Medium Term Cycles in Developing Countries

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Abstract

We build a two country asymmetric DSGE model that embeds a structure of technology creation and diffusion similar to the product-lifecycle. As a result, three linkages propagate the shocks to the developed economy into the developing one at different frequencies. In the short run, these shocks affect the demand for exports from the developing country. These shocks also affect variation in number of technologies exported and transferred for production to the developing country. Since technologies diffuse, on average, slowly, these mechanisms affect the technology in the developing country in the medium term. We calibrate the model to the US and Mexico and find that, both in the data and in the model, high frequency US fluctuations lead medium term fluctuations in Mexico. These US-driven fluctuations account for between 57% and 67% of the differential in volatility between Mexico and the US.

Keywords: Business Cycles in Developing Countries, Co-movement between Developed and Developing economies, Volatility, Extensive Margin of Trade, Product Life Cycle, FDI.

JEL Classification: E3, O3.

"Poor Mexico! So far away from God and so close to the United States."
Attributed to Dictator Porfirio Diaz, 1910.

1 Introduction

How do shocks to developed economies affect economic fluctuations in developing countries? Are these shocks a significant determinant of the differential in volatility between developing and developed economies?

To answer these questions, we build a two country asymmetric DSGE model. One of the countries is developed (i.e. the US) while the other is a developing country (i.e. Mexico). One salient feature of the model is that the technology in each country, measured by the number of intermediate goods available for production, is endogenous. At the core of the mechanisms that determine the technology, we have a version of the product lifecycle of Vernon (1966) and Wells (1972). New intermediate goods are invented through R&D in the US. After their producers engage in some additional investments, they can be exported to Mexico. Finally, after engaging in foreign direct investment (FDI), the production of the intermediate good that embodies the technology is transferred to Mexico and the intermediate good is exported to the US.

These mechanisms have significant effects on the business cycle dynamics of Mexico. First, shocks to the US affect the demand for Mexico' exports. This effect of US shocks on Mexican exports drives the co-movement of the US and the Mexican economy in the short run.

In addition to the demand for Mexican exports, US shocks also affect the flow of new technologies both exported and transferred for production to Mexico. In particular, they affect the value of exporting and transferring technologies, inducing pro-cyclical investment in exporting new technologies and FDI flows which are consistent with the empirical evidence. But, on average, the diffusion of technology through these channels takes time. As a result, fluctuations in the speed of diffusion of US technologies to Mexico in response to US shocks affect the Mexican economy in the medium term.[1]

[1] To be precise, we follow the definitions of medium term used by Comin and Gertler (2006). In particular, the sort run or high frequency will be measured using an HP filter which roughly isolates frequencies associates with cycles of amplitude smaller than 8 years. The medium term refers to

This yields a prediction that can be tested. Specifically, high frequency fluctuations in US output should lead medium term fluctuations in Mexican output. Interestingly, this pattern of co-movement between the Mexican and US output at different frequencies seems to be borne by the data. This finding is related to Aguiar and Gopinath (2007), who argue that, in a reduced form sense, shocks to developing countries are more persistent than shocks to developed economies. Our model provides a micro-foundation for this claim based on the slow diffusion of technologies.

Unlike US shocks in Mexico, Mexican shocks have a very small effect in the US economy. This is the case because trade with Mexico represents a relatively small share of US trade and because new technologies flow from the US to Mexico and not vice-versa. This finding opens a new avenue to explaining the differential in volatility between Mexican and US GDP. To what extent is the higher volatility of the Mexican economy due to more volatile Mexican shocks and to what extent is it the result of the larger response of the Mexican economy to foreign shocks?

In section 5, we calibrate the variance of the US and Mexican shocks in order to match the observed volatility of GDP in Mexico and the US at the high frequency. We find that the differential effect of foreign shocks accounts for 57% of the higher volatility in Mexico at the high frequency and for 67% over the medium term cycles. Hence, we conclude that the international amplification and propagation of shocks to the developed economies are an important source of volatility in developing countries.

One feature of our model is that FDI is the only capital flow between the US and Mexico. That is, physical capital is immobile and there is no international borrowing and lending. In this sense, our analysis is complementary to more conventional small open economy macro models where there is international borrowing and lending.[2] It is important to note, though, that our assumption on the composition of international capital flows is consistent with the evidence over the last 20 years where approximately 70% of the capital flows to developing countries are FDI (Loayza and Serven, 2006). The FDI share is even larger when restricting attention to private capital flows and

frequencies associated with cycles of amplitude between 8 and 50 years. The medium term cycle is the "sum" of the high frequency and the medium term. That is, it captures cycles with amplitude smaller than 50 years. Comin and Gertler (2006) show that despite that time series are relatively short, medium term cycles can be identified in the data quite precisely.

[2] See for example, Mendoza (2008), for a very interesting SOE model with imperfect credit markets.

when focusing in Latin America and Asia.

Rather than introducing many shocks and enriching the model with features that are now standard in business cycle analysis (e.g. habit, credit frictions, adjustment costs, price and wage rigidities, Taylor rule, ...) we believe that it is more transparent to have a more stripped down model with just one type of shock per country. This allows us to focus our modelling efforts in the mechanisms that we believe are key to understanding the co-movement between Mexico and the US at the different frequencies.

Of course, this strategy comes at the cost of not fitting the data so well. However, overall the model does a fairly good job in capturing the unconditional moments of macro variables in both the US and Mexico at both the high frequency and medium term. Further, it will be clear what additional mechanisms and shocks should be incorporated to improve the model performance. For example, we argue that including credit frictions in Mexico would allow the model to do a better job in capturing the high volatility of consumption, and terms of trade shocks would also help capture the high volatility of trade flows between Mexico and the US.

Our model is related to many strands of the literature on international and international macro. So many, that we find more economical to describe the connections as we they become apparent. However, broadly speaking, our model bridges the gap between the macro business cycle tradition that has studied economic fluctuations in developed countries (e.g. Neumayer and Perri, 2005) and the new trade literature that has emphasized the relevance of the extensive margin of trade and of the sunk cost that companies need to incur in order to affect it (Melitz, 2003 and Bernard et al., 2007).[3]

The rest of the paper is organized as follows. Section 2, presents some basic stylized facts about economic fluctuations in Mexico and the US at both high and medium

[3]One paper that also combines macro business cycles and trade is Ghironi and Melitz (2005). There are several important differences between this model and ours. Ghironi and Melitz emphasize the role of heterogeneity and the extensive margin of trade in a stylized symetric business cycle model which is best applied to two developed economies. We model explicitly the asymetries between developing and developed economies and introduce in addition to the extensive margin of trade, innovation (i.e. R&D) and FDI. Our model also has endogenous labor supply and capital accumulation in the business cycle tradition. We, however, allow for much less heterogeneity than Ghironi and Melitz.

term frequencies. Section 3 presents our model. Section 4 presents the symmetric equilibrium. Section 5 presents the calibration, the impulse response functions and evaluates the model's ability to capture the basic features of the data. Section 6 concludes.

2 Some basic facts

In this section we review and present three stylized facts about economic fluctuations in developing countries and their connection to the business cycles of developed economies.

The first observation is about the relative volatility of developing and developed economies.[4] Table 1 reports the standard deviation of GDP per working age person[5] at the business cycle (or high) frequency (first row) and over the medium term cycle[6] (second row) for the US and Mexico. Mexico's business cycle is approximately twice more volatile than the US (2.6% vs. 1.3%).

However, macro data not only fluctuate at the high frequency. In the second row of Table 1 we can see that in Mexico there is significantly larger volatility over the medium term cycle than over business cycle frequencies.[7] Interestingly, while this is just barely the case for the US (1.3% vs. 1.5%), the difference between the volatility at the high frequency (2.6%) and over the medium term cycle (3.7%) in Mexico is much larger. As a result, once we incorporate variation at the medium term into the analysis the volatility of Mexican economy becomes almost 2.5 times larger than the volatility of the US economy.

The second important observation is that developed and developing economies co-

[4] This finding has been well documented in the literature. see, for example, Neumeyer and Perri (2005).

[5] In what follows we scale all variables by working age person. That is all persons with age between 16 and 64.

[6] That is, high plus medium term frequency. Formally this captures fluctuations associated with cycles that have periods smaller than 50 years.

[7] Comin and Gertler (2006) also document a significantly larger volatility for the US over the medium term cycle than at the high frequency because theie sample is 1948-2001. An interesting finding is that a significant contributor to the great moderation in the US has been the reduction of the volatility at medium term (vs. high) frequencies.

move. Figure 1 plots three series: US GDP filtered using an HP filter to capture the high frequency (i.e. business cycle) fluctuations; Mexican GDP also HP filtered, and Mexican GDP filtered to capture only fluctuations over the medium term.[8] Comparing the high frequency GDP series we can observe a strong positive co-movement between the US and Mexico. The correlation coefficient is 0.43 and, despite the short length of the series, it is significant at the 10% level.

Frankel and Rose (1997, 1998) and the literature that has followed since have shown that co-movement at the high frequency is associated with trade. That is, countries that trade more tend to have more synchronized business cycles. Table 2 supports this claim. It shows that US GDP is correlated at the high frequency with trade flows between the US and Mexico and that Mexican GDP is also correlated with Mexican imports from the US.

However, there is more than just business cycle co-movement in Figure 1. There seems to be also co-movement at lower frequencies. High frequency fluctuations in Mexico are contemporaneously associated with medium term fluctuations in Mexican GDP. This could be rationalized, for example, by small open economy models where either shocks are persistent or there are propagation mechanisms that induce such a persistence.

A more surprising finding is that high frequency fluctuations in the US are also positively correlated to medium term fluctuations in Mexico. This is formalized in Table 3 where we report the cross-correlogram between high frequency fluctuations in both US and Mexican GDP and medium term fluctuations in several Mexican variables including GDP. While the maximum correlation between Mexican GDP at the high frequency and the medium term occurs contemporaneously and then it declines steeply, the correlation between high frequency US GDP and medium term Mexican GDP increases as we consider longer leads of the US GDP.

Of course, these correlations do not imply, per se, that US high frequency fluctuations cause medium term fluctuations in Mexican GDP. That is not even relevant at this stage. However, it is reassuring that we still find a similar pattern when using VAR methods to identify high frequency innovations to US and Mexican GDP.

[8] Specifically, we use a Band Pass filter to isolate fluctuations associated with cycles with periods between 8 and 50 years. Despite the length of the time series, Comin and Gertler (2006) show that the identifies fluctuations at these frequencies are statistically significant.

Specifically, we identify US shocks and Mexican shocks by running bivariate VARs under the identification restriction that innovations to US GDP may affect Mexico contemporaneously but innovations to Mexican GDP (or any other Mexican variable) do not affect the US contemporaneously. Figures A1 and A2 (in the Appendix) show that the unconditional findings from Table 3 persist.

This lead of high frequency output fluctuations in the US over medium term fluctuations in Mexico is more difficult to rationalize by small open economy models. It is not clear how a transitory foreign shock would affect the Mexican economy in medium term and even less clear why this effect would occur with a lag. One possible interpretation of these observations is that there are mechanisms that slowly affect the Mexican productive capacity in response to US shocks. As we show next in our model, two such mechanisms are US direct investment in Mexico (i.e. FDI) and investments in starting to export US intermediate goods to Mexico. It is reassuring that US FDI to Mexico (as a share of Mexican GDP) co-moves pro-cyclically with US GDP (Table 2). This co-movement is statistically significant, despite the length of our period of analysis, when we remove some noise from the FDI series by filtering it to keep the medium term fluctuations (Table 3).

3 Model

Before presenting the model, we briefly describe its main features. Ours is a two country model with trade in intermediate goods. The number of intermediate goods available for production determines the technology to produce new capital. Three margins determine the number of intermediate goods available for production. First, R&D investments in the North (N) lead to the development of new intermediate goods. Second, the owner of the patent of the intermediate good can engage in a stochastic investment to export the intermediate good to the South (S). Third, finally, she can transfer the production of the intermediate good to S to take advantage of their comparative advantage in intermediate good production through another stochastic investment (FDI). Capital markets are assumed to be perfect within countries but international capital flows are ruled out other than FDI.

3.1 Resource constraints

Let Y_{ct} be gross final output. In each country, final output may be used for consumption, C_{ct}, investment, I_{ct}, paying overhead costs, O_{ct}, and government spending, G_{ct}. In addition, $N's$ output can be used to conduct research and development, S_t, that leads to new intermediate goods and to make intermediate goods suitable for export to S, X_t^g. $N's$ firms can also conduct foreign direct investment by using $S's$ final output to transfer the production of the intermediate goods to S, X_t^T. The aggregate resource constraints can then be written as follows:

$$Y_{Nt} = C_{Nt} + I_{Nt} + O_{Nt} + G_{Nt} + S_t + X_t^g \tag{1}$$

$$Y_{St} = C_{St} + I_{St} + O_{St} + G_{St} + X_t^T \tag{2}$$

In turn, let J_{ct} be newly produced capital and $\delta(.)$ be the depreciation rate of capital. Then capital evolve as follows:

$$K_{ct+1} = (1 - \delta(U_{ct}))K_{ct} + J_{ct} \tag{3}$$

where $\delta(U_{ct})$ is the depreciation rate which is increasing and convex in the utilization rate as in Greenwood, Hercowitz and Huffman (1988).

Next, let P_{ct}^k be the price of this capital in units of domestic final output. Given competitive production of final capital goods :

$$J_{ct} = (P_{ct}^k)^{-1} I_{ct} \tag{4}$$

A distinguishing feature of our framework is that P_{ct}^k evolves endogenously in each country. One of the key sources of variation in P_{ct}^k is the pace at which new technologies embodied in new intermediate goods arrive in the economy which depends on the agents response to overall macroeconomic conditions, as we describe below.

3.2 Capital

Physical capital is immobile across countries. It is produced in two stages. First, a continuum of N_{ct}^K differentiated firms construct new capital. Each uses as input the continuum A_{ct} of the differentiated intermediate capital goods available for production in the economy. Let $J_{ct}(r)$ be new capital produced by firm r and $I^r_{ct}(s)$ the amount of intermediate capital the firm employs from supplier s. Then

$$I_{ct}(r) = \left(\int_0^{A_{ct}} I^r_{ct}(s)^{\frac{1}{\theta}} ds \right)^{\theta} \tag{5}$$

with $\theta > 1$. Note that each supplier s of intermediate capital goods has a bit of market power. Profit maximization implies that she sets the price of the s intermediate capital good as a fixed markup θ times the marginal cost of production. In N, it takes one unit of final output to produce one unit of intermediate. So, the marginal cost is unity. To capture the comparative advantage of the South in assembling manufacturing goods (e.g. Iyer, 2005), we assume that it takes $1/\xi(< 1)$ units of country S output to produce a unit of a intermediate good in S.

In addition, there is an iceberg transport cost of shipping the good internationally. In particular, $1/\psi$ (where $\psi < 1$) units of the good need to be shipped so that one unit arrives.

Observe that there are efficiency gains in producing new capital from increasing the number of intermediate inputs, A_{ct}. These efficiency gains reflect embodied technological change and are the main source of variation in the relative price of capital, P^k_{ct}, over the medium term. Shortly, we relate the evolution of A_{ct} to an endogenous technology adoption process.

New capital, J_{ct}, is a CES composite of the output of the N^K_{ct} capital producers, as follows:

$$J_{ct} = \left(\int_0^{N^K_{ct}} I_{ct}(r)^{\frac{1}{\mu^K}} dr \right)^{\mu^K} \tag{6}$$

with $\mu^K > 1$.

We allow the number of capital producers N^K_{ct} to be endogenously determined by a free entry condition in order to generate high frequency variation in the real price of capital that is consistent with the evidence (e.g. Comin and Gertler, 2006).[9] As will become clear, we will be able to decompose P^k_{ct} into the product of two terms: the medium term wholesale price, $\overline{P}^k_{ct}$, that is governed exclusively by technological

[9] Alternatively, we could have counter-cyclical markups to generate the observed high frequency fluctuations in the relative price of capital. These two formulations would have similar implications in our model.

conditions in the medium term and a high-frequency component, $P^k_{ct}/\bar{P}^k_{ct}$, that is instead governed by cyclical factors.

We assume that the per period operating cost of a final capital good producer, o^k_{ct} is

$$o^k_{ct} = b^k_c \overline{P}^k_{ct} K_{ct} \tag{7}$$

where b^k_c is a constant. That is, the operating costs grow with the medium term replacement value of the capital stock in order to have balanced growth. As in Comin and Gertler (2006), this captures the notion that the operating costs are increasing in the sophistication of the economy, as measured by $\overline{P}^k_{ct} K_{ct}$. At the margin, the profits of capital producers must cover this operating cost. This arbitrage condition pins down N^k_{ct} :

$$\frac{\mu^K_c - 1}{\mu^K_c} P^K_{ct}(r) J_{ct}(r) = b^k_c \overline{P}^k_{ct} K_{ct} \tag{8}$$

Since operating costs are not very cyclical but operating profits are, this formulation yields pro-cyclical net entry in equilibrium.

3.3 Technology

The efficiency of the production of new capital goods depends on the number of intermediate goods available for production A_{ct} as well as their origin. To characterize the technology available in a country, we need to take a stand on the processes of invention, international diffusion and transfer of production. Following the literature on the product lifecycle (Vernon, 1966), we assume that intermediate goods are first invented in country N. At this initial stage, the intermediate goods are local in the sense that they can only be used in N. We denote by A^l the number of intermediate goods at this stage. The intermediate good producer can undertake a stochastic investment which, if successful, makes the intermediate good exportable to country S, though it is still produced in N. We denote by A^g the number of intermediate goods at this stage. At a final stage, the production of intermediate goods can be transferred to S in order to take advantage of the comparative advantage of S in producing intermediate goods. This entails another stochastic investment though this time it is in terms of country S output. These investments constitute the flow of FDI from N to S. A^T denotes the number of intermediate goods whose production has been transferred to S. The total number of intermediate goods available in each country is therefore given by

$$A_{Nt} = A_t^l + A_t^g + A_t^T \tag{9}$$

$$A_{St} = A_t^g + A_t^T. \tag{10}$$

Technology flows determine trade flows. Country N exports to S the A^g intermediate goods which have become exportable while S exports to N the A^T intermediate goods whose production has been transferred to S. The only other good that is traded in this economy is energy as we discuss below.

Next we present formally the conditions that characterize the technology dynamics in each economy.

Creation of new intermediate goods

Innovators in N can create new intermediate goods by investing final output into R&D activities. R&D is financed with loans from the households. As is common practice in the literature, we assume a technology for creating new specialized goods that permits a simple decentralization of the innovation process. In particular, let $S_t(p)$ be the total amount of R&D by innovator p. Let φ_t be a productivity parameter that the innovator takes as given and let $1 - \phi$ the probability that any existing intermediate good becomes obsolete in the subsequent period. Then, the law of motion for the stock of technologies developed by innovator p is:

$$A_{Nt+1}(p) - A_{Nt}(p) = \varphi_t S_t(p) - (1-\phi)A_{Nt}(p) \tag{11}$$

We assume that φ_t depends on the aggregate stock of innovations in N, A_{Nt}, the medium term wholesale value of the capital stock $\overline{P}_{Nt}^k K_{Nt}$, and aggregate research and development expenses S_t as follows:

$$\varphi_t = \chi A_{Nt} \left(\frac{S_t}{\overline{P}_{Nt}^k K_{Nt}} \right)^{\rho-1} (\overline{P}_{Nt}^k K_{Nt})^{-1} \tag{12}$$

with $0 < \rho \leq 1$ and where χ is a scale parameter. As with Romer (1990), there is a positive spillover of the current stock of innovations on the creation of new products, i.e. φ_t increases linearly in A_t. The formulation differs from Romer in two respects, however. First, the productivity of the R&D technology is scaled by the technological sophistication of the economy, as measured by $\overline{P}^k_{ct} K_{ct}$. Intuitively, the cost of producing new inventions rises proportionately over time with the scale of economic activity. This scaling factor ensures that the equilibrium growth rate of new projects is stationary. In addition, the scaling factor is smoothed in the short run so that it does not affect the business cycle dynamics. Secondly, we introduce an aggregate congestion to R&D conducted through the factor $(S_t/(\overline{P}^k_{Nt} K_{Nt}))^{\rho-1}$. This permits us flexibility in calibrating the impact of R&D on innovation in a way that is consistent with the evidence from the productivity literature.

By developing an intermediate good, an innovator is granted a patent which ensures his right to be the sole producer of the intermediate good and hence to enjoy the associated monopolistic rents. Let v_t be the market value of the patent to produce an intermediate good that at this point can only be sold in country N. In equilibrium, agents engage in R&D activities until the cost of developing a new intermediate good equalizes its expected market value. Formally,

$$1/\varphi_t = \phi R^{-1}_{Nt} \mathbb{E}_t v_{t+1}, \tag{13}$$

where the LHS is the cost and the RHS is the discounted value.

The market value of the patent to produce an intermediate good that can be currently sold only in country N is given by the following expression:

$$v_t = \max_{x_t} \pi_t - x^g_t + R^{-1}_{Nt} \phi \mathbb{E}_t \left[\lambda \left(\Gamma^g_t x^g_t \right) v^g_{t+1} + \left(1 - \lambda \left(\Gamma^g_t x^g_t \right)\right) v_{t+1} \right], \tag{14}$$

where π_t denotes the per period profits of a local intermediate goods producer, x^g_t is the number of units of final output spent by the innovator in adapting the intermediate good for use in country S, $\lambda(\Gamma^g_t x^g_t)$ is the associated probability of a successful adaptation where function $\lambda(.)$ satisfies $\lambda' > 0$, $\lambda'' < 0$, v^g is the market value of the patent to produce a global intermediate good (i.e. one that can be exported to country S), and Γ^g_t is a scaling factor, taken as exogenous by the innovator which adjust slowly over time and ensures balance growth, and equal to

$$\Gamma^g_t = \frac{b^g}{(\overline{P}^k_{Nt} K_{Nt}/A^l_t)} \tag{15}$$

where b^g is a positive constant and A^l in the number of intermediate goods that are sold only in N.[10]

Investment in exporting

Intermediate goods' producers at N can expand the market for their products by exporting them to S. Prior to this, however, the producer must successfully market the intermediate good in S and adapt it to be suitable for production in S. The optimal intensity of this investment equalizes at the margin the cost and the expected benefits of exporting the intermediate good to S as shown in the following first order condition:

$$1 = \overbrace{R_{Rt+1}^{-1}\phi}^{\text{discounting}} \overbrace{\Gamma_t^g \lambda' \left(\Gamma_t^g x_t^g\right)}^{\text{Mg. } \triangle \text{ in } \lambda^g} \overbrace{\mathbb{E}_t \left(v_{t+1}^g - v_{t+1}\right)}^{\triangle \text{ in value}} \tag{16}$$

The marginal cost of investing one unit of output in exporting the good (LHS) is 1, while the expected marginal benefit is equal to the associated increase in the probability of exporting times the discounted gain from transforming the local good in a global intermediate good.

In the symmetric equilibrium, all producers of local intermediate goods invest the same amount in making the good exportable to S, and, as a result, face the rate of transformation of local into global intermediate goods, λ_t^g. The law of motion for A^g is

$$A_t^g = \phi\lambda_{t-1}^g (A_{ct-1} - A_{t-1}^g - A_{t-1}^T) + \phi(1 - \lambda_{t-1}^T) A_{t-1}^g \tag{17}$$

After expanding the market to S, the value of an intermediate good, v_t^g, is given by

$$\begin{aligned} v_t^g = \max_{x_t} \pi_t^g - e_t x_t^T + \\ R_{Nt}^{-1}\phi\mathbb{E}_t \left[\lambda\left(\Gamma_t^T x_t^T\right) v_{t+1}^T + \left(1 - \lambda\left(\Gamma_t^T x_t^T\right)\right) v_{t+1}^g\right], \end{aligned} \tag{18}$$

where π_t^g denotes the per period profits of a global intermediate goods producer, x_t^T is the number of units of country $S's$ final output spent by the innovator in transferring the production of the intermediate good to S, e_t is the exchange rate (dollars per peso), $\lambda(\Gamma_t^T x_t^T)$ is the associated probability of successfully completing this foreign direct investment, where function $\lambda(.)$ satisfies $\lambda' > 0$, $\lambda'' < 0$, v^T is the market value

[10] The dynamics of the economy are robust to variations in the scaling factors as long as they ensure balance growth.

of the company that produces a transferred intermediate good, and Γ_t^T is a scaling factor, taken as exogenous by the innovator and equal to

$$\Gamma_t^T = \frac{b^T}{(\overline{P}_{Nt}^k K_{Nt}/A_t^g)} \tag{19}$$

where $b^T > 0$, A_t^g denotes the number of intermediate goods exported from N to S, and e_t denotes the price of $N's$ currency in terms of $S's$ currency.

Foreign direct investment

Let λ_t^T be the rate at which the production of global intermediate goods is transferred from N to S. The law of motion for the stock of transferred intermediate goods, A_t^T, can be written as follows:

$$A_t^T = \phi\lambda_{t-1}^T A_{t-1}^g + \phi A_{t-1}^T \tag{20}$$

The intensity of FDI's investment, x_t^T, equalizes the private marginal costs and expected benefits of transferring the production to S. Intuitively, the marginal cost of investing one unit of $S's$ output in FDI (LHS) is e_t, while the expected marginal benefit is equal to the associated increase in the probability of succeeding in the FDI times the discounted gain from transferring the production of the intermediate good to S.

$$e_t = \overbrace{R_{Nt+1}^{-1}\phi}^{\text{discounting}} \overbrace{\Gamma_t^T \lambda'\left(\Gamma_t^T x_t^T\right)}^{\text{Mg. } \triangle \text{ in } \lambda^T} \overbrace{\mathbb{E}_t\left(v_{t+1}^T - v_{t+1}^g\right)}^{\triangle \text{ in value}} \tag{21}$$

Finally, the market value of an intermediate good whose production has been transferred to S is given by

$$v_t^T = \pi_t^T + R_{Nt+1}^{-1}\phi E_t v_{t+1}^T, \tag{22}$$

where π_t^T denotes the per period operating global profits of the company that produces a transferred intermediate good.

3.4 Production of gross output

Now that we have described the creation and diffusion of intermediate goods which determine the technology available to produce new capital, we proceed to describe the production function for gross output. As for new capital, gross output, Y_{ct}, is produced in two stages. In a first stage, each of N_{ct} differentiated output producers, indexed by j, combine capital, K_{cjt}, labor, L_{cjt}, and energy, E_{cjt}, to produce its differentiated output, $Y_{ct}(j)$ according to the following Cobb-Douglas technology:

$$Y_{ct}(j) = (1+g)^t \left(U_{cjt} K_{cjt}\right)^{\alpha} E_{cjt}^{\eta} \left(L_{cjt}\right)^{1-\eta-\alpha} \tag{23}$$

where g is the exogenous growth rate of disembodied productivity,[11] and U denotes the intensity of utilization of capital. The markets where firms rent the factors of production (i.e. labor and capital) are perfectly competitive.[12]

In a second stage, gross output, Y_{ct}, is produced competitively by aggregating the N_{ct} differentiated final goods as follows:

$$Y_{ct} = [\int_0^{N_{ct}} Y_{ct}(j)^{\frac{1}{\mu}} dj]^{\mu} \tag{24}$$

where $\mu(>1)$ is inversely related to the price elasticity of substitution across goods. In the symmetric equilibrium that follows, μ, will be the gross markup that each final good producer will charge.

Producers of differentiated output must pay every period an overhead cost, o_{ct}, given by

$$o_{ct} = b_c \overline{P}_{ct}^k K_{ct}. \tag{25}$$

Free entry equalizes the per period operating profits to the overhead costs determining the number of final goods firms N_{ct}.[13]

$$\frac{\mu-1}{\mu} P_{ct}(j) Y_{ct}(j) = b_c \overline{P}_{ct}^k K_{ct} \tag{26}$$

[11] For simplicity, we assume that it is exogenous. It is quite straightforward to endogenize it as shown in Comin and Gertler (2006).

[12] As shown in Comin and Gertler (2006), the shocks to the preference parameter μ_w can be interpreted without loss of generality as wage markup shocks in an environment where labor is supplied by monolistically competitive agents.

[13] As with the capital sector, counter-cyclical variation in markups would be equivalent to entry by final goods firms.

3.5 Energy endowments

Oil represents a significant share of Mexican imports to the US. To account for this in the calibration of the model, we assume that the government in country S is endowed with E^e_{St} units of energy. Let E_{ct} denote the aggregate consumption of energy in country c. We consider the scenario where country S is a net exporter of energy and country N is a net importer of energy. Specifically, country N imports E^x_t units of energy to country S, and buys the rest of its energy needs, E^w_t, from the rest of the world. The energy consumption in each country satisfies the following identities:

$$E_{St} = E^e_{St} - E^x_t \tag{27}$$

$$E_{Nt} = E^w_t + E^x_t \tag{28}$$

For simplicity, we assume that the price of energy, P^E, is fixed.

3.6 Households

There is a representative household that consumes, supplies labor and saves. It may save by either accumulating capital or lending to innovators. The household also has equity claims in all monopolistically competitive firms. It makes one period loans to innovators and also rents capital that it has accumulated directly to firms. It is important to stress, though, that there is no international lending and borrowing. That is, US FDI in Mexico is the only item in the Mexican financial account.

Let C_{ct} be consumption and μ^w_{ct} a preference shifter. Then the household maximizes the present discounted utility as given by the following expression:

$$\mathbb{E}_t \sum_{i=0}^{\infty} \beta^{t+i} \left[\ln C_{ct} - \mu^w_{ct} \frac{(L_{ct})^{\zeta+1}}{\zeta+1} \right]$$

subject to the budget constraint

$$C_{ct} = \omega_{ct} L_{ct} + \Pi_{ct} + [D_{ct} + P^k_{ct}] K_{ct} - P^k_{ct} K_{ct+1} + R_{ct} B_{ct} - B_{ct+1} - T_{ct} \tag{29}$$

where Π_{ct} reflects the profits of monopolistic competitors paid out fully as dividends to households, D_{ct} denotes the rental rate of capital, B_{ct} is the total loans the household makes at $t-1$ that are payable at t, and T_{ct} reflects lump sum taxes.

Government

Government spending is financed every period with lump sum transfers and the revenues from energy:

$$G_{ct} = T_{ct} + P^E E^e_{ct} \tag{30}$$

4 Symmetric equilibrium

The economy has a symmetric sequence of markets equilibrium. The endogenous state variables are the aggregate capital stocks, K_{ct}, and the number of local, global and transferred intermediate goods, A^l_t, A^g_t and A^T_t. The following system of equations characterizes the equilibrium:

Aggregate resource constraints.– In N

$$\begin{aligned} Y_{Nt} &= C_{Nt} + S_t + x^g_t A^l_t + \overbrace{\frac{\mu-1}{\mu} Y_{Nt} + \frac{\mu^K - 1}{\mu^K} P^K_{Nt} J_{Nt}}^{\text{overhead costs}} + G_{Nt} \\ &\quad \underbrace{+ \overbrace{\frac{P^K_{Nt} J_{Nt}}{\mu^K \theta a_{Nt}} (1 + \frac{A^g_t}{A^l_t})}^{\text{intermediates sold to N}} + \overbrace{e_t \frac{P^K_{St} J_{St}}{\mu^K \theta a_{St}} \frac{A^g_t}{A^T_t} \left(\frac{\psi e_t}{\xi}\right)^{\frac{1}{\theta-1}}}^{\text{intermediates sold to S}}}_{\text{production of investment goods}} \end{aligned} \tag{31}$$

In S

$$\begin{aligned} Y_{St} &= C_{St} + x^T_{St} A^g_t + \overbrace{\frac{\mu-1}{\mu} Y_{St} + \frac{\mu^K - 1}{\mu^K} P^K_{St} J_{St}}^{\text{overhead costs}} + G_{St} \\ &\quad \underbrace{+ \overbrace{\frac{P^K_{Nt} J_{Nt}}{e_t \mu^K \theta a_{Nt}} \frac{A^T_t}{A^l_t} \left(\frac{\psi \xi}{e_t}\right)^{\frac{1}{\theta-1}}}^{\text{intermediates sold to N}} + \overbrace{\frac{P^K_{St} J_{St}}{\mu^K \theta a_{St}} \xi^{\frac{1}{\theta-1}}}^{\text{intermediates sold to S}}}_{\text{production of investment goods}} \end{aligned} \tag{32}$$

Optimal factor demand.–

$$(1-\alpha-\eta)\frac{Y_{ct}}{L_{ct}} = \mu w_{ct} \tag{33}$$

$$\alpha\frac{Y_{ct}}{K_{ct}} = \mu\left[D_{ct}+\delta(U_{ct})P_{ct}^{K}\right] \tag{34}$$

$$\alpha\frac{Y_{ct}}{U_{ct}} = \mu\delta'(U_{ct})P_{ct}^{K}K_{ct} \tag{35}$$

$$\eta\frac{Y_{ct}}{E_{ct}} = \mu P_{ct}^{E},\ \text{where } P_{Nt}^{E}=P_{t}^{E},\ P_{St}^{E}=\frac{P_{t}^{E}}{e_t} \tag{36}$$

Relative price of capital.– Let's define the variable a_{Nt} as the ratio of the effective number of intermediate good in N relative to A_t^l, and a_{St} as the ratio of the effective number of intermediate goods in S relative to A_t^T. Formally,

$$a_{Nt} = \left[1+\frac{A_t^g}{A_t^l}+\frac{A_t^T}{A_t^l}\left(\frac{\psi\xi}{e_t}\right)^{\frac{1}{\theta-1}}\right] \tag{37}$$

$$a_{St} = \left[\frac{A_t^g}{A_t^T}\left(\frac{\psi e_t}{\xi}\right)^{\frac{1}{\theta-1}}+1\right] \tag{38}$$

These variables are useful to characterize the level of technology in each country and, in particular, the relative price of capital which is given by

$$P_{Nt}^{K} = \overbrace{\mu^{K}\theta}^{\text{Markups}}\ \overbrace{N_{kNt}^{-(\mu_{kN}-1)}(a_{Nt}A_t^l)^{-(\theta-1)}}^{\text{Mg. cost of production}} \tag{39}$$

$$P_{St}^{K} = \overbrace{\mu^{K}\theta}^{\text{Markups}}\ \overbrace{\frac{(N_{kSt})^{-(\mu_{kS}-1)}}{\xi}(a_{St}A_t^T)^{-(\theta-1)}}^{\text{Mg. cost of production}} \tag{40}$$

The relative price of capital is equal to a markup factor times the marginal cost of producing one unit of capital. The markup factor is given by the product of the markups charged by intermediate good producers (θ) and final capital good producers (μ^K). The marginal cost of producing one unit of capital is equal to the marginal cost of producing one unit of intermediate good (i.e. 1 for N and $1/\xi$ for S) times the efficiency gains from using many intermediate goods and final capital goods to produce new capital.

As we have seen above, a larger number of final capital goods and intermediate goods are available in booms. This increases the efficiency in producing new capital and, therefore, reduces the cost of producing new capital in terms of output (i.e. the relative price of capital). Hence, the model predicts a counter-cyclical price of capital as we observe in the data (e.g. Comin and Gertler, 2006).

However, different mechanisms are responsible for the fluctuations in the relative price of capital at different frequencies. The number of final capital producers, N_c^K, is stationary and varies mostly at the high-frequency inducing high frequency fluctuations in the price of capital. Exchange rate fluctuations induce high-frequency shifts in the composition of locally and foreingly produced intermediate goods, as captured by the term a_{ct}, similarly driving high-frequency fluctuations in P_{ct}^K. Finally, since the total number of intermediate goods available in production is a state variable, A_t^T and A_t^l only fluctuate in the medium term driving medium and low frequency fluctuations in the relative price of capital.

Given this characterization of how the various forces affect the relative price of capital at the various frequencies, we define the medium term wholesale price of capital, $\bar{P}_{ct}^K$, as follows:[14]

$$\bar{P}_{Nt}^K = (A_{Nt})^{-(\theta-1)} \tag{41}$$

$$\bar{P}_{St}^K = (A_{St})^{-(\theta-1)} \tag{42}$$

Profits.– The operating profits for a local intermediate good producer are:

$$\pi_t^l = \left(1 - \frac{1}{\theta}\right) \frac{P_{Nt}^K J_{Nt}}{\mu_{kN} a_{Nt} A_t^l}$$

The operating profits for a global intermediate good producer are:

$$\pi_t^g = \left(1 - \frac{1}{\theta}\right) \frac{P_{Nt}^K J_{Nt}}{\mu_{kN} a_{Nt} A_t^l} + \left(1 - \frac{1}{\theta}\right) e_t \frac{P_{St}^K J_{St}}{\mu_{kS} a_{St} A_t^T} \left(\frac{\psi e_t}{\xi}\right)^{\frac{1}{\theta-1}}$$

The operating profits for a transferred intermediate good producer are:

$$\pi_t^T = \left(1 - \frac{1}{\theta}\right) \frac{P_{Nt}^K J_{Nt}}{\mu_{kN} a_{Nt} A_t^l} \left(\frac{\psi \xi}{e_t}\right)^{\frac{1}{\theta-1}} + \left(1 - \frac{1}{\theta}\right) e_t \frac{P_{St}^K J_{St}}{\mu_{kS} a_{St} A_t^T}$$

[14] Clearly, our analysis would be identical if we made the medium term wholesale price of capital a function of A_t^T or A_t^l since these variables do not deviate from A_t^S and A_t^N, respectively, in the short run.

Optimal investment in exporting.– The amount of output invested in increasing the number of exportable intermediate goods, A_t^g, is determined by the following condition.

$$x_t^g = \frac{\epsilon \lambda_t^g \phi}{A_t^l R_{Nt}} \mathbb{E}_t \left[v_{t+1}^g - v_{t+1}^l \right]$$

An increase in the gap between the value of global and local intermediate goods leads to more intensive investments in exporting intermediate goods, x_t^g. Since booms in both Mexico and the US increase $v_{t+1}^g - v_{t+1}^l$,[15] investments in exporting intermediate goods will be pro-cyclical with respect to both US and Mexico GDPs.

Optimal investment in FDI.– The amount of $S's$ output invested by N's entrepreneurs to transfer the intermediate goods production to S, x_t^T, is determined by following condition.

$$e_t x_t^T = \frac{\epsilon_T \lambda_{St}^T \phi}{A_t^g R_{Nt}} \mathbb{E}_t \left[v_{t+1}^T - v_{t+1}^g \right] \tag{43}$$

In a similar vein as the exporting decision, the amount of resources invested in FDI is increasing in the gap in value between a transferred and a global intermediate good, $v_{t+1}^T - v_{t+1}^g$. In addition, x_t^T increases when the real exchange rate of the dollar appreciates (i.e. e_t declines). Fluctuations in these two variables determine the cyclical properties of FDI flows. In particular, booms in both the US and Mexico increase the value of transferred intermediate goods relative to global creating to pro-cyclical FDI flows. In addition, Mexican demand shocks will tend to appreciate the dollar leading to higher FDI inflows from the US into Mexico.

International equilibrium.– The real exchange rate, e_t, fluctuates to equilibrate the balance of payments between N and S. Given the international financial structure assumed in the economy, the Mexican trade deficit minus the profits from intermediate goods transferred to Mexico must be financed by US FDI flows into Mexico. That is, the current account plus the financial account in in S must be zero.

[15] Booms in S increase the gap because global goods can currently be sold in S while local will only be exportable in the future. Booms to N increase the gap because, as we shall see below, they also induce short run booms in S and therefore lead to higher foreign demand for the inetermediate good.

$$\overbrace{\underbrace{\frac{Q_{Nt}J_{Nt}A_t^T}{\mu_{kNt}a_{Nt}A_t^l}\left(\frac{\psi\xi}{e_t}\right)^{\frac{1}{\theta-1}} + P_t^E E_t^x - \frac{e_t Q_{St}J_{St}A_t^g}{\mu_{kSt}a_{St}A_{St}^T}\left(\frac{\psi e_t}{\xi}\right)^{\frac{1}{\theta-1}}}_{S's \text{ Trade balance}} \underbrace{-\Pi_t^T}_{S's \text{ Net income}}}^{\text{Current account balance in } S} = - \overbrace{e_t X_t^T}^{S's \text{ financial account balance}} \tag{44}$$

5 Calibration and simulations

In this section we explore the ability of the model to generate cycles at short and medium term frequencies that resemble those observed in the data in developed and, specially, in developing economies. We solve the model by loglinearizing around the deterministic balanced growth path and then employing the Anderson-Moore code, which provides numerical solutions for general first order systems of difference equations. We first describe the calibration before turning to some numerical exercises.

5.1 Calibration

The calibration we present here is meant as a benchmark. We have found that our results are robust to reasonable variations around this benchmark. To the extent possible, we use the restrictions of balanced growth to pin down parameter values. Otherwise, we look for evidence elsewhere in the literature. There are a total of twenty-four parameters. Twelve appear routinely in other studies. The other twelve relate to the process of development and international diffusion of intermediate goods.

We begin with the standard parameters. A period in the model is set to a year. We set the discount factor β equal to 0.95, to match the steady state share of non-residential investment to output. Based on steady state evidence we also choose the following number: (the capital share) $\alpha = 0.33$; (government consumption to output) $G_N/Y_N = 0.2$ and $G_S/Y_S = 0.1$; (the depreciation rate) $\delta = 0.1$; and (the steady state utilization rate) $U = 0.8$, based on the average capacity utilization level in the postwar period as measured by the Board of Governors. We set the inverse of the Frisch elasticity of labor supply ζ at unity, which represents an intermediate value for the range of estimates across the micro and macro literature. Similarly, we set the elasticity the change in the depreciation rate with respect the utilization rate, $(\delta''/\delta')U$ at 0.15, used for example in Jaimovich and Rebelo (2009) and Comin, Gertler and Santacreu (2009). Finally, based on evidence in Basu and Fernald (1997), we fix the steady state gross valued added markup in the consumption goods sector, μ^c equal to 1.1 and the corresponding markup for the capital goods sector, μ^k at 1.15.

We set the population of the US relative to Mexico to 3. Similarly, we set the relative productivity levels in final goods production so that US GDP is approximately 12 times Mexico's GDP.

We next turn to the "non-standard" parameters. The estimates for the obsolescence rate have range from the 4% per year in Caballero and Jaffe (1992) to around 20% in Pakes and Schankerman (1984). Based on this range we consider an obsolescence rate of 10% which implies a value for ϕ of 0.9. The steady state growth rates of GDP and the relative price of capital in the model are functions of the growth rate of new technologies, which in our model are used to produce new capital, and of the exogenous growth rate of disembodied productivity, g. By using the balanced growth restrictions and matching the average growth rate of non-farm business output per working age person (0.024) and the average growth rate of the Gordon quality adjusted price of capital relative to the BEA price of consumption goods and services (-0.026), we can identify the growth rate of disembodied productivity, g, and the productivity parameters in the technologies for creating new intermediate goods, χ. Accordingly, we set: $g = 0.0072$ and $\chi = 2.69$.

There is no direct evidence on the gross markup ϑ for specialized intermediate goods. Given the specialized nature of these products, it seems that an appropriate number would be at the high range of the estimates of markups in the literature for other types of goods. Accordingly we choose a value of 1.5, but emphasize that our results are robust to reasonable variations around this number.

There is also no simple way to identify the elasticity of new intermediate goods with respect to R&D, ρ. Griliches (1990) presents some estimates using the number of new patents as a proxy for technological change. The estimates are noisy and range from about 0.6 to 1.0, depending on the use of panel versus cross-sectional data. We opt for a conservative value of 0.65 in the lower range. The calibrations of ϑ, ϕ, χ and ρ yield a R&D share in US GDP of approximately 1 percent which is in line with the average of private R&D expenditures in the investment goods sector over GDP over the period 1960-2006.

In the model there are six parameters that govern the interactions between N and S. We calibrate them by matching information on trade flows, and FDI between the US and Mexico and micro evidence on the cost of exporting and the relative productivity of US and Mexico in manufacturing. First, we follow Iyer (2005) and set ξ to 2, to match the Mexican cost advantage over the US in manufacturing. We set the inverse of the iceberg transport cost parameter, ψ, to 0.95,[16] the steady state probability of exporting an intermediate good, λ^g, to 0.0875, and the steady state probability of transferring the production of an intermediate good to S, λ^T, to 0.0055 to approximately match the share in Mexican GDP of Mexican exports and imports to and from the US (i.e. 18% and 14%, respectively) and the share of intermediate goods produced in the US that are exported to Mexico. Specifically, Bernard, Jensen, Redding and Schott (2007) estimate that approximately 20 percent of US durable manufacturing plants export. However, these plants produce a much larger share of products than non-exporters. As a result, the share of intermediate goods exported should also be significantly larger. We target a value of 33% for the share of intermediate goods produced in the US that are exported. This yields an average diffusion lag to Mexico of 11 years which seems reasonable.

Das, Roberts and Tybout (2006) has estimated that the sunk cost of exporting for Colombian manufacturing plants represents between 20 and 40 percent of their annual revenues from exporting. We set the elasticity of λ^g with respect to investments in exporting, ρ_g, to 0.85 so that the sunk cost of exporting represents approximately 30 percent of the revenues from exporting. The elasticity of λ^T with respect to FDI expenses, ρ_T, together with the steady state value of λ^T determine the share of US FDI in Mexico in steady state. We set ρ_T to 0.5 so that the US FDI in Mexico represents approximately 2% of Mexican GDP.

The value of the Mexican oil production $P^E E_S$ is set to to match the share of Mexican oil exports in GDP. The elasticity of gross output with respect to oil (η) is set to 1.5% following the calculations in Blanchard and Gali (2007).

Finally, we fix the autocorrelation of the preference/wage markup shock to 0.6 so

[16] Interestingly, the value of ψ required to match the trade flows between the US and Mexico is smaller than the values used in the literature (i.e. 1/1.2 in Corsetti et al., 2008) because of the closeness of Mexico and the US and their lower (inexistent after 1994) trade barriers.

that the model generates an autocorrelation that approximately matches that of the total markup as measured by Gali, Gertler and Lopez Salido (2002).

5.2 Impulse response functions

To be clear, the exercises that follow are meant simply as a first pass at exploring whether the mechanisms we emphasize have potential for explaining the data: They are not formal statistical tests. As we discussed earlier, we treat innovations to the wage markup, μ_{ct}^{w}, both domestic and in the foreign country as the only sources of disturbances to the economy. The literature has shown that shocks to the wage markup can be interpreted as exogenous fluctuations in the household labor market power (Comin and Gertler, 2006), or in the marginal income tax rate. We keep in mind, though, that this simple mechanism is meant as a short-cut for a richer description of countercyclical wage markup behavior.[17]

Of course, wage markup shocks and other shocks that can be subsumed in the markup are not the only source of fluctuations in the economy. The RBC literature, for example, has focused on the ability of technology shocks to account for the high frequency variation in the data. Our analysis, instead, explores the whether the various mechanisms that determine how technology evolves in response to non-technological shocks to μ_{ct}^{w} can explain the variation both at high and medium term frequencies.

Before confronting the data, we gain some intuition for the workings of the model by examining the model impulse responses to our shocks. Figure 2 displays the impulse response functions to a wage markup shock in N. Solid lines are used for the responses in S while dashed lines represent the responses in N.

A positive wage markup shock contracts $N's$ labor supply causing a recession in N. The initial decline in hours worked (panel 2) is approximately 80% of the decline in gross output. The decline in economic activity is further amplified by exit in the final goods sector. The response of US output to the shock (panel 1) is much more persistent than the shock itself (panel 12) due to the endogenous propagation mechanisms of the model. The long run effect of the shock on output is approximately

[17] As discussed in GGLS (2002), a model with either nominal or real wage rigidities can generate a countercyclical wage markup.

45% of its initial response.

The decline in output reduces the marginal product of capital and the marginal value of utilizing the capital stock resulting in declines in both investment (panel 4) and the utilization rate in N. In line with the observed co-movement patterns, US consumption also declines due to the decline in permanent income (panel 3). However, the presence of transitory fluctuations in income make consumption less volatile than output.

The decline in nominal investment reduces the demand for both final capital goods and intermediate goods. As a result, some final capital goods producers exit the market leading to a decline in N^K. Similarly, the return to developing new intermediate goods also declines leading to an immediate decline in R&D expenses (panel 7). Both of these mechanisms have important implications for the evolution of the relative price of capital (panel 6). The exit of final capital goods producers leads to a immediate increase in P_N^K due to the loss in the efficiency of production at the retail stage. Given the evolution of entry and exit, this force is only effective in the short run. Medium term fluctuations in the relative price of capital are driven by the rate at which new intermediate goods are developed. The decline in R&D expenses slows down this rate leading to a permanent decline in the efficiency of production of new capital and to a permanent increase in the medium and long term in P_N^K.

These factors also affect the evolution of standard productivity measures. US labor productivity declines initially because output's fall is larger than the fall in hours worked. As with output, the shock has a permanent effect on labor productivity because it permanently reduces the number of intermediate goods developed in the US (relative to the steady state trend, panel 8). TFP declines in the short run because of the decline in capacity utilization which is unmeasured in existing measures of the capital stock (panel 9). In the medium term, however, the decline in TFP is driven by the decline (relative to the steady state) in the number of intermediate goods which reduces the efficiency of production of new capital leading to an overstatement in the existing measures of capital by the BEA.

In addition to R&D expenses, the US wage markup shock also affects the speed of international diffusion of technology both through the extensive margin of trade and FDI (panel 7). In particular, the value of a transferred intermediate good declines more than the value of a global good which, in turn, declines more than the value of a local good.[18,19] As a result, fewer resources are devoted to exporting new intermediate goods to Mexico and to transferring the production of the goods to Mexico.

It is interesting to note that the domestic impact of a wage markup shock to N is very similar to the impulse response functions to this same shock in a closed economy version of this model developed by Comin and Gertler (2006). This suggest that modelling jointly developed and developing economies is not very important to understand the cyclical properties of developed economies.

One obvious advantage of building a multi-country model is that it allows us to explore the magnitude of the effect of US shocks on the Mexican economy. One key finding from Figure 2 is that a US shock has important effects on the Mexican economy. Upon impact, the shock causes a decline in the demand for Mexican output due to the drop in the US demand of Mexican intermediate goods. The initial decline in Mexican output (0.045), however, is significantly lower than in US (0.46). This is in part the case because, given the size of the trade flows, the initial drop in demand is larger in the country hit by the shock.

Unlike the US, the response of Mexican output to a US shock is hump-shaped. At the root of this response we find the dynamics of international technology diffusion. As discussed above, the shock reduces the value for US firms of starting to export a new intermediate good and of conducting FDI. This results in a lower flow of new global and transferred intermediate goods which gradually reduces more and more the stock of intermediate goods in Mexico (relative to the steady state) reaching the minimum 5 years after the shock. Since productivity is determined by the stock of intermediate goods, the slow international diffusion of new technologies also leads to a gradual decline in Mexican productivity which causes a hump-shaped response of output.[20]

[18] The log-deviation from steady state of the values of a local and a global intermediate good decline by very similar ammounts in response to a US shock. However, since the steady state value of a global is significantly larger than the value of a local intermediate good, the decline in the value of the former is larger than in the latter.

[19] The value of a transferred intermediate good declines despite the profits earned by the producer of such a good do not decline initially. π^T does not decline because the apreciation of the dollar induces capital goods producers to use more intensively intermediate goods produced in Mexico. This effect compensates for the aggregate decline in demand.

[20] In the US the response to the shock is monotonic because of the larger effect of the shock in

It's worth making a few observations about the strength of the international diffusion of technology as propagation mechanisms. First, the peak effect of the US shock in Mexico is larger than the peak effect of the same shock in the US. Second, the peak effect in Mexico arrives several years after the shock has hit the US economy. One consequence of these two observations is that US shocks will cause significant volatility over medium term in the Mexican economy. Finally, the US shock, which (remember!) was temporary, has a permanent effect on Mexican output.

The productivity dynamics in Mexico have important effects on all the other variables too. The response of TFP mimics the response of output. Initially, the decline in TFP is driven by the decline in utilization, but in the medium term, the main driving force is the decline in the efficiency of investment which in part is not captured by existing measures of the capital stock.

The initial response of Mexican consumption to the US shock is larger than the response of output. Intuitively, this is the case because Mexican consumers foresee the slowdown in the diffusion of new technologies which will lead to subsequent declines (relative to trend) in output and income in the coming years. In short, they understand that the shock leads to a larger decline in permanent than in transitory income.

In a similar vein, the small initial decline in Mexican output induces a small decline in real wages. As a result, Mexican workers experience a small substitution effect which is dominated by the large income effect when confronting their labor supply decisions. This explains why hours worked initially increase in Mexico in response to a US wage markup shock.

The US wage markup shock leads to a lower demand which reduces the US demand for foreign intermediate goods and energy. Initially, this decline is larger than the decline in Mexican imports of global intermediate goods generating a trade surplus in the US. To balance this trade surplus, the dollar appreciates as reflected by the decline in the real exchange rate, e_t.

The appreciation of the dollar raises the price in pesos of global intermediate goods. Mexican capital producers respond to this by using domestically produced intermediate goods (relatively) more intensively. Despite this, producing new capital becomes more expensive in Mexico as reflected by the initial increase in P_S^K. Interestingly, de-

domestic demand and because technology diffuses faster domestically than internationally.

spite the initial increase in P_S^K, the initial decline in real investment is not very large because agents foresee that the slowdown in the international diffusion of technology will lead to higher prices of new investment in the future.

Figure 3 displays the impulse response functions to a Mexican wage markup shock in the US (dashed) and in Mexico (solid). The effect of a Mexican shock in Mexico shares some similarities with the effect of a US shock in the US but also has some critical differences. The domestic effect of the shocks are similar in the short run. Specifically, hours worked declines, output declines upon impact and then recovers, investment and capacity utilization collapse and consumption declines but significantly less than output.

The differences, however, are equally striking. First, the Mexican shock has only a transitory effect on Mexican GDP. Indeed, this effect is as transitory as the shock itself. In other words, the propagation mechanisms in the Mexican economy do not propagate Mexican shocks into the medium term. This is in sharp contrast with the domestic effects of a US shock which are importantly propagated into the medium term by the endogenous technology mechanisms. The implication of this finding is that Mexican shocks are a less significant source of fluctuations in Mexico over the medium term. The most important driver of medium term fluctuations in Mexico in our model are shocks to the US economy.

Second, a Mexican shock has virtually no effect in the US. This follows from the difference in size between the two economies but more importantly from the fact that technologies flow from the US to Mexico and not otherwise.

In contrast, Mexican shocks induce short run dynamics in the international macro variables that are consistent with some stylized facts highlighted by the international macro literature (e.g. Neumeyer and Perri, 2005). Following a positive Mexican wage markup shock, Mexican imports of US intermediate goods decline more than the exports to the US generating a trade surplus in Mexico. This is consistent with Neumeyer and Perri's finding that in a sample of developing countries (which includes Mexico) the current account is counter-cyclical.[21]

To balance the current account, the peso appreciates with respect to the dollar. This, in turn, reduces the relative price of capital in Mexico because foreign intermedi-

[21] The other fact emphasized by Neumeyer and Perri is that real interest rates are counter-cyclical in developing countries. This is also the case in our model as shown by Figure 3.

ate goods become cheaper. The recession in Mexico together with the more expensive peso leads to an immediate collapse of FDI flows into Mexico. This sudden decline in the capital inflows to the developing country which coincides with recessions in developing countries is the key regularity that the "sudden stop" literature has tried to explain (e.g. Calvo 1998).

In contrast with the response to the US shock, the collapse in FDI that follows a Mexican shock is very transitory and has a very small effect on the stock of new technologies in Mexico over the medium term. This also seems consistent with the Mexican experience where after the sudden stop in 1994, FDI recover very quickly. Further, the transitory consequences of the Mexican shock together with the boom that started to experience the US economy in the second half of the 1990s explains the quick recovery of Mexico.

TFP and labor productivity also respond pro-cyclically to the Mexican wage markup shock driven by the decline in the utilization rate which typically is unmeasured in the national statistics.

Next, we turn to the quantitative evaluation of the model.

5.3 Simulations

To explore quantitatively the model predictions we simulate the two-country economy described in section 3. Prior to that, we need to calibrate the standard deviation of the shocks that drive the fluctuations of our economy. We do this by requiring the model to match the high frequency volatility of GDP in Mexico and the US. This yields a volatility of the wage markup shock of 3.6% in the US and 4.75% in Mexico.

Volatility and co-movement

We next explore how similar are the economic fluctuations produced by the model and those of the Mexican economy. We do so by comparing moments of artificial data generated by the model economy with the unconditional moments of the actual data. To be clear, our goal is not to match each and every of the many moments we report. That is clearly impossible with a model that abstracts from some important features such as credit frictions which may be important, for example, to explain the volatility of consumption in developing countries. For the shake of clarity, we also tie our hands very much by having only one type of shocks. Our more modest goal is just to do a fair job in reproducing the volatility patterns and to roughly capture the co-movement patterns between Mexico and the US.

Table 4 reports the standard deviations of the high frequency and medium term cycle fluctuations in our variables of interest both in the data and in the model. By construction, the model does a good job in reproducing the volatility of output in the US and Mexico at the high frequency. What is remarkable is that it also does a good job in generating the observed volatility over the medium term. That shows that the model induces the right amount of propagation of high frequency shocks into the medium term. Interestingly, the model roughly achieves that for both the US and Mexico despite our finding that the Mexican economy fluctuates relatively more over the medium term than the US economy. This result is a direct consequence of asymmetries introduced in the model through the product life-cycle dynamics.

The model generates too much volatility in US consumption and too little in US investment. In Mexico, the volatility of investment, FDI over GDP and imports from the US are quite similar to the series generated by the model both at the high frequency and over the medium term. The model underpredicts the volatility of exports to the US and Mexican consumption. This surely reflects the relevance of financial frictions (which will amplify the volatility of consumption) and terms of trade shocks (which will increase the volatility of exports). Having said that, we consider that overall the model does a fair job in reproducing the volatilities of Mexican and US macro series specially given that it has only one shock for the US and one for Mexico.

Table 5 reports the first order autocorrelation of simulated series. The model roughly generates the observed persistence of macro series in both the US and Mexico at the high frequency and over the medium term cycles despite the relatively low persistence of the shocks. The model does over predict the persistence of the share of US FDI in Mexican GDP. This surely reflects that FDI flows have a high frequency component that responds to forces other than the profits opportunity that arise from transferring technology captured by the model. Given that our model does not incorporate that component, it is natural that FDI flows in our simulations are slightly less volatile at the high frequency than in the data and more persistent. By the same token, the high frequency co-movement between GDP and FDI is higher in the model than in the data (Table 6).[22]

Table 6 reports the contemporaneous correlation between the high frequency component of the main variables of interest in Mexico and both HP filtered output in Mexico and the US. The model roughly captures the contemporaneous correlation between Mexican variables and Mexican output at the high frequency. The correlation between US GDP and Mexican consumption is lower in the data than as predicted by the model. This may reflect domestic credit frictions that make Mexican consumption more dependent on Mexican conditions than a model without credit market imperfections such as ours would predict. Similarly, the model underpredicts the correlation in high frequency between US GDP and Mexican investment on the one hand and trade flows with the US (mainly imports from the Us) on the other. These discrepancies between the model and the data seem to point to the importance of allowing for other shocks that affected simultaneously the Mexican and the US economies in the high frequency. Examples of such shocks are shocks to the global aggregate demand or, if we allowed for some form of international capital markets, to the global interest rate.[23] These are natural extensions of our model.

Inter-frequency co-movement

One of the most striking facts presented in section 2 is the lead of US HP-filtered output over Mexican output over the medium term. Next we evaluate the model's ability to reproduce this finding and explore what features of the model induce this co-movement pattern.

The first row in Table 7 reports the correlation between medium term output in Mexico and HP-filtered US output at various lags in the data. The second row reports the average cross-correlation across the 1000 simulations of our model. This confirms the model's ability to generate the co-movement patterns between the US and Mexico at different frequencies. In particular, the lead of short term US fluctuations over medium term movements in Mexican output.

[22]However, once we remove some noise from the FDI series by keeping only the medium term component the correlation between FDI and GDP in the model and data is significantly more similar. The contemporaneous correlations with HP-filtered US GDP, the correlations are 0.39 (model) vs. 0.53 (data) For Mexican GDP, the correlations are 0.45 (model) vs. 0.23 (data).

[23]Note that including some of these additional shocks would also reduce the contemporaneous correlation between Mexican GDP and Mexican exports to the US which is also higher in the model than in the data.

But what features of the model induce this pattern of co-movement? To answer this question we compute the same cross-correlogram when simulating the model with only US shocks (row 3) and with only Mexican shocks (row 4). In the first case we see a clear and strong lead of US high frequency fluctuations over Mexican medium term fluctuations. However, when we consider only Mexican shocks, we observe a positive correlation contemporaneously but there is no lead of the US over Mexico. Therefore, the lead of the US over the Mexican medium term fluctuations is driven by the response of the Mexican economy to US shocks.

When the US is booming the amount of resources devoted to both covering the sunk costs of exporting new intermediate goods to Mexico and conducting foreign direct investment into Mexico increase. Because, it takes time for these investments to affect the level of technology in Mexico, this effect affects the Mexican productivity only over the medium term. Mexican shocks also induce fluctuations in the extensive margin of trade and inward FDI. However, as we have shown in section 5.2, the response of the extensive margin of trade and FDI to a US shock is much more prolonged than to a Mexican shock inducing a more persistent effect on the technology available for production in Mexico.

Absent these endogenous technology mechanisms, it is hard to imagine how a model can propagate foreign short term shocks into the medium term inducing the observed lead-lag relationship. We conjecture that small open economy models will not be able to generate this pattern. In small open economy models, foreign influences affect the economy through shocks to the interest rate which is exogenous. The response of the Mexican economy to such a shock will be similar to the response we have in Figure 3 to a Mexican wage markup shock. This is the case because the entry and exit mechanisms induces counter-cyclical fluctuations in the price of capital which affect the cost of capital in a similar way as shocks to the international cost of borrowing. Hence, small economy models will generate a pattern of co-movement between the high frequency US output and the medium term component of Mexican output similar to the one reported in the Mexico only shocks (row 4) which is inconsistent with the data.

Implications for Aggregate Volatility

We conclude our analysis by returning to the questions that motivated our analysis. Specifically, how important are US shocks for Mexican economic fluctuations. We can answer this question with the help of our model. Table 8a decomposes the volatility of the simulated series of output in both countries between the fluctuations driven by US and Mexican shocks. The first two columns report the contributions to the standard deviation of HP filtered output while the second two columns focus on output over the medium term cycle. As mentioned above, Mexican shocks account for a small fraction of US fluctuations (6% at high frequency and 7% over the medium term cycle). US shocks, instead, represent a very significant source of Mexican fluctuations. At the high frequency, 35% of Mexican volatility is driven by US shocks, while over the medium term cycle, US shocks induce 42% of the volatility in Mexican GDP.

This asymmetry in the effect of foreign shocks in the US and the Mexican economies can help us understand better the sources of the higher volatility in Mexico. To this end, Table 8b decomposes the Mexico-US differential in GDP in two components. The first term captures the difference in volatility from domestic shocks. The second term measures the difference in volatility from foreign shocks. These terms reflect both differences in the standard deviations of shocks as well as potentially different responses to the shocks.[24] We report the percentage contribution of each of these two components to the differential in volatility between Mexico and the US both at the high frequency and in the medium term cycles.

Two conclusions emerge from this analysis. First, the differential in the response to foreign shocks in Mexico and the US is the main determinant of the higher volatility of the Mexican economy vis a vis the US. Second, the importance of foreign shocks is larger over the medium term. Specifically, foreign shocks account for approximately 57 percent of the differential in volatility at the high frequency and for about 67 percent of the differential over the medium term cycles. This is the case because the extensive margin of trade and FDI propagate US shocks in Mexico affecting Mexican productivity over the medium term.

[24] Note that, since the variance of mexican shocks is larger than the variance of US shocks, foreign shocks can only contribute to the Mexico-US difference in volatility through the difference responses of the economies to foreign shocks.

6 Conclusions

We have developed a two country asymmetric business cycle model to study how significant are shocks to developed as a source of volatility in developed economies. Our model, explicitly builds three linkages between the developed and the developing country. In addition to the standard demand for exports from the developing country, business cycles in the developed economy affect the cycle in the developing one because they affect the firms' decision of incurring in the investments necessary to start exporting new goods and to conduct FDI in the developing country. These two "new" mechanisms generate a lead of high frequency fluctuations in the US over Mexican fluctuations over the medium term which we have observed in the data.

This asymmetry in the response to foreign shocks opens a new avenue towards explaining the higher volatility we observe in developing countries. In the Mexican case, we have quantified that between 57% and 67% of the differential in volatility in Mexico over the US is due to the different effect of foreign shocks in these economies.

By modelling the interaction between developed and developing economies, our model can help us understand better the large impact that the recession that the US is experiencing currently is having in developing economies that had otherwise sound fundamentals. When the recession started in late 2007, the effect on developing countries was relatively small. But now that we are more than a year into the US recession, economic activity in developing economies is declining significantly. Our model predicts that the recession in developing countries will be longer and more severe than in the US. The ongoing drop in FDI and investments in the extensive margin of trade will reduce significantly productivity in developing countries over the medium term. As a result, economic activity will continue to deteriorate even when the US shock is over and the US economy starts to recover.

In this paper we have not explored the policy implications of our analysis. That seems an interesting line of research that we plan on pursuing in the future. for this, it may be necessary to enlarge the number of shocks and to introduce some frictions that we have ignored in our model for the shake of clarity such as price rigidities.

Though our model has not incorporated domestic credit market imperfections, they are an important feature of developing economies and it would be interesting to extend our analysis along this dimension in future work. In this case, the details of the mechanism may matter, but our educated guess is that, due to the important effects we have observed of shocks on the medium term evolution of productivity, the effect of disruptions in credit markets would be amplified and propagated further by our endogenous technology mechanisms.

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Table 1: Volatility of GDP per worker (1990-2006)

Frequency	**USA**	**MEXICO**
High Frequency (HP filter)	0.013	0.026
Medium Term Cycle (period <50 years)	0.015	0.037

Note: High frequency filtered with a Hoddrick-Prescott filter with filter parameter set at 100.
Medium term cycle filtered using a Band-Pass filter that keeps cycles associated with periods smaller than 50 years.

Table 2: Contemporaneous Correlations

MEXICO	**GDP USA**	**GDP MEXICO**
GDP	0.43*	1
IMPORTS (FROM US)	0.61***	0.83***
EXPORTS (TO US)	0.68***	0.08
INVESTMENT	0.6***	0.62***
FDI INFLOWS (FROM US)/ GDP	0.23	0.11

Note: Period 1990-2006. All variables but FDI are scaled by working age population in Mexico.
All variables have been HP-filtered.
(*) , (**), (***) denote significance at 10, 5 and 1%.

Table 3: Cross-Correlogram Across Frequencies

MEDIUM TERM COMPONENT OF MEXICAN	LAGS OF HP-FILTERED US GDP 0	1	2	3
GDP	0.28	0.49*	0.53**	0.39
IMPORTS (FROM US)	0.56**	0.64***	0.42	0.01
EXPORTS (TO US)	0.57**	0.47*	0.22	-0.12
INVESTMENT	0.79***	0.72***	0.32	-0.21
FDI INFLOWS (FROM US)/ GDP	0.53**	0.52**	0.34	0.08

MEDIUM TERM COMPONENT OF MEXICAN	LAGS OF HP-FILTERED MEXICAN GDP 0	1	2	3
GDP	0.5**	0.36	0.15	-0.05
IMPORTS (FROM US)	0.41*	0.17	-0.16	-0.38
EXPORTS (TO US)	0.17	0.04	-0.01	0.01
INVESTMENT	0.48**	-0.05	-0.5**	-0.66***
FDI INFLOWS (FROM US)/ GDP	0.24	-0.02	-0.25	-0.33

Note: Period 1990-2006. All variables but FDI are scaled by working age population in Mexico.
Medium term component is obtained by Band-Pass filtering keeping the cycles with periods between 8-50 years.
(*) , (**), (***) denote significance at 10, 5 and 1%.

Table 4 : Volatility Model vs. Data

	High Frequency		Medium term Cycle	
MEXICO	**Data**	**Model**	**Data**	**Model**
GDP	0.026	0.026 (0.016 , 0.039)	0.037	0.035 (0.019 , 0.061)
CONSUMPTION	0.031	0.0150 (0.01 , 0.021)	0.040	0.018 (0.01 , 0.027)
INVESTMENT	0.079	0.069 (0.038 , 0.114)	0.082	0.10 (0.047 , 0.191)
IMPORTS (FROM US)	0.090	0.069 (0.04 , 0.108)	0.117	0.096 (0.048 , 0.172)
EXPORTS (TO US)	0.090	0.043 (0.024 , 0.071)	0.134	0.062 (0.029 , 0.12)
FDI/GDP	0.004	0.003 (0.001 , 0.006)	0.004	0.010 (0.004 , 0.023)
US	**Data**	**Model**	**Data**	**Model**
GDP	0.013	0.014 (0.009 , 0.021)	0.015	0.018 (0.01 , 0.03)
CONSUMPTION	0.008	0.019 (0.012 , 0.027)	0.012	0.023 (0.014 , 0.036)
INVESTMENT	0.064	0.036 (0.017 , 0.061)	0.084	0.053 (0.023 , 0.097)

Note: High frequency corresponds to cycles with periods lower than 8 years and is obtained by filtering simulated data with a Hodrick-Prescott filter. Medium term cycles corresponds to cycles with periods shorter than 50 years and is obtained by filtering simulated data with a Band-Pass filter.

Table 5 : First Order Autocorrelation Model vs. Data

	High Frequency		Medium Term	
Mexico	Data	Model	Data	Model
GDP	0.34 (-0.19, 0.87)	0.30 (-0.24, 0.66)	0.68 (0.46, 0.9)	0.55 (0.02, 0.84)
CONSUMPTION	0.57 (-0.06, 1.2)	0.14 (-0.33, 0.51)	0.72 (0.3, 1.14)	0.37 (-0.12, 0.73)
INVESTMENT	0.28 (-0.07, 0.62)	0.43 (-0.07, 0.67)	0.32 (-0.04, 0.68)	0.65 (0.18, 0.87)
IMPORTS (FROM US)	0.37 (0.01, 0.72)	0.34 (-0.13, 0.7)	0.59 (0.19, 0.99)	0.58 (0.07, 0.85)
EXPORTS (TO US)	0.75 (0.31, 1.17)	0.48 (0.01, 0.76)	0.85 (0.52, 1.17)	0.68 (0.24, 0.88)
FDI/GDP	-0.34 (-0.89, 0.22)	0.53 (0.11, 0.78)	-0.17 (-0.61, 0.27)	0.79 (0.42, 0.97)
US	Data	Model	Data	Model
GDP	0.53 (0.13, 0.93)	0.28 (-0.19, 0.64)	0.60 (0.2, 1.0)	0.52 (0.03, 0.82)
CONSUMPTION	0.50 (0.2, 0.79)	0.15 (-0.31, 0.54)	0.54 (0.24, 0.84)	0.39 (-0.12, 0.76)
INVESTMENT	0.65 (0.26, 1.03)	0.66 (0.34, 0.82)	0.77 (0.43, 1.1)	0.79 (0.55, 0.9)

High frequency corresponds to cycles with periods lower than 8 years and is obtained by filtering simulated data with a Hodrick-Prescott filter. Medium term cycles corresponds to cycles with periods lower than 50 years and is obtained by filtering simulated data with a Band-Pass filter. The reported model measures are the average of the first order autocorrelations from the Monte Carlo consisting of 1000 17-year long simulations. 95 percent confidence intervals in parenthesis.

Table 6: Contemporaneous Correlation with Mexican Output

MEXICO	GDP USA		GDP MEXICO	
	Data	Model	Data	Model
GDP	0.43	0.09 (-0.50, 0.62)	1.00	1.00
CONSUMPTION	0.02	0.65 (0.2, 0.9)	0.78	0.56 (0.12, 0.87)
INVESTMENT	0.60	0.00 (-0.54, 0.52)	0.62	0.92 (0.78, 0.98)
IMPORTS (FROM US)	0.61	-0.19 (-0.67, 0.37)	0.83	0.91 (0.77, 0.98)
EXPORTS (TO US)	0.68	0.22 (-0.35, 0.67)	0.08	0.90 (0.73, 0.98)
FDI/GDP	0.23	0.70 (0.33, 0.91)	0.11	0.63 (0.2, 0.88)

Note: Period 1990-2006. All variables but FDI are scaled by working age population in Mexico.
All variables have been HP-filtered. The model statistics are the average of the contemporaneous
cross-correlations from the Monte Carlo consisting of 1000 17-year long simulations.
In parenthesis 95 percent confidence intervals.

Table 7: Cross-Correlogram Across Frequencies

		Lags of High Frequency US Output			
		0	**1**	**2**	**3**
ALL SHOCKS	Data	0.28	0.49	0.53	0.39
	Model	0.14	0.25	0.30	0.25
ONLY US SHOCKS	Model	0.17	0.38	0.47	0.43
ONLY MEXICAN SHOCKS	Model	0.27	-0.08	-0.43	-0.64

High frequency corresponds to cycles with periods lower than 8 years and is obtained by filtering simulated data with a Hodrick-Prescott filter
Medium term cycles corresponds to cycles with periods lower than 50 years and is obtained by filtering simulated data with a Band-Pass filter
The reported measures are the average of the contemporaneous cross correlations from the Monte Carlo consisting of 1000 17-year long simulations.

Table 8a: Decomposition of output volatility

	High Frequency		Medium Term Cycle	
	US volatility	**Mexican volatility**	**US volatility**	**Mexican volatility**
US Shocks	0.94	0.35	0.93	0.42
Mexico Shocks	0.06	0.65	0.07	0.58

Note: Share of output volatility in the relevant country at the relevant frequency associated to shocks either from the US or Mexico High frequency fluctuations are isolated using a Hodrick-Prescott filter with filtering parameter 100. Medium term cycle is obtained by using a Band Pass filter that isolates fluctuations associated with cycles of period shorter than 50 years.

Table 8b: Diferential in output volatility

	High Frequency	**Medium Term Cycle**
Domestic shocks	0.43	0.33
Foreign shocks	0.57	0.67

Note: Share of the difference between the standard deviation of Mexican output and US output at the relevant frequency associated to domestic vs. foreign shocks.

Figure 1: Evolution of GDP per working age population in Mexico and the US filtered at different frequencies

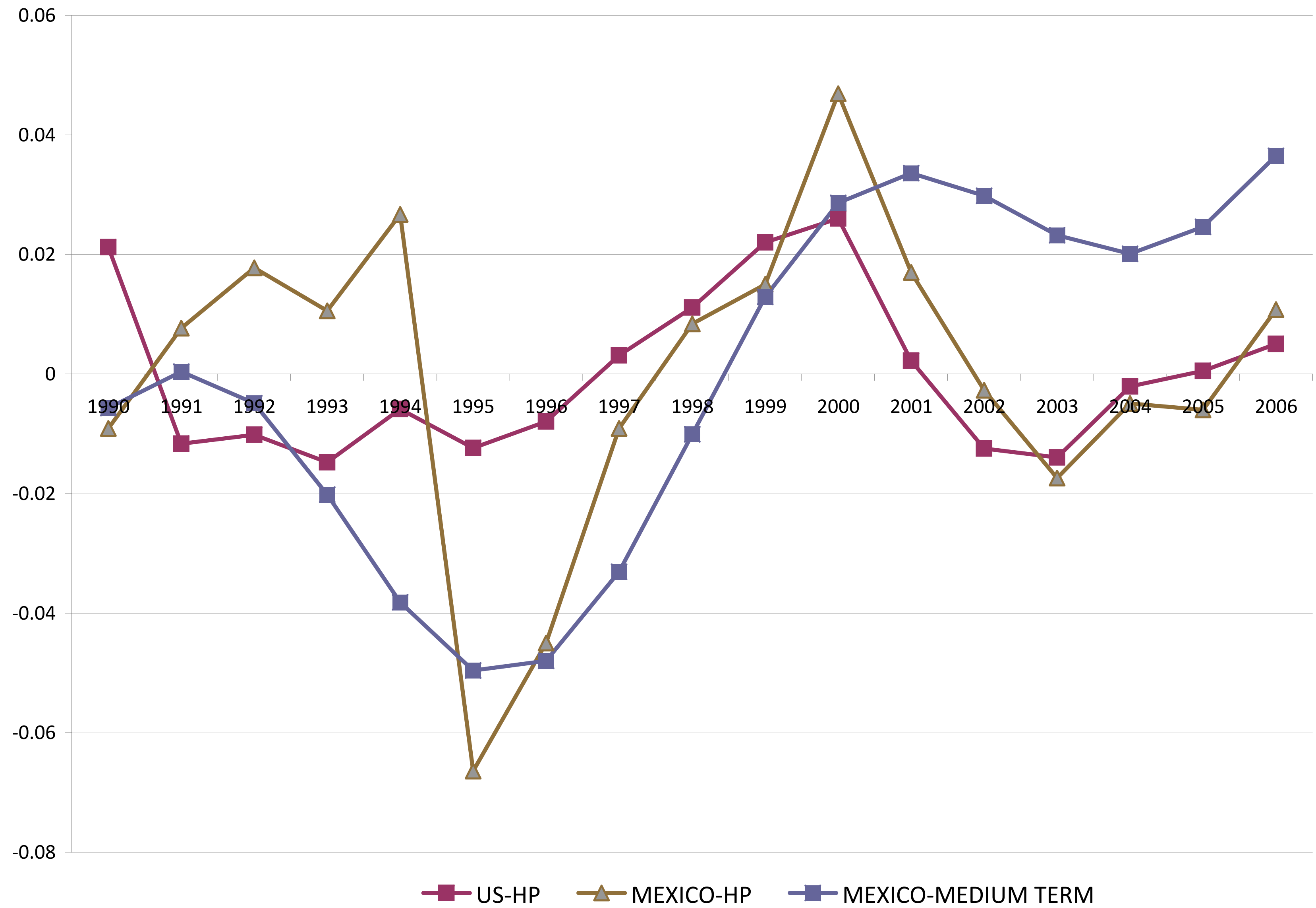
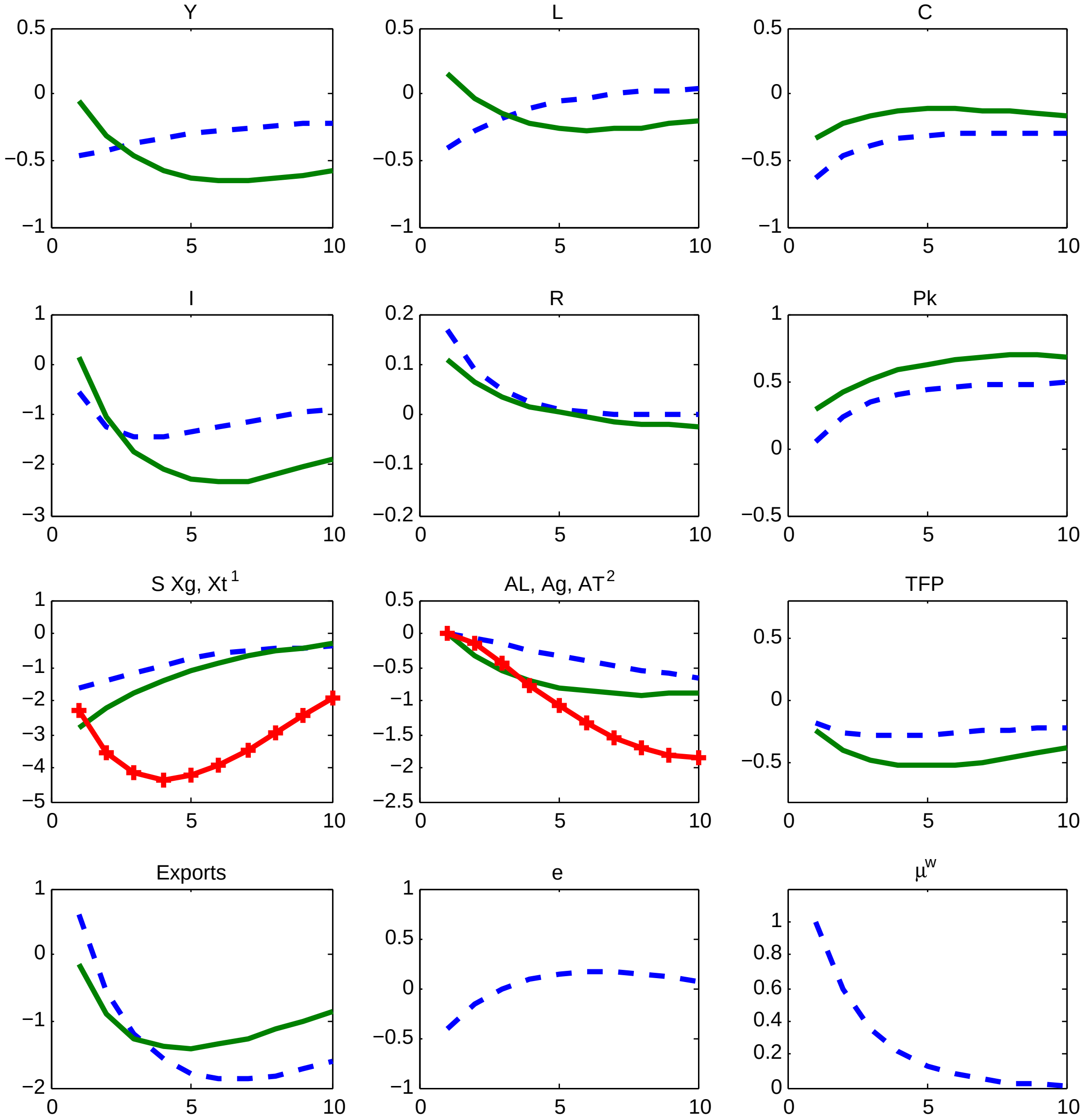


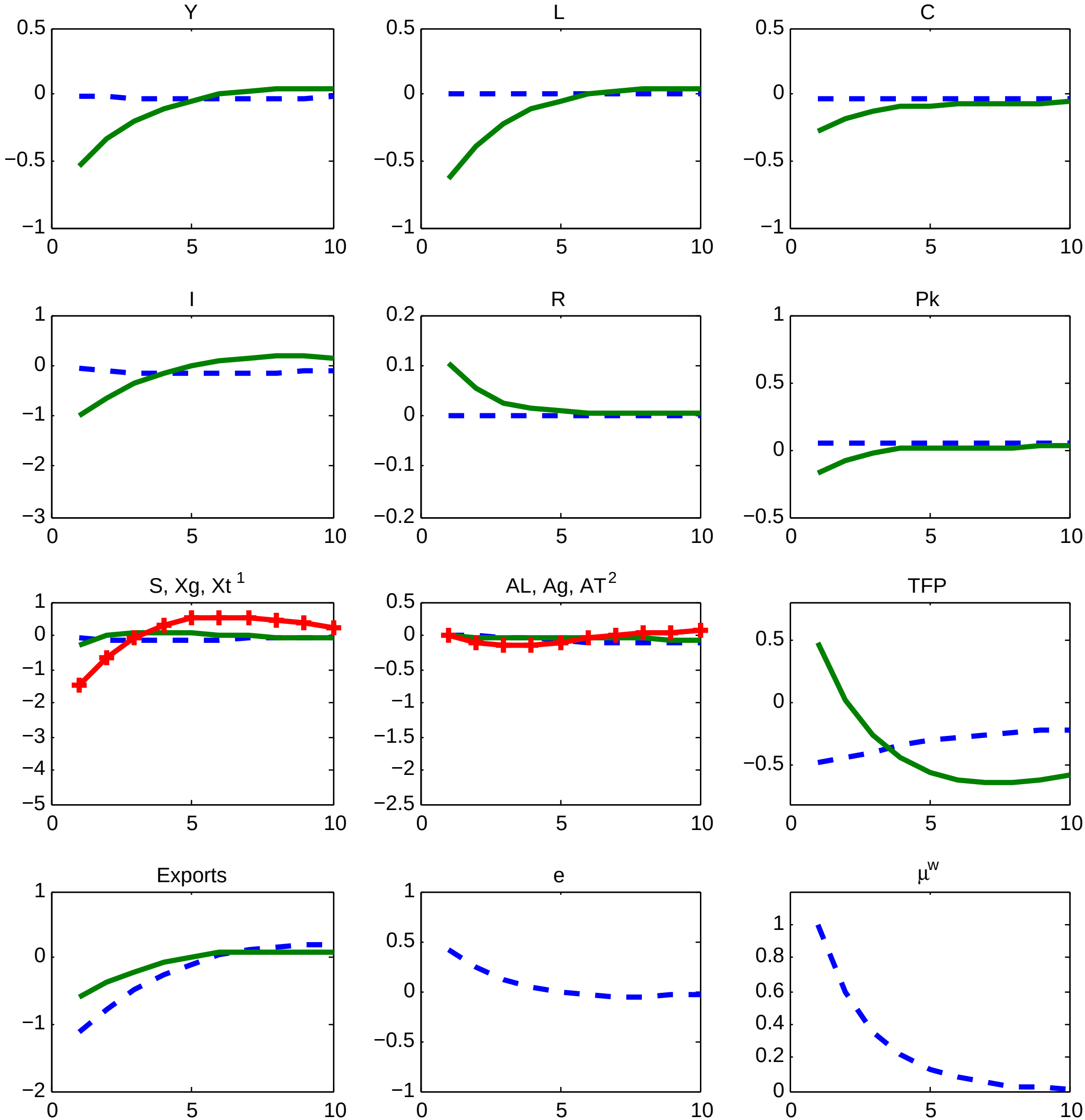
Figure 2, Impulse Responses to a US Wage Markup Shock



[1] Research and development expenditures (S, −−), investments in exporting (Xg,−) and FDI (Xt, −+)

[2] Local Intermediate Goods (AL,−−), Exported Intermediate Goods(Ag,−) and Transfered Intermediate Goods(AT,−+)

Figure 3, Impulse Responses to a Mexico Wage Markup Shock



[1] Research and development expenditures (S, −−), investments in exporting (Xg, −) and FDI (Xt, −+)

[2] Local Intermediate Goods (AL, −−), Exported Intermediate Goods(Ag, −) and Transfered Intermediate Goods(AT, −+)