( t \)

4. the goods market also clears (due to Walras’ Law), \( c_t + c_t^* = y_t + y_t^* \), for all \( t \).

The equilibrium conditions can then be summarized as:

\[
c_t^{-\sigma} - r_t \lambda_t^B + r_t \lambda_t^{B^*} = \beta r_tE_t \left[c_t^{-\sigma}\right] \tag{2.6}
\]

\[
c_t^*^{-\sigma} - r_t \lambda_t^{B^*} + r_t \lambda_t^{B^*} = \beta r_tE_t \left[c_t^*^{-\sigma}\right] \tag{2.7}
\]

\[
\frac{b_{t+1}}{r_t} = b_t + y_t - c_t \tag{2.8}
\]

\[
\frac{-b_{t+1}}{r_t} = -b_t + y_t^* - c_t^* \tag{2.9}
\]

\[
\lambda_t^B \left[\frac{b_{t+1}}{y_t} + B\right] = 0 \tag{2.10}
\]

\[
\lambda_t^{B^*} \left[\frac{-b_{t+1}}{y_t^*} + B^*\right] = 0 \tag{2.11}
\]

Where we have used the bond market clearing condition to substitute out \( b_t^* \).
\begin{align}
\lambda_t^B \left[ B - \frac{b_{t+1}}{y_t} \right] &= 0 \\
\lambda_t^{B^*} \left[ B^* + \frac{b_{t+1}}{y_t^*} \right] &= 0
\end{align}

We can distinguish five cases that are summarized by equilibrium conditions (2.6)-(2.13):

1. The case where no borrowing or lending constraint is binding for either country. In this case the lagrange multipliers associated to the borrowing and lending limits are equal to zero, i.e. \( \lambda_t^B = \lambda_t^{B^*} = 0 \) and \( \lambda_t^B = \lambda_t^{B^*} = 0 \), and the Euler equations (2.6)-(2.7) reduce to their standard expressions.

2. The borrowing constraint binds for the domestic country, i.e. \( \frac{b_{t+1}}{y_t} = -B \). The Lagrange multiplier of the domestic borrowing constraint, \( \lambda_t^B \), which reflects the shadow value of relaxing the constraint marginally, is therefore positive.

3. The lending constraint binds for the domestic country, that is \( \frac{b_{t+1}}{y_t} = B^* \), and \( \lambda_t^{B^*} > 0 \).

4. The borrowing constraint binds for the foreign country, \( \frac{b_{t+1}}{y_t^*} = B^* \) and \( \lambda_t^B > 0 \).

5. The lending constraint binds for the foreign economy, \( \frac{b_{t+1}}{y_t^*} = -B^* \), and \( \lambda_t^{B^*} > 0 \).

2.3 Financial openness and capital liberalization in the model

In the framework of the model we think of financial market openness as being reflected in the tightness of the respective borrowing and lending constraints the countries are facing. Therefore, a relaxation of a country’s lending or borrowing constraints can be interpreted as a reduction of capital controls on that country’s capital outflows or inflows. Before we discuss the choice of these constraints in our model, let us first consider two special cases that are nested in our model setup and correspond to the more standard cases, known as the ‘financial autarky’ case and as the incomplete markets ‘bond economy’ case.

First, if \( B = B^* = B = B^* = 0 \) then the world is in financial autarky. In this case there is no international consumption risk sharing - the bond cannot be used at all to insure against country idiosyncratic consumption risk.\(^5\)

\(^5\)In the endowment case therefore volatility of the endowment directly translates into the volatility of consumption. In the model with capital, the domestic country can even under financial autarky engage in at least some consumption smoothing through increasing or running down its capital stock.
The second special case is the scenario in which the bond can be freely traded across countries, that is $\bar{B}$, $\bar{B}^*$, $\underline{B}$ and $\underline{B}^*$ are sufficiently high, such that none of the constraints ever binds. This case coincides with the standard case of what is known as the incomplete markets ‘bond economy’ case. It is well known that under this case, even though markets are incomplete, the outcome is very close to the perfect risk sharing case under complete markets, where consumption in both economies perfectly co-moves (see Baxter and Crucini (1995)).

We interpret intermediate cases between financial autarky and no limits in borrowing and lending as reflecting intermediate stages of financial account openness, with the state of liberalization being more advanced as $\bar{B}$ and $\bar{B}^*$, and $\underline{B}$ and $\underline{B}^*$ increase. The presence of limits in bond holdings in these intermediate cases makes it hard for the countries’ economic agents to perfectly insure against country specific shocks. Since agents dislike the possibility of being left without any consumption at any point in time, they have an incentive to build up a buffer stock of savings to facilitate consumption smoothing, that is they have precautionary savings motives. This will be the crucial mechanism with which we are able to generate large imbalances with our model. As long as borrowing constraints are not ‘too’ relaxed, such that consumption smoothing is not too close to perfect risk sharing, precautionary savings motives have a significant impact on the equilibrium policy functions.

The experiment we undertake is the following. The initial borrowing constraints, denoted $\bar{B}^{BL}$ and $\bar{B}^{*BL}$ (BL stands for ‘before liberalization’) for the domestic and foreign country respectively and capital outflow limits, $\bar{B}^{BL}$ and $\bar{B}^{*BL}$, are initially set to some constant fraction of steady state world output, i.e. $\bar{B} = \frac{\bar{b}}{y}$ and $\bar{B}^* = \frac{\bar{b}^*}{y}$ and similarly for the capital outflow limit, $\bar{B} = \frac{\bar{b}}{y}$ and $\bar{B}^* = \frac{\bar{b}^*}{y}$. We model the RoW’s reduction of controls on capital outflows as a relaxation of the lending constraint to a new level $\bar{B}^{AL}$ (‘after liberalization’), with $\bar{B}^{AL} > \bar{B}^{*BL}$. Rather than modeling the process of liberalization as something that took place gradually over time, we make the simplifying assumption that liberalization occurs at once. That is, we consider a one-time permanent relaxation in the RoW’s lending constraint, which the representative agents of both countries learn about instantly. If the capital outflow constraints for the RoW initially are tighter than the US borrowing constraint, $\bar{B}^{*BL} < \bar{B}^{BL}$, this implies that the US economy can achieve lower consumption volatility. It should be noted that, clearly, also the RoW is able to a better smooth its consumption in response to the relaxation. The drop in US consumption volatility is bigger, however, since

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6However, there still is a ‘natural debt limit’ and a ‘No Ponzi’ condition that needs to be satisfied.

7As shown by Anagnostopoulos (2006) a global solution when there are relatively restrictive borrowing limits instead of a local approximation solution avoids the well-known problem of non-stationarity of bonds in the model.
agents are more risk averse when consumption is rather low.\(^8\) Accordingly, the US motive to hold precautionary assets decreases by more than the RoW’s motive for buffer assets.

The modeling of financial markets, that is, the assumption that there only exists one internationally traded bond, is clearly overly simplistic. In particular, it cannot address questions of portfolio choice or give any rationale to why gross asset and liability positions have risen drastically. We however also see the simplicity of our model and the fact that the standard workhorse international macro-model is nested in our setup as an advantage. We show that even in a simple setup and with only aggregate (country specific) risk we can explain a sizable portion of the US net external deficits through effects of capital liberalization.

2.3.1 Model solution and parametrization

**Solution method** To address the question we are interested in, local approximation techniques like log-linearization around the non-stochastic steady state cannot be used. Instead, we need to use a global solution technique that can explicitly account for the influence of second moments on agent’s policy functions and that also allows treatment of occasionally binding inequality constraints.

We use time iteration techniques as described by Coleman (1990) and increased its speed by using the endogenous grid points method developed by Carroll (2006) which reduces the number of non-linear equations the the algorithm needs to solve. Time iteration has several advantages as compared to standard dynamic programming as it preserves the continuous nature of the state space since it relies on interpolation techniques, and it easily allows to take into account inequality constraints. In particular, we make guesses on the policy rules as functions of the economy’s state variables. In the endowment economy we obtain policy rules for bond holdings and the interest rate as functions of last period bond holdings and the two endowment processes, \(b'(b'; y', y^*)\) and \(r'(b'; y', y^*)\). Further details about the solution technique are provided in the appendix.

**Parameters values** Table 2.1 presents our baseline parameter values for the quantitative experiments of our model economy, chosen such as to match U.S. quarterly data versus the rest of the world. Most parameter choices are relatively standard in the literature, which we briefly outline first. We then discuss the choice of the borrowing and lending constraints, for

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\(^8\)That is, utility is concave.
which there is no previous (nor obvious) choice.

The coefficient of risk aversion $\sigma$ is set to 2, a very standard choice in macroeconomics. The discount factor $\beta$ is set as to match a 4% annual interest rate in the non-stochastic steady state. The exogenous process follows a bivariate AR(1) with a coefficient of autocorrelation $\rho$ of 0.98 (and no cross-correlation) and standard deviation of the exogenous process $\sigma_\varepsilon$ set to 0.0075 as estimated by Fogli and Perri (2006) for the US economy.

The analysis of the endowment economy model is quite useful to build intuition we can show how borrowing and lending constraints and their relaxation matter for the equilibrium net foreign asset position. It is convenient to start with a completely symmetric initial parametrization. The two economies are equal in terms of country size (set to one-half), long term output levels ($\overline{y} = \overline{y}^* = 1$), as well as their initial borrowing and lending constraints,

$$\overline{B}^{BL} = \overline{B}^{*BL} = \overline{B}^{BL} = \overline{B}^{*BL} = .5.$$


2.3.2 Main results

We now turn to the quantitative predictions of our model economy when we relax the effective borrowing constraint faced by the US. To build intuition we start from an initial setting where both economies are symmetric. Before discussing the experiment of the relaxation in the domestic country’s borrowing constraint we want to comment on the general effect of borrowing constraints in a stochastic environment. The presence of borrowing constraints give households of both countries an incentive to engage in precautionary saving, to store away some extra assets in the ‘good’ states of nature for the ‘bad’ states in which the constraint may bind and in which they may not be able to borrow as much as they would desire in world markets. In our endowment economy the only asset available to be used as a buffer is the bond. Since both economies are initially symmetric and the bond must be held in zero net supply, this means that none of two countries can actually have positive holdings of the international bond. As first observed by Ayagari (1994), as a result of motives to hold precautionary buffer assets, when the (gross) real interest rate would be at their certainty equivalent level $\frac{1}{\beta}$ there would be an excess demand for savings. Under uncertainty, therefore, the asset price needs to be higher relative to its non-stochastic level to clear the bond market, or, equivalently, the real interest rate needs to be lower than in a non-stochastic world.

For displaying the mechanism of the model it does not matter whether the domestic country’s ability to borrow is restricted because of its own actual constraints on borrowing,
$b_{t+1} \geq -B y_t$, or whether it is constrained because the foreign economy is restricted from holding the domestic country’s financial assets, i.e. $b_{t+1} \geq B^* y_t^*$. Since what matters is the domestic country’s effective borrowing constraint, $B = \max\left(-B y_t, -B^* y_t^*\right)$, we will conduct our experiment in terms of a relaxation of this effective constraint. We model the increase in financial openness of capital outflows for the ROW as a one-time permanent relaxation of the effective US’ borrowing constraint from 50% of its current output level to 100% of its output. This means that before capital liberalization the effective borrowing constraints are $B^{BL} = B^{*BL} = 0.5$, and are equal to $B^{*AL} = 0.5$ and $B^{AL} = 1.0$) after liberalization. We assume that the RoW economy still faces the same borrowing limit as before, as in practice the ability of obtaining external finance for many emerging market countries is still limited. Two reasons are behind this fact, first, these economies are financially less developed. Second, after the recurrent crises that some of the emerging markets have faced during the end of the 90’s, they suffered limitations in their ability to borrow internationally. With this parametrization we capture the asymmetry in borrowing in financial markets and therefore the differences in the ability to manage consumption uncertainty. We choose the mid 1980 as the date for the experiment which coincides with the start of the decline in the U.S. net foreign asset position.

Figure 2.3 shows the response of main macroeconomic variables in the face of the U.S. increased ability to borrow in international markets in comparison to RoW. Since the foreign household’s motive to engage in precautionary savings has remained unchanged and it therefore now has, relative to the US, a stronger desire for precautionary savings we observe (in panel 2 of figure 2.3) a U.S. current account deficit and a gradual decline in the U.S. net foreign asset position as the economy transitions to a new steady state. Note that we measure the quantitative responses of the current account (and consumption) in relation to current output which since we used a quarterly calibration is in quarters, and are therefore different than in the data not annualized. On an annualized basis, the current account deficit to GDP is therefore substantially larger. After the relaxation of the domestic country’s borrowing constraint, its desire to hold assets for precautionary savings has dropped for two reasons: on the one hand it can use the bond more freely in response to random output shocks and can achieve better consumption smoothing and therefore a lower consumption volatility for any given risk it faces. On the other hand, the borrowing constraint itself has softened, and

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9 In principle the responses shown in figure 2.3 need to be derived from averages over a large number of simulations, such that the stochastic behavior of the economy can be ‘aggregated away’ and only the deterministic change in the policy functions -that reflects the change in the importance of precautionary savings- is left over. To save computational time we instead feed $\sigma = 0$ in the ‘simulation’ (however, the policy functions themselves have, of course, been obtained from a stochastic setting with $\sigma$ as indicated in section 2.3.1).
therefore the probability that the constraint binds at any moment in time has decreased and the desire to hold assets as a buffer to avoid these eventualities decreases.

The decrease in the importance of U.S.’ precautionary savings lowers its demand for the asset and, as a consequence, pushes up the interest rate (panel 4 of figure 2.3) which gives the RoW a motive to forgo consumption today. As interest rates increase the RoW finds it optimal to save and enjoy some higher consumption in the future. The consumption responses in panel 3 of figure 2.3 show that domestic consumers become relatively more impatient. The drop in the precautionary savings motive leads them to consume more relative early on at the expense of consumption in future periods, such that the long run value of U.S. consumption at the new steady state is at a lower level permanently.

It is important to note that figure 2.3 does not plot the responses to a particular shock, nor did we assume that the mean or variance of the endowment processes has changed at any point in time. The response in figure 2.3 is entirely due to the decrease in the importance of the precautionary savings motive for the U.S. economy, that stems from the domestic country’s improved ability to smooth consumption, and plots the expected path as the economy transitions to the new implied steady state.

**Sensitivity Analysis** Figure 2.4 presents some sensitivity analysis. The first column presents the equilibrium response of our baseline parametrization for values of the coefficient of relative risk aversion $\sigma$ equal to 1, 2 (baseline) and 5, respectively. As can be seen, the higher is the degree of risk aversion, the smaller is the reduction of the importance of US’ precautionary motives and therefore, the smaller is the accumulation of net foreign debt.

Given the difficulty to parameterize the borrowing limits, we consider it especially important to do sensitivity analysis on different values of the effective borrowing constraints. The quantitative response of net foreign assets to a relaxation depends on two things: one, the degree to which the constraints where initially restricting asset trade, and two, the amount by which the effective constraints are relaxed. The panels in the second and third columns therefore show variations in the assumptions on these constraints either before or after capital liberalization.

We plot the first set of sensitivity experiments with respect to the borrowing constraints in column 2 of figure 2.4 under varying degrees of ’initial financial market openness’ and show
the responses of the economic variables for three different parameterizations. The first assumes that initially international financial markets were very closed (the constraints change from $B^{BL} = B^{*BL} = 0.01$ to $B^{*AL} = 0.01$ and $B^{AL} = 0.5$), the second set of responses repeat the baseline case, and the third starts out in a situation where international financial markets were (relatively) open to begin with (from $B^{BL} = B^{*BL} = 1.0$ to $B^{*AL} = 1.0$ and $B^{AL} = 1.5$). Since precautionary motives are highest when financial markets can hardly be accessed as a means to engage in consumption smoothing, the drop in the net foreign asset position is strongest in the case where international financial markets are initially very closed.

The third column of figure 2.4 shows different cases for 'the extent of liberalization', that is, for different assumptions on by how much the effective borrowing constraint is relaxed. We show the baseline case, and the changes in the constraints from $B^{BL} = B^{*BL} = 0.5$ to $B^{*AL} = 0.5$ and $B^{AL} = 1.5$, and from $B^{BL} = B^{*BL} = 0.5$ to $B^{*AL} = 0.5$ and $B^{AL} = 2.5$. Not surprisingly, the decline in the net foreign asset position is more pronounced the higher the extent of the relaxation.

We summarize the new stochastic steady states obtained 20 years after financial account liberalization in table 2.2. Taking into account that the current level of US net foreign assets has achieved almost 25% of GDP the results obtained under our experiments are quite significant. In 2006 our baseline experiment for the endowment economy accounts for a net foreign debt of about -15 percent of domestic output. The new steady state level of net foreign assets of approximately -23% is reached at around 80 years later.

In order to compare the results obtained with our approach with the recent contribution of Fogli and Perri (2006) we also run the experiment of the ‘great moderation’ in US business cycle volatility. Column 2 of figure 2.5 plots the results of the great moderation. 10 Column 3 of figure 2.5 then incorporates both facts: capital liberalization plus ‘great moderation’. The results from these experiments are reported for different values of the coefficients of relative risk aversion.

---

10 Note that the model used by Fogli and Perri (2006) is different as they include capital accumulation in their model. We also include an additional asset in the next section.
2.4 A model with production and capital accumulation

It can be argued that in a setup in which agents’ only option to save and to smooth consumption intertemporally is by making use of the international bond, that the effects of changes in the strength of precautionary savings motives across countries have an unrealistically strong impact on the external position. We therefore now turn to a model setup in which the domestic representative agent is owner of the economy’s capital stock which is used in production. This gives her another asset that can be used to smooth intertemporal consumption and to hold savings for precautionary reasons. Now, the domestic representative agent maximizes eq. (2.1) with respect to borrowing constraint (2.4) and lending limit (2.5). As in the endowment economy, international asset markets can therefore be used only incompletely for consumption smoothing purposes. The budget constraint under this set-up and the law of motion for capital are:

\[ c_t + x_t + \frac{b_{t+1}}{r_t} = \omega_t n + r^k_t k_t + b_t \]  \hspace{1cm} (2.14)

\[ k_{t+1} = (1 - \delta)k_t + x_t - \phi \frac{2}{\phi} \left[ \frac{k_{t+1} - k_t}{k_t} \right]^2 \]  \hspace{1cm} (2.15)

where \( k_t \) is capital, \( w_t \) and \( r^k_t \) refer to the wage rate and the return of capital. To avoid a counterfactual volatile investment, \( x_t \), there are adjustment costs to install new capital. Households are assumed to supply their labor inelastically. For simplicity, we continue to model the foreign country’s output as an endowment process (or, implicitly, continue to hold the foreign capital stock fixed).\(^{11}\)

Firms produce output according to a Cobb-Douglas production function and face a country specific productivity. They are assumed to be competitive such that profit maximization leads to factors being paid their marginal products.

\[ \max \pi = (z_t k_t^{\alpha} n^{1-\alpha} - \omega_t n - r^k_t k_t) \]  \hspace{1cm} (2.16)

Technologies are modeled as exogenous processes which follow a bivariate autoregressive process of order 1.\(^{12}\)

\[
\begin{pmatrix}
\ln(z_t) - \ln(\bar{z}) \\
\ln(z_t^{*}) - \ln(\bar{z}^*)
\end{pmatrix} = A \begin{pmatrix}
\ln(z_{t-1}) - \ln(\bar{z}) \\
\ln(z_{t-1}^{*}) - \ln(\bar{z}^*)
\end{pmatrix} + \begin{pmatrix}
\varepsilon_t \\
\varepsilon_t^{*}
\end{pmatrix} \]  \hspace{1cm} (2.17)

\(^{11}\)This is done mainly for ease of computation.

\(^{12}\)This is the same assumption we made for the endowment model, just that the exogenous processes describe productivity instead of output.
where $z$ is a parameter reflecting the mean productivity, $A$ is a 2x2 matrix of coefficients describing the autocorrelation properties of the process, and $e = (\varepsilon_t, \varepsilon^*_t)'$ is a vector of shocks from a bivariate normal distribution with mean zero and variance-covariance matrix $V(e)$, i.e. $e_t \sim N(0, V(e))$.

The equilibrium of this economy is defined as a path of interest rates $r = \{r_t\}_{t=0}^{\infty}$ and input prices $w = \{w_t\}_{t=0}^{\infty}$ and $r^k = \{r^k_t\}_{t=0}^{\infty}$ together with consumption plans $c = \{c_t\}_{t=0}^{\infty}$ and $c^* = \{c^*_t\}_{t=0}^{\infty}$, capital accumulation plans $k = \{k_t\}_{t=0}^{\infty}$ and debt plans $b = \{b_t\}_{t=0}^{\infty}$ and $b^* = \{b^*_t\}_{t=0}^{\infty}$ such that households and firms solve their optimization problem and markets for bonds, consumption and capital clears in each market.

The equilibrium conditions of the full model are given by the set of equilibrium conditions of the endowment model, equations (2.6)-(2.13) -where the budget constraints are replaced by their versions of equation (2.14) - plus the additional Euler equation with respect to the choice of the optimal capital stock, given by:

$$
\left(1 + \frac{\phi}{k_t} \left(\frac{k_{t+1}}{k_t} - 1\right)\right) c_t^{-\sigma} = \beta E_t \left\{ c_{t+1}^{-\sigma} \left[(1 - \delta) + \alpha z_{t+1} \left(\frac{k_{t+1}}{n}\right)^{\alpha - 1} + \frac{\phi}{k_{t+1}} \left(\frac{k_{t+2}}{k_{t+1} - 1}\right) k_{t+1}\right] \right\}
$$

**Solution method and parameters values** The model is solved with the same technique as in the endowment economy model. In the full model with production we iterate on policy function guesses of $b''$, $k''$ and $r'$ as functions of $(b', k'; z', z^*)$.

In the model with capital we have another set of standard parameters. Table 2.1 presents our baseline parameter values for the quantitative experiments of our model economy. The capital share $\alpha$ is set equal to 0.36. The quarterly depreciation rate, $\delta$, is set to 2.5%. In order to avoid counterfactual volatile investment, we include quadratic capital adjustment costs with parameter $\phi$ equal to 8. The domestic economy’s country size parameter $n$ is taken to be 0.25 which corresponds approximately to the US population share in the OECD in 2007. The level of long run productivity in the US is taken to be slightly higher than in the RoW, with parameters $Z = 1.01$ and $Z^* = 1$.

For the model with capital we aim to capture a more realistic setting and allow for differences in country size and productivity, and, more importantly, differences in initial borrowing and lending constraints and the catching up of the RoW’s financial account openness. We
claim that the US borrowing and lending constraints, $B^{BL}$ and $B^{BL}$, in the period before liberalization in the rest of the world are already relatively loose, and set these to 100% of US output. For the RoW, while for most countries capital was not being prevented from flowing into the country, there were tight controls on capital outflows. We assume, for simplicity, an equally loose borrowing constraint, $B^{*BL}$, for the RoW up to 100% of its output. The outward capital controls reflect this in a relatively tight constraint on the RoW’s lending, $B^{*BL}$, which will be set to 50% of RoW’s output level. We assume after capitals controls in the RoW have been dismantled, the bond holdings of the rest of the world can also take on 100% of its output level, $B^{*AL} = y^\ast$.

### 2.4.1 Responses to financial account liberalization in the full model with capital

In the previous section we have seen that large imbalances can result from changes in financial openness, reflected in changes in the effective borrowing constraint of the domestic economy. This may not seem surprising given that in the endowment economy the internationally traded bond is the only asset which can be used for agents’ desired holding of buffer assets. Then, any change in the relative importance of the precautionary savings motive of the US vs. the RoW is necessarily expressed in (large) equilibrium responses of the long run external asset position.

In the model with capital the domestic agent is allowed another asset that can help her in the desire to achieve smooth consumption on the one hand, and for precautionary motives on the other hand. It is because of the latter that the long-run level of the capital stock in a stochastic equilibrium lies above the deterministic steady state capital stock, reflecting that also capital is held as a buffer against having to have very low consumption in bad states of the economy.

Figure 2.6 presents the equilibrium responses when the RoW is initially facing a high level of capital controls and is therefore very much restricted from holding foreign assets. After capital liberalization takes place in the RoW, the foreign lending constraint softens which also relaxes the US’ effective borrowing constraint. In particular, we parameterize the initial constraints the US is facing such that it would be able to borrow and lend up to 50% of its current output level, that is, $B^{BL} = B^{BL} = 0.5$. For the RoW, before capital liberalization, the initial constraint on capital outflows is set to $B^{*BL} = 0.01$, essentially entirely preventing the RoW from taking their financial wealth abroad. Controls on capital inflows were much less prevalent even before liberalization, and we assume the RoW’s borrowing constraint ini-
entially to be $B^*B_L = 0.5$. After liberalization, when capital controls in the RoW have been dismantled, the RoW’s lending constraint is also at 50\% of its output level, $B^{*AL} = 0.5$. We can observe that the US net foreign asset position before the onset of capital liberalization in the rest of the world is slightly positive\(^{13}\) and then starts its subsequent decline. Our model is therefore able to rationalize the stylized facts we observe in the data - which were presented in figure 2.1 and figure 2.2 - as a result of the process of capital liberalization. As figure 2.6 shows, the drop in the US net foreign asset position remains substantial in the capital model, despite the fact that part of the decrease of buffer stock holdings that result from lower precautionary motives of the US is expressed by lowering investment, and therefore, by a decrease in the economy’s long-run capital stock level. The experiment of the capital model also gives a quantitative indication on these effects. While the drop in domestic variables (investment, capital stock) are relatively small quantitatively, the effects on the external position are quite substantial - a model prediction that is in line with the experience of the US economy.

### 2.5 Conclusions

Since the mid 80’s we have observed a persistent decline in the US net foreign asset position. Contrary to conventional wisdom, where an adjustment was expected, the US continues to be the main world net borrower. In this paper we have quantitatively explored the role of the process of capital liberalization and risk aversion in driving the US net foreign asset position into deficit. For doing so we used a stylized two country one good model with borrowing and lending constraints.

We have shown that the current US net external imbalance can be a natural outcome of the catching up process of other advanced and emerging market economies in terms of financial account openness in the last 25 years.

\(^{13}\)In fact, with our choice of initial constraints, it would be even more positive if the long run productivity levels across the two countries were equal.
Appendix
Appendix

The models in section 2.2.1 are solved by making policy function guesses combined with the method of endogenous grid points. Below we briefly outline the steps of the algorithm used:

- We discretize the exogenous process following Adda and Cooper (2003). We use the Adda Cooper method instead of the more conventional Tauchen and Hussey (1991) since, as shown by Floden (2007), the accuracy of the discretization in terms of the unconditional variance of $y$ and $y^*$ ($z$ and $z^*$) is better under this method when the degree of autocorrelation is high and when there are only few discretization nodes. In the following, we denote $t+1$ variables with a prime (accordingly $b''$ is $b_{t+2}$). We construct a grid of endogenous state variables at time $t+1$. For the endowment economy we therefore have, for each combination of $y'$ and $y^*$, a one-dimensional grid in $b'$ which consists of $nb$ grid points and ranges from $\min(-B, B^*)$ to $\max(B, -B^*)$. For the capital economy we construct, for each combination of $z'$ and $z^*$, a 2-dimensional grid in $k', b'$ consisting of $nk*nb$ grid points. The range for $k'$ is set from 0.7 to 1.3 times the non-stochastic steady state level of the capital stock.

- Set counter equal to 1. We make initial policy function guesses using the log-linear solution as starting point. In the endowment economy guesses are made for $b''(b'; y', y^*)$ and $r'(b'; y', y^*)$. In the capital economy initial guesses are made for $b''(k', b'; z', z^*)$, $k''(k', b'; z', z^*)$, and $r'(k', k^*, b'; z', z^*)$.

- Using these initial policy function guesses, and using the discretized states and transition matrix for the exogenous processes, the conditional expectations in the Euler Equations can be computed. In particular, in both economies, we compute $E[c' - \sigma]$ and $E[c'^* - \sigma]$ from equations (2.6)-(2.7). For the capital economy we also derive an expression for $E[c' - \sigma (f_{k'} + 1 - \delta + \Phi_{k'})]$ from equation (2.18).

- Using the so computed expressions for the conditional expectations, the values of $b$ (or, respectively, the values of $k$ and $b$) are found for each grid-point $b'$ (combination of grid-points $k'$ and $b'$) by using a nonlinear equations solver.

- Finally, the policy function guesses are updated using interpolation methods. As the function $b'(b; y, y^*)$ and $r(b; y, y^*)$ (or, in the capital economy, $k'(k; b; z, z^*)$, $b'(k, b; z, z^*)$ and $r(k, b; z, z^*)$) are known, one can obtain the updated guesses by interpolating $b''$ and $r'$ at points $(b'; y', y^*)$ (or, in the capital economy, $k'', b''$ and $r'$ at points $(k', b'; z', z^*)$).

- The above steps are repeated until convergence is achieved.
Table 2.1: Baseline parameter values

<table>
<thead>
<tr>
<th>parameter</th>
<th>value 1</th>
<th>value 2</th>
<th>value 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \sigma )</td>
<td>5</td>
<td>( \alpha )</td>
<td>0.36</td>
</tr>
<tr>
<td>( \beta )</td>
<td>.9895</td>
<td>( \delta )</td>
<td>0.0255</td>
</tr>
<tr>
<td>( \eta )</td>
<td>1</td>
<td>( \phi )</td>
<td>8</td>
</tr>
<tr>
<td>( \rho )</td>
<td>.98</td>
<td>( n )</td>
<td>0.25</td>
</tr>
<tr>
<td>( \sigma_x )</td>
<td>.0075</td>
<td>( Z, Z^* )</td>
<td>1.01, 1</td>
</tr>
</tbody>
</table>

Table 2.2: Sensitivity analysis

Sensitivity analysis endowment economy model

Risk aversion, \( \sigma \)

<table>
<thead>
<tr>
<th>( \sigma )</th>
<th>impact 1</th>
<th>impact 2</th>
<th>impact 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \sigma = 2 )</td>
<td>-12.94</td>
<td>-11.83</td>
<td>-10.11</td>
</tr>
</tbody>
</table>

Borrowing constraints: changes in differences

\[ B_{BL} = B_{BL} = 0.01 \]
\[ \rightarrow B_{AL} = 0.5 \]
\[ \rightarrow B_{AL} = 1.0 \]
\[ \rightarrow B_{AL} = 1.5 \]

Ext. Imb. | -12.94 | -20.87 | -26.02 |

Borrowing constraints: changes in level

\[ B_{BL} = B_{BL} = 0.5 \]
\[ \rightarrow B_{AL} = 1 \]
\[ \rightarrow B_{AL} = 1.5 \]
\[ \rightarrow B_{AL} = 2.0 \]

Ext. Imb. | -20.58 | -12.94 | -7.46 |

Notes: Impact on external imbalances as percentage of GDP to different parameter values
### Table 2.3: Baseline algorithm parameters

#### 1. Endowment economy

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</thead>
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<tr>
<td>bonds</td>
<td>nodes$_b$</td>
<td>31</td>
</tr>
<tr>
<td>output</td>
<td>nodes$_y$</td>
<td>5</td>
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</tbody>
</table>

#### Size of the grid

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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>max</td>
<td>$y_{\text{max}}, y_{\text{max}}^* = -0.032$</td>
<td></td>
</tr>
<tr>
<td>min</td>
<td>$y_{\text{min}}, y_{\text{min}}^* = 0.032$</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>bonds</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>before max</td>
<td>$b_{\text{max}}, b_{\text{max}}^* = -0.500$</td>
<td></td>
</tr>
<tr>
<td>before min</td>
<td>$b_{\text{min}}, b_{\text{min}}^* = 0.500$</td>
<td></td>
</tr>
<tr>
<td>percentage of st.st output max</td>
<td>50%</td>
<td></td>
</tr>
<tr>
<td>percentage of st.st output min</td>
<td>50%</td>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>bonds</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>after max</td>
<td>$b_{\text{max}}, b_{\text{max}}^* = -1.000$</td>
<td></td>
</tr>
<tr>
<td>after min</td>
<td>$b_{\text{min}}, b_{\text{min}}^* = 0.500$</td>
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</tr>
<tr>
<td>percentage of st.st output max</td>
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<td></td>
</tr>
<tr>
<td>percentage of st.st output min</td>
<td>50%</td>
<td></td>
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#### 2. Capital economy

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</thead>
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<td>nodes$_b$</td>
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</tr>
<tr>
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<td>nodes$_k$</td>
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</tr>
<tr>
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<td>nodes$_z$</td>
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#### Size of the grid

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</thead>
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<td>max</td>
<td>$z_{\text{max}}, z_{\text{max}}^* = 1.042$</td>
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</tr>
<tr>
<td>min</td>
<td>$z_{\text{min}}, z_{\text{min}}^* = 0.959$</td>
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</table>

<table>
<thead>
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<th>capital</th>
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</tr>
</thead>
<tbody>
<tr>
<td>max</td>
<td>$k_{\text{max}} = 8.540$</td>
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</tr>
<tr>
<td>min</td>
<td>$k_{\text{min}} = 15.859$</td>
<td></td>
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</table>

<table>
<thead>
<tr>
<th>bonds</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>before max</td>
<td>$b_{\text{max}}, b_{\text{max}}^* = -0.013$</td>
<td></td>
</tr>
<tr>
<td>before min</td>
<td>$b_{\text{min}}, b_{\text{min}}^* = 0.633$</td>
<td></td>
</tr>
<tr>
<td>percentage of st.st output max</td>
<td>1%</td>
<td></td>
</tr>
<tr>
<td>percentage of st.st output min</td>
<td>50%</td>
<td></td>
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</tbody>
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<table>
<thead>
<tr>
<th>bonds</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>after max</td>
<td>$b_{\text{max}}, b_{\text{max}}^* = -0.633$</td>
<td></td>
</tr>
<tr>
<td>after min</td>
<td>$b_{\text{min}}, b_{\text{min}}^* = 0.633$</td>
<td></td>
</tr>
<tr>
<td>percentage of st.st output max</td>
<td>50%</td>
<td></td>
</tr>
<tr>
<td>percentage of st.st output min</td>
<td>50%</td>
<td></td>
</tr>
</tbody>
</table>
Figure 2.1: Average financial openness index compiled by Chinn and Ito (2005) for different groups of countries compared with US

Figure 2.2: US current account and net foreign assets as percentage of GDP. Source: IMF statistics, Lane and Milesi-Ferretti database and World Development Indicators

65
Figure 2.3: Response to a relaxation in the US effective borrowing constraint
Figure 2.4: Response to a relaxation in the US effective borrowing constraint: column 1) different coefficients of risk aversion, column 2) different initial levels of debt limits and, column 3) and different sizes of relaxation.
Figure 2.5: Response to a relaxation in the US effective borrowing constraint: Column 1) different coefficients of risk aversion, Column 2) great moderation in US income volatility and, Column 3) great moderation and US borrowing limit relaxation.
Figure 2.6: Response to an relaxation of controls on capital outflows in the RoW
Chapter 3

On double marginalization
3.1 Introduction

Recent empirical studies have found that there are different degrees of nominal rigidities faced by firms at the border level and at the final consumer level. The analysis of micro data on U.S. import and export prices by Gopinath and Rigobon (n.d.) shows that import price rigidity has increased during the period of 1994-2005, the mean duration of prices has raised and rigidities are more present in differentiated goods prices. They have also found that exchange rate pass-through at the border level of US import prices is low, being on average 22%. This empirical results have important implications for understanding and modeling the transmission of shocks and for optimal monetary policy.

The source of price stability has been thoroughly analyzed from a theoretical perspective to tackle two of the main puzzles in the open economy literature, that is exchange rate volatility one one hand and the low degree of exchange rate pass-through on the other. Several arguments have been put forward to explain both phenomena, one is the role played of price stickiness,\(^1\) other focus on the real side of the economy. The latter approach, takes into account the change on demand elasticities due either to the presence of local distributors or to ‘deep habits’. First, the presence of distribution services developed by Corsetti et al. (2003) alters the demand elasticities of final consumers creating a motive for a strategic behavior of firms and creates an endogenous pricing to market pricing behavior. Depending on the source of the shock, firms have an incentive to charge different prices to domestic or foreign retailers. They analyze a model where wholesale firms are monopolistically competitive and distribution firms operate in a competitive environment. The second case, developed in a recent paper Corsetti, Dedola and Leduc (2007) they also show how this demand elasticity can be altered when downstream firms or retailers are also monopolistically competitive and both layers of firms face Calvo adjusting price mechanism. The third case developed by Schmitt-Grohe, Uribe and Ravn (2007), is the role of ‘deep habits’ on varieties that affect the elasticity.

In this paper I develop a model with local distributors that enjoy monopoly power. I focus on the analysis of the impact of nominal rigidities either at the upstream or downstream firms in the transmission of shocks and in the strategic behavior of firms when changing prices.

The structure of the model is the following. There are two countries, home and foreign. Upstream firms in each country produce a good using labor and capital as inputs and it is sold to downstream firms located at home and abroad. Downstream firms make this traded

\(^1\)such as Chari, Kehoe and McGrattan (2002) in a standard two country model setting and Corsetti, Dedola and Leduc (2003) where they analyze the impact of nominal rigidities in a vertically integrated economy
goods available to final consumers using a basket of non-traded local inputs. To produce non-traded goods it is required the use of capital and labor inputs too. Then, these final goods are aggregated using a Dixit-Stiglitz aggregator. Each traded good is produced by a monopolist and sold to a downstream firm active in each market, this firm also enjoys monopoly power when selling the good to the final consumer.\footnote{Here I depart from Corsetti et al. (2007) where upstream monopoly firms sell to a continuum of monopolistic firms. In this case upstream firms that enjoy monopoly power sells to a particular downstream firm that operates in a particular industry and also enjoys monopoly power. This might have implications for the enforcement of the contract, as it affects the elasticity of substitution among producers.} Therefore, the final consumer faces a price with double marginalization over the marginal cost. Upstream firms are then able to discriminate prices between home and foreign downstream firms. Both firms can face a quadratic adjustment cost when changing prices. Corsetti et al. (2007) employ a similar model but nominal rigidities are introduced \textit{à la} Calvo. This introduces price dispersion and an extra reason for price discrimination for upstream firms. In Corsetti, Dedola and Leduc (2006) they also introduce nominal rigidities, firms face a quadratic cost in adjusting prices, but in their calibration inflation is the same for all sectors. In this paper we assume that the different sectors in the economy face different nominal rigidities.%3

The introduction of nominal rigidities in open macroeconomics has been widely analyzed. Early work that has investigated the effect of sticky prices in the international literature is Obstfeld and Rogoff (1995) in a set-up where monopolist do not have the incentive to discriminate across countries, that is, they set prices in their own currency (Producer currency pricing, PCP) one period in advance and there are no deviations from the law of one price. Betts and Devereux (1996) and Betts and Devereux (2000) allow the monopolist to discriminate across countries, what is called pricing-to-market (PTM), can reset prices with certain frequency \textit{à la} Calvo (1983) and set prices in the currency where the product is sold (local currency pricing, LCP). Chari, Kehoe and McGrattan (1998) show that the mild response of consumer prices to exchange rate movements is due to sticky prices in the local currency. The mechanism is the following: a monetary injection in the domestic economy depreciates the nominal exchange rate, as prices are sticky, the relative foreign price increase leads also to a real exchange rate depreciation. Output, consumption and employment increases in both countries. Due to costs in adjusting capital, consumption absorbs the shock and with a high coefficient of risk aversion an empirical plausible high real exchange rate volatility can be achieved. This, however, leads to a zero exchange rate pass-through, which is counterfactual.\footnote{see Calstrom, Fuerst and Ghironi (2006) for a discussion on determinacy of the Taylor Rule when sectors face different nominal rigidities and labor is immobile across sectors. Given that in this model the monetary process is exogenous and labor is mobile across sectors we do not face this problem, the introduction of a Taylor Rule as monetary policy will raise this issue, but we leave this for future research.}
While in the early theoretical literature the pricing to market comes as an exogenous decision, Corsetti et al. (2003) endogenize the pricing-to-market behavior by introducing a competitive distribution sector. The distribution firms bring traded goods to the final consumer using a bundle of non-traded goods. The price elasticity of substitution is inversely related to the weight of the distribution sector in the economy. In a symmetric steady state, price elasticities will be the same in both economies, but not in the face of shocks. If wholesale firms enjoy monopoly power will discriminate prices across markets as price elasticities are different due to distribution sector. While consumers have a constant elasticity of substitution (CES) consumption function, the price paid by consumers is not the same as the price set by the producers. This wedge allows, from the producers perspective, the elasticity of demand to not be constant. Under this set up, Corsetti and Dedola (2005) achieve deviations from the law of one price (loop) in spite of the PCP assumption. Their main result is that the degree of exchange rate pass-through depends on the shocks hitting the economy. The inclusion of a distribution sector in a dynamic general equilibrium framework has been extensively analyzed by Corsetti and Dedola (2005) and Corsetti et al. (2003) to study the exchange rate disconnect puzzle and the Backus-Smith puzzle, i.e. the low degree of international consumption sharing, as well as the transmission of shocks. On the other hand, in a partial equilibrium set-up, the role of distribution services or vertically integrated economies has been analyzed by Burstein, Neves and Rebelo (2003) and Erceg and Levin (n.d.) and Monacelli (2003).

The paper is organized as follows: Section 3.2 presents and solves the model with a distribution sector and analyzes the cases where prices are flexible and when firms face quadratic adjustment costs. Section 3.3 discusses the values used for the quantitative results of the model. Section 3.4 analyzes the role of double marginalization and nominal rigidities for business cycles and impulse responses on mark-ups and prices. Section 3.5 concludes and suggests directions for further research.

3.2 The model with distribution sector and double marginalization

In this section I present a standard 2 country model with a vertically integrated production structure where there are wholesale (upstream) firms and retail (downstream) firms that bring the good to the final consumer together with a non-tradable input. The main departures from the model developed by Corsetti et al. (2006) are first, that now retail firms enjoy
monopoly power when setting their prices and, second, they face nominal rigidity when adjusting prices. The first assumption leads to double marginalization over marginal costs on final consumer prices as well as different demand elasticity to prices that leads to endogenous price to market discrimination across countries.

3.2.1 Household problem

This two-country model is populated by a continuum of households that maximize lifetime utility by choosing consumption, bond holdings, real money holdings, capital and labor supply. The production technology is Cobb-Douglas and markets are incomplete, i.e. they can only trade a risk-free bond. Households face a static problem, that is, they decide how much to consume from the three different types of goods: home, foreign and non-traded. The also face a dynamic problem where they target to smooth consumption over time. Households maximize lifetime utility:

\[ \sum_{t=0}^{\infty} \beta^t U \left( C_t, L_t, \frac{M_t}{P_t} \right) \]

Where \(0 < \beta < 1\) is the discount factor. Here \(C_t\) denotes the consumption basket defined below, \(L_t\) denotes labor services supplied by the household and \(\frac{M_t}{P_t}\) are real money holdings. Households own capital, make investment decisions and rent it to firms. Capital stock evolves according to the following law of motion:

\[ K_{t+1} = I_{H,t} + (1 - \delta)K_t - \frac{\phi}{2} \left( \frac{K_{t+1}}{K_t} - 1 \right)^2 \]

Where \(K_t\) stands for stock of capital and \(\delta\) is the rate of depreciation of capital. Capital is freely mobile across sectors but they face quadratic adjustment costs. Agents maximize utility subject to a budget constraint (in nominal terms):

\[ P_t C_t = (1 + i_t)B_{H,t-1} - B_{H,t} + (1 + i_t^*)B_{F,t-1}e_t - B_{F,t}e_t + \pi_{H,t} + \pi_{N,t} + \pi_{D,t} + W_t L_t + M_{t-1} - M_t + T_t - \hat{P}_{H,t}I_{H,t} \]

Households derive income from working, they obtain a wage \(W\), domestic firm profits from the different sectors: upstream firms \(\pi_H\), non-traded good firms producers \(\pi_N\) and distribution firms \(\pi_D\). And the proceeds of holding state-contingent assets and money holdings. Agents can work in both sectors at the same time. And with this income they decide how
much to consume and how much to invest for next period.

Markets are incomplete and can only trade riskless bonds \( B_t \) and face a quadratic adjustment cost so as to preserve stationarity in the model following Schmitt-Grohe and Uribe (2003). Where the nominal exchange rate is defined as the number of domestic currency per foreign unit. Profits obtained when there are no nominal rigidities in adjusting prices, are denoted with \( \pi \) and defined below, are lump-sum distributed across households.

\[
\begin{align*}
\pi_{H,t} &= P_{H,t} Y_{H,t} - W_t s_h L_t - R_t s_h k_t K_t \\
\pi_{N,t} &= P_{N,t} Y_{N,t} - W_t (1 - s_h) L_t - R_t (1 - s_h) K_t \\
\pi_{D,t} &= P_{DH,t} Y_{DH,t} - \bar{P}_{H,t} Y_{H,t} - P_{N,t} Y_{N,t}
\end{align*}
\]

Preferences Domestic firms produce varieties \( h \) of goods that are imperfect substitutes and are aggregated using a Dixit and Stiglitz (1977) aggregator.

\[
C_{H,t} \equiv \left[ \int_0^1 C_t(h) \frac{\theta-1}{\theta-1} dh \right]^{\theta/(\theta-1)}
\]

Similarly foreign firms produce \( f \) varieties.

\[
C_{F,t} \equiv \left[ \int_0^1 C_t(f) \frac{\theta-1}{\theta-1} df \right]^{\theta/(\theta-1)}
\]

Where \( \theta \) is the constant elasticity of substitution among varieties.

The consumption baskets are aggregated using an Armington aggregator and consumer based prices indexes are computed accordingly.

\[
C_{T,t} = [\alpha_H^{1-\rho} C_{H,t}^{\rho} + (1 - \alpha_H)^{1-\rho} C_{F,t}^{\rho}]^{\frac{1}{\rho}}
\]

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The consumption basket with traded and non-traded goods:

\[ C_t = \left[ \alpha_N^{1-\phi}C_{N,t}^\phi + (1 - \alpha_N)^{1-\phi}C_T^{\phi \phi} \right]^{\frac{1}{\phi}} \]

Where \( \alpha_H \) is the share of domestic consumption of domestically produced goods. The elasticity of substitution between home and foreign goods is equal to \( \frac{1}{1-\rho} \). The elasticity of substitution between traded and non-traded goods \( \frac{1}{1-\chi} \). The elasticities of substitution among non traded varieties \( \theta_N \) and among traded varieties \( \theta_T, \theta_D \). Table 3.1 summarizes the optimality conditions of the households.

**Asset markets structure** The way agents can insure in the international markets affect the transmission of shocks and how prices react. In the numerical exercise we analyze the incomplete market case. When asset markets are complete, the first order conditions with respect to bond holdings (3.3) and the foreign equivalent are equated and by iterating back to zero, the following relation is obtained \( rer = \kappa \frac{U^*_c}{U^*_C} \). Under this market structure the marginal utilities derived from consumption are equated in both countries at all states of nature. Where \( \kappa \) is normalized to 1 when computing an equilibrium. With a productivity shock under complete market a country borrows or lends and the terms of trade do not move.

On the other hand, under financial autarky in the face of a productivity shock agents cannot borrow or lend in order to smooth consumption, therefore, terms of trade move to clear markets. The international business cycle literature usually assumes a one good model to analyze the correlation among macroeconomic variables, as for example Baxter and Crucini (1995), however, relative price movements, between differentiated goods might be a way of risk sharing as shown by Backus and Smith (1993) under financial autarky.

**Dynamic problem first order conditions** The first order conditions holding with equality of the maximization problem of the household are the following:

\[ C_t : \]
\[ \lambda_t = \frac{U_{c,t}}{P_t} \quad (3.1) \]

\[ L_t : \]
\[ -U_{l,t} = \lambda_t W_t \quad (3.2) \]

\[ B_t : \]
\[ \lambda_t = \beta (1 + i_{t+1}) \lambda_{t+1} \quad (3.3) \]
\[ K_{t+1}: \]
\[ \lambda_t(1 + \phi_t(\cdot)) = \beta (1 - \delta + F_{k,t+1} + \phi'_{t+1}(\cdot)) \lambda_{t+1} \quad (3.4) \]

Where equation (3.1) is the first order condition with respect to consumption, where the representative household decides the optimal level of spending, which it will be optimally allocated across goods (see next section). Then, (3.2) is the first order condition for labor where the marginal rate of substitution between labor and consumption equals the real wage. Equation (3.3) is the euler equation that states the intertemporal marginal rate of substitution and eq. (3.4) is the first order condition with respect to capital.

**Static problem first order conditions**  Goods are imperfect substitutes and they are aggregated into three different bundles. Consumers allocate their consumption between tradable and non-tradable, between home and foreign goods and between consumption goods and all other goods, i.e. capital investment and financial assets. The price faced by the final consumer of the final good is equal to the mark-up over the marginal cost. This marginal cost is a combination of the wholesale price, denoted with a bar, and a share of the price of the bundle of non traded goods \( P_{N,t} \). The final price faced by the consumer has double marginalization as there are two layers of monopoly power. These optimal conditions are summarized in table 3.1.

**Price indexes**  Due to distribution costs and the mark-up set by retail firms there is a wedge between the producer price and the final price faced by the final consumer. This price is a mark-up over the marginal cost of bringing the traded good to the final consumer. The marginal cost, due to the Leontieff assembly technology, is equal to the price at the upstream level and the price of the basket of non-traded goods needed to distribute it. Then the price index of tradable goods and the consumer price index are equal to:

\[
P_{T,t} = \left[ \alpha_H P_{H,t}^{\frac{\sigma}{\rho}} + (1 - \alpha_H) P_{T,t}^{\frac{\sigma}{\rho}} \right]^{\frac{\rho - 1}{\rho}}
\]

\[
P_t = \left[ \alpha_N P_{N,t}^{\frac{\sigma}{\phi}} + (1 - \alpha_N) P_{T,t}^{\frac{\sigma}{\phi}} \right]^{\frac{\phi - 1}{\phi}}
\]
3.2.2 Production structure and technology

Technology This is a three sector economy. A fraction of firms produce tradable goods, other fraction produces non-tradable, and there are distribution firms that aggregate tradable and non-tradable goods to bring them to the final consumer. Non-tradable goods can be consumed directly by the domestic agents or they are demanded by the domestic distribution firms that require non-traded goods as an input so that traded goods can arrive to the final consumer. Upstream firms use capital and labor as an input for production and technology follows an exogenous process. Firms exploit their monopoly power. The implications derived from these assumptions are that for firms is optimal to discriminate prices across markets. Output has constant returns to scale and constant marginal marginal productivity.

The technology in the non tradable sector is the following:

\[ Y_t(n) = Z_{N,t}K_t^{\eta}(n)L_t^{1-\varsigma}(n) \]

To produce a non-traded good a firm needs capital \( K_t \) and labor \( L_t \) inputs. Where \( Z_{N,t} \) is the technology in the non-traded sector and follows an exogenous process. The parameter \( \varsigma \) is the labor share in that sector.

Similarly, the up-stream firms in the tradable sector face the following technology constraint in producing each variety:

\[ Y_t(h) = Z_{H,t}L_t^{\epsilon}(h)K_t^{1-\epsilon}(h) \]  \hspace{1cm} (3.5)

Where \( Z_{H,t} \) is the technology in the traded sector and follows an exogenous process. The parameter \( \epsilon \) is the labor share in the traded sector.

Finally, for the downstream firms they assemble the final good by using as inputs a traded good and a basket of non-traded goods in a Leontieff manner, following Corsetti and Dedola (2005). To bring one unit of traded good you require a bundle \( \eta \) of non traded goods.

\[ \eta = \left[ \int_0^1 \eta(n) \frac{\eta^{\eta-1}}{\eta^{\eta-1}} \, dn \right]^{\frac{\eta N}{\eta N-1}} \]

subject to technology to produce a final good that is Leontieff.
3.2.3 Optimal pricing in a flexible price environment

A. Non-traded goods sector  The non-traded good sector produces goods that are only consumed at the domestic economy and are used to bring traded goods to the final consumer. The optimal quantity is determined by the demand from domestic consumers. As firms in this sector are also monopolistically competitive the optimal price in the absence of nominal rigidities is such that they charge a mark-up over marginal costs.

\[ p_t(n) = \frac{\theta_N}{\theta_N - 1} MC_{N,t} \]

Where the marginal costs in the non-traded sector are equal to:

\[ MC_{N,t} = \frac{1}{Z_{N,t}} W^\varsigma R_t^{(1-\varsigma)} \]

The properties of this pricing function is that is an increasing positive function to marginal costs and that the mark-up over marginal cost of producing is constant.

B. Downstream firms/Distribution sector and the role of double marginalization  The distribution sector brings traded goods, either produced domestically or at foreign, to the consumer. Normally it is assumed that the distribution firms are perfectly competitive. The price faced by final consumers has double marginalization over marginal costs.

The final consumer when buying a good from the tradable sector faces two costs, the cost of producing the good plus the costs of delivering that good. As Corsetti et al. (2003), Erceg and Levin (n.d.) and Burstein et al. (2003) it is assumed that in order to bring one unit of tradable good, either domestic or foreign, a basket of on differentiated non-traded goods.

Here we analyze the case were there is double marginalization, that is, firms in the distribution sector also enjoy certain degree of monopoly power. The problem is solved backwards as the market structure is vertical. The distribution sector is monopolistically competitive therefore they can charge a mark-up over marginal costs. The home downstream firm maximizes profits:
\[ \pi_{DH,t} = P_{DH,t}Y_{DH,t} - \bar{P}_h C_{H,t} - P_{N,t} \eta C_{H,t} \]

And subject to demand for home produced goods subject to distribution services:

\[ Y_{DH,t} = C_{DH,t} = \alpha_H \left( \frac{P_{DH,t}}{P_{T,t}} \right)^{-\theta_T} C_{T,t} \]

Let \( P_{DH,t} \) denote the price of home produced goods consumed by final consumers, this includes the basket of non-traded goods needed to reach the final consumer. Then, \( \alpha_H \) is the weight of home goods in the traded basket, \( -\theta_T \) is the elasticity of substitution among traded varieties. \( P_{T,t} \) the price index of traded goods. And \( C_{T,t} \) the basket of traded goods. From the input minimization problem (see below) and re-arranging the maximization problem in terms of the marginal costs of production \( MC_{DH,t} \) the problem becomes:

\[ \pi_{DH,t} = (P_{DH,t} - MC_{DH,t}) C_{DH,t} \]

Where the marginal cost is defined as:

\[ MC_{D,t}(h) = \bar{P}_t(h) + \eta P_{N,t} \]

Where \( \bar{P}_t(h) \) is the price of good \( h \) charged by the producer and \( P_{N,t} \) is the price index of the basket of non-traded goods needed to distribute the tradable good.

First order conditions with respect \( P_{DH,t} \) is equal to:

\[ P_{D,t}(h) = \frac{\theta_H}{\theta_H - 1} MC_{D,t}(h) \]

Substituting for marginal costs and algebra we obtain the following expression for the optimal price for a home produced good.

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\[ P_{D,t}(h) = \frac{\theta_H}{\theta_H - 1} MC_{D,t}(h) = \left( \frac{\theta_H}{\theta_H - 1} \right) \left( 1 + \eta \frac{\theta_H}{\theta_N} \left( \frac{MC_t(n)}{MC_t(h)} \right) \right) MC_t(h) \]

C. Wholesale/Upstream firms pricing to market  Firms maximize profits in the domestic market, they are monopolistic competitors, subject to the demand of home produced good of variety \( h \) from the distribution sector and technology.

The domestic firms in the tradable sector will face the following optimizing problem. As firms are monopolistically competitive they set prices and they are ready to meet demand.

\[ \max \pi_t, \bar{p}_t(h) \bar{p}_t^*(h) = [\bar{p}_t(h) c_t(h) + e_t \bar{p}_t^*(h) c_t^*(h)] - MC_{H,t} (c_t(h) + c_t^*(h)) \]

Where \( \bar{p}_t(h) \) stands for the wholesale price faced by domestic intermediate firms in domestic currency. And \( \bar{p}_t^*(h) \) is the price of the domestic good sold at foreign in foreign currency, and when pre-multiplied by the nominal exchange rate \( e_t \) (number of domestic units to buy one foreign unit) we obtain the price set in domestic units. Marginal costs \( MC_{H,t} \) are defined as:

\[ MC_{H,t} = \frac{1}{Z_{H,t} \varepsilon (1 - \varepsilon)^{1 - \varepsilon}} W_t \varepsilon (1 - \varepsilon)^{1 - \varepsilon} \]

subject to demand from consumers, both at home and abroad:

\[ c_t(h) = \left( \frac{p_t(h)}{P_{H,t}} \right)^{-\theta_H} C_{H,t} \]
\[ c_t^*(h) = \left( \frac{p_t^*(h)}{P_{H,t}} \right)^{-\theta_H} C_{H,t}^* \]

Where the final price paid by firms is a mark-up over the marginal cost of producing a home produced good and the cost of bring it to the final consumer:
\[ p_t(h) = \frac{\theta_D}{\theta_D - 1} (\bar{p}_t(h) + \eta P_{N,t}) \]

First order conditions:

\( \bar{p}_t(h) : \)

\[ \bar{p}_t(h) = \frac{\theta_D}{\theta_D - 1} \frac{\theta_H}{\theta_H - 1} \left( MC_{H,t} + \frac{\eta}{\theta_H} P_{N,t} \right) \]

\( \bar{p}_t^*(h) : \)

\[ e_t \bar{p}_t^*(h) = \frac{\theta_D}{\theta_D - 1} \frac{\theta_H^*}{\theta_H^* - 1} \left( MC_{H,t} + e_t \frac{\eta^*}{\theta_H^*} P_{N,t}^* \right) \]

The wholesale price in the domestic economy of the domestic traded good depends on the mark-up and marginal costs. In this case, the mark-up, contrary to the usual models, is state contingent that is it depends on relative technologies, between the traded and the non-traded sector.

The firm set prices in the producer currency. Wholesale prices increase when marginal costs increase or when the components of the contingent mark-up, that is, the marginal costs of the non-traded good in the host economy and due to exchange rate movements, increases. Optimal price setting leads to deviations from the law of one price, unless \( \eta = 0 \). With a state contingent mark-up, the law of one price does not hold as in general the components of the mark-up will not be equal in both economies. But it is recovered in the steady state as demand elasticities are equal in both economies. Restriction on \( \eta \) and \( \eta^* \) have to be imposed to guarantee that there are no international arbitrage opportunities between wholesale and retail sectors.\(^4\)

**Endogenous mark-up** In the presence of distribution services we can observe that the mark-up over marginal cost depends on relative productivity. The mark-up of prices over marginal cost is denoted by:

\[ \mu_t(h) = \frac{P_{D,t}(h)}{MC_t(h)} \]

\(^4\)see Corsetti et al. (2003) for further details.
contrary to the previous cases it is time varying and mark-ups are endogenous.

\[ \mu_t(h) = \left( \frac{\theta_H}{\theta_H - 1} \right) \left( \frac{\theta_H}{\theta_H - 1} \right) \left( 1 + \eta \frac{\theta_N}{\theta_N - 1} \frac{MC_t(n)}{MC_t(h)} \right) \]

\[ \mu_t(h) = \left( \frac{\theta_H}{\theta_H - 1} \right) \left( \frac{\theta_H}{\theta_H - 1} \right) \left( 1 + \eta \frac{\theta_N}{\theta_N - 1} \frac{Z_H}{Z_N} \frac{W^\xi R_{1-\xi}^1}{\zeta(1-\xi)^{(1-\xi)}} \frac{\xi^\varepsilon(1-\xi)^{(1-\xi)}}{W^\varepsilon R_{1-\varepsilon}^1} \right) \]

Firms set mark-ups depending on the relative productivities of the traded and non-traded sector. The impact of these differences will depend on the size of the distribution sector \( \eta \) in the economy. In the case of imported goods the mark-up will also depend on exchange rate movements.

The mark-up in steady state when there are distribution services \( \eta > 0 \).

\[ \mu(h) = \left( \frac{\theta_H}{\theta_H - 1} \right) \left( \frac{\theta_H}{\theta_H - 1} \right) \left( 1 + \eta \frac{\theta_N}{\theta_N - 1} \frac{Z_H}{Z_N} \frac{W^\xi R_{1-\xi}^1}{\zeta(1-\xi)^{(1-\xi)}} \frac{\xi^\varepsilon(1-\xi)^{(1-\xi)}}{W^\varepsilon R_{1-\varepsilon}^1} \right) \]

Furthermore if \( \varepsilon = \zeta \), that is capital shares are equal in both sectors, then the steady state mark-up is equal to:

\[ \mu(h) = \left( \frac{\theta_H}{\theta_H - 1} \right) \left( \frac{\theta_H}{\theta_H - 1} \right) \left( 1 + \eta \frac{\theta_N}{\theta_N - 1} \frac{Z_H}{Z_N} \right) \]

When there are distribution services the steady state mark-up is higher than in the standard monopolistic case. Also the presence of monopoly power for the retailer raises the final price faced by the final consumer.

**Demand price elasticities and state contingent mark-ups** One of the main features when introducing a distribution sector is that firms can price to market as demand elasticities are not constant. The elasticity is computed as follows:

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Prades, Elvira (2008), Essays on International Macroeconomics
European University Institute

10.2870/19235
When computing the effect of a price change on the demand for variety \((\bar{h})\) we observe that it depends on the exchange rate and relative marginal costs. These results have been deeply analyzed by Corsetti and Dedola (2005). These leads to incomplete pass-through and does not have a linear relationship with the exchange rate.

### 3.2.4 Optimal pricing when firms face nominal rigidities in adjusting prices

Now, we turn to the problem of the firms when firms face nominal rigidities, they face quadratic adjustment cost when changing prices.\(^5\) With identical and constant elasticity of demands across countries, it is hard to reconcile price flexibility with violations of the law of one price. However, with internationalized production by which local labor is used to produce for the local market, local wage stickiness can translate into rigid prices in local currency, even when firms are free to costless alter prices.

Corsetti and Dedola (2005) introduce rigidities in adjusting wages. In their model workers are heterogenous and are monopolistic suppliers of a differentiated type of labor. So there are nominal rigidities as workers and firms agree on the nominal wage one period in advance.

#### A. The Domestic firm in the non-tradable sector

Firms maximize profits and they choose prices subject to the demand function from the distribution sector and final consumers of the non-traded good, technology and the market clearing condition. In this case mark-up over price is constant and non state contingent compared to the tradable sector. The firm problem is now dynamic and they discount future profits with the subjective discount factor of households as they are the owners of the firm.

\[
p_t(n)y_t(n) - MC_t(n)y_t(n) - AC_t(n)y_t(n)
\]

\(^5\)There are other ways to introduce nominal rigidities such as predetermined prices or staggering á la Calvo (1983). With Rotemberg adjustment costs all firms are adjusting prices constantly, although is costly. The Phillips curve obtained in both cases are equal up to a first order approximation.
Where, the demand for the home good depends on the price of the variety relative to the price of all other goods.

\[ y_t(n) = \left( \frac{p_t(n)}{P_{N,t}} \right)^{-\theta} C_{N,t} \]

Profits are equal to:

\[
E_t \sum_{\tau=1}^{\infty} D_{t,\tau} \left[ p_{\tau}(n) \left( \frac{p_{\tau}(n)}{P_{N,\tau}} \right)^{-\theta} Y_{N,\tau} - MC_{\tau}(n) \left( \frac{p_{\tau}(n)}{P_{N,\tau}} \right)^{-\theta} (Y_{N,\tau} - AC_{\tau}(n)) \right]
\]

In adjusting prices firms face a quadratic adjustment cost, where \( \kappa_n \) measures the degree of price stickiness in the non-traded sector. If \( \kappa_n = 0 \) prices are flexible.

\[
AC_{\tau}(n) = \frac{\kappa_n}{2} \left( \frac{p_{\tau}(n)}{\pi p_{\tau-1}(n)} - 1 \right)^2 \left( \frac{p_{\tau}(n)}{P_{N,\tau}} \right)^{-\theta} (Y_{N,\tau})
\]

And the market clearing condition is:

\[
Y_{N,\tau} = (C_{N,\tau} + \eta C_{H,\tau} + \eta C_{F,\tau})
\]

Now, the presence of adjustment cost prevents firms to set prices equal to the desired markup over marginal cost. The first order condition with respect \( p_t(n) \) is:

\[
(1 - \theta) p_{\tau}(n) + \theta MC_{\tau}(n) + \theta \frac{\kappa_n}{2} \left( \frac{p_{\tau}(n)/p_{\tau-1}(n)}{\pi} - 1 \right)^2
\]

\[-\kappa_{dh} \left( \frac{p_{\tau}(n)/p_{\tau-1}(n)}{\pi} - 1 \right) \left( \frac{p_{\tau}(n)/p_{\tau-1}(n)}{\pi} \right)
\]

\[+E_t D_{t,t+1} \kappa_n \left( \frac{p_{t+1}(n)/p_t(n)}{\pi} - 1 \right) \left( \frac{p_{t+1}(n)/p_t(n)}{\pi} \right) \left( \frac{Y_{N,t+1}}{Y_{N,t}} \right) = 0
\]

Log-linearizing the optimal price and combined with the log-linearized price index one can obtain the typical forward looking Phillips curve:
\[ \hat{\pi}_{N,t} = \lambda_N m_c N,t + \beta E_t \hat{\pi}_{N,t+1} \]

Where \( \lambda_N \equiv \frac{(\theta_N - 1)}{\kappa_n \pi_N} \).

**B. Downstream firms/Distribution sector and the role of double marginalization when prices are costly to adjust** There are two types of retailers, the ones that bring domestic goods to the final consumer and the importers retailers, that bring foreign goods to domestic consumers. Firms in the distribution sector they now enjoy monopoly power/monopolistic competition (\(^？\)), but they face Rotemberg adjustment costs if they decide to change prices.

**b.1 Retail domestic goods** First we solve the problem of the firm when selling home produced goods at home.

\[
E_t \sum_{t=\tau}^{\infty} D_{t,\tau} \left[ (p_\tau(d_h) - MC_{DH,\tau}(d_h) - AC_\tau(d_h)) \left( \frac{p_\tau(d_h)}{P_{D,\tau}} \right)^{\theta_H} C_{DH,\tau} \right]
\]

The cost of adjusting the price from home produced goods is:

\[
AC_\tau(d_h) = \frac{\kappa dh}{2} \left( \frac{p_\tau(d_h)}{\pi p_{\tau-1}(d_h)} - 1 \right)^2
\]

First order condition w.r.t. \( p_\tau(d_h) \)

\[
(1 - \theta) p_\tau(d_h) + \theta MC_\tau(d_h) + \theta \frac{\kappa dh}{2} \left( \frac{p_\tau(d_h)/p_{\tau-1}(d_h)}{\pi} - 1 \right)^2 \quad \text{(3.7)}
\]

\[
-\kappa_n \left( \frac{p_\tau(d_h)/p_{\tau-1}(d_h)}{\pi} - 1 \right) \left( \frac{p_\tau(d_h)/p_{\tau-1}(d_h)}{\pi} \right) \quad \text{(3.8)}
\]

\[
+ E_t D_{t,t+1} \kappa dh \left( \frac{p_{t+1}(d_h)/p_t(d_h)}{\pi} - 1 \right) \left( \frac{p_{t+1}(d_h)/p_t(d_h)}{\pi} \right) \left( \frac{C_{H,t+1}}{C_{H,t}} \right) \quad \text{(3.9)}
\]

\[
= 0 \quad \text{(3.10)}
\]

Then the log-linearized expression for domestic inflation is:

---

*This expression is similar to the one obtained under Calvo pricing, both ways of modeling nominal rigidities lead to the same Philips-curve up to the first order approximation. While inflation dynamics in a Calvo set-up are driven by the parameter of how many firms are allowed to change prices and the discount factor, in the with the Rotemberg the parameters that affect \( \lambda \) are the adjustment cost \( \kappa \) and the elasticity of substitution among varieties \( \theta \). For simplicity there is no inflation in steady. See more details in the parametrization section.*

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\[ \hat{\pi}_{H,t} = \lambda_H \hat{m}_{H,t} + \beta E_t \hat{\pi}_{H,t+1} \]

Where \( \lambda_H \equiv \frac{(\theta_H - 1)}{\kappa_H \pi_H} \). And \( \pi_H \) is the steady state inflation.

**b.2 Retail importer goods** Similarly for imported goods sold by retailers. The maximization problem they face:

\[ E_t \sum_{\tau=1}^{\infty} D_{t,\tau} \left[ (p_r(d_f) - MC_{DF,\tau}(d_f) - AC_{\tau}(d_f)) \left( \frac{p_r(d_f)}{P_{D,\tau}} \right)^{-\theta_H} C_{DF,\tau} \right] \]

Where the marginal cost they face is the price of the foreign good paid to the foreign wholesaler and the required basket of non-traded input needed o bring the foreign good to the final consumer.

\[ MC_{DF,\tau}(d_f) = \bar{p}_t(f) + \eta P_{N,t} \]

And the functional form the quadratic adjustment cost in prices:

\[ AC_{\tau}(d_f) = \frac{\kappa_{df}}{2} \left( \frac{p_r(d_f)}{p_{r-1}(d_f)} - 1 \right)^2 \]

Where \( \kappa_{df} \) is a parameter that determines the cost of adjusting prices and \( \pi \) is the gross steady state inflation in the economy. So, the term compares the evolution of prices of the variety with respect the general inflation. \( D_t \) is the discount factor, when \( D_{t,t} = 1 \). The price index \( P_{D,t} \) aggregates the price of the home and foreign goods distributed at home.

First order condition w.r.t. \( p_r(d_f) \)

\[
(1 - \theta) p_r(d_f) + \theta MC_{\tau}(d_f) + \theta \kappa_{df} \left( \frac{p_r(d_f)/p_{r-1}(d_f)}{\pi} - 1 \right)^2
- \kappa_{df} \left( \frac{p_r(d_f)/p_{r-1}(d_f)}{\pi} - 1 \right) \left( \frac{p_r(d_f)/p_{r-1}(d_f)}{\pi} \right)
+ E_t D_{t,t+1} \kappa_{df} \left( \frac{p_{r+1}(d_f)/p_r(d_f)}{\pi} - 1 \right) \left( \frac{p_{r+1}(d_f)/p_r(d_f)}{\pi} \right) \left( \frac{C_{F,t+1}}{C_{F,t}} \right)
= 0
\]

\[ \hat{\pi}_{F,t} = \lambda_F \hat{m}_{F,t} + \beta E_t \hat{\pi}_{F,t+1} \]
Where we can obtain the inflation dynamics of imported goods and $\lambda_F \equiv \frac{(\theta_F - 1)}{\kappa_{f\pi_F}}$.

**C. Upstream firms**  Now we can distinguish several cases whether downstream firms face nominal rigidities or not and whether up-stream face them or not. We check how up-stream firms strategically set up prices.

If the upstream firm faces quadratic adjustment cost the problem of the firm becomes dynamic:

$$E_t \sum_{t=1}^{\infty} D_{t,\tau} \left[ \bar{p}_t(h) c_t(h) + e_t \bar{p}_t^*(h) c_t^*(h) \right] - MC_{H,t} (c_t(h) + c_t^*(h)) - AC_t(h) (c_t(h) + c_t^*(h))$$

subject to demand from consumers, both at home and abroad:

$$c_t(h) = \left( \frac{p_t(h)}{P_{H,t}} \right)^{-\theta_H} C_{H,t}$$

$$c_t^*(h) = \left( \frac{p_t^*(h)}{P_{H,t}^*} \right)^{-\theta_H} C_{H,t}^*$$

Where the final price paid by firms is a mark-up over the marginal cost of producing a home produced good and the cost of bring it to the final consumer.

The general expression for the first order condition with respect to $\bar{p}_t(h)$ is the following:

$$\bar{p}_t(h):$$

$$\left( \frac{p_t(h)}{P_{H,t}} \right)^{-\theta_H} C_{H,t}$$

$$-\theta_H (\bar{p}_t(h) - MC_{H,t}) \left( \frac{p_t(h)}{P_{H,t}} \right)^{-\theta_H^{-1}} C_{H,t} (1 - \frac{1}{P_{H,t}}) \frac{\partial p_t(h)}{\partial \bar{p}_t(h)} = 0$$

I first focus in the case where the upstream firm does not face nominal rigidities but takes into account that the downstream firm does. By looking to equation 3.7 we can observe how demand for final good of variety $h$ can be re-written as an implicit function that depends on the optimal price set by up-stream firms and down-stream firms.
\( f(\bar{p}_t(h), p_t(h)) = 0 \)

In the case where the retail firms face nominal rigidities the optimal price is:

\[ \frac{dp_t(h)}{\bar{p}_t(h)} = -\frac{f_{\bar{p}_t(h)}}{f_{p_t(h)}} \]

### 3.2.5 On strategic interactions

Based on Woodford (2003) and Corsetti et al. (2007) I discuss the reaction of firms in optimal pricing which can lead to strategic complementarities or strategic substitutability. In Woodford (2003) he deals in a different set-up where each household provides a type of labor input needed to produce a good of type i, here labor is not homogeneous. He analyzes what happens when there are specific factor markets versus homogeneous factor markets. Woodford argues that the assumption of a common factor implies immediate factor price equalization which is far from realistic. Also the extreme assumption that factors are sector/industry specific which it will imply that long-run issues cannot be tackled seems to be satisfying. In this manner the fact of having nominal rigidities with monopolistic competition allows for an analysis of the short-run dynamics.

In this paper the idea is similar, as the up-stream firm provides an input type to produce a final good of type i. This is assumed instead of using an homogeneous (competitive) input good market.

**Strategic complementarity** A raise in the marginal costs will lead to a decline of the desired mark-up. Aggregate nominal spending is given and the suppliers of individual good i are to simultaneously choose the price of \( p_t(i) \). If an increase in the prices charged for other goods increases the optimal price to charge for one's own good. On the contrary, goods will be **strategic substitutes** if the optimal strategy is to raise the desired mark-up set up by producers.
3.2.6 Monetary policy

For simplicity there is an exogenous supply of money that follows an AR(1) process and no money growth in the steady state.

\[ m_{t+1} = \rho m_t + \varepsilon_{t+1} \]

3.2.7 Definition of equilibrium

Considering a symmetric equilibrium within a country and interpreting all variables in per-capita terms the equilibrium is defined as follows. Given the stochastic processes the home allocations \( \{C_t, C_{H,t}, C_{F,t}, C_{N,t}, B_{t+1}, L_t, sht, Mt, \bar{P}_{H,t}, \bar{P}_{F,t}, \bar{P}_{N,t} \text{ and } W_t \} \) and their foreign counterparts, \( \{C_t^*, C_{H,t}^*, C_{F,t}^*, C_{N,t}^*, B_{t+1}^*, L_t^*, sht^*, Mt^*, \bar{P}_{H,t}^*, \bar{P}_{F,t}^*, \bar{P}_{N,t}^* \text{ and } W_t^* \} \) that satisfy the following conditions:

- both home and foreign individual allocations solve consumers problem given prices and profits
- home and foreign firms maximize profits
- goods, labor and bond markets clear
- resource constraints are satisfied.

At each date \( t \), the equilibrium satisfies equations (3.3) and (3.2), and their foreign counterparts, the resource constraint (??) and its foreign counterpart the price indexes, the static optimal demand equations and consumption indexes, the aggregate supply, (3.2.2)(3.5) and its foreign counterparts, the optimal price equations of both economies.

The model cannot be solved in closed form solution and needs to resort on a numerical approximation solution (we use the Schmitt-Grohé algorithm). The first order conditions, the market clearing and the resource constraints after being aggregated have been log-linearized around a symmetric equilibrium (see Appendix). The stochastic process are set equal to their unconditional mean and variances to zero. In addition, the individuals hold no international traded bond and there is no growth in the money supply and no inflation.
3.3 Baseline parameter values

This section describes the benchmark parameters used for the numerical experiments. Table 3.2 summarizes the parameters used for the baseline model and table 3.3 the different degree of nominal rigidities faced at different levels in the vertically integrated model. We use the Schmitt-Grohé and Klein algorithms to solve the model numerically and we report impulse responses and statistics of the simulated model averaged over 100 simulations over 100 periods.

Preferences and production

The functional form used for the agent utility is:

\[ U \left( C_t, \frac{M_{t+1}}{P_t}, L_t \right) = C_t^{1-\sigma} + \chi \left( \frac{M_t}{P_t} \right)^{1-\sigma} + \kappa \frac{(1 - L_t)^{1-\nu}}{1-\nu} \]

The coefficient of risk aversion \( \sigma \) is set equal to 2. The parameter \( \kappa \) is set as to match that labor supply equals to one third of the time endowment in the steady state. Money demand is determined residually so it does not play any role in the results, so the parameter \( \chi \) is set arbitrarily equal to 0.1.

Elasticity of substitution

First, the mark-up estimations are taken from Scarpetta (1990), are around 1.15, therefore we can derive the value of the elasticities of substitution between non-traded and traded goods \( \theta_D, \theta_N \) and \( \theta_T \).

The steady state mark-up for the traded good is:

\[ mk_t(h) = \frac{\theta_D}{\theta_D - 1} \frac{\theta_H}{\theta_H - 1} \left( 1 + \eta \frac{\theta_N}{\theta_N - 1} \frac{MC_{N,t}}{MC_{H,t}} \right) \]

For the non-traded good:

\[ mk_t(n) = \frac{\theta_N}{\theta_N - 1} \]

For the distribution firms the steady state mark-up over is:

\[ mk_t(d) = \frac{\theta_D}{\theta_D - 1} \]

The consider two values for the elasticity of substitution between home and foreign \( \frac{1}{1-\rho} \), high and low, following Corsetti and Dedola (2005) where they show that this parameter has important implications for the transmission mechanism. And the elasticity of substitution between traded and non-traded goods \( \frac{1}{1-\chi} \) is taken from Mendoza (1991).
The model has been calibrated to find the steady state of the economy to match features of the US economy. The share \( \alpha_F \) of imported goods in the consumption basket of tradable \( C_T \) has been set to match that the import share with respect to GDP is equal to 10\%. The share in the basket of total consumption goods of non-traded goods \( \alpha_N \) has been set to match the fact that the share of the non-traded sector with respect to GDP is 0.50\% on average. For the especial case where firms are monopolistically competitive the following strategy for calibration has been used. The level of technology at the traded sector is twice more productive than the technology at the non-traded sector. The parameter \( \eta \) is set as to match the empirical estimation that estimate that the price traded goods account for 50\% of the final price in steady state.

Labor share for tradables \( \epsilon \) and labor share for non-tradables \( \zeta \) is taken from Stockman and Tesar (1995). Capital depreciates \( \delta \) at an annually a 10\%. The adjustment cost on investment \( \phi \) is set such that the investment to gdp volatility matches the observed in the US data.

For the adjustment costs in changing prices is normally used the estimation of Bils and Klenow (2004) 4.3 months. We carry different experiments: downstream firms face larger costs in changing prices. Gopinath and Rigobon (n.d.).

**Productivity shocks** The vector \( Z = \{Z_T, Z_N, Z_T^*, Z_N^*\} \) represents sectoral technology shocks in home and foreign. They follow a trend stationary AR(1) process.

\[
Z' = \lambda Z + u
\]

In line with the international business cycle literature we assume that shocks are very persistent and the autocorrelation is \( \rho = 0.95 \) and the matrix of variance and covariance correlation of shocks are taken from the estimates from Corsetti and Dedola (2005) where they use disaggregated output series from traded and non-traded output of the US and Europe.

**Monetary Policy** The autocorrelation of monetary shocks for the impulse responses analysis \( \rho_m \) is equal to 0.84. For the simulation of the economy to compute business cycle statistics and other price relations we assume that there is no stochastic component.
3.4 Response of pricing behavior of firms to shocks

In this section we analyze the behavior of prices and mark-ups in response to shocks to productivity at different levels in the vertically integrated economy. The responses of prices, mark-ups, inflation are analyzed. Different types of shocks can hit the economy, these can be to:

- productivity in the tradable sector
- in the non-tradable sector, and
- an increase in the monetary supply

**Impact on optimal prices** In figure (1) prices fall in the face of a persistent increase in productivity in the domestic economy. Domestic wholesale firms reduce the price charged to distributors, both at home and abroad.

**Impact of domestic shocks on mark-ups** In figure (2) the response of mark-ups both for domestic wholesale firms and retail firms to a shock originated at the domestic economy are plotted. While in figure (3) the response to that same shock of foreign based firms.

In the first row the impulse responses to a productivity shock in the tradable sector is reported. In the presence of nominal rigidities mark-ups are state contingent as prices are costly to adjust and due to the presence of the distribution sector. We compute mark-ups as the ratio of the price faced by the consumer/distributor divided by the marginal cost of producing the good/bringing the good to the final consumer.

\[
m_k(h) = \frac{\bar{p}_{H,t}}{MC_{H,t}}
\]

\[
m_k(f) = \frac{\bar{p}_{F,t}}{MC_{H,t}}
\]

\[
m_k(n) = \frac{\bar{p}_{N,t}}{MC_{N,t}}
\]

The response of mark-ups depend on the weight of the distribution sector and the degree of nominal rigidities at different layers of the vertically integrated economy.
When the domestic economy is hit with a positive productivity shock in the tradable sector, the marginal cost of producing goods declines. Mark-up set by upstream domestic firms increases due to the presence of distribution services and nominal rigidities. While the mark-up set by foreign firms to sell foreign produced goods at home fall and remains unchanged for goods sold at foreign.

The fact of having nominal rigidities at the retail level seems not to have a great impact on pricing to market decisions for up-stream firms, contrary to the result obtained with Calvo pricing. However, mark-ups at retail level are more volatile if they are the only firms subject to nominal rigidities. Foreign retail firms that distribute home produced goods will charge higher mark-ups, while mark-ups form upstream firms and downstream distributing foreign goods fall.

In the first row the impulse responses to a productivity shock in the domestic non-tradable sector is reported. This type of shock is country specific. It only affects the marginal cost at the domestic economy. However upstream firms take into account the change in output when taking its pricing decision.

**Law of one price and exchange rate pass-through** 3.2 In this economy there are two mechanism that are producing deviations from the law of one price. One is the presence of distribution services, the other nominal rigidities in adjusting prices faced by firms. We can observe how there are deviations from the law of one price by looking at the plots (see below). If the law of one price holds, that is any movement in the exchange rate is passed to the foreign retail firm, then we observe no deviations from the steady state line. Here there are deviations due to \( \eta \) and due to the nominal rigidities.

\[
\zeta = \left( \frac{e \bar{p}_r^*(h)}{\bar{p}_r(h)} \right)
\]

At the consumer level (note that these are not the same goods as to bring them to the final consumer distribution services are needed):

\[
\zeta = \left( \frac{e p_r^*(h)}{p_r(h)} \right)
\]

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**Impact on inflation** The presence of nominal rigidities affects inflation. As expected the path of CPI inflation is affected from where the rigidity stems. A short coming of the analysis is that the monetary policy is exogenous, it would be interesting to introduce an interest rate rule (to be done).

**Nominal exchange rate, real exchange rate and terms of trade** The evidence is that there is a strong positive correlation between the real exchange rate and the terms of trade. Models assuming LCP give a counterfactual result. Here we obtain a positive correlation even when there nominal rigidities.

**Exchange rate pass-through** We evaluate the import price of the foreign good. The price paid by distributor firms when prices are flexible.

\[
P_{F,t} = \theta_F \left( 1 + \frac{\eta}{\theta_F (\theta_N - 1) e_t MC_{F,t}} MC_{N,t} \right) e_t MC_{F,t}
\]

\[
\bar{p}_t(f) = \frac{\theta_D}{\theta_D - 1} \frac{\theta_H^*}{\theta_H^* - 1} \left( eMC_{F,t} + \frac{\eta}{\theta_H} P_{N,t} \right)
\]

With nominal rigidities, the price of foreign goods charged to retailers at home is:

\[
(1 - \theta) \bar{p}_t(f) + \theta e_t MC_t(f) + \theta \frac{\kappa_f}{\pi} \left( \frac{\bar{p}_t(f) / \bar{p}_{t-1}(f)}{\pi} - 1 \right)^2
\]

\[-\kappa_f \left( \frac{\bar{p}_{t+1}(f) / \bar{p}_t(f)}{\pi} - 1 \right) \left( \frac{\bar{p}_t(f) / \bar{p}_{t-1}(f)}{\pi} \right)
\]

\[+ E_t D_{t,t+1} \kappa_f \left( \frac{\bar{p}_{t+1}(f) / \bar{p}_t(f)}{\pi} - 1 \right) \left( \frac{\bar{p}_t(f) / \bar{p}_{t-1}(f)}{\pi} \right) \left( \frac{C_{F,t+1}}{C_{F,t}} \right)
\]

\[= 0
\]

**3.5 Conclusions**

In this paper we analyze the impact of transmission of shocks in a vertically integrated open economy when upstream and downstream firms face nominal rigidities in adjusting prices. Placing nominal rigidities at different levels has implications for mark-ups set by firms.

Future work would lie on optimal monetary policy issues. Until now, money follows an exogenous process and we showed how in a vertically integrated economy with different sec-
tors facing different degrees of nominal rigidities can affect the transmission mechanism of shocks. Supply side shocks (i.e. productivity shocks) and demand shocks (i.e. monetary shocks) affect the volatility of firms mark-ups. This asymmetry may pose a problem to the monetary authority when implementing optimal monetary policy.

Another interesting avenue that could be explored under this set-up is to evaluate the role of double marginalization and nominal rigidities in terms of welfare for the two economies. When the economy is hit by shocks and there are different degrees of price rigidities at different levels of the vertically integrated production set-up, as the costs of nominal exchange rate volatility will be borne by the different group of agents of the economy.
Appendix
Table 3.1: Summary of household static first order conditions

<table>
<thead>
<tr>
<th>Domestic Demand</th>
</tr>
</thead>
<tbody>
<tr>
<td>$c_t(h) = \left( \frac{p_t(h)}{P_{H,t}} \right)^{-\theta} C_{H,t}$</td>
</tr>
<tr>
<td>$C_{H,t} = \alpha_H \left( \frac{P_{H,t}}{P_{T,t}} \right)^{\frac{1}{\phi-1}} C_{T,t}$</td>
</tr>
<tr>
<td>$c_t(f) = \left( \frac{p_t(f)}{P_{F,t}} \right)^{-\theta} C_{F,t}$</td>
</tr>
<tr>
<td>$C_{F,t} = (1 - \alpha_H) \left( \frac{P_{F,t}}{P_{T,t}} \right)^{\frac{1}{\phi-1}} C_{T,t}$</td>
</tr>
<tr>
<td>$c_t(n) = \left( \frac{p_t(n)}{P_{N,t}} \right)^{-\theta} C_{N,t}$</td>
</tr>
<tr>
<td>$C_{T,t} = \alpha_T \left( \frac{P_{T,t}}{P_{T}} \right)^{\frac{1}{\phi-1}} C_{T}$</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Foreign Demand</th>
</tr>
</thead>
<tbody>
<tr>
<td>$c_t^<em>(h) = \left( \frac{p_t^</em>(h)}{P_{H,t}} \right)^{-\theta} C_{H,t}^*$</td>
</tr>
<tr>
<td>$C_{H,t}^* = (1 - \alpha_F) \left( \frac{P_{H,t}}{P_{T,t}} \right)^{\frac{1}{\phi-1}} C_{T,t}^*$</td>
</tr>
<tr>
<td>$c_t^<em>(f) = \left( \frac{p_t^</em>(f)}{P_{F,t}} \right)^{-\theta} C_{F,t}^*$</td>
</tr>
<tr>
<td>$C_{F,t}^* = \alpha_F \left( \frac{P_{F,t}}{P_{T,t}} \right)^{\frac{1}{\phi-1}} C_{T,t}^*$</td>
</tr>
<tr>
<td>$c_t^<em>(n) = \left( \frac{p_t^</em>(n)}{P_{N,t}} \right)^{-\theta} C_{N,t}^*$</td>
</tr>
<tr>
<td>$C_{T,t}^* = \alpha_T \left( \frac{P_{T,t}}{P_{T}} \right)^{\frac{1}{\phi-1}} C_{T}^*$</td>
</tr>
</tbody>
</table>

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Table 3.2: Parameter values

<table>
<thead>
<tr>
<th>Benchmark model</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Risk aversion</td>
<td>$\sigma$ 2.00</td>
</tr>
<tr>
<td>Labor Share</td>
<td>$\kappa$ 0.77</td>
</tr>
<tr>
<td>Velocity</td>
<td>$\chi$ 0.10</td>
</tr>
<tr>
<td>Elasticity of substitution b/w:</td>
<td></td>
</tr>
<tr>
<td>- Home and Foreign</td>
<td>$\frac{1}{1-\rho}$ 1.50</td>
</tr>
<tr>
<td>- Traded and non-traded</td>
<td>$\frac{1}{1-\chi}$ 0.74</td>
</tr>
<tr>
<td>- Home non-traded</td>
<td>$\theta_N$ 7.70</td>
</tr>
<tr>
<td>- Home traded</td>
<td>$\theta_T$ 15.70</td>
</tr>
<tr>
<td>- Home traded</td>
<td>$\theta_D$ 15.70</td>
</tr>
<tr>
<td>Share home traded goods</td>
<td>$\alpha_T$ 0.60</td>
</tr>
<tr>
<td>Share non-traded goods</td>
<td>$\alpha_N$ 0.41</td>
</tr>
<tr>
<td>Distribution margin</td>
<td>$\eta$ 1.22</td>
</tr>
<tr>
<td>Labor share tradables</td>
<td>$\varepsilon$ 0.61</td>
</tr>
<tr>
<td>Labor share non-tradables</td>
<td>$\zeta$ 0.55</td>
</tr>
<tr>
<td>Depreciation rate</td>
<td>$\delta$ 0.03</td>
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<tr>
<td>adjustment cost on capital</td>
<td>$\phi$ 3.00</td>
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<tr>
<td>Monetary policy:</td>
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</tr>
<tr>
<td>a) Exogenous process</td>
<td></td>
</tr>
<tr>
<td>- autocorrelation</td>
<td>$\rho$ 0.95</td>
</tr>
<tr>
<td>- standard deviation of the shock</td>
<td>$\sigma_m$ 0.00</td>
</tr>
</tbody>
</table>

Table 3.3: Nominal rigidities

<table>
<thead>
<tr>
<th>Price adjustment cost parameter</th>
<th>$\kappa_N$</th>
<th>$\kappa_H$</th>
<th>$\kappa_D$</th>
</tr>
</thead>
<tbody>
<tr>
<td>non-traded</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>traded</td>
<td>0.00</td>
<td>7.70</td>
<td>7.70</td>
</tr>
<tr>
<td>distributors</td>
<td>0.00</td>
<td>0.00</td>
<td>7.70</td>
</tr>
<tr>
<td></td>
<td>0.00</td>
<td>7.70</td>
<td>0.00</td>
</tr>
<tr>
<td></td>
<td>flexible prices</td>
<td>Nominal rigidities</td>
<td></td>
</tr>
<tr>
<td>--------------------------------</td>
<td>-----------------</td>
<td>--------------------</td>
<td>----------</td>
</tr>
<tr>
<td></td>
<td>both</td>
<td>wholesale</td>
<td>retail</td>
</tr>
<tr>
<td><strong>Productivity $Z_T$</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nominal exchange rate</td>
<td>-0.02</td>
<td>-0.05</td>
<td>-0.07</td>
</tr>
<tr>
<td>Real exchange rate</td>
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<td>0.00</td>
<td>-0.03</td>
<td>-0.06</td>
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<td>1.26</td>
<td>1.19</td>
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<td>-3.08</td>
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<td>0.03</td>
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Table 3.5: Deep Ratios

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<tr>
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Burstein et al. (2003)

Table 3.6: International Business Cycle Statistics for the Model

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<td></td>
<td>Flexible prices</td>
<td>Nominal Rigidities</td>
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<tr>
<td></td>
<td>both</td>
<td>Wholesale</td>
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<td>Standard deviation (relative to gdp)</td>
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<td>Consumption</td>
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<td>corr(rer,tot)</td>
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Figure 3.1: Percentage deviation from steady state of domestic variables to a 1% shock.

Producers and Consumers Prices:

- **Sold domestically**
  - Domestic goods
  - Imported goods

- **Exported goods**

- **Domestic goods**

- **Imported goods**

---

Prades, Elvira (2008), Essays on International Macroeconomics
European University Institute

10.2870/19235
Domestic Upstream firms | Domestic Down-stream firms
---|---
Sold domestically | Exported goods | Domestic goods | Imported goods

Mark-up wholesale to $Z_T$

Mark-up wholesale to $Z_N$

Mark-up retail to $Z_T$

Mark up domestic retailer to $Z_T$

Mark-up wholesale to $M_s$

Mark-up retail to $M_s$

Mark up retail to $M_s$

Nominal rigidities
Rigidities wholesale
Rigidities retail
Flexible prices

Figure 3.2: Percentage deviation from steady state of domestic variables to a 1% shock
<table>
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<th>mark up retail to Z_T</th>
<th>mark up domestic retailer to Z_T</th>
<th>mark up wholesale to M_s</th>
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</tr>
</tbody>
</table>

Figure 3.3: Percentage deviation from steady state of foreign variables to a 1% shock.

Prades, Elvira (2008), Essays on International Macroeconomics
European University Institute

10.2870/19235
Figure 3.4. Percentage deviation from steady state of law of one price and inflation to a 1% shock

Prades, Elvira (2008), Essays on International Macroeconomics
European University Institute
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