October 2005

Sudden Stops, Sectoral Reallocations, and the Real Exchange Rate

Preliminary

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ABSTRACT

A “sudden stop” of foreign capital flows in a developing country tends to be followed by a switch from trade deficits to surpluses, a sharp depreciation of the real exchange rate, and a decrease in output and total factor productivity. We further document that there is substantial reallocation taking place across the nontradable and tradable goods sectors. Using Mexico’s 1994-95 crises as an archetypal example, we find that output falls more in the nontradable goods sector and recovers more slowly than in the tradable goods sector as labor and capital are shifted from the nontradable to the tradable good sector. We construct a multisector model in which it is costly to shift resources across sectors, and calibrate it to the Mexican economy. In contrast to other models of sudden stops, we do not model any other shocks affecting the economy, which allows us to isolate the effects of the sudden stop. When the calibrated model is subjected to a sudden stop of capital inflows it is able to replicate the sectoral patterns we find in the data and account for the movements in the real exchange rate and the relative price of tradables and nontradables.

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*Timothy J. Kehoe and Kim J. Ruhl. This paper has benefited from discussions with George Alessandria, David Backus, Patrick Kehoe and the participants at the “Micro Foundations of Real Exchange Rates” conference at the Carnegie Bosch Institute. The views expressed herein are those of the authors and not necessarily those of the Federal Reserve Bank of Minneapolis or the Federal Reserve System.
1. Introduction

Episodes in which foreign lenders will no longer extend credit to a county – *sudden stops* in the language of Calvo – continue to plague economies trying to deal with the lack of credit, and economists trying to understand their causes and effects. Many authors have focused on why these sudden stops occur and what economic fundamentals may drive these episodes. In this paper, we instead analyze the real effects that accompany these sudden stops with a focus on how they differ across sectors that produce tradable goods or nontradable goods.

We then construct a simple quantitative model in which a country produces tradable and nontradable goods and calibrate it to Mexico in 1989. When we subject the model to a sudden stop (the debt crises in 1994-95) it can reproduce the behavior of the real exchange rate, the trade balance, and the price of nontradable goods.

There have been numerous theories and models put forth to explain why sudden stops occur; see, for example, Calvo (1988), Calvo (1998), Kaminsky and Reinhart (1999) and Cole and Kehoe (2000). In many of the models constructed to analyze a government’s decision to default on its debt the authors must assume an exogenous penalty for default. A common assumption is that some fraction of a country’s output disappears when it is in default. This assumption is based on the observation that a sharp, substantial decline in gross domestic product (GDP) usually coincides with the onset of the sudden stop. These observations come from a second line of inquiry that focuses on the effects of the sudden stop on the economy. Empirically, papers such as Guidotti, Sturzenegger and Villar (2004), Calvo and Talvi (2005) and Meza and Quintin (2003) have looked at the effects of sudden stops on the aggregate economy. These studies have documented the declines in GDP and total factor productivity (TFP) that accompany sudden stops. Burstein, Neves and Rebelo (2003) and Mendoza (2005) study the real exchange rate devaluations from sudden stops and the large role that nontradable good prices play in these devaluations. In this paper, we focus on the effects of a sudden stop on the disaggregated economy. When credit is restricted, we find that output in the tradable good sector falls by less than output in the nontradable good sector and that labor and investment move from the nontradable good to the tradable good sector. We also find that changes in the relative price of tradable to nontradable goods can account for some of the movement in real exchange rates. We document these characteristics for the sudden stop in Mexico in 1994-95.
Building on the differential effects of a sudden stop on the 2 sectors that we find in the data, we construct a model that features both tradable and nontradable good sectors. A key component of the model is costly labor adjustment. In a model with these features, an unforeseen sudden stop leaves the economy with a suboptimal allocation of labor and capital across the two sectors. The country – which was financing imports through foreign borrowing – now faces a relatively scarce supply of tradable goods, driving up their price relative to nontradable goods, creating an incentive to move resources into the tradable goods sector to increase production. The real frictions lead to only partial adjustment of labor and capital between the two sectors. When we calibrate the model to the Mexican economy and subject it to a sudden stop the model can replicate the sectoral patterns that we see in the data, as well as the trade balance and the real exchange rate.

Accounting for the declines in GDP and TFP that coincide with sudden stops is challenging. Chari, Kehoe and McGrattan (2005) show that standard equilibrium models predict not an output decrease, but an output increase from an abrupt tightening of collateral constraints. They note that generating an output decrease requires frictions that have negative effects on output large enough to overcome the natural response to a decrease in credit. The costs of moving labor and capital across sectors in our model does provide a direct channel through which sudden stops could affect output and TFP. Moving labor uses up output, leading to a decrease in GDP. Since GDP is falling and the amount of labor being “used” is constant, these costs manifest themselves as decreases in measured TFP. In our calibrated model, however, the costs actually incurred are not large enough to account for the change in GDP or the decrease in TFP.

Mendoza and Smith (2004) and Neumeyer and Perri (2005) introduce financial frictions into small open economy models by requiring firms to borrow funds to pay in advance for labor or imported inputs and these models are able to account for many of the characteristics of emerging market economies. Meza and Quintin (2003) allow for labor hoarding and variable capital utilization. Our approach differs in two respects; while their models focused on single good environments, we model two sectors so that we can make predictions about the effects of sudden stops on tradable and nontradable industries; we also take the sudden stop to be
the only exogenous force in the model, while the others use exogenous processes for TFP or interest rates. Calvo (1998) appeals to the same kinds of changes in tradable and nontradable good prices that we do, but envisions these changes generating effects through banks having made loans at the old relative prices. Under the new relative prices, some of these loans are nonperforming. We abstract from the banking sector in this model to quantitatively assess how far a standard model can go in explaining the effects of sudden stops.

We also discuss another commonly cited idea that changes in the terms of trade (real exchange rate) that accompany sudden stops make imported intermediates more expensive and act like a decrease in TFP. We show that under standard national accounting definitions of GDP, changes in the terms of trade cannot have a first order effect on GDP, and thus cannot affect TFP. Though there may be second order effects if the change in the terms of trade is large enough, our quantitative model – which does display a large change in the terms of trade following the sudden stop – suggests that these effects were not at work in Mexico during the crisis.

In Section 2 we document the facts surrounding the sudden stop in Mexico in 1994-95. Section 3 discusses, and dismisses, the idea that deteriorations of the terms of trade can show up as changes in GDP or TFP. Sections 4 and 5 lay out our multisector model and calibrate it to Mexico in 1989. Section 6 presents discusses the results of this model and compares its predictions to the data while section 7 and 8 consider extensions to the model. Section 9 concludes.

2. The Effects of a Sudden Stop

In this section we highlight the empirical properties of Mexico’s opening to foreign capital in the late 1980s – the *apertura* – and the sudden stop in 1994-95. We choose to focus on Mexico because it is an archetypical example of a sudden stop and a country with the needed sectoral data. Preliminary analysis into other episodes suggests that the facts we document here are widely applicable to countries in a debt crisis and we leave to future work compiling these facts for a large number of countries. We structure our analysis around 4 observations about the economy’s response to a sudden stop. A sudden stop of foreign capital inflows is
usually followed by (i) a switch from trade deficits to trade surpluses, (ii) a sharp depreciation of the real exchange rate, (iii) a decrease in output, and (iv) a decrease in TFP.

Figure 1 plots the balance of Mexico’s financial account less net foreign direct investment as a share of GDP. The data is taken from the balance of payments accounts and includes net portfolio investment and the net inflows of banks and the government. As Mexico opened its capital markets the country went from being a net lender to a net borrower. In the second quarter of 1994 there was a decline in borrowing that brought net inflows to -0.96 percent of GDP, but the decline was reversed in the third quarter and Mexico was accumulating external capital at the same rate it was a year before. In the last quarter of 1994 Mexico’s sudden stop occurs and the financial account falls to -0.95 percent of GDP and bottoms out in the first quarter of 1995 at -4.62 percent of GDP. Capital inflows temporarily spiked in the third quarter of 1996 and the first quarter of 1997 before returning to steady inflows in the late 1990s.

A natural question to ask is whether or not there were foreseeable conditions in Mexico that may have led to this abrupt withdrawal of credit. To address this question we plot the interest rate paid by Mexico on foreign debt in Figure 2. We measure the interest rate in two parts. The first part is the U.S. treasury bill rate. The second component is the Mexico-specific interest rate spread. This series is the J.P. Morgan Emerging Market Bond Index spread on Brady Bonds computed after stripping out the collateralized principal. This component is widely used to measure country specific risk premia. The sum of these two components is the interest rate on external borrowing by Mexico. Two things are clear from the figure: changes in the rate paid by Mexico are due almost entirely to country specific factors and the risk premia on Mexican debt did not increase before the crisis. In November of 1994 the risk premia on Mexican debt was 4.56 percent, which was less than the average spread from 1991 through November of 1994. Not until December, the first month of the crisis, did the risk premia increase to 8.90 percent and then peak at 16.37 in March of 1994. The behavior of interest rates makes it clear that this sudden really was sudden and largely unforeseen.
Sectoral Responses to Sudden Stops

Most of the empirical research on sudden stops has focused on the economies at the aggregate level. In this section we divide the aggregate economy into two sectors, one which produces goods that are tradable and one that produces goods that are nontradable. The classification of a good, much less an industry, as either tradable or nontradable is difficult, but we follow Stockman and Tesar (1995) and Betts and Kehoe (2001) in assigning the agriculture, mining, and manufacturing sectors as producing tradable goods and construction and services to be nontradable.

At the onset of the sudden stop, the trade balance immediately went into surplus. As can be seen in Figure 3 the trade balance went from -8.4 percent of GDP in 1994 to a 2.7 percent surplus in 1995 and stayed positive until 1997. Mexico continued running trade deficits, although they were smaller in magnitude after the sudden stop. The adjustment to the trade balance during a sudden stop is a robust fact; Guidotti et al. (2004) study 313 sudden stop episodes and find that the current account adjusts in 265 of them.

The sudden stops in these countries were also accompanied by large devaluations of the real exchange rate. We define the real exchange rate for Mexico, vis-à-vis the United States as

\[ RER_{\text{mex,us}} = NER_{\text{mex,us}} \frac{P_{\text{us}}}{P_{\text{mex}}}, \]  

(1)

Where \( NER_{\text{mex,us}} \) is the Peso to Dollar exchange rate and \( P_j \) is inflation in country \( j \), as measured using gross output deflators. We plot the log real exchange rate for Mexico in Figure 4. In Mexico the real exchange rate depreciates by 35 percent from 1994 to 1995 and appreciates as the sudden stop ends, returning to its 1994 level around the year 2000. We further break down the depreciation of the real exchange rate into its sectoral components. To do this, we decompose the real exchange rate in (1) as

\[ RER_{\text{mex,us}} = \left( NER_{\text{mex,us}} \frac{P_{\text{mex}}^{\tau}}{P_{\text{mex}}} \right) \left( \frac{P_{\text{us}}^\tau}{P_{\text{mex}}^\tau} \right) = RER_{\text{mex,us}}^{\tau} \times RER_{\text{mex,us}}^{\gamma}, \]  

(2)

where we define the price of tradable goods, \( P_{\text{mex}}^\tau \), as the gross output deflator for agriculture, mining, and manufacturing. The first term in the decomposition measures deviations from the law of one price. If the law of one price held, this term would be identically one. The
second term in the decomposition is the relative price of nontradable to tradable goods and does not include the nominal exchange rate. Taking logs we have

\[ rer_{mex,us} = rer^T_{mex,us} + rer^N_{mex,us}. \]  

We plot \( rer^N \) for Mexico vis-à-vis the U.S. in Figure 4. When Mexico opens to capital flow in the late 1980s the relative price of tradable to nontradable goods tracks the appreciation of the real exchange rate and depreciates – though less so – during the sudden stop.

In Figure 5 we plot value added for the tradable and nontradable good sectors in Mexico. As can be seen, value added in the nontradable good sectors falls more than in the tradable good sectors and recovers at a much slower rate. In Mexico, tradable good value added falls half as much as nontradable good value added and grows faster for the next 5 years. The shift in production from the nontradable sector to the tradable sector is the focus of our analysis and the key ingredient in our model below.

The shift from nontradable good production can also be seen in the allocation of labor across the two sectors. Figure 7 plots the share of tradable good employment in total employment in Mexico. In Mexico, as in most industrialized countries, there is a steady trend of labor leaving the tradable good sector for the nontradable good sector. During the sudden stop, though, there is an abrupt stop in the movement of workers out of the tradable good sector, which amounts to – relative to the trend – a reallocation of workers to the tradable good sector. In the model that follows, we will abstract from the secular trend in employment, so we focus on the linear detrended path for employment, as seen in Figure 8. The 6.54 percent increase in tradable good employment, as can be seen in the figure, is the statistic we would like our model to reproduce.

The sectoral data shows that there is more going on during a sudden stop than can be seen at the aggregate level. In response to a sudden stop, the relative price of tradable to nontradable goods increases, leading to a shift of resources away from the nontradable good sectors into the tradable goods sectors. If there are frictions that impede the movement of labor and capital across sectors, then understanding how sudden stops effect the two sectors
can help us to better understand the aggregate variables that interest policy makers and economists. We turn to these aggregate responses next.

**Aggregate Responses to Sudden Stops**

As can be seen in Figure 6, GDP per working age person fell about 9.0 percent from 1994 to 1995 in Mexico, which coincided with a 7.6 percent decline in TFP. Output recovered following the sudden stop, growing more than twice as fast in 1995-2001 than in 1988-1994. To further understand the effects of a sudden stop, we use the neoclassical growth model to decompose the changes in output per working age person into changes in labor effort, capital accumulation and the residual, TFP. To do so, we use an aggregate production function of the form,

\[
Y_t = A_t K_t ^{\alpha} L_t ^{1-\alpha}
\]

where \(Y_t\) is output, \(A_t\) is total factor productivity, \(K_t\) is capital and \(L_t\) is hours worked in period \(t\). Following Hayashi and Prescott (2002) and Kehoe and Prescott (2002), we write the production function in terms of output per working age person and measures of factor inputs that are constant along a balanced growth path,

\[
\frac{Y_t}{N_t} = A_t ^{\alpha} \left( \frac{K_t}{Y_t} \right) ^{\alpha} \frac{L_t}{N_t},
\]

where \(N_t\) is the working age population. When TFP grows at a constant rate (i.e., when \(A_t = \bar{A} g^{(1-\alpha)\rho}\)) the neoclassical growth model implies a unique balanced growth path in which the capital output ratio, \(K_t/Y_t\), and the hours worked per working age person \(L_t/N_t\) are constant and output per working age person grows at the rate \(g-1\).

To compute (5) we use real GDP as our measure of output, the population aged 15-64 as the working age population, hours worked data, and capital stocks constructed from real investment. To construct the capital stocks, beginning with a value of the capital stock in 1950, we cumulate real investment according to

\[
K_{t+1} = (1-\delta) K_t + I_t
\]
with the depreciation rate equal to 0.035 for Mexico. We choose the initial capital stock, $K_{1950}$, so that the capital output ratio in 1950 is the same as the average capital output ratio from 1951-1960. With output, labor inputs and capital stocks, we compute TFP as the residual

$$A_t = \frac{Y_t}{K_t^\alpha L_t^{1-\alpha}}. \tag{7}$$

The results of our growth accounting for Mexico are presented in Table 1. In the period leading up to the sudden stop, output per working age person grew at an average rate of 0.72 percent per year, about two-thirds of which can be accounted for by TFP growth and about one-third of which can be accounted for by an increase in the rate of capital accumulation. The dramatic effect of the sudden stop can be seen in the second line of the table, as output per working age person falls 9.02 percent. During this period the TFP factor falls by even more, 11.34 percent, while the capital factor increases by 4.31 percent and the labor factor falls by about 2 percent. Since the end of the crisis, Mexico has averaged a growth rate of output per working age person of 1.52 percent per year, with most of the growth being accounted for by growth in TFP.

As we have seen in Table 1, a sudden stop of foreign capital inflows are followed by sharp declines in aggregate output and TFP. Movements in the capital output ratio and hours worked tend to be much smaller. These results are similar to those in Meza and Quintin (2003) which also uses a growth accounting framework to study sudden stops in Mexico and countries affected by the Asian crisis in the late 1990s. These results make it clear that any theory that hopes to explain the drop in output following a sudden stop must also deliver a sharp decline in aggregate TFP. In thinking about changes in output growth and TFP in open economies, a common mechanism cited has been the role of international relative prices, i.e. the terms of trade. In the next section we show why this cannot be what drives the responses we have seen in this section.
3. Import Prices and TFP

An appealing way to think about foreign trade is to liken it to a production technology available to the country; a country’s exports are the inputs to the technology and these inputs are turned into outputs that are recorded as a country’s imports. Exports are transformed into imports at the rate \( \frac{p_s}{p_m} \), which is just the inverse of the terms of trade. Viewed in this way, an increase in the terms of trade acts much like a technology shock: the same amount of exports now produces a smaller amount of imports. This way of thinking makes it natural to explore the ways in which the changes in the terms of trade in Mexico have translated into changes in TFP. A careful inspection of the national accounting procedures, however, reveals that the terms of trade cannot have a direct effect on a country’s GDP and, therefore, cannot have a direct effect on its TFP. This is well understood by economists interested in index numbers and national income accounting. See, for example, Diewert and Morrison (1986) and Kohli (1983). It is less well understood by at least some macroeconomists.

Changes in the terms of trade are treated as a price phenomenon in computing real GDP and thus are “undone” by the appropriate price indices. This implies that real GDP can not be directly affected by a change in the terms of trade, and thus changes in the terms of trade can not show up as changes in TFP. Changes in the terms of trade do have a direct effect, however, in the value of a country’s income. An increase in the terms of trade lowers the purchasing power of the country, which can be very painful in terms of consumption and welfare, but cannot impact TFP directly.

To appreciate these points, we consider two simple examples that illustrate the differences between the national income accounting treatment of a closed economy that suffers a productivity drop in a production sector and that of an open economy that suffers a deterioration in its terms of trade.

First consider the closed economy. In this economy there is one factor of production, labor, which is supplied inelasticity, \( \ell = \ell \). There are two goods produced. One of them, the y good, is consumed by consumers and used in the production of the second good, the m
good. The y good is produced using labor and intermediate inputs of the m good. The m good is produced using only intermediate inputs of the y good. The production functions are

\[ y = f(\ell, m) \]
\[ m = \frac{x}{a}, \]

where \( f \) is a constant returns to scale production function and \( a \) is a unit output requirement. Feasibility requires that

\[ c + x = y. \]

Normalizing the base period price of the y good to be 1, we can write real GDP on the expenditure side as

\[ c = y - x. \]

On the output side, real GDP can be calculated as the base period value of gross output minus the base period value of intermediate inputs:

\[ y = f(\ell, m) - p_0(m + x) = f(\ell, m) - x \]

where \( p_0 = a \) is the base period price of the m good.

To calculate the impact of an increase in \( a \), a drop in productivity in the m good sector, we note that a competitive economy solves

\[ \max_m f(\bar{\ell}, m) - am. \]

If \( f \) is continuously differentiable, we can take the first order condition

\[ f_m(\bar{\ell}, m) = a \]

and use the implicit function theorem to obtain

\[ m'(a) = \frac{1}{f_{mm}(\bar{\ell}, m(a))} < 0 \]

How does real GDP change?

\[ Y(a) = f(\bar{\ell}, m(a)) - am(a) \]
\[ Y'(a) = f_m(\bar{\ell}, m(a))m'(a) - am'(a) - m(a) = -m(a) < 0. \]

Real GDP and productivity decline.
Now consider and open economy with the same structure as that of the closed economy except that \( m \) is imported intermediate inputs, \( x \) is exports, and \( p = a \) is terms of trade. To make the analysis identical to that in the closed economy we assume balanced trade, 
\[
pm = x.
\]
Real GDP is now
\[
c + x - p_0m = y - p_0m = f(\ell, m) - p_0m.
\]
where \( p_0 \) is price of imports (relative to exports) in the base year. A competitive economy continues to solve
\[
\max_m f(\ell, m) - pm
\]
with the corresponding first order condition defining an implicit function \( m(p) \):
\[
f_m(\ell, m) = p
\]
\[
m'(p) = \frac{1}{f_{mm}(\ell, m(p))} < 0
\]
An increase in \( p \) – a deterioration in the terms of trade – has the identical impact on consumption and welfare as the decline in productivity in the closed economy. But what happens to real GDP and productivity?
\[
Y(p) = f(\ell, m(p)) - p_0m(p)
\]
\[
Y'(p) = f_m(\ell, m(p))m'(p) - p_0m'(p) = (p - p_0)m'(p)
\]
To the extent that the terms of trade in the period before the deterioration takes place, \( p \), are close to the terms of trade in the base period, \( p_0 \), there is no change at all in measured real GDP or in productivity. If \( p < p_0 \), real GDP may even increase, although this effect is of second order compared to the decline in consumption.

Nominal GDP represents the current value of both production and income in both open and closed economies. Real GDP and real income, though equivalent in a closed economy, are not necessarily equivalent in an open economy. The difference between real GDP and real gross domestic income (GDI) arises from the deflation of the trade balance. Real GDP is computed by deflating the current value of the components of GDP by their respective implicit price deflators, \( P \),
\[ GDP_t = \frac{C_t}{P_t^{cl}} + \frac{I_t}{P_t^{cl}} + \frac{G_t}{P_t^{cl}} + \frac{X_t - M_t}{P_t^{cl}} \]

while real income may be computed as

\[ GDI_t = \frac{C_t}{P_t^{cl}} + \frac{I_t}{P_t^{cl}} + \frac{G_t}{P_t^{cl}} + \frac{X_t - M_t}{P_t^{cl}}. \]  \hspace{1cm} (8)

Notice that real GDP, a measure of production, values exports as an output and imports as an input, while real GDI values the nominal trade balance in terms of the amount of imports that can be purchased. The U.S. Bureau of Economic Analysis refers to (8) as command-basis GDP, rather than real gross domestic income as defined in the United Nations 1993 System of National Accounts (United Nations, 2001). United Nations (2001) also allows for several definitions of real GDI that differ by the index used to deflate \( X_t - M_t \), including the export price index or the domestic absorption price index.

4. Model

We model Mexico as a small open economy with perfect foresight over the world interest rate and the path of population growth. In 1988 the economy is closed to foreign capital inflows. The economy opens to foreign capital – the apertura – in 1990 and receives large capital inflows. Four years later, Mexico experiences a sudden stop; foreign investors unexpectedly stop lending to the country in 1995.

Consumers

The country is populated by a continuum of identical consumers, \( n_t \), whose growth is exogenous and equal to the growth of the Mexican adult-equivalent population. We differentiate the total population from the working age population; we denote the working age population \( \ell_t \) and match it to the evolution of people aged 15-64 in Mexico. Consumers derive utility from consuming tradable goods, \( c_T \), and nontradable goods, \( c_X \). The consumers inelastically supply labor at wage rate, \( w_t \), invest in capital, and borrow and lend internationally when the economy is open to foreign capital. The consumers’ problem can be written
\[
\max_{\{c_t, i_t, b_t\}} \sum_{t=0}^{\infty} \beta^t \left( \left\{ \begin{array}{l}
\varepsilon \left( \frac{c_{t+1}}{n_i} \right)^\rho + \left( 1 - \varepsilon \right) \left( \frac{c_{t+1}}{n_i} \right)^\rho \end{array} \right\} - 1 \right) / \psi
\]

s.t. \( p_T c_t + p_N c_{N_t} + q_D i_{D_t} + q_N i_{N_t} + b_{t+1} = \ell_i + (1 + r_t) b_t + r_{D_t} k_{D_t} + r_{N_t} k_{N_t} + T_t \)

\[
k_{j,t+1} = (1 - \delta) k_{j,t} + \phi(i_{j,t}, k_{j,t}) k_{j,t} \quad j = D, N
\]

\[
c_{t,D} \geq 0, \quad c_{N_t} \geq 0, \quad b_t \geq -A
\]

\[
b_0, k_{D_0}, k_{N_0} \text{ given.}
\]

When the economy is closed to foreign capital, the interest rate \( r_t \) is endogenously determined by domestic conditions. When the economy is open to foreign capital the world interest rate is exogenously given as \( r^*_t \) which is constant through time. Bonds are denominated in units of the imported good, which implies that a real devaluation debt more expensive in terms of domestically produced goods. Consumers augment the capital stocks in the domestic tradable goods sector, \( k_D \), and the nontradable good sector, \( k_N \), through investment \( i_D \) and \( i_N \). As in Lucas and Prescott (1971), adjusting the capital stock is costly. The investment function is

\[
\phi(k_{j,t}, i_{j,t}) = \frac{\delta^{1-\eta}}{\eta} \left( \frac{i_{j,t}}{k_{j,t}} \right)^\eta - \frac{(1-\eta)}{\eta} \delta \quad j = D, N,
\]

where \( \eta < 1 \) implies a convex cost of adjusting the capital stocks. Consumers rent capital to domestic firms at rate \( r_{i,t} \).

**Production**

There are 5 types of goods in the model: a domestically produced tradable good, \( y_D \), an imported good, \( m \), a composite tradable good, \( y_T \), a domestically produced nontradable good, \( y_N \), and an investment good, \( y_I \). All goods are sold in perfectly competitive markets.

The domestic tradable good and the nontradable good are produced using capital, labor, the composite tradable good, and the nontradable good. The maximization problem solved by the producer of the domestic tradable good can be written...
\[
\max \sum_{t=1}^{\infty} \beta^t \frac{U^c_t p_{t,0}}{U_0 p_t} \left[ p_{D_t} y_{D_t} - p_{D_t} \Theta_D (\ell_{D_t}, \ell_{D_{t-1}}) \ell_{D_{t-1}} - r_{D_t} k_{D_t} - w_t \ell_{D_t} \right]
\]

s.t. \( y_{D_t} = \min \left[ z_{TD_t} / a_{TD}, z_{ND_t} / a_{ND}, A_D k_{D \tau_t}^{\alpha_D} \ell_{D\tau_t}^{1 - \alpha_D} \right] \)

where \( z_{TD} \) and \( z_{ND} \) are, respectively, the amounts of the composite tradable and nontradable good used in production of the domestic tradable good and \( a_{TD} \) and \( a_{ND} \) are the associated share parameters. A firm gives up some output if it chooses to adjust employment. The adjustment function takes the quadratic form consistent with Sargent (1978) and Cooper and Willis (2003) that has been successful at matching aggregate employment volatilities,

\[
\Theta_D (\ell_{D_t}, \ell_{D_{t-1}}) = \theta_D \left( \frac{\ell_{D_t}}{\ell_{D_{t-1}}} - 1 \right)^2.
\] (10)

Nonconvex models of labor adjustment, as in Cooper, Haltiwanger and Willis (2004), have been shown to be important for matching firm level observations on employment, but our focus on aggregate quantities justifies the more tractable quadratic form. The firm level decisions being made during a sudden stop are certainly interesting, but we leave those to future research.

Analogously, the producer of the nontradable good solves

\[
\max \sum_{t=1}^{\infty} \beta^t \frac{U^c_t p_{t,0}}{U_0 p_t} \left[ p_{N_t} y_{N_t} - p_{N_t} \Theta_N (\ell_{N_t}, \ell_{N_{t-1}}) \ell_{N_{t-1}} - r_{N_t} k_{N_t} - w_t \ell_{N_t} \right]
\]

s.t. \( y_{N_t} = \min \left[ z_{TN_t} / a_{TN}, z_{NN_t} / a_{NN}, A_N k_{N \tau_t}^{\alpha_N} \ell_{N\tau_t}^{1 - \alpha_N} \right] \)

\[
\Theta_N (\ell_{N_t}, \ell_{N_{t-1}}) = \theta_N \left( \frac{\ell_{N_t}}{\ell_{N_{t-1}}} - 1 \right)^2.
\]

The composite tradable good is made up of the imported tradable good and the domestically produced tradable good using a standard Armington Aggregator production function. The composite tradable good producer solves

\[
\max p_{N_t} y_{N_t} - p_{D_t} x_{D_t} - (1 + \tau_t) m_i
\]

s.t. \( y_{N_t} = M \left( \mu x_{N_t}^{\gamma} + (1 - \mu) m_t^{\gamma} \right)^{1/\gamma} \).
The parameter $\mu$ governs the share of imports in production and the elasticity of substitution between domestically produced goods and imports is $1/(1-\zeta)$. Note that the numeraire in this model is the imported good, making it’s f.o.b. price unity, but the imports are subject to domestically levied tariffs, $\tau$. The price of a unit of the composite tradable good has the usual form,

$$p_{Ti} = \frac{1}{M} \left( \mu^{1-\zeta} p_{Di}^{1-\zeta} + (1-\mu)^{1-\zeta} (1+\tau)^{1-\zeta} \right)^{\frac{1-\zeta}{\zeta}}. \quad (11)$$

Investment goods are produced using the composite tradable good and the nontradable good using a Cobb-Douglas production function. The investment good producing firm’s problem can be written

$$\max q, y_{\ell} - p_{Ni} z_{Ni} - p_{Ti} z_{Ti}$$

$$y_{\ell} = Gz_{Ti}^{\gamma} z_{Ni}^{1-\gamma},$$

where $q$ is the price of the investment good.

Lastly, foreign demand for the domestically produced tradable good is

$$x_{ Fi} = \left( (1+\tau_{Fi}) p_{Di} \right)^{-\frac{1}{1-\zeta}},$$

where $\tau_{Fi}$ is the tariff imposed by the rest of the world on imports. This export demand function implies that the rest of the world has a composite tradable production function that is also of the Armington form and has the same elasticity of substitution between imports and domestic goods.

**Market Clearing**

Market clearing in the domestic tradable good market requires

$$x_{Di} + x_{Fi} = y_{Di} - \Theta_D \left( \ell_{Di}, \ell_{Di-1} \right).$$

Market clearing in the nontradable good market requires

$$c_{Ni} + z_{Ni} + z_{NDi} + z_{NNDi} = y_{Ni} - \Theta_N \left( \ell_{Ni}, \ell_{Ni-1} \right).$$

Market clearing in the composite tradable good market requires

$$c_{Ti} + z_{Ti} + z_{TDi} + z_{TNDi} = y_{Ti}.$$
Market clearing in the investment good market requires
\[ i_D + i_N = y_f. \]
Balance of payments in this economy requires
\[ m_t + b_{t+1} = p_{D,t} x_f + (1 + r^*_f) b_t, \]
which implies balanced trade when the economy is closed to foreign borrowing \((b_t = 0)\).

5. Calibration

We assign values to the model’s parameters so that the model replicates key features of the Mexican economy. The multisector nature of this model requires data on the interactions between the tradable and nontradable sectors in the economy. We construct an input-output matrix for Mexico in 1989 to summarize these interactions, as shown in Table 2. Unless otherwise stated, we calibrate the model to 1989 data, so we drop the \( t \) subscript in what follows. We take the United States to stand in for the rest of the world; in 1994 the U.S. accounted for 69 percent of total merchandise imports to Mexico and 84 percent of Mexico’s exports went to the United States. The U.S. was Mexico’s largest lender as well, making up 62 percent of foreign direct investment into Mexico in 1994. We summarize the baseline model’s calibration in Table 4.

Production Parameters

The parameters in the production functions for the domestic tradable and nontradable are computed from the input-output matrix in Table 2. The intermediate good share parameters are set to match the share of intermediate goods used in the input-output matrix. For example, to compute \( a_{TD} \), the share of the tradable good used in the production of the domestic tradable good, we take the amount of the tradable good used as an input to tradable good production and divide it by the gross output (value added plus intermediate consumption) of the tradable good sector,
\[ a_{TD} = z_{TD} / y_D. \]
Given the Cobb-Douglas form of the capital and labor aggregate used in production, the parameters \( \alpha_D \) and \( \alpha_N \) are calculated as the return to capital in the sector divided by value added in the sector. The scale parameters in the capital labor aggregate are computed as
\[ A_j = \frac{y_j}{k_j^{\alpha_j} \ell_j^{1-\alpha_j}}, \quad j = D, N. \]

The cost of adjusting the labor used in the tradable and nontradable good sectors requires specifying parameters \( \theta_D \) and \( \theta_N \), as can be seen in equation (10). We restrict the two parameters to be equal and choose the value so that the shift in labor into the tradable good sector is 6.77 percent, as it is in the detrended data in Figure 10.

Calibrating the investment good technology requires choosing the share parameter, \( \gamma \), and the scale parameter, \( \Gamma \). The first order conditions from the investment firm’s problem can be manipulated to yield the usual formula for the share of tradable goods in investment good production,

\[ \gamma = \frac{P_I z_I}{q_I y_I}. \quad (12) \]

The numerator of the right hand side of (12) is the use of tradable goods in investment and the denominator is the total gross output of the investment sector. These values can be read directly from the input-output matrix in Table 2.

Calibrating the Armington Aggregator, is straightforward once the elasticity of substitution between imports and domestic tradables, \( \frac{1}{1-\zeta} \), is chosen. As discussed in Ruhl (2003), there is debate over this elasticity as business cycle models tend to imply low elasticities, while analysis of trade policy episodes suggests elasticities much higher. We choose \( \zeta = 0.5 \), implying an elasticity of 2.0 and discuss the sensitivity of our results to this parameter choice below. Given a value of \( \zeta \) the first order conditions from the firm’s problem yield

\[ \frac{\mu}{1-\mu} = \frac{p_D}{1+\tau} \left( \frac{m}{x_D} \right)^{\zeta-1}. \]

With prices normalized to 1 in the base year, \( \mu \) can be calculated using data on the value of imports and the value of domestically produced tradable goods used in producing tradable goods. The scale parameter, \( M \), is chosen so that the price of the composite tradable good in (11) is unity. The export demand function scale parameter, \( D \), is chosen so that year 0 exports in the model are the same as exports reported in the 1989 input output matrix.
**Consumer Parameters**

We set the period in our model to be one year, and choose the discount factor, $\beta$, to be consistent with annual real interest rates in the United States, our proxy for the rest of the world. We choose the world interest rate, $r^*$, to be 5.0 percent per year which implies $\beta = 0.95$. Following Kravis, Heston and Summers (1982) and Stockman and Tesar (1995), we set $\rho = -1$ so that the elasticity of substitution between tradable and nontradable goods in consumption is 0.5. The parameter $\varepsilon$ governs the share of tradable and nontradable goods in consumption. The first order conditions from the consumer's problem yields the familiar condition,

$$\frac{\varepsilon}{1 - \varepsilon} = \frac{p_T}{p_N} \left( \frac{c_T}{c_N} \right)^{1 - \rho}.$$  

Normalizing the base year prices to be 1, the value of $\varepsilon$ can be computed using the final consumption of tradable and nontradable goods from the input-output matrix in Table 3. The risk aversion parameter, $\psi$, is set to $-1$ so that the intertemporal elasticity of substitution is 0.5. We choose the rate of depreciation, $\delta$, to be 6 percent per year. The curvature parameter in the investment function, (9), is set to 0.99 which imposes almost no cost on adjusting the capital stock. The slight curvature in the investment function is used only to keep our computational algorithm from choosing negative investments during a sudden stop.

**6. Baseline Model Results**

Before subjecting the model to a sudden stop, it is useful to briefly study the model under open capital markets. Without the sudden stop, the only exogenous variables in the model are the number of working aged and adult equivalent persons and the initial capital stocks. The initial capital stocks are set to their 1989 values and the population growth rates are taken from the data. When Mexico opens to capital flows its stock of capital is much lower than it will be in the steady state. After opening to foreign borrowing the agents run trade deficits and accumulate capital until a steady state is reached, as is shown in Figure 10. Essentially, the dynamics are those of the neoclassical growth model in a small open
economy. It is important to stress that we take no other variables – including TFP – as exogenous to the model.

**Sudden Stop**

To solve for the model's equilibrium when a sudden stop occurs, we first compute the equilibrium of the model when Mexico opens to international capital flows and expects them to stay open, as in the previous section. Using the equilibrium values for the capital and labor stocks in 1994 we resolve the model from 1994 onward, imposing that no further borrowing is possible in 1995 and 1996. Solving the model in this way assumes that agents do not foresee the sudden stop, but have perfect foresight over the length of the sudden stop and the path of world interest rates.

When the sudden stop occurs, tradable goods, which were being financed by a trade deficit, are now relatively scarce and the price of tradable goods relative to nontradable goods increases. Since this sudden stop is unforeseen, the economy does not have capital and labor properly allocated across the two sectors. Labor and capital are costly to move, so agents choose to only partially adjust to the change. The results of this model are summarized in Figure 11.

Figure 11(a) plots the trade balance, as a fraction of GDP, in both the model and the data. As in all of the graphs that follow the data are plotted as a solid line and the model's variable is plotted as a dashed line. The model does a good job of reproducing the shape of trade balance, but is too volatile. The trade balance goes negative when the country opens to capital flows and sharply reverses when the sudden stop occurs. As the sudden stop ends, the trade balance returns to a deficit in both the model and the data. Figure 11(b) plots the detrended movements in the share of labor that is used in the tradable good sector. The parameter in the labor adjustment function was chosen so that the magnitude of the shift of labor is the same in the model as in the data, but the shape and timing of the shift are determined by the model. In the model the shift of labor into the tradable good sector happens quicker than in the data, peaking in 1996 compared to 2000 in the data, but overall the model can account for reallocation of labor following a sudden stop.
Figures 11(c) and 11(d) display the model’s predictions for prices compared with the data. Figure 11(c) plots the log real exchange rate. The model does a good job of accounting for the appreciation of the real exchange rate when Mexico opens to capital flows and then displays the same sharp depreciation when the economy is subjected to a sudden stop. As the sudden stop ends, the real exchange rate reappreciates, as in the data. When the model is subjected to a sudden stop, the price of tradable goods relative to nontradable goods increases, which can be seen in Figure 11(d), which displays the (bilateral) relative price of nontradable goods to tradable goods, $rer^N$. Again, we see the model does a good job of accounting for the appreciation of the relative price of nontradable goods as the economy opens and displays a sharp depreciation during the sudden stop. The model’s relative prices are more volatile than the data, though.

Lastly, Figures 11(g) and 11(h) display the aggregate quantities that are frequently discussed when studying sudden stop episodes. In Figure 11(g) we plot GDP per working age person from the data and the model. Though the model’s GDP per working age person does not display much growth during the sudden stop, it does not reproduce the fall in GDP that we see in the data. This result implies that the real costs associated with moving labor across the two sectors are small in this calibrated version of the model. Such a small drop in GDP implies that our computed TFP falls very little as well. As can be seen in Figure 11(h), the one-half percent fall in TFP that accompanies the sudden stop in our model is small compared to the fall in TFP. As we noted in section 3, though the terms of trade cannot have a first order impact on real GDP, large enough changes can have a significant second order impact. The terms of trade increase almost 22 percent (more than twice that in the Mexican data plotted in Figure 9) following the sudden stop in the model. The fact that GDP and TFP decline so little implies that the second order effects in a calibrated model are small.

7. Country Risk Premia

As can be seen in Figure 12, the interest rate at which Mexico could borrow declined over a period of 3 or 4 years following the apertura before reaching a value near the world interest rate. These higher interest rates are usually regarded as country specific risk premia and the
gradual elimination of these premia reflect the idea that Mexico gradually gained credibility as it instituted structural changes. In the baseline model we assumed that interest rates immediately fell to the world interest rate following the apertura and the sudden stop. Since we do not model the structural changes taking place in the Mexican economy, we take as exogenous a time varying risk premia on the rate at which Mexico can borrow from the rest of the world. In the notation of our model, this implies that

$$r_t^* = r^* + \sigma_t^{\text{mex}},$$

where $\sigma_t^{\text{mex}}$ is the risk premium paid in period $t$. We choose the risk premia so that the interest rates we feed the model (when the country is open to capital flows) are similar to the ones in the data. Figure 12 plots the interest rates in the baseline model, the risk premia model and the data.

We plot the variables from the model with risk premia in Figure 13. When the interest rate on Mexican debt is decreased as in the data, the model performs much better, particularly as Mexico opens to capital inflows. Gradually lowering interest rates eases Mexico into the foreign capital market, as seen by the evolution of the trade balance in Figure 13(a). Adding this feature to the model also greatly improves the model’s ability to account for the behavior of the real exchange rate. As can be seen in Figure 13(c), the real exchange rate in the model appreciates much like the data as Mexico opens its capital markets. The real depreciation following the sudden stop is now almost exactly as in the data and the reappreciation after the sudden stop also fits the data well.

The relative price of tradables to nontradables in the model also looks more like those in the data. As can be seen in Figure 13(d), $rer^N$ no longer appreciates sharply as the economy opens to capital. The depreciation during the sudden stop is also smaller than it was in the baseline model, though it is still about twice as large as that in the data. Though the risk premia allow the model to account for the prices and trade balance, the model still cannot generate the decline in TFP and GDP we see in the data.
8. Foreseen “Sudden” Stop

Although interest rates, as seen in Figure 2, provide strong evidence that the sudden stop in Mexico was an unforeseen event, in this section we examine the predictions of the model when the sudden stop is known one year in advance. To do so, we solve the model for the equilibrium in which there is no sudden stop, as in the baseline and risk premia models. We then resolve the model starting in 1993 imposing that no further borrowing is allowed in 1995 and 1996. This information structure assumes that agents have perfect foresight over the oncoming sudden stop, but have 1 year in which to adjust for it.

We present the results from the “no surprise” model in Figure 14. In each subfigure we plot the “no surprise model,” the “surprise model,” which is the risk premia model, and the data. In Figure 14(a) we see that when agents have a year’s time to adjust for the sudden stop they cutback on their borrowing early, which we do not see in the data. The same pattern holds for the shift of labor across sectors in 14(b) and the movements in relative prices in 14(c) and 14(d). The intuition for the result is simple: agents foresee the coming sudden stop and realize that the convex nature of adjustment costs makes it optimal to begin adjusting early to minimize the size of the adjustments in any period. The outcome of this foresight is that all of the features in the data that turn sharply at the onset of the sudden stop now come one period earlier. As is clear from the figures, allowing for the sudden stop to be anticipated worsens the model’s ability to match the data.

9. Conclusion

In this paper we study sudden stops from a relatively new perspective: we focus on the effects of sudden stops on tradable goods sectors relative to nontradable good sectors. Looking at the data in this way we find that the nontradable good sector suffers a large decline in output and a slower recovery from the sudden stop. We document how resources are transferred from the nontradables sector to the tradables sector and how the relative price of the two goods changes. These facts provide insights into how sudden stops may move through the economy; namely, through relative price effects.
We constructed a simple model with tradable and nontradable goods and calibrated it to Mexico in 1989. When we subject the model to a sudden stop – and nothing else – we find the model can account for 116 percent of the depreciation in real exchange rates and 113 percent of the trade balance reversal. The model also does a good job of capturing the output shift from the nontradables sector to the tradables sector. Though the simple model can account for the behavior of the disaggregated economy, the model cannot account for the changes in aggregate TFP and GDP. Stronger frictions that decrease output and productivity are need. The model presented here provides a simple framework in which these frictions can be added in future work.
Table 1

Average growth rates in Mexico (percent)

<table>
<thead>
<tr>
<th>Commodity</th>
<th>Output per working age person $Y_t/N_t$</th>
<th>TFP factor $A_t^{1/\alpha}$</th>
<th>Capital factor $(K_t/Y_t)^{\alpha}$</th>
<th>Labor factor $L_t/N_t$</th>
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<tbody>
<tr>
<td>1990-1994</td>
<td>0.715</td>
<td>0.449</td>
<td>0.278</td>
<td>-0.011</td>
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<tr>
<td>1995-2004</td>
<td>1.523</td>
<td>1.307</td>
<td>-0.069</td>
<td>0.285</td>
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</table>

Table 2

<table>
<thead>
<tr>
<th>Commodity</th>
<th>Input</th>
<th>Final Demand</th>
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<tbody>
<tr>
<td></td>
<td>Tradable</td>
<td>Nontradable</td>
</tr>
<tr>
<td>Tradable</td>
<td>27.24</td>
<td>9.02</td>
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<tr>
<td>Nontradable</td>
<td>9.76</td>
<td>19.42</td>
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<tr>
<td>Total intermediate consumption</td>
<td>36.00</td>
<td>28.44</td>
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<tr>
<td>Employee compensation</td>
<td>21.29</td>
<td>43.71</td>
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<tr>
<td>Return to capital</td>
<td>13.58</td>
<td>21.42</td>
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<tr>
<td>Value added</td>
<td>34.87</td>
<td>65.13</td>
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<tr>
<td>Imports</td>
<td>14.98</td>
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<tr>
<td>Tariffs</td>
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<tr>
<td>Total Gross Output</td>
<td>86.85</td>
<td>93.57</td>
</tr>
<tr>
<td>Parameter</td>
<td>Value</td>
<td>Statistic</td>
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<tr>
<td>-----------</td>
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<tr>
<td><strong>Consumer Parameters</strong></td>
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<tr>
<td>$\beta$</td>
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<td>real world interest rate, in percent</td>
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<td>$\varepsilon$</td>
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<td>tradable good share in consumption</td>
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<td>$\rho$</td>
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<td>elasticity of subs. tradable and nontradable goods in consumption</td>
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<td>$\psi$</td>
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<td>intertemporal elasticity of substitution</td>
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<td>$\delta$</td>
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<td>depreciation</td>
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<td><strong>Producer Parameters</strong></td>
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<td>$a_{ID}$</td>
<td>0.38</td>
<td>share of tradable inputs in domestic tradable production</td>
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<td>$a_{NE}$</td>
<td>0.14</td>
<td>share of nontradable inputs in domestic tradable production</td>
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<td>$a_{IN}$</td>
<td>0.10</td>
<td>share of tradable inputs in domestic nontradable production</td>
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<td>$a_{NN}$</td>
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<td>$A_N$</td>
<td>1.62</td>
<td>scale production to nontradable value added in base year</td>
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<td>$A_D$</td>
<td>2.19</td>
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<td>$\alpha_N$</td>
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<td>capital’s share of nontradable good income</td>
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<tr>
<td>$\alpha_D$</td>
<td>0.39</td>
<td>capital’s share of domestic tradable good income</td>
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<td>$\theta_N, \theta_D$</td>
<td>5.01</td>
<td>change in tradable goods share of total employment, in percent</td>
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<td><strong>Trade Parameters</strong></td>
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<td>$M$</td>
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<td>normalize tradable composite price</td>
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<tr>
<td>$\mu$</td>
<td>0.66</td>
<td>ratio of domestic tradable good to imports</td>
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<td>$\zeta$</td>
<td>0.50</td>
<td>elasticity of substitution between domestic tradable and imports</td>
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<tr>
<td>$D$</td>
<td>14.98</td>
<td>scale export demand to equal exports in base year</td>
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References


Figure 1

Mexico: external financial flows

Figure 2

Mexico: interest rates (dollar denominated debt)
Figure 5
Mexico: sectoral value added

Figure 6
Mexico: output and TFP
Figure 9
Mexico: terms of trade

Figure 10
Capital stock
Figure 12

Mexico: interest rates

solid line = data
solid line = base model
broken line = risk premia model
Figure 13

Mexico: trade balance

Mexico: traded good employment, detrended

Mexico: real exchange rates

Mexico: nontraded/traded good prices

Mexico: sectoral value added

Mexico: sectoral value added

Mexico: GDP per working age person

Mexico: Total Factor Productivity
Figure 14

Mexico: trade balance

Mexico: traded good employment, detrended

Mexico: real exchange rates

Mexico: nontraded/traded good prices

Mexico: sectoral value added

Mexico: GDP per working age person

Mexico: Total Factor Productivity