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Financial Frictions and Total Factor Productivity: Accounting for the Real Effects of Financial Crises*

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Abstract

Financial crises in emerging economies are accompanied by a large fall in total factor productivity. We explore the role of financial frictions in exacerbating the misallocation of resources and explaining this drop in TFP. We build a two-sector model of a small open economy with a working capital constraint to the purchase of intermediate goods. The model is calibrated to Mexico before the 1995 crisis and subject to an unexpected shock to interest rates. The financial friction generates an endogenous fall in TFP and output and can explain more than half of the fall in TFP and 74 percent of the fall in GDP per worker.

Keywords: Financial crises; total factor productivity; financial frictions

JEL classification: E32; F41; G01.

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1 Introduction

The financial crises of the last decade in emerging economies have been accompanied by a large fall in total factor productivity. As Calvo et. al. (2006) show, GDP in these sudden stop episodes declined on average by 10 percent, the bulk of which can be attributed to a drop in TFP.[1] Investigating the forces behind these movements in total factor productivity is crucial to understand the real effects of financial crises.

A decline in TFP of this magnitude must be a result of not merely a misallocation of resources, but a misallocation that worsens during crises. In this paper we explore the role of financial frictions in exacerbating existing inefficiencies and explaining the drop in measured TFP. There is ample micro evidence that financial constraints and the increase in the cost of credit affected the performance of firms during the crisis,[2] however their aggregate impact on output is unclear.

We build a deterministic dynamic two-sector model of a small open economy with a working capital constraint where firms have to finance a part of their purchase of intermediate goods prior to production. The economy consists of a traded and non traded goods sector, each of which use labor, capital and intermediate goods to produce output. The output of both sectors is combined to produce a final good and an intermediate good. The former is used as both a consumption and an investment good and the latter for production. The economy exports and saves in traded goods. Besides intertemporal adjustment costs for capital, the financial constraint on the purchase of intermediate goods is the only friction in the baseline model.

An exogenous increase in interest rates has a twofold effect. First, it increases the wedge between the producer cost and the user cost of intermediate goods worsening existing allocative inefficiency. The main objective of our paper is to quantify the impact of this channel on TFP. Second, an increase in interest rates reduces the demand for non traded goods, leading to a fall in their relative price and a real exchange rate depreciation.

[1] The sudden stop episodes studied include the Latin American debt crises of the 1980s, the Mexican crisis of the first half of the 1990s and the East Asian and Russian crises of the late 1990s.

[2] Aguiar (2005) and Pratap et. al (2003) show that the presence of dollar denominated debt depressed firm investment during the 1994 crisis in Mexico. Pratap and Urrutia (2004) build a model that accounts for most of the fall of investment in Mexico due to balance sheet effects of a real exchange rate depreciation.

We calibrate our model to the Mexican economy prior to the sudden stop of 1994 and introduce the sequence of interest rates observed in Mexico during the sudden stop as an unexpected shock. The experiment delivers a reduction in aggregate TFP of about 3.5 percent which accounts for 52 percent of the TFP drop in the data and 74 percent of observed fall in real GDP per worker. The model is also consistent with a current account reversal and a real exchange rate depreciation, or an increase in the price of traded goods relative to the price of non traded goods, as observed in the data. However, the baseline model also predicts that the depreciation of the real exchange rate should reallocate inputs from the non traded to the traded goods sector, leading to a large increase in the output of the latter and a corresponding decline in that of the former. As we show in the following section, this runs counter to the facts.

Our results on the impact of interest rate shocks on aggregate TFP survive a set of alternative experiments designed to assess their robustness with respect to (i) the strength of the financial friction; (ii) the size of the interest rate increase during the crisis; (iii) the degree of substitutability between intermediate goods and other production factors; and (iv) the presence of additional frictions to the reallocation of capital and labor across sectors. The latter experiment, which is consistent with the observed sectoral movement of factors of production across the two sectors by design, still delivers a 2.5 percent drop in aggregate TFP.

Our paper borrows a key insight from Chari, Kehoe and McGrattan (2005) who show that a sudden stop does not generate a fall in output in a frictionless economy. They suggest that financial constraints on the purchase of inputs can generate TFP effects and output drops only if they create a wedge between the user and producer price of these inputs. We build a fully fledged model with such constraints and quantitatively assess their plausibility to explain the real effects of financial crises.

We also contribute to a more general literature on financial frictions and sudden stops in emerging economies. Mendoza (2010) and Mendoza and Yue (2009) use financial frictions as a device to amplify the economy's aggregate response to a sequence of bad realizations of exogenous TFP shocks. In contrast, we show that financial frictions can endogenously generate a large fall in TFP after an unexpected interest rate shock, highlighting the different response of the traded and non traded goods sectors. In this sense, our paper complements the analysis in Kehoe and Ruhl (2009), who demonstrate that deterministic two-sector models of a small open economy can reproduce the current account reversal and real exchange rate depreciation following a sudden stop. Without financial frictions however, their model cannot generate an output drop. In a related exercise, Benjamin and Meza (2009) analyze the real effects of Korea's 1997 sudden stop and generate TFP effects out of a sudden stop. Their mechanism is not financial frictions, but a reallocation of resources towards low-productivity sectors, which in their model correspond to non-tradable, consumption goods. We do not observe such a reallocation pattern in the Mexican data.

Our paper is also related to a more general literature on resource misallocation as a source of low TFP. Restuccia and Rogerson (2008) and Hsieh and Klenow (2009) show that barriers to equating the marginal product of labor and capital across establishments can depress manufacturing TFP substantially. Buera, Kaboski and Shin (2010) show that financial frictions can cause a misallocation of capital among heterogenous firms with adverse consequences for aggregate TFP. Unlike these papers, the misallocation we consider is not across production units but in the input mix used by all firms.

Finally, our paper relates to Neumeyer and Perri (2005) in that we also analyze the role of a financial friction, modelled as a working capital constraint for firms, as a propagation mechanism for external interest rates shocks. However our friction affects the purchase of intermediate goods instead of the wage bill, as in their paper, which allows us to obtain TFP effects. In their model, any output drop generated by an increase in interest rates is due to a decline in the labor supply and equilibrium employment. As discussed before, sudden stops in emerging economies are characterized by large falls in TFP and comparatively minor reductions in labor so we simplify our model and consider labor supply to be exogenous.

The paper is organized as follows. The next section presents the empirical evidence on the Mexican financial crisis. In section 3 we set out the baseline model with the financial friction and calibrate it to the Mexican economy. We subject this economy to an increase in interest rates and show that our model can account for a large fraction of the fall in aggregate TFP and output. In Section 4 we perform some robustness checks on our results with alternative specifications of the model or the experiment. Finally, we conclude.

2 Data

Exchange Rates and Interest Rates The main events associated with the Mexican crisis of 1994 are well documented. On December 20 1994, the government devalued the peso by 15 percent in response to capital outflows and a run on the currency. Two days later, the peso was allowed to float, when the initial devaluation proved to be insufficient to halt capital flight. Between 1994 and 1995, the average nominal exchange rate depreciated by almost 90 percent. Coupled with a price increase of 35 percent, this implied a real exchange rate depreciation of more than 55 percent.

[FIGURE 1 HERE]

The left panel of Figure 1 shows the evolution of the multilateral, CPI based, real exchange rate (peso to the dollar), calculated by the Central Bank of Mexico using a basket of 118 currencies. The dotted line shows the ratio of the prices in the traded goods sector to prices in the non-traded goods sector.[3] The increase in this price ratio due to the devaluation was 8 percent, a much smaller magnitude than the 58 percent depreciation of the real exchange rate. The subsequent trend however, mirrored the behavior of the real exchange rate and the series edged closer from 1998 onwards.

Interest rates shot up simultaneously. The right panel of the same figure shows a measure of the domestic interest rate in dollar terms based on the return on 28 day Mexican treasury bills (CETES).[4] The interest rate fell steadily from 1988 to 1994, a period of financial liberalization in Mexico. During the sudden stop it increased to almost 50 percent, from a level of 7 percent in 1994. In 1996 it fell slightly to 30 percent and slowly declined to pre-crisis levels. This is the change in interest rates that we will use for the crisis scenario. Its large

[3] The price index of each sector is calculated as the weighted average of the price indices of all the economic activities encompassed by it. The weights are calculated as the share of the activity in sectoral value added. While the precise definition of a traded or non traded good is sometimes contentious, we define the traded goods sector as comprising of agriculture, manufacturing and mining, while the non traded goods sector consists of construction, and all services.

[4] In our model borrowing takes place in terms of the traded good. The domestic interest rate in terms of dollars is the closest analog to this in the data. Ideally, we would like to have an *ex-ante* interest rate in dollars, but the information to construct it is not available. Instead, we construct an *ex-post* short run rate as the difference between the interest rate in pesos and the devaluation rate over the next month.

magnitude reflects not only the perceived risk of default of the Mexican government[5] but also the quantitative restrictions to borrowing implied by the sudden stop of foreign capital.

It is hard to get a direct measure of the real cost of short run borrowing for businesses in Mexico during the crisis, but casual evidence suggests that it was not far off the 50 percent implied by the ex-post CETES rate in dollars.[6] We also provide an alternative measure based on firm level data of (arguably large) Mexican firms listed on the stock market in Figure 1. We calculate the cost of credit for the median firm dividing the real value of interest payments by the real value of the stock of bank debt. As observed in the figure, this real implict interest rate increased to 42 percent in 1995, and was 30 percent the following year, very much in line the ex-post CETES rate in dollars.

Output and TFP The real effects of the devaluation and interest rate hike were immediate. The top left panel of Figure 2 shows that real GDP, which had been growing at about 4 percent per annum fell by over 6 percent in 1995. This decline was more pronounced in the non traded goods sector than in the traded goods sector, as the second and third panels of the figure show.

[FIGURE 2 HERE]

Using detrended data on sectoral value added, labor and capital we perform a standard growth accounting exercise to decompose the fall in real GDP in 1995.[7] We use detrended data to abstract from the long run growth rate of the total labor force and productivity, as these features are absent in our model. Table 1 shows the results. As expected, TFP is the

[5] For example, the return on the J.P. Morgan Emerging Markets Bond Index Plus (EMBI+) for Mexico increased from 5 to 15 percent from 1994 to 1995, and remained close to 10 percent till the end of 1996 (see Uribe and Yue 2006). This index captures the country specific risk of sovereign default.

[6] In April 1995, the New York Times reported that entrepreneurs faced interest rates of over 100%. On August 24 of the same year the Mexican government announced a \$1.1 billion plan to guarentee interest rates at half their current level. Under the plan, the interest rate on the first \$31,400 of business loans would be reduced from about 60% to 25%.

[7] Data for value added at constant prices and employment (in number of workers) comes from INEGI's national income and product accounts. Data for capital stock by sector is obtained from Banco de Mexico surveys and is not corrected for utilization. Labor is detrended at the annualized rate of growth of total employment from 1988 to 2002 ($n = 0.0195$). Capital and GDP are detrended at the rate $(1+g)(1+n)-1$, where $g = 0.0125$ corresponds to the annualized growth rate of per worker GDP in the same period. TFP is detrended at the rate $(1+g)^{1-\alpha}-1$. We use the same rates to detrend total and sectoral variables. Finally, we use the factor shares $\alpha^T = 0.48$, $\alpha^N = 0.36$, and $\alpha = 0.4$. The choice of these values will be discussed in detail in the calibration section.

Table 1: Growth Accounting for Mexican Economy - Detrended Variables

Annual Growth Rate: 1994-95	Total	Traded Sector	Non-traded Sector
GDP	-9.2%	-6.3%	-10.2%
Capital	0.3%	1.2%	-0.6%
Labor	-4.8%	-4.9%	-4.7%
TFP	-6.7%	-4.4%	-7.2%

main driving force behind the output drop both at the economy-wide and sectoral levels, explaining 73 percent of the overall fall in GDP.

The lower right panel of Figure 2 shows the evolution of aggregate and sectoral detrended TFP during and following the Mexican crisis. The immediate collapse in TFP was higher in the non-traded sector. What is remarkable is that during the recovery TFP grew at a faster rate in the traded sector (2.2 percent per year) than in the non-traded sector, where productivity staganated for the rest of the decade.

Decline in Intermediate Inputs The trajectory of intermediate inputs' use is harder to measure. The national income and products accounts indicate a fall of 4.5 percent (7.8 percent detrended) in the use of intermediate goods in 1995. This figure however, is somewhat misleading, since between 1988 and 2000 the NIPA estimates are based on fixed coefficients from an input output table created in 1985.[8] This implies that by construction, NIPA reports the ratio of intermediate goods use to gross output as constant in this period. The Economic Census provides an alternative source of information based on micro data every five years. Their estimates indicate that the total use of intermediate goods between 1993 and 1998 (the next available data point) fell by 19 percent. The intermediate goods to gross output ratio, which was relatively stable around 65 percent in 1988 and 1993, fell to about 55 percent in 1998. While the Census does not provide data for 1995, it seems clear that there was a large decline in the use of intermediate goods. In addition, the consumption of energy, one of the most important intermediate goods, fell by over 10 percent in this period, as documented by Meza and Quintin (2006).

The use of trade credit, which is typically used to finance intermediate good consump-

[8] A new input output table, under construction in 2005, has not been released to the public yet.

tion also fell in this period. While macro data on trade credit is not available, data from firms listed on the Mexican stock exchange show that as a fraction of short term liabilities, the stock of trade credit outstanding fell from 24 percent in December 1994 to 20 percent by the end of 1995. Recovery to pre-crisis levels occurred only by 1997.

Inter-Sectoral Reallocation of Resources Figure 3 shows the share of the traded goods sector in GDP, labor and capital. In line with the experience of most industrialized economies, the long term process of structural transformation in Mexico saw a decline in the importance of the traded goods sector, as services eclipsed manufacturing in importance. The large devaluation in 1995, together with the passage of NAFTA the year before, reversed this trend and the share of traded goods in output increased by about 0.8 percent in that year, consistent with the trends for sectoral TFP discussed before.[9]

[FIGURE 3 HERE]

Interestingly, this was not accompanied by a similar increase in the share in labor and capital. While the pace of the decline in the share of labor slowed, and the share of capital increased after about two years, there was not the large and immediate reallocation of resources that a standard frictionless model would predict after the devaluation.

3 The Baseline Model

In this section we set up the baseline model with the financial friction. As mentioned earlier, the model economy is a small open economy which produces traded and non traded goods. Both goods are combined to produce a final good which is consumed and invested. Traded and non traded goods are also combined to produce the intermediate good used in their production. In addition, the traded good is exported and used for borrowing and lending. A representative firm in each sector produces according to a constant returns to scale production function using capital, labor and intermediate goods.

[9] Meza and Urrutia (2010) analyze the long run behavior of the real exchange rate in Mexico and linked it to this process of structural transformation of the economy, together with a decline in the cost in foreign borrowing due to financial liberalization.

We introduce the financial friction as a working capital requirement for production. As in Mendoza and Yue (2009), intermediate goods must be purchased in advance of production using (short term) borrowing in traded goods.[10] In the small open economy, the interest rate on these loans is given by the world real interest rate. During the sudden stop, an increase in interest rates, through its effects on the purchase of intermediate goods, will increase the cost of production.

A representative consumer supplies labor and rents capital to each sector, demands final goods, invests in capital goods, and borrows or lends from abroad at the world interest rate. At each period, all factor and goods markets clear. The price of the final good is the numeraire. We now describe this economy in detail.

Consumers The representative consumer is endowed with one unit of labor which is supplied inelastically. Each period, the consumer consumes the final good C_t, saves/borrows in foreign bonds B_{t+1} valued at the price of traded goods p_t^T (relative to the final good) and invests in capital K_{t+1}. The consumer problem can be written as

$$\max_{C_t, K_{t+1}, B_{t+1}} \sum_{t=0}^{\infty} \beta^t \left[\frac{C_t^{1-\sigma} - 1}{1-\sigma} \right]$$

subject to the budget constraint

$$C_t + K_{t+1} + p_t^T B_{t+1} = w_t + \left[r_t + (1-\delta) \right] K_t + (1 + r_t^*) \, p_t^T B_t - \frac{\psi_K}{2} \left(\frac{K_{t+1} - K_t}{K_t} \right)^2$$

The rental rate on capital is r_t, and the depreciation rate is δ. The interest rate on bonds is given by r_t^*. The intertemporal costs of adjustment of capital are governed by the parameter ψ_K and β is the discount factor.

Final Goods Producers The final good is used for consumption and investment and is produced using the non traded good Q_t^N and the traded good Q_t^T. Each period, the producer

[10] Schwartzman (2010) provides evidence that output reallocates from industries with high inventory to variable cost ratios towards industies with lower ratios in times of interest rate increase, indicating that holding these inventories in advance of production may be costly.

of the final good solves the following problem

$$\max_{Q_t^T, Q_t^N} \left\{ Y_t - p_t^T Q_t^T - p_t^N Q_t^N \right\}$$

where the production technology is given by

$$Y_t = \left[\gamma \left(Q_t^T \right)^\rho + (1-\gamma) \left(Q_t^N \right)^\rho \right]^{\frac{1}{\rho}}. \tag{1}$$

with $\rho < 1$ and $\gamma \in (0,1)$. The price of the final good is the numeraire.

Traded and Non traded Goods Producers Traded and non traded goods are produced domestically by representative firms in each sector $i = T, N$ with a Cobb Douglas production function

$$Y_t^i = A_t^i \left[\left(K_t^i \right)^{\alpha_i} \left(L_t^i \right)^{1-\alpha_i} \right]^{\varepsilon_i} \left(M_t^i \right)^{1-\varepsilon_i}, \tag{2}$$

using capital, labor L_t^i and intermediate goods M_t^i, with $\alpha_i, \varepsilon_i \in (0,1)$.[11]

Production in this sector is subject to the working capital constraint mentioned earlier. A fraction κ of the purchase of intermediate goods needs to be financed by within period loans, at an interest rate $\widehat{r}_{t+1}$. Hence the firm's problem in the i^{th} sector ($i = T, N$) can be written as

$$\max_{K_t^i, L_t^i, M_t^i} p_t^i Y_t^i - w_t L_t^i - r_t K_t^i - p_t^M (1-\kappa) M_t^i - p_t^M \kappa (1 + \widehat{r}_{t+1}) M_t^i$$

or equivalently,

$$\max_{K_t^i, L_t^i, M_t^i} p_t^i Y_t^i - w_t L_t^i - r_t K_t^i - \widetilde{p}_t^M M_t^i$$

where

$$\widetilde{p}_t^M = p_t^M (1 + \kappa \widehat{r}_{t+1}) \tag{3}$$

The loans are supplied by competitive financial intermediaries at an interest rate determined below.[12]

[11] In subsection 4.3 we explore the impact of a non-unitary elasticity of substitution between intermediate goods and the capital and labor composite input.

[12] In our model intermediate inputs and final goods are assumed to be produced simultaneously, even

Financial Intermediary In each period t, firms need to borrow an amount $\kappa p_t^M M_t$, measured in terms of the domestic final good, where $M_t = M_t^T + M_t^N$. The competitive financial intermediary borrows an equivalent amount from abroad in traded goods, namely $\frac{\kappa p_t^M M_t}{p_t^T}$ at the interest rate r_{t+1}^*, repayable next period. The firms repay the intermediary the amount $(1 + \widehat{r}_{t+1}) \kappa p_t^M M_t$ within the same period t. The intermediary stores this amount, converts it to traded goods at time $t+1$, and returns it to the foreign lender.[13] The zero profit condition for the intermediaries implies that their costs of funds must equal the amount received from firms. In other words

$$\left(1 + r_{t+1}^*\right) \frac{\kappa p_t^M M_t}{p_t^T} = (1 + \widehat{r}_{t+1}) \frac{\kappa p_t^M M_t}{p_{t+1}^T}.$$

which gives us the interest rate

$$\widehat{r}_{t+1} = \left(1 + r_{t+1}^*\right) \frac{p_{t+1}^T}{p_t^T} - 1.$$

In what follows, we will find it convenient to define the gross real interest rate as

$$R_{t+1} = \left(1 + r_{t+1}^*\right) \frac{p_{t+1}^T}{p_t^T} \tag{4}$$

Intermediate Goods Producers: The production function for intermediate goods is given by

$$M_t = A_M \left(\widetilde{M}_t^T\right)^{\phi} \left(\widetilde{M}_t^N\right)^{1-\phi}$$

though one requires the other as is standard in the static input-output table methodology. However, the working capital constraint suggests a timeline inside a period: Firms buy the intermediate goods first and then produce the final output. We thank an anonymous referee for pointing out this dissonance between the sequential timing of financial decisions and the simultaneous timing of production. We can resolve this by assuming that contracts are written between firms and the financial intermediary prior to production and the actual delivery of intermediate goods takes place simultaneously with the production of final goods.

[13] The assumption that firms borrow from financial intermediaries rather than from intermediate goods producers themselves is an important one, since, as we discuss later, it creates a wedge between the user cost and producer price of intermedate goods and distorts the input mix. If the intermediate goods producers were to directly lend their own funds to the firms to purchase inputs, this wedge would disappear.

where $\phi \in (0,1)$ and $\widetilde{M}_t^T$ and $\widetilde{M}_t^N$ are the demand for traded and non traded goods used as inputs for intermediates. The problem of the representative firm can be written as

$$\max_{\left\{M_t, \widetilde{M}_t^T, \widetilde{M}_t^N\right\}} p_t^M M_t - p_t^T \left(\widetilde{M}_t^T\right) - p_t^N \left(\widetilde{M}_t^N\right)$$

subject to

$$M_t = A_M \left(\widetilde{M}_t^T\right)^{\phi} \left(\widetilde{M}_t^N\right)^{1-\phi}$$

Equilibrium The market clearing conditions for this model are:

(i) for the final good

$$Y_t = C_t + K_{t+1} - (1-\delta) K_t + \frac{\psi_K}{2} \left(\frac{K_{t+1} - K_t}{K_t}\right)^2 + R_{t+1} \kappa p_t^M M_t - R_t \kappa p_{t-1}^M M_{t-1} \tag{5}$$

The last two terms are included because they represent the amount of the final good that the financial intermediary stores today less the amount stored from the previous period, which is needed for the repayment of the loans of the last period.

(ii) for tradable and non-tradable goods

$$\begin{aligned} Q_t^T + \widetilde{M}_t^T + NX_t &= Y_t^T \\ Q_t^N + \widetilde{M}_t^N &= Y_t^N \end{aligned}$$

where NX_t are net exports.

(iii) for intermediate goods

$$M_t^T + M_t^N = M_t$$

and

(iv) for capital and labor

$$\begin{aligned} K_t^T + K_t^N &= K_t \\ L_t^T + L_t^N &= 1 \end{aligned}$$

Macroeconomic Aggregates GDP in this economy can be expressed as

$$\begin{aligned} GDP_t &= Y_t + p_t^T NX_t && (6)\\ &= p_t^T Y_t^T + p_t^N Y_t^N - p_t^M M_t && (7)\\ &= w_t + r_t K_t + (R_{t+1} - 1)\, \kappa p_t^M M_t && (8) \end{aligned}$$

using the value of final goods, the sum of all value added and the total income in the economy respectively. The last term in equation (8) is the income of the intermediary in the current period and is equal to $\left(\widetilde{p}_t^M - p_t^M\right) M_t$. We also define real GDP at constant prices as

$$RGDP_t = p_0^T Y_t^T + p_0^N Y_t^N - p_0^M M_t \tag{9}$$

and measure aggregate TFP, as

$$TFP_t = \frac{RGDP_t}{(K_t)^{0.4}} \tag{10}$$

The last definition corresponds to the Solow residual computed using an aggregate Cobb-Douglas production function with a capital share of 0.4 and is consistent to our measure of aggregate TFP in the data.

The current account balance can be derived by noting that the budget constraint of the consumer

$$w_t + r_t K_t = C_t + K_{t+1} - (1-\delta) K_t + \frac{\psi_K}{2}\left(\frac{K_{t+1} - K_t}{K_t}\right)^2 + p_t^T B_{t+1} - (1 + r_t^*)\, p_t^T B_t$$

can be written as

$$\begin{aligned} & Y_t + p^T NX_t - (R_{t+1} - 1)\, \kappa p_t^M M_t \\ = \; & Y_t - R_{t+1} \kappa p_t^M M_t + R_t \kappa p_{t-1}^M M_{t-1} + p_t^T B_{t+1} - (1 + r_t^*)\, p_t^T B_t \end{aligned}$$

by using the equality between equations (6) and (8) on the left hand side and substituting equation (5) on the right hand side.

This implies that the balance of payments identity is

$$p_t^T B_{t+1} - (1 + r_t^*)\, p_t^T B_t - \kappa p_t^M M_t + R_t \kappa p_{t-1}^M M_{t-1} = p_t^T N X_t$$

where the net foreign asset position of the country includes not only the stock of foreign bonds, but also (with a minus sign) the debt position of financial intermediaries.

Given an initial capital stock K_0 and an initial net asset position B_0, the deterministic equilibrium in this model is the solution to a system of non linear equations, details of which are given in Appendix A.

3.1 Calibration

We calibrate the model to match key features of the Mexican economy on the eve of the crisis. To quantify the interactions between sectors, we use the input output tables reported in Kehoe and Ruhl (2009).

Production Function Parameters For the traded goods sector the following two ratios suffice to identify production function parameters

$$\begin{aligned} \frac{\text{Intermediates Consumption}}{\text{Value Added}} &= \frac{(1-\varepsilon_T)}{\varepsilon_T} = 1.103 \\ \frac{\text{Employee Compensation}}{\text{Value Added}} &= \frac{(1-\alpha_T)\,\varepsilon_T}{\varepsilon_T} = 0.521 \end{aligned}$$

These two equations give us the values for $\varepsilon_T = 0.475$ and $\alpha_T = 0.479$.

Similarly for the non traded goods sector

$$\begin{aligned} \frac{\text{Intermediates Consumption}}{\text{Value Added}} &= \frac{(1-\varepsilon_N)}{\varepsilon_N} = 0.438 \\ \frac{\text{Employee Compensation}}{\text{Value Added}} &= \frac{(1-\alpha_N)\,\varepsilon_N}{\varepsilon_N} = 0.642, \end{aligned}$$

implying that $\varepsilon_N = 0.696$ and $\alpha_N = 0.358$. Not surprisingly, the traded goods sector is more capital intensive and uses intermediates more extensively than the non traded goods sector.

Intermediate Goods Production Parameters: To get the parameter ϕ, i.e. the proportion of traded goods used in the production of intermediate goods, we note that the first order conditions for the intermediate goods producers imply

$$\frac{p_t^T \widetilde{M}_t^T}{p_t^N \widetilde{M}_t^N} = \frac{\phi}{1-\phi}$$

The counterpart to this in the input output tables is

$$\frac{\text{Traded Goods Used as Intermediates}}{\text{Non Traded Goods Used as Intermediates}} = 1.243$$

which results in a value of $\phi = 0.554$.

Financial Constraint The fraction of intermediate goods that need to be bought on credit, κ is a key parameter of the model, since it governs the size of the wedge between the producer and user cost of intermediate goods. This is calibrated using a combination of firm level data and macro data. κ can be decomposed as

$$\begin{aligned} \kappa &= \frac{\text{Intermediate goods bought on credit}}{\text{Intermediate goods}} \\ &= \left(\frac{\text{Intermediate goods bought on credit}}{\text{Gross Output}}\right) \times \left(\frac{\text{Gross Output}}{\text{Intermediate goods}}\right) \end{aligned}$$

The numerator of the first term is hard to estimate. However, from firm level data we have a measure of short term debt liabilities.[14] Using this data for the numerator and the sum of total sales and inventories for the denominator gives us the first ratio.[15] The second ratio comes from the NIPA data and is the ratio of gross output to total intermediate goods. The product of these ratios gives us a value of $\kappa = 0.7$.[16] This is lower than the value of $\kappa = 1$ used in Neumeyer and Perri (2005) and Uribe and Yue (2006), although in both these papers

[14] As mentioned in the model section, this ratio cannot be calibrated to trade credit, i.e. credit extended by intermediate goods producers to firms, since that does not create a wedge between the user and the producer cost of intermediate goods.

[15] The data comes from the Mexican stock market and consists of firms that are listed or have issued commercial paper in the period 1989-1999. The ratio of short term debt to output was about 30% at the beginning of 1994 and increased sharply to 39% by the end of the year and stood at 41% at the end of 1995.

[16] Given parameter values, $\kappa = 0.7$ implies a model predicted debt to GDP ratio of about 40% in steady state. The ratio of non-household private debt to GDP was slightly over 50% in 1994.

the working capital constraint applies to the wage bill. However, it is higher than the 10 percent value used in Mendoza and Yue (2009), who calibrate it to the volatility of the trade balance. We experiment with a range of values to explore the sensitivity of our results to this parameter in subsection 4.1.

Utility Function and Final Good Production Parameters We set $\sigma = 2$, which gives us an intertemporal elasticity of substitution of consumption of 0.5. Following Kehoe and Ruhl (2009) and Stockman and Tesar (1995) we set $\rho = -1$, consistent with an elasticity of substitution between traded and non traded goods of 0.5. To get γ note that the first order conditions from the final goods producer problem imply that

$$\frac{p^T}{p^N} = \frac{\gamma}{1-\gamma}\left(\frac{Q^N}{Q^T}\right)^2$$

Relative to a base price ratio, we can identify γ from the ratio of traded goods to non traded goods used in the production of final goods. Since final goods in our model are used for consumption and investment, we use the input output table to get

$$\frac{\gamma}{1-\gamma} = \left(\frac{Q^T}{Q^N}\right)^2 = \left(\frac{C^T + I^T}{C^N + I^N}\right)^2 = 0.295$$

which implies a γ of 0.228.

Outside the crisis, the interest rate r^* is set to 5 percent, consistent with average world real interest rates. The consumer's discount factor β is set to $\frac{1}{1+r^*}$.

Parameters calibrated to the steady state The parameters that remain to be characterised are the scale parameters A_T, A_N and A_M. We also need to specify the initial stock of assets B_0 and the adjustment costs of capital ψ_K. We compute a steady state equilibrium for the model economy, and calibrate the values of A_T and A_M and B_0 relative to A_N, which is set to 1. The goal is to jointly match three targets, the share of labor in the traded goods sector, the investment to output ratio and the trade balance in 1994. While we do not claim that the Mexican economy was in a steady state in 1994, given the appreciating real exchange rate, declining interest rates and the increasing share of the non traded goods sector in the

Table 2: Calibrated Parameters

Statistic	Target	Parameter	Value
Ratio of T to N final goods	0.295	γ	0.228
Share of Labor in T sector value added	0.521	α_T	0.479
Ratio of intermediates to T sector value added	1.103	ε_T	0.475
Share of Labor in N sector value added	0.642	α_N	0.358
Ratio of intermediates to N sector value added	0.438	ε_N	0.696
Ratio of T to N intermediate goods	1.243	ϕ	0.554
Fraction of intermediates bought on credit	0.70	κ	0.70
Depreciation Rate		δ	0.05
Elasticity of substitution between T and N	0.5	ρ	-1.0
Intertemporal elasticity of substitution	0.5	σ	2.0
World Interest Rate	0.05	r^*	0.05
Fraction of Total Labor in T goods sector	0.35	A_T	1.676
Ratio of Investment to GDP	0.20	A_M	0.126
Ratio of Net Exports to GDP	-0.05	B_0	0.020
Investment to GDP Ratio in 1995	0.15	ψ_K	1.15

economy over the five previous years, calibrating to a steady state or transition is irrelevant for our purposes, except as a means to get initial conditions for the experiment.[17]

Finally, the adjustment cost parameter ψ_K is calibrated to match the the investment to GDP ratio in 1995. The parameters calibrated and the statistics they match are summarized in Table 2.

3.2 The Experiment

To understand how the economy fares after a sudden stop, we perform the following experiment. Beginning from a steady state calibrated to match key features of the Mexican economy in 1994, as described in the previous section, we increase the interest rate, r^*_{t+1} for two periods, to 50 percent in the first period and 30 percent in the second period, as observed in the data in Figure 1. The interest rate hike is a perfect surprise to agents, but

[17]We also checked the robustness of our results to the steady state assumption for the Mexican economy previous to the crisis. In particular, we changed the initial conditions K_0 and B_0 and perform the same experiment. While initial conditions matter for the behavior of the model in the periods following the crisis, they do not change our predictions on the initial TFP and output effects significantly. The results are available upon request.

once it occurs, they know for how long it will last.[18]

TFP and Output Effects The top two panels of figure 4 show the resulting fall in aggregate TFP and real GDP after the interest rate hike. Both measures fall by 3.5 percent, accounting for 52 percent of the observed decline in TFP and 74 percent of output per worker in the data. Since our model does not admit a role for variations in labor supply, which account for about one third of the decline in real GDP in the data (as seen in Table 1), we compare its predictions to macroeconomic aggregates per worker.[19]

[FIGURE 4 HERE]

To understand these results, notice that as interest rates increase the wedge between the producer price and the user price of intermediate goods also increases. In our model this is measured as

$$\left(\widetilde{p}_t^M - p_t^M\right) = \left(R_{t+1} - 1\right) \kappa p_t^M$$

where

$$R_{t+1} = \left(1 + r_{t+1}\right) \frac{p_{t+1}^T}{p_t^T}$$

The increase in the wedge comes from two sources: first the interest rate itself, and second from the change in the price of traded goods relative to the final good. The increase in the wedge exacerbates the allocative inefficiency in the economy by distorting the mix of inputs in production, which shows up in the aggregate as a fall in TFP. In Appendix B we show analytically, in the context of a simplified stationary one sector model, how changes in interest rate map into changes in TFP in the presence of a working capital constraint.

The Real Exchange Rate and Current Account Since the economy saves in traded goods, the demand for non-traded goes down as interest rates increase, depressing their price and leading to a depreciation of the real exchange rate. The lower left panel of Figure 4

[18] Notice that this is not a very important assumption since agents have limited ability to hedge against the interest rate shock in the model. As Meza and Quintin (2008) and Pratap and Quintin (2010) show, the only difference between a perfect foresight and a perfect surprise scenario is that in the former the capital output ratio in the economy, counterfactually, falls before the shock.

[19] Real GDP per worker and aggregate TFP in the model are constructed using equations (9) and (10). Variables in the data are detrended following the same procedure as in Section 2.

shows the model predicted price of traded goods relative to the price of non traded goods and compares it to the data. The model predicts an increase of 9.8 percent, as compared to 8 percent observed in the data. This is short of the 55 percent depreciation of the real exchange rate observed in the data, which is expected, since our model does not allow for deviations in the law of one price for traded goods. As interest rates come back to their pre-crisis level, the real exchange rate also returns to its 1994 levels. In the data the return was much more gradual.

In addition, the model predicts a current account reversal as the lower right panel in Figure 4 shows, although it overpredicts the magnitude of the changes. From a deficit of about 5 percent the current account to GDP ratio increased to a surplus of about 4 percent in the data and about 10 percent in the model. As the interest rate returns to normal, the trade balance deteriorates, again, at a faster rate in the model than in the data.

Sectoral Output and the Intersectoral Reallocation of Resources Thus far the model has performed remarkably well in explaining the behavior of macroeconomic aggregates following the sudden stop. This aggregate picture however, obscures discrepancies at the sectoral level. The top two panels of figure 5 show the model predicted and the actual (detrended) GDP per worker in the traded and non traded goods sector respectively. As the figures make clear, the baseline model does not confirm to the data in some important dimensions.

[FIGURE 5 HERE]

The model predicts an increase in the real GDP per worker in the traded goods sector of almost 10 percent, whereas in the data it declined by about 1.6 percent. It also greatly over-predicts the decline of real GDP in the non traded goods sector. The middle panels show the fall in TFP in each sector generated by the model. Contrary to the data, the model predicts that TFP fell by much more in the traded goods sector. Despite this fall in TFP, GDP in the traded goods sector increases due to a large reallocation of labor and capital from the non traded to the traded goods sector, following the real depreciation. The data however, does not support the reallocation of productive factors implied by the model, as the two lowest panels of Figure 5 show.

4 Sensitivity Analysis

We perform several experiments to assess the robustness of our results with respect to (i) the strength of the financial friction; (ii) the size of the interest rate hike during the crisis; (iii) the degree of substitutability between intermediate goods and other production factors; and (iv) the presence of additional frictions to the reallocation of capital and labor across sectors. Our results survive these alternative experiments, although the size of the fall in TFP after the crisis varies in each of them.

4.1 Strength of the Financial Friction

The parameter κ, i.e. the strength of the financial constraint plays a key role in our analysis. Unfortunately no clear counterpart to κ exists in the data. We calibrate $\kappa = 0.7$, which as mentioned earlier, implies a model predicted debt to GDP ratio of about 40 per cent. Data from the central bank shows that the private non household debt to GDP ratio in 1994 was 50 percent. Although it is plausible that 80 percent of all debt is short term in emerging economies, all short term debt may not be used to buy intermediate goods.[20] Accordingly, the top panel of Table 3 shows the steady state model predicted debt to GDP ratios of alternative values of κ, and the fall in GDP associated with each of these during a sudden stop. The figures in parenthesis are the fraction of TFP or GDP per worker in the data that can be accounted for by the sudden stop in each case.

Given the calibration of our model in steady state, each value of κ implies a different debt to GDP ratio. As the top panel of Table 3 shows, a value of κ of 0.4 is consistent with a much lower debt to GDP ratio of 24 percent and can account for between 25 and 30 percent of the fall in real GDP. Higher values of κ imply a larger debt to GDP ratio, but also account for a larger fraction of the drop in TFP. We conclude that, in our model, the financial friction plays a key role in explaining the responses of the real economy to an interest rate shock.

[20] A recent survey by the central bank of Mexico indicates that in 2009, more than 60% of all debt, short and long term, was used to purchase intermediate goods. Using this information implies a κ between 0.6 and 1.0, depending on the estimate of the ratio of gross output to intermediates use employed.

Table 3: The Effect of the Financial Constraint and Alternative Interest Rate Shocks

Financial constraint κ	Implied Debt/GDP $\kappa \frac{p_t^M M_t}{GDP_t}$	Percent Change in TFP	GDP
0.7 *(baseline)*	0.40	-3.5 (52.1)	-3.5 (74.2)
0.6	0.35	-2.8 (41.7)	-2.8 (59.0)
0.4	0.24	-1.5 (22.0)	-1.5 (31.2)
Steady State Interest Rate	Interest Rate Shock	Percent change in TFP	GDP
0.05 (baseline)	.50	-3.5 (52.1)	-3.5 (74.2)
0.17 ($\delta = 0.05$)	.42	-2.07 (31.16)	-2.07 (44.07)
0.17 ($\delta = 0.10$)	.42	-2.02 (30.46)	-2.02 (43.08)

4.2 Interest Rate Shock

So far we have used the interest rate on government bonds to calibrate the magnitude of the interest rate shock in our experiment, since our deterministic model with representative firms implies that the interest rate paid by firms and financial intermediaries does not contain an idiosyncratic risk premium. However, the interest rates shown in Figure 1 that are calculated from firm level data indicate that the average cost of borrowing before the crisis was about 17 percent. This cost rose to 42 percent during the crisis and fell to 30 percent in the subsequent year. While this figure is derived from a sample of publicly traded firms which are not representative of the economy as a whole, it is worth verifying the effects on TFP and real GDP if we calibrate the steady state of our model to a 17 percent interest rate and the magnitude of the shock to 42 percent.

The bottom panel of Table 3 shows the effects of calibrating the steady state to an interest rate of 17 percent and the interest rate shock to 42 percent. The higher steady state interest rate requires us to recalibrate the parameters to match the same steady state targets, i.e. the investment to output ratio, the share of labor in the traded goods sector and the trade balance as a fraction of GDP. With such a high interest rate it is not possible to match the investment to output ratio without increasing the depreciation rate substantially. Accordingly, we present results for different values of δ as well.

As the table shows, with the smaller interest rate shock the model can account for about 40 percent of the fall in real GDP and about 30 percent of the fall in TFP. This is a smaller effect than in the baseline model, but still substantial. Changing the depreciation rate has a minimal effect on these results.

4.3 Substitutability of Intermediate Inputs

The baseline model assumes a unitary elasticity of substitution between intermediate goods and a composite of capital and labor inputs. To understand the importance of this asumption, notice that if the production function was Leontief then the change in interest rates will have no impact on real GDP, since the interest rate will not distort the mix of inputs into production.[21] More generally, as intermediate goods and capital/labor become less sustitutable, we would expect a a smaller TFP decline as interest rates rise.

We perform a sensitivity analysis of our results with respect to the elasticity of substitution between intermediate goods and the capital/labor aggregate using a more general CES production function:

$$Y_t^i = A_t^i \left[\varepsilon_i \left[\left(K_t^i\right)^{\alpha_i} \left(L_t^i\right)^{1-\alpha_i} \right]^{\eta} + (1-\varepsilon_i) \left(M_t^i\right)^{\eta} \right]^{\frac{1}{\eta}}$$

for $i = T, N$ and changing the value of the parameter η. The relevant elasticity of substitution is $\frac{1}{1-\eta}$. Our baseline (Cobb-Douglas) model assumes $\eta = 0$ and the Leontief case arises as $\eta \to -\infty$. In order to make the results comparable to the baseline model we recalibrate the weights ε_i in the production function for each sector as we change the parameter η to obtain the same ratio of intermediates to gross output in the initial steady state (see Table 2).

Table 4 summarizes the predictions of the model for the same experiment of increasing interest rates to their observed 1995-96 levels under different values for the elasticity of substitution. We focus on two variables: (i) the fall in the proportion of intermediate inputs as a fraction of gross output $\left(\frac{p_0^m M_t}{p_0^T Y_t^T + p_0^N Y_t^N}\right)$ predicted for 1995 and (ii) the fall in aggregate

[21] We thank an anonymous referee for making this point.

Table 4: The Role of the Substitutability of Intermediate Goods and Other Inputs

Elasticity $\frac{1}{1-\eta}$	Percent Change in M/Y	TFP
1.2	-22.0	-4.2
1.1	-20.9	-4.0
1 *(baseline)*	-18.9	-3.5
0.9	-13.5	-3.4
0.7	-9.2	-2.8
0.5	-3.1	-2.1

TFP predicted for the same year. As expected, lowering the degree of substitutability for intermediate inputs reduces the fall in the proportion of intermediates used in production and the fall in TFP. Still, reducing this elasticity as low as 0.5 reduces the fall in the use of intermediates to about 3 percent (from 19 percent in the baseline) and the fall in aggregate TFP to a still significant 2 percent. On the other hand, increasing the elasticity of substitution to more than one has the opposite effect and amplifies the impact of interest rates on the use of intermediates and on TFP.

The question remains: What is a reasonable value for this elasticity of substitution? The discipline must come from the behavior of firms in their use of intermediate inputs during the crisis. Unfortunately, as discussed in Section 2, the data on the use of intermediate inputs for Mexico is scarce at best. Data from the Economic Censuses conducted in 1993 and 1998, before and after the crisis, indicate that intermediate inputs as a fraction of gross output declined by 16.3 percent between these two years. From Table 4 , this suggests an elasticity of substitution around 0.95, not far from the unitary elasticity assumed in the baseline model.

4.4 Reallocation Frictions

The baseline model has some counterfactual implications for the reallocation of factors of production. As discussed at the end of Section 3, the movement of factors across sectors observed in the data is much slower than what a model without reallocation frictions would predict. As a robustness check for our results we introduce two frictions into the baseline model. First, a labor adjustment cost is incurred if labor moves from one sector to another.

For analytical convenience, we assume that this cost is borne by the consumer.[22] Second, we assume that capital is completely sector specific and can be augmented only by new investment in that particular sector.[23]

A detailed decription of the equilibrium conditions for this alternative model can be found in the Appendix A.2. For now, it suffices to present the budget constraint of the representative consumer to clarify the main assumptions and to introduce notation:

$$C_t + K_{t+1}^T + K_{t+1}^N + p_t^T B_{t+1} =$$

$$w_t^T \theta_t + w_t^N (1-\theta_t) + \left[r_t^T + (1-\delta)\right] K_t^T + \left[r_t^N + (1-\delta)\right] K_t^N + (1+r_t^*)\, p_t^T B_t$$
$$-\frac{\psi_K}{2}\left(\frac{K_{t+1}^T - K_t^T}{K_t^T}\right)^2 - \frac{\psi_K}{2}\left(\frac{K_{t+1}^N - K_t^N}{K_t^N}\right)^2 - \frac{\psi_L}{2}\left(\theta_t - \theta_{t-1}\right)^2$$

The representative consumer now chooses consumption, savings, investment in each sector K_{t+1}^T and K_{t+1}^N, as well as the fraction of their labor endowment to be supplied to the traded goods sector θ_t. The parameter ψ_L controls the reallocation cost of labor. We do not take a stand on whether this cost reflects human capital losses due to sector specific skills, the cost of unemployment spells or deadweight losses incurred by firms in their firing and hiring decisions. Our quadratic adjustment cost function should be seeing as a reduced form encompassing different possible stories.[24]

As in the previous section, we compute the steady state equilibrium and choose parameters to match the Mexican economy in 1994. All parameters are calibrated as described in the previous section. In addition, the labor adjustment parameter ψ_L is calibrated to deliver the labor share of the traded goods sector in 1995. We perform the same experiment as before where interest rates are unexpectedly increased for two periods.

Unlike our baseline model, the model with reallocaton frictions is broadly consistent

[22] Pratap and Quintin (2010) show that workers who change occupations during the crisis in Mexico saw their wages fall by about 10% more than those who did not move, even after controlling for individual characteristics, as age and education.

[23] Ramey and Shapiro (2001) show that there is a large degree of asset specificity in capital goods.

[24] The labor market friction and the capital specificity imply that factor prices do not equate across each sector and are now sector specific as well. As documented in Meza and Urrutia (2010), changes in the relative wage of workers in the traded and non-traded goods sectors have been important in Mexico during the 1988-2002 period, reflecting systematic deviations from sectoral wage equalization.

Table 5: Decomposing the Effects of Frictions

Specific Capital	Labor AC	Financial Friction	Percent Change in Aggregate TFP
no	no	no	0.00
yes	no	no	-0.36
no	yes	no	-0.29
yes	yes	no	-0.44
no	yes	yes	-2.93
yes	no	yes	-3.36

with sectoral patterns, as shown in Figure 6. The assumption of capital specificity ensures that no capital is immediately reallocated after the sudden stop. Labor too, does not move immediately from the non traded goods sector to the traded goods sector. The model predicts a fall of about 1.4 percent in real GDP per worker in the traded goods sector, and a 3.4 percent fall in the non traded goods sector, accounting for almost 90 percent of the former and more than half (57 percent) of the latter. TFP also fell in both sectors, more in the non traded than in the traded goods sector.

[FIGURE 6 HERE]

These results are not so interesting per se, as we have designed the model in order to moderate the movement of production factors across sectors. However, it provides a useful robustness check for our results on real output and TFP. Both magnitudes fall by 2.5 percent in the model with reallocation frictions, compared to 3.5 percent in the baseline model. This still accounts for more than half of the observed fall in real GDP per worker and a third of the fall in TFP.[25]

[25] Somewhat counterintuitively, the reallocation frictions actually mitigate the misallocation of resources engendered by the financial friction. We conjecture that this is because of the rate of growth of the price of tradable goods, which enters in the definition of the gross interest rate governing the size of the wedge between the producer and user cost of intermediate goods:

$$R_{t+1} = (1 + r_{t+1}) \frac{p_{t+1}^T}{p_t^T}$$

With allocative frictions, prices overshoot initially as interest rates rise, but return more gradually to their initial level, as sectoral output adjusts to meet the initial change in sectoral demand. This implies smaller values for the wedge and therefore less misallocation due to financial frictions.

Finally, since we have combined three different frictions, it is also worth clarifying the role of each in explaining aggregate and sectoral changes in TFP and GDP. Table 5 summarizes the effects of shutting down each friction. In a frictionless version of our economy, an interest rate shock does not have any aggregate effects and only alters the real exchange rate and the sectoral composition of output. The labor market friction or the capital specificity, individually or jointly only have second order effects on TFP. The introduction of the financial constraint with just one of these frictions produces a fall in TFP but cannot account for the sectoral patterns of GDP since the other factor can always adjust to meet the increased demand for the traded good after the sudden stop. Both frictions on factor markets, along with the financial constraint are necessary to simultaneously generate the fall in TFP and the sectoral patterns observed in the data.

5 Conclusions

Accounting for the real effects of a financial crisis is a difficult task without relying on exogenous technology shocks. Previous attempts in the literature indicate the need for adding some type of frictions to standard dynamic general equilibrium models to generate a transmission mechanism from a purely financial crisis to real activity.

In this paper we explore the role of a particular financial friction, a working capital constraint on the purchase of intermediate goods. We show that this constraint provides a powerful mechanism to generate drops in output following an interest rate hike by exacerbating a static misallocation of inputs that looks like a fall in TFP. Our model also explains the real exchange rate depreciation and the current account reversal observed in these episodes. Adding frictions to the reallocation of capital and labor across sectors make the model consistent with the sectoral drops in output.

Since our main interest is in capturing the behaviour of the economy in the immediate aftermath of the crisis, neither the model nor the experiment have been designed to account for the recovery in GDP that took place after two years. The recovery can be attributed to a sustained increase in TFP in the traded goods sector which is likely a result of structural reforms and a fall in tariffs related to trade liberalization. In our model the only way for

TFP to increase is through a fall in interest rates. In the experiment interest rates come back to their pre-crisis levels after two periods, and so does the economy.

Another limitation of our analysis is that we take the changes in the domestic interest rate as given. This implies that we take as given not just the foreign interest rate, using the small open economy assumption, but also the deviations from the interest parity conditions which seems to be large in a sudden stop episode. Whether these deviations come from additional frictions in the banking sector is an interesting topic for future research, as are the kind of market imperfections can provide microfoundations to the working capital constraints. As we have shown, this is an avenue worth exploring.

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A Solution of the Model

A.1 Baseline Model

From the consumer's problem, the first order conditions are:

$$\left(\frac{C_{t+1}}{C_t}\right)^{\sigma} = \beta R_{t+1} \tag{11}$$

$$\left[1+\frac{\psi_K}{K_t}\left(\frac{K_{t+1}-K_t}{K_t}\right)\right] R_{t+1} = r_{t+1} + (1-\delta) + \psi_K \left(\frac{K_{t+2}-K_{t+1}}{K_{t+1}}\right)\frac{K_{t+2}}{K_{t+1}^2} \tag{12}$$

where the former is the Euler equation which governs the choice of intertemporal consumption and the latter the no-arbitrage condition between financial and physical assets. Recall that

$$R_{t+1} = (1+r_t^*)\,\frac{p_{t+1}^T}{p_t^T}.$$

First order conditions from the final goods producers 'problem are

$$\begin{aligned} p_t^N &= (1-\gamma)\left(\frac{Y_t}{Q_t^N}\right)^{1-\rho} && (13)\\ p_t^T &= \gamma\left(\frac{Y_t}{Q_t^T}\right)^{1-\rho}. && (14) \end{aligned}$$

Profit maximization by the traded and non traded goods producers implies that

$$\begin{aligned} w_t &= (1-\alpha_T)\,\varepsilon_T \frac{p_t^T Y_t^T}{L_t^T} = (1-\alpha_N)\,\varepsilon_N \frac{p_t^N Y_t^N}{L_t^N} && (15)\\ r_t &= \alpha_T \varepsilon_T \frac{p_t^T Y_t^T}{K_t^T} = \alpha_N \varepsilon_N \frac{p_t^N Y_t^N}{K_t^N} && (16) \end{aligned}$$

and for intermediates

$$\begin{aligned} M_t^T &= (1-\varepsilon_T)\,\frac{p_t^T Y_t^T}{\widetilde{p}_t^M}\\ M_t^N &= (1-\varepsilon_N)\,\frac{p_t^N Y_t^N}{\widetilde{p}_t^M} \end{aligned}$$

where

$$\widetilde{p}_t^M = [1 + \kappa (R_{t+1} - 1)] p_t^M$$

For intermediate goods producers, the input demand functions are given by

$$\widetilde{M}_t^T = \phi \frac{p_t^M M_t}{p_t^T} \tag{17}$$

$$\widetilde{M}_t^N = (1 - \phi) \frac{p_t^M M_t}{p_t^N} \tag{18}$$

which implies

$$p_t^M = \frac{\left(p_t^T\right)^{\phi} \left(p_t^N\right)^{1-\phi}}{A_m \left[\phi^{\phi} (1 - \phi)^{1-\phi}\right]} \tag{19}$$

Market clearing conditions:

(i) for the final good

$$Y_t = C_t + K_{t+1} - (1 - \delta) K_t + \frac{\psi_K}{2} \left(\frac{K_{t+1} - K_t}{K_t}\right)^2 + R_{t+1} \kappa p_t^M M_t - R_t \kappa p_{t-1}^M M_{t-1}$$

(ii) for tradable and non-tradable goods

$$\begin{aligned} Q_t^T + \widetilde{M}_t^T + NX_t &= Y_t^T \\ Q_t^N + \widetilde{M}_t^N &= Y_t^N \end{aligned} \tag{20}$$

where NX_t are net exports.

(iii) for intermediate goods

$$M_t^T + M_t^N = M_t$$

and

(iv) for capital and labor

$$\begin{aligned} K_t^T + K_t^N &= K_t \\ L_t^T + L_t^N &= 1 \end{aligned}$$

Assuming that the economy converges to the new steady state in T periods, we solve this model as a system of $9 \times T$ equations for 9 sequences $\{K_{t+1}\}$, $\{K_t^T\}$, $\{L_t^T\}$, $\{C_t\}$, $\{Q_t^T\}$, $\{B_{t+1}\}$, $\{M_t^T\}$, $\{M_t\}$ and $\left\{\widetilde{M}_t^N\right\}$, where each sequence corresponds to a vector of T components. The equations are:

1. Arbitrage equation:

$$\left[1 + \frac{\psi_K}{K_t}\left(\frac{K_{t+1} - K_t}{K_t}\right)\right] R_{t+1} = r_{t+1} + (1 - \delta) + \psi_K \left(\frac{K_{t+2} - K_{t+1}}{K_{t+1}}\right) \frac{K_{t+2}}{K_{t+1}^2}$$

2. Feasibility for the final good

$$C_t + K_{t+1} - (1 - \delta) K_t + \frac{\psi_K}{2}\left(\frac{K_{t+1} - K_t}{K_t}\right)^2 + R_{t+1}\kappa p_t^M M_t - R_t \kappa p_{t-1}^M M_{t-1} = Y_t$$

3. Static equation equating r_t across sectors

$$\frac{p_t^T}{p_t^N} = \frac{\alpha_N}{\alpha_T}\left(\frac{Y_t^N}{K_t - K_t^T}\right)\left(\frac{K_t^T}{Y_t^T}\right)$$

4. Static equation equating w_t across sectors

$$(1 - \alpha_T)\,\varepsilon_T \frac{p_t^T Y_t^T}{L_t^T} = (1 - \alpha_N)\,\varepsilon_N \frac{p_t^N Y_t^N}{1 - L_t^T}$$

5. Euler equation

$$\left(\frac{C_{t+1}}{C_t}\right)^\sigma = \beta R_{t+1}$$

6. Feasibility for domestic tradable goods, using the balance of payments identity

$$Q_t^T + \widetilde{M}_t^T + \left[B_{t+1} - (1 + r_t^*) B_t\right] - \frac{p_t^M}{p_t^T}\kappa M_t + \frac{p_{t-1}^M}{p_t^T} R_t \kappa M_{t-1} = Y_t^T$$

7. Optimal choice of intermediate goods in the traded goods sector

$$M_t^T = (1 - \varepsilon_T)\,\frac{p_t^T Y_t^T}{\widetilde{p}_t^M}$$

8. Optimal choice of intermediate goods in non-traded goods sector

$$M_t - M_t^T = (1-\varepsilon_N)\,\frac{p_t^N Y_t^N}{\widetilde{p}_t^M}$$

9. Optimal demand of non-tradable goods by intermediate producer

$$\widetilde{M}_t^N = (1-\phi)\,\frac{p_t^M M_t}{p_t^N}$$

where, apart from the endogenous variables, we define

$$\begin{aligned} L_t^N &= L_t - L_t^T \\ M_t^N &= M_t - M_t^T \\ K_t^N &= K_t - K_t^T. \end{aligned}$$

Y^T and Y^N are given from equation (2) in the text, Q^N from equation (20), Y_t from equation (1). We get the prices p_t^T and p_t^N from equations (13) and (14) respectively. We substitute for r_t from (16) and p_t^M from (19). $\widetilde{M}_t^T$ is given by equation (17). R_t and $\widetilde{p}_t^M$ are defined from equations (4) and (3) in the text respectively.

A.2 Model with Reallocation Frictions

The first order conditions for the consumer can now be written as

$$\left(\frac{C_{t+1}}{C_t}\right)^{\sigma} = \beta R_{t+1}$$

$$\begin{aligned} \left[1+\frac{\psi_K}{K_t^T}\left(\frac{K_{t+1}^T - K_t^T}{K_t^T}\right)\right] R_{t+1} &= r_{t+1}^T + (1-\delta) + \psi_K \left(\frac{K_{t+2}^T - K_{t+1}^T}{K_{t+1}^T}\right)\frac{K_{t+2}^T}{\left(K_{t+1}^T\right)^2} \\ \left[1+\frac{\psi_K}{K_t^N}\left(\frac{K_{t+1}^N - K_t^N}{K_t^N}\right)\right] R_{t+1} &= r_{t+1}^N + (1-\delta) + \psi_K \left(\frac{K_{t+2}^N - K_{t+1}^N}{K_{t+1}^N}\right)\frac{K_{t+2}^N}{\left(K_{t+1}^N\right)^2} \end{aligned}$$

and

$$\left(w_t^T - w_t^N\right) = \psi_L \left[(\theta_t - \theta_{t-1}) - \left(\frac{1}{R_{t+1}}\right)(\theta_{t+1} - \theta_t)\right]$$

The Euler equation between savings and consumption is as before. Since capital is sector specific, there are two arbitrage equations, one for each sector. The last equation is the arbitrage equation for labor, and states that the wage differential between the two sectors should be equal to the dynamic cost of adjustment.

The first order conditions for the final goods and intermediate goods producers are as before. For the traded and non traded goods producers, the first order conditions are

$$w_t^T = (1 - \alpha_T)\,\varepsilon_T \frac{p_t^T Y_t^T}{L_t^T} \tag{21}$$

$$w_t^N = (1 - \alpha_N)\,\varepsilon_N \frac{p_t^N Y_t^N}{L_t^N} \tag{22}$$

$$r_t^T = \alpha_T \varepsilon_T \frac{p_t^T Y_t^T}{K_t^T} \tag{23}$$

$$r_t^N = \alpha_N \varepsilon_N \frac{p_t^N Y_t^N}{K_t^N} \tag{24}$$

The market clearing conditions are

(i) for the final good

$$\begin{aligned} Y_t \;=\;& C_t + K_{t+1} - (1-\delta)\,K_t + \frac{\psi_K}{2}\left(\frac{K_{t+1}^T - K_t^T}{K_t^T}\right)^2 + \frac{\psi_K}{2}\left(\frac{K_{t+1}^N - K_t^N}{K_t^N}\right)^2 \\ &+ \frac{\psi_L}{2}\left(\theta_t - \theta_{t-1}\right)^2 + R_{t+1}\kappa p_t^M M_t - R_t \kappa p_{t-1}^M M_{t-1} \end{aligned}$$

where $K_t = K_t^T + K_t^N$.

(ii) for tradable and non-tradable goods

$$\begin{aligned} Q_t^T + \widetilde{M}_t^T + NX_t &= Y_t^T \\ Q_t^N + \widetilde{M}_t^N &= Y_t^N \end{aligned}$$

(iii) for intermediate goods

$$M_t^T + M_t^N = M_t$$

and

(iv) for production factors

$$\begin{aligned} K_t^T + K_t^N &= K_t \\ L_t^T &= \theta_t \\ L_t^N &= (1-\theta_t) \end{aligned}$$

This model can be solved for the following endogenous sequences: $\{K_{t+1}\}$, $\left\{K_t^T\right\}$, $\left\{L_t^T\right\}$, $\{C_t\}$, $\left\{Q_t^T\right\}$, $\{B_{t+1}\}$, $\left\{M_t^T\right\}$, $\{M_t\}$ and $\left\{\widetilde{M}_t^N\right\}$ using the following equations

1. Arbitrage equation:

$$\left[1+\frac{\psi_K}{K_t^T}\left(\frac{K_{t+1}^T-K_t^T}{K_t^T}\right)\right]R_{t+1} = r_{t+1}^T + (1-\delta) + \psi_K\left(\frac{K_{t+2}^T-K_{t+1}^T}{K_{t+1}^T}\right)\frac{K_{t+2}^T}{\left(K_{t+1}^T\right)^2}$$

2. Feasibility

$$\begin{aligned} Y_t &= C_t + K_{t+1} - (1-\delta)K_t + \frac{\psi_K}{2}\left(\frac{K_{t+1}^T-K_t^T}{K_t^T}\right)^2 + \frac{\psi_K}{2}\left(\frac{K_{t+1}^N-K_t^N}{K_t^N}\right)^2 \\ &\quad + \frac{\psi_L}{2}(\theta_t-\theta_{t-1})^2 + R_{t+1}\kappa p_t^M M_t - R_t\kappa p_{t-1}^M M_{t-1t} \end{aligned}$$

3. Static equation equating returns to capital across sectors

$$\frac{r_{t+1}^T + (1-\delta) + \psi_K\left(\frac{K_{t+2}^T-K_{t+1}^T}{K_{t+1}^T}\right)\frac{K_{t+2}^T}{\left(K_{t+1}^T\right)^2}}{\left[1+\frac{\psi_K}{K_t^T}\left(\frac{K_{t+1}^T-K_t^T}{K_t^T}\right)\right]} = \frac{r_{t+1}^N + (1-\delta) + \psi_K\left(\frac{K_{t+2}^N-K_{t+1}^N}{K_{t+1}^N}\right)\frac{K_{t+2}^N}{\left(K_{t+1}^N\right)^2}}{\left[1+\frac{\psi_K}{K_t^N}\left(\frac{K_{t+1}^N-K_t^N}{K_t^N}\right)\right]}$$

4. Dynamic equation for labor allocation

$$\left(w_t^T - w_t^N\right) = \psi_L\left[(\theta_t-\theta_{t-1}) - \left(\frac{1}{R_{t+1}}\right)(\theta_{t+1}-\theta_t)\right]$$

5. Euler equation for bonds

$$\left(\frac{C_{t+1}}{C_t}\right)^\sigma = \beta R_{t+1}$$

6. Feasibility for domestic tradable goods, using BOP identity

$$Q_t^T + \widetilde{M}_t^T + \left[B_{t+1} - \left(1 + r_t^*\right) B_t\right] - \frac{p_t^M}{p_t^T} \kappa M_t + \frac{p_{t-1}^M}{p_t^T} R_t \kappa M_{t-1} = Y_t^T$$

7. Optimal choice of intermediates in tradable sector

$$M_t^T = \left(1 - \varepsilon_T\right) \frac{p_t^T Y_t^T}{\widetilde{p}_t^M}$$

8. Optimal choice of intermediates in non-tradable sector

$$M_t - M_t^T = \left(1 - \varepsilon_N\right) \frac{p_t^N Y_t^N}{\widetilde{p}_t^M}$$

9. Optimal demand of non-tradable goods by intermediate producer

$$\widetilde{M}_t^N = (1 - \phi) \frac{p_t^M M_t}{p_t^N}$$

where we define

$$L_t^T = \theta_t \text{ and } L_t^N = 1 - \theta_t$$

$$\begin{aligned} M_t^N &= M_t - M_t^T \\ K_t^N &= K_t - K_t^T \end{aligned}$$

Y_t^T and Y_t^N are obtained from their respective production functions as before, and Q_t^N from the market clearing equation for non traded goods. Similarly, Y_t^T can be obtained from equation (1) as before, and p_t^T and p_t^N from equations (13) and (14) respectively. Wages in each sector are given by the marginal product of labor, i.e. equations (21) and (22) and the rental rate on capital in each sector by the marginal product of capital, as in equations (23) and (24). As before, p_t^M and $\widetilde{M}_t^T$ are derived from the first order conditions for the intermediate goods producrers. R_t and $\widetilde{p}_t^M$ are defined from equations (4) and (3) in the text respectively.

B Working Capital Constraint and TFP in a One Sector Model

The mechanism behind the fall in TFP resulting from a sudden stop plays a central role in our analysis and is worth exploring further. Using a simple one sector model we can show that the constraint on working capital introduces a wedge between the price paid by firms and the price paid to the intermediate goods producers. A sudden stop increases the size of this wedge and increases allocative inefficiency which shows up as a fall in TFP. We illustrate this insight by solving for steady state output and TFP in a simpler one sector version of our model and show its relationship to the working capital constraints. This allows us to highlight the underlying intuition behind the mechanism clearly.

Consider a small open economy with infinitely lived representative consumers and a representative firm. The consumer owns the firm, supplies a unit of labor inelastically, invests in capital K_{t+1} and borrows or lends B_{t+1} at the world interest rate r^*_{t+1} each period. The firm produces output by renting capital K_t and buying labor L_t from households and purchasing intermediate goods from intermediate goods producers. The working capital constraint implies that every period the firm must purchase a fraction κ intermediate goods with loans from financial intermediaries. All prices are in terms of the final good price.

B.1 Consumers:

The representative consumer's problem can be written as

$$\max_{C_t, K_{t+1}, B_{t+1}} \sum_{t=0}^{\infty} \beta^t \left[\frac{C_t^{1-\sigma} - 1}{1-\sigma} \right]$$

subject to

$$C_t + K_{t+1} + B_{t+1} = w_t + \left[r_t + (1-\delta) \right] K_t + (1 + r^*_t) B_t - \frac{\psi_K}{2} \left(\frac{K_{t+1} - K_t}{K_t} \right)^2$$

where δ is the depreciation rate of capital and ψ_K is the cost of adjustment of capital.

B.2 Firms:

Firms combine capital, labor and intermediate goods in a constant returns to scale technology to produce a single good which is used for consumption, investment as well as for the production of intermediate goods. The price of this good is used as the numeraire. Each period, firms purchase a fraction κ of their intermediate goods financed with within period loans from a financial intermediary at an interest rate $\widehat{r}_{t+1}$. The firm's problem can be written as

$$\max_{K_t, L_t, M_t} Y_t - w_t L_t - r_t K_t - \widetilde{p}_t^M M_t$$

where w_t and r_t are the wage rate and the rental rate of capital respectively,

$$Y_t = \left(K_t^{\alpha} L_t^{1-\alpha}\right)^{\varepsilon} M_t^{1-\varepsilon}$$

and

$$\widetilde{p}_t^M = p_t^M \left(1 + \kappa \widehat{r}_{t+1}\right)$$

B.3 Intermediate Goods

The intermediate goods producers transform $\widetilde{M}_t$ units of the final good into intermediate goods M_t using a linear technology, i.e.

$$M_t = A_M \widetilde{M}_t$$

The intermediate goods producers problem can be written as

$$\max_{\widetilde{M}_t} p_t^M M_t - \widetilde{M}_t$$

This implies that

$$p_t^M = \frac{1}{A_M}$$

B.4 Financial Intermediaries

Competitive financial intermediaries borrow an amount $\kappa p_t^M M_t$ at the international interest rate r_{t+1}^* which is repayable next period. Firms borrow this amount from the intermediaries and repay

$(1+\widehat{r}_{t+1})\,\kappa p_t^M M_t$ in the same period. The intermediary stores these funds overnight and pays the lenders back next period. The zero profit condition for the intermediaries implies that

$$\left(1+r_{t+1}^{*}\right)\kappa p_t^M M_t=\left(1+\widehat{r}_{t+1}\right)\kappa p_t^M M_t$$

and

$$\widehat{r}_{t+1}=r_{t+1}^{*}$$

From now, we will find it convenient to refer to the gross interest rate $R_{t+1}=\left(1+r_{t+1}^{*}\right)$.

B.5 Equilibrium and Steady State

In the goods market

$$\begin{aligned} Y_t &= C_t+K_{t+1}-(1-\delta)\,K_t+\frac{\psi_K}{2}\left(\frac{K_{t+1}-K_t}{K_t}\right)^2 \\ &\quad +\widetilde{M}_t+R_{t+1}\kappa p_t^M M_t-R_t\kappa p_{t-1}^M M_{t-1}+NX_t \end{aligned}$$

where NX_t are net exports.

In the labor market

$$L_t=1$$

GDP in this economy can be defined as follows:

$$\begin{aligned} GDP_t &= Y_t-p_t^M M_t \\ &= C_t+K_{t+1}-(1-\delta)\,K_t+NX_t+\frac{\psi_K}{2}\left(\frac{K_{t+1}-K_t}{K_t}\right)^2 \\ &= w_t+r_tK_t+(R_{t+1}-1)\,\kappa p_t^M M_t \end{aligned}$$

using the value added method, the expenditure method and the income method respectively.

We define $1+\chi_t=1+\kappa r_{t+1}^{*}$ as the wedge between the producer and user price of intermediate goods. We also define the constant

$$\Delta=(\alpha\varepsilon)^{\frac{\alpha}{1-\alpha}}\,(1-\varepsilon)^{\frac{1-\varepsilon}{e(1-\alpha)}}\,A_M^{\frac{1-\varepsilon}{\varepsilon(1-\alpha)}}$$

Using standard techniques we can solve the model and show that in steady state

$$
\begin{aligned}
Y &= \Delta\left(\delta+r^*\right)^{-\frac{\alpha}{1-\alpha}}\left(\frac{1}{1+\chi}\right)^{\frac{1-\varepsilon}{\varepsilon(1-\alpha)}} \\
K &= \Delta\left(\alpha\varepsilon\right)^{\frac{1}{\alpha}}\left(\delta+r^*\right)^{-\frac{1}{1-\alpha}}\left(\frac{1}{1+\chi}\right)^{\frac{1-\varepsilon}{\varepsilon(1-\alpha)}}
\end{aligned}
$$

and

$$
\begin{aligned}
GDP &= Y-p^M M \\
&= \Delta\left(\delta+r^*\right)^{-\frac{\alpha}{1-\alpha}}\left(\chi+\varepsilon\right)\left(\frac{1}{1+\chi}\right)^{\frac{1-\alpha\varepsilon}{\varepsilon(1-\alpha)}}
\end{aligned}
$$

TFP in this economy can be written as

$$
TFP=\frac{GDP}{K^\alpha}=\frac{\Delta^{1-\alpha}\left(\chi+\varepsilon\right)}{\alpha\varepsilon}\left(\frac{1}{1+\chi}\right)^{\frac{1}{\varepsilon}}
$$

It is also straightforward to show that for $0<\varepsilon<1$,both TFP and GDP are declining in the wedge, i.e.

$$
\begin{aligned}
\frac{\partial GDP}{\partial\chi} &= \Delta\left(\delta+r^*\right)^{-\frac{\alpha}{1-\alpha}}\left(\frac{1}{1+\chi}\right)^{1+\frac{1-\alpha\varepsilon}{\varepsilon(1-\alpha)}}\left[\chi-\frac{\chi}{\varepsilon}\left(\frac{1-\alpha\varepsilon}{\varepsilon-\alpha\varepsilon}\right)\right]<0 \\
\frac{\partial TFP}{\partial\chi} &= \frac{1}{\alpha\varepsilon}\left(\frac{1}{1+\chi}\right)^{1+\frac{1}{\varepsilon}}\left[\chi-\frac{\chi}{\varepsilon}\right]<0
\end{aligned}
$$

Finally the intermediate goods to output ratio is

$$
\frac{M}{Y}=\left(\frac{1-\varepsilon}{1+\chi}\right)A_M
$$

which is also inversely related to the wedge.

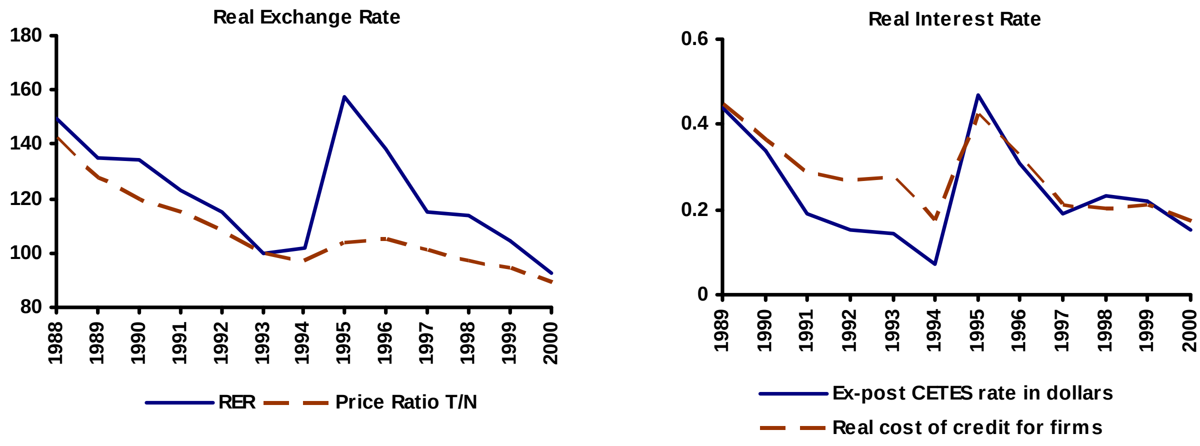

Figure 1: Real Exchange Rate and Real Interest Rate in Mexico

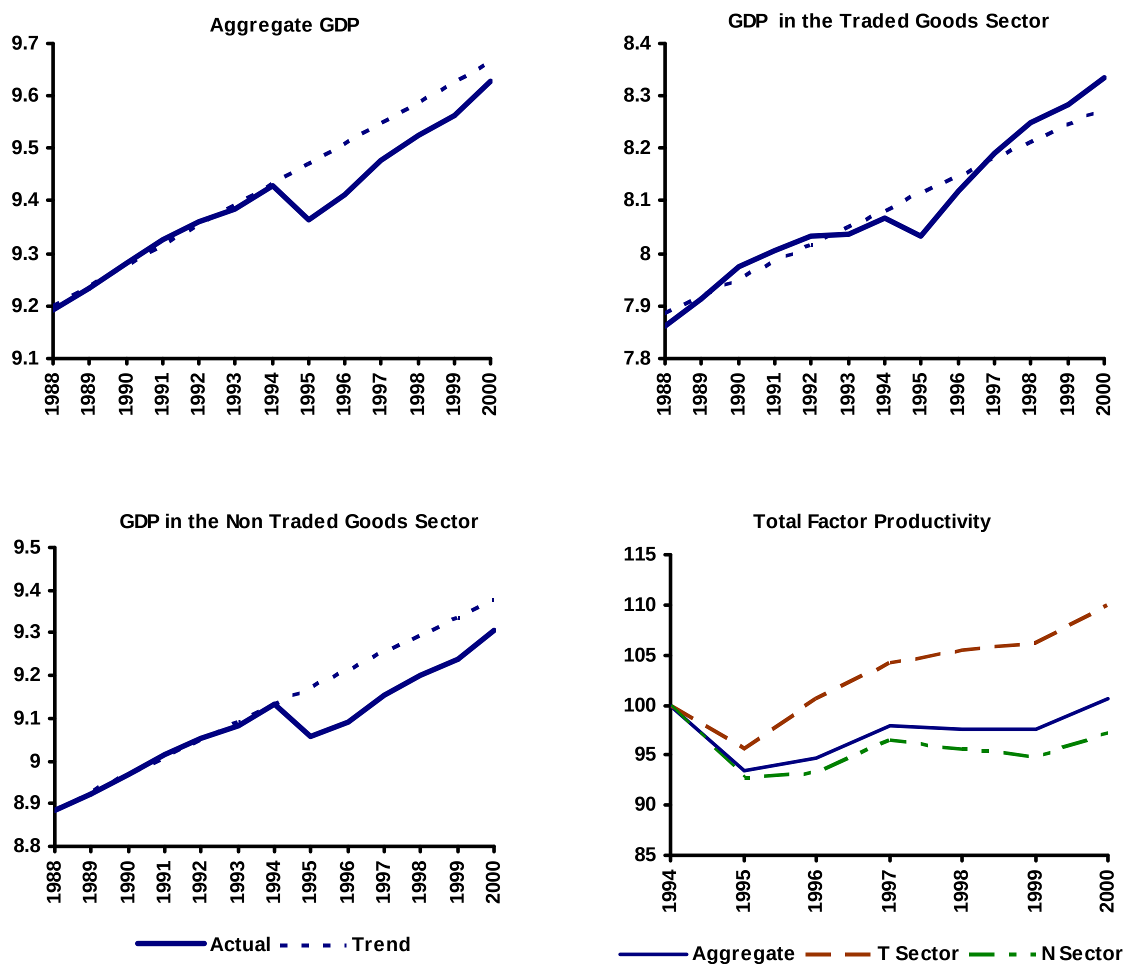

Figure 2: Output and Total Factor Productivity in Mexico

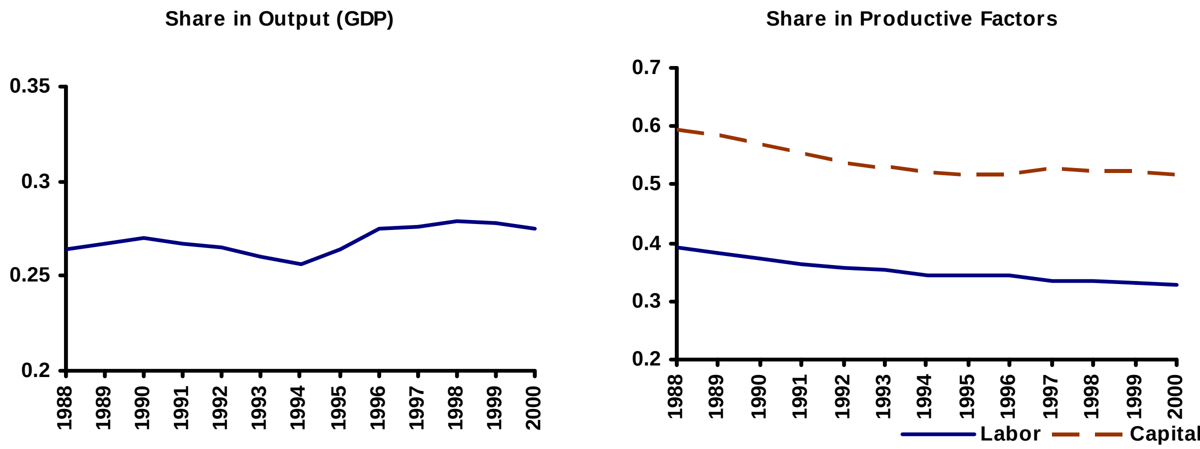

Figure 3: Share of Traded Goods in Output, Labor and Capital

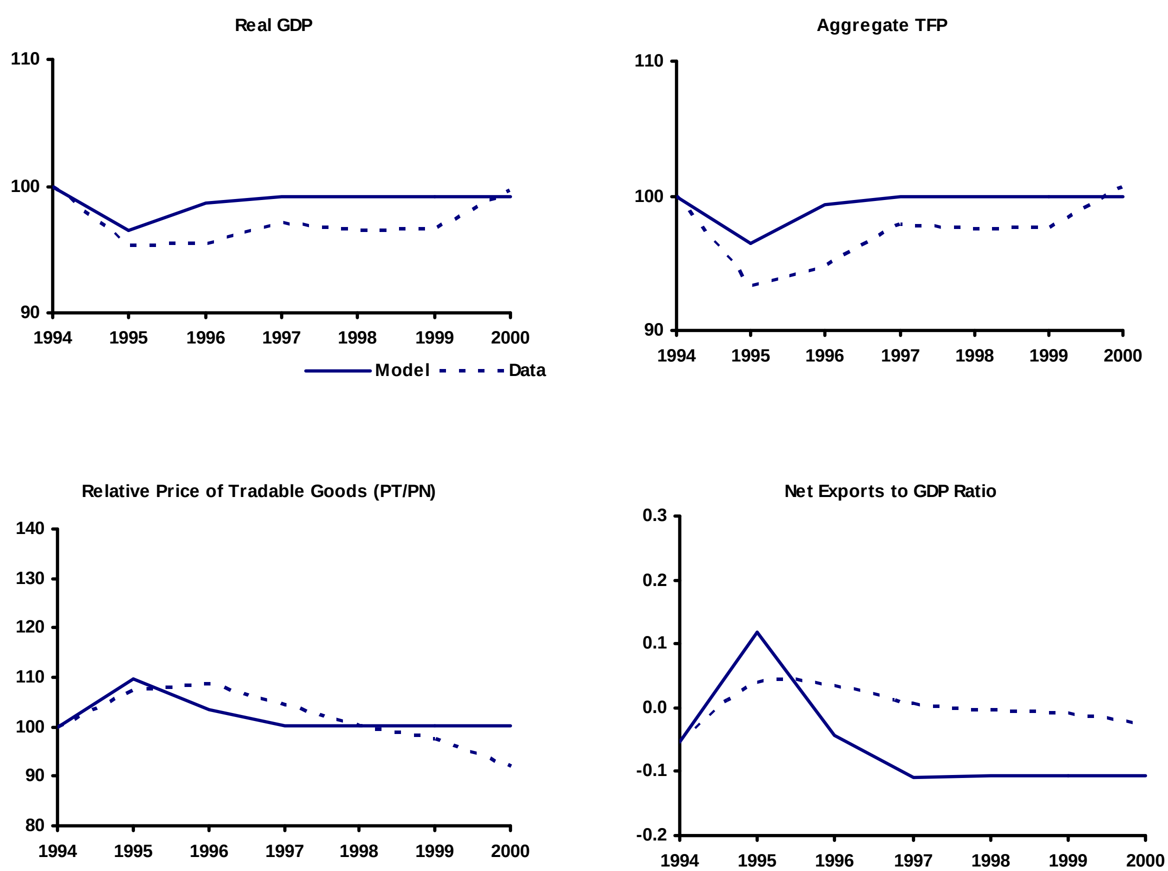

Figure 4: Aggregates in the Baseline Model

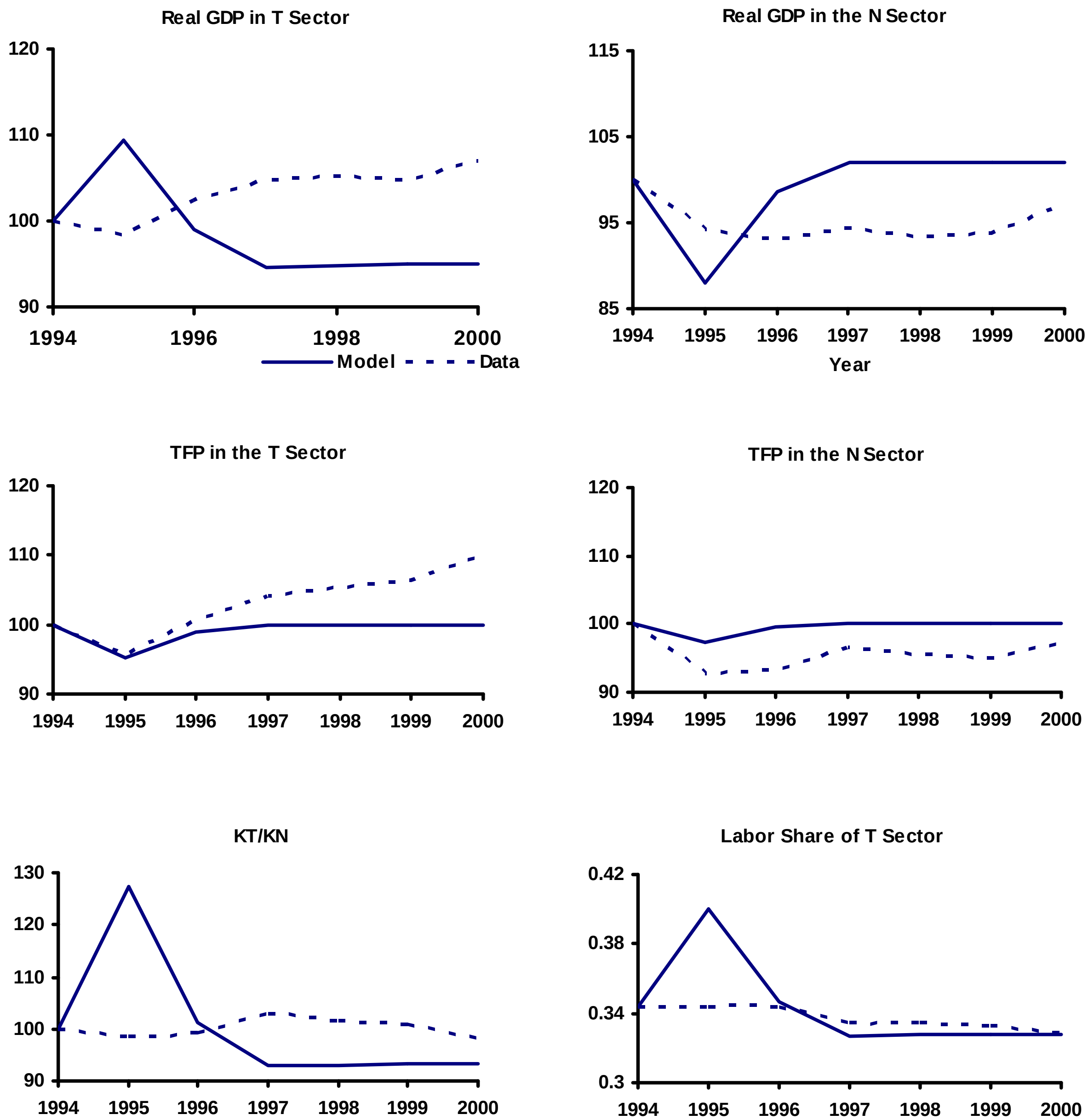

Figure 5: Sectoral Patterns in the Baseline Model

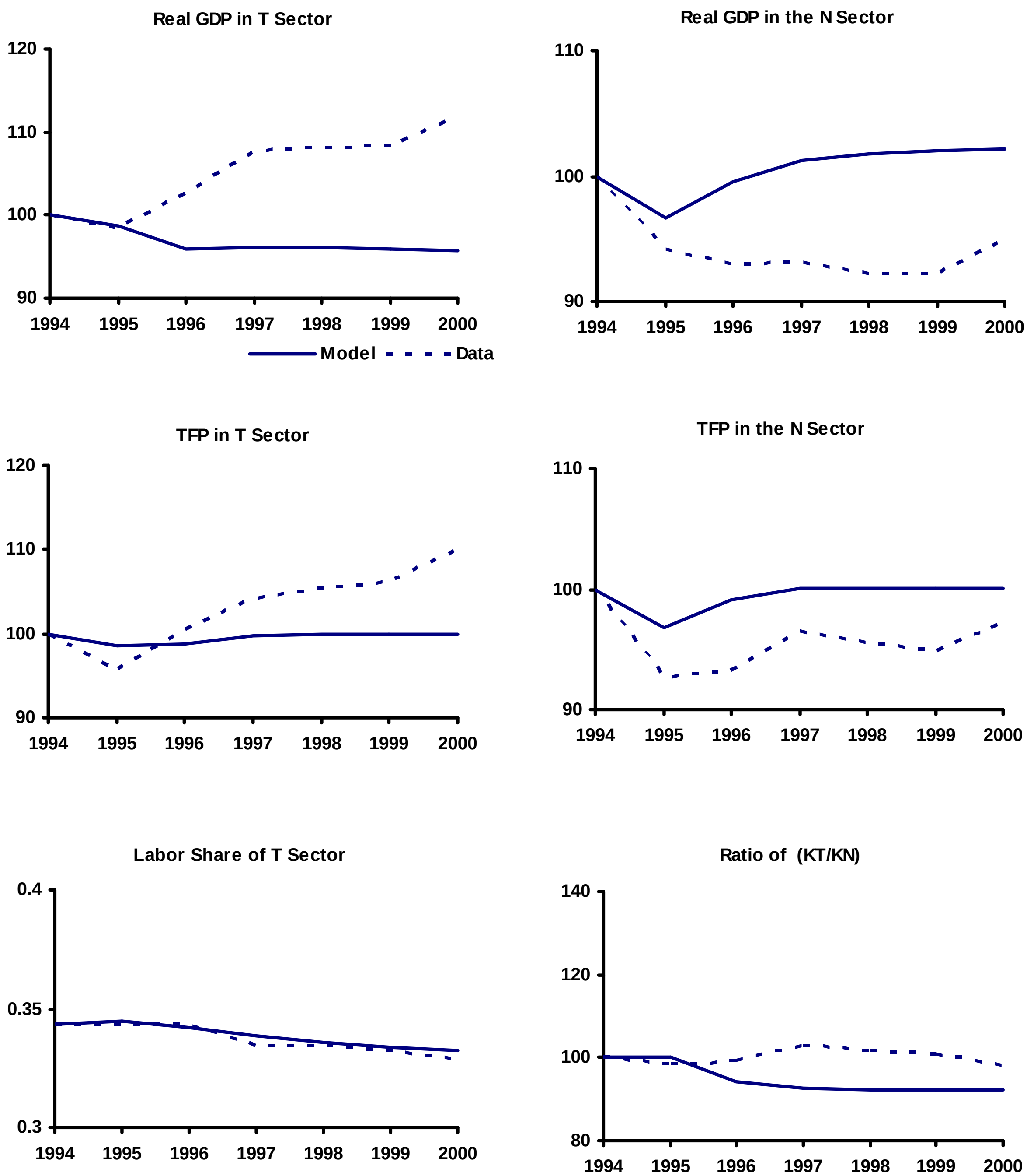

Figure 6: Sectoral Patterns in the Model with Reallocation Frictions