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Essays on Exchange Rates and Prices

A dissertation submitted in partial satisfaction
of the requirements for the degree
Doctor of Philosophy in Economics

by

Federico Grinberg

2015

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Abstract of the Dissertation

Essays on Exchange Rates and Prices

by

Federico Grinberg

Doctor of Philosophy in Economics

University of California, Los Angeles, 2015

Professor Ariel Tomas Burstein, Chair

In these essays, I examine exchange rates and prices in the context of a small open economy.

My first chapter is an empirical study of the behavior of nominal and real exchange rates in Mexico in the last 20 years. I present facts for exchange rate pass-through to prices, using both aggregate prices and CPI micro-data. I structure the evidence in two sets of facts that highlight the importance of real shocks and monetary regime in explaining changing patterns of aggregate prices and the CPI micro data. The first set shows that the nominal and real exchange rates have a strong co-movement at short and medium run horizons. Second, real exchange rate movements are mostly explained by changes in relative prices between 'at the dock' prices and retail prices. Third, there is a large nominal exchange rate shock, the reason behind the incomplete exchange rate pass-through and the increase in the real exchange rate is not a slow price adjustment of goods that are actually traded, but a less-than-proportional adjustment of retail prices. The second set of facts analyzes the behavior of individual prices used to compute the CPI. First, there is a positive correlation between the fraction of prices that adjust per period (i.e., the frequency of price adjustment) and the level of inflation. Second, this correlation and the role of these changes in the fraction of adjusting prices in inflation is mostly explained by the exchange rate pass through after the 1994 large currency devaluation episode.

In the second chapter I study the role of nominal price rigidities in accounting for low CPI inflation after large currency depreciations. Using a small open economy model

with menu-cost nominal frictions calibrated to micro data from Mexico's Consumer Price Index, I find that in episodes of large depreciations, the effects of nominal rigidities in retail prices are quantitatively small and short-lived. The incomplete exchange rate pass-through to consumer prices is largely a result of a fall in real wages caused by negative real shocks and nominal stickiness in wages

In my third chapter I present a model of a small open economy subject both to a collateral constraint and downward rigidity in wages. These constraints will interact generating external shocks amplification and, in the presence of a currency peg regime, it also generates unemployment. This can be seen as an example that captures two main themes for small open economies: real exchange rigidities and consumption volatility. The contributions of my chapter are twofold. First, I show how financial amplification effects caused by 'over borrowing can generate high unemployment rates without resorting to extreme wage rigidity as in Schmitt-Grohé and Uribe (2011). Second, it shows that the exchange rate policy faces a tradeoff between unemployment and tradable consumption when the collateral constraint binds. These two insights reflect the tradeoff of maintaining a currency peg during a crises: higher unemployment or an amplification of financial amplification of shocks.

The dissertation of Federico Grinberg is approved.

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2015

To my wife Julia,

to my mom, Alicia, and to Julio,

There are no words to express my gratitude to all of them.

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CHAPTER 1

The Exchange Rate and Prices' Margins of Adjustment. Six Facts for Mexico.

1.1 Introduction

This chapter presents evidence on the relationship between the nominal exchange rate, inflation and the changes in the pattern of prices' setting and connects this to the behavior of the real exchange rate. It exploits store-level data used to construct Mexico's Consumer Price Index. The micro data goes from April 1994 to December 2010, covering a period of high inflation and unanchored inflation expectations (1995-1999) and a period during which the Mexican Central Bank implemented a successful inflation targeting regime (2000-2010). The objective is to jointly analyze the dynamics of the price setting process and the behavior of the real exchange rate.

The data also encompasses two large nominal exchange depreciations. At the end of 1994 there was a massive run against the peso that triggered the 'Tequila' crisis. In the first six months of 1995 the nominal exchange rate had devalued by more than 90%. This made inflation to go from low and stable levels to a peak of more than than 41% in 1995.

Since the end of the 1990s, Mexico has experienced low and stable inflation rates well below the 10%.[1] In this context, the 2008 international financial crisis triggered a capital outflow and trade collapse that depreciated the nominal exchange rate by more than 30% in six months. However, in this episode consumer prices reacted much less and inflation in 2009 was only 6%.

Together with these considerable fluctuations in the nominal exchange rate and different responses of consumer prices, here I document the role of changes in individual

[1]Since 2002, Mexico's Central Bank implemented an inflation targeting regime and set a 3% annual inflation target. See Capistrán et al. (2012).

price setting. In particular, I show that changes in these patterns of individual price adjustment are closely associated to a large and permanent nominal exchange rate shock in the 'Tequila' crisis in 1994/1995. Six months after the devaluation, roughly half of the increase in inflation is explained by an increase in how many prices changed per month. Thus, while this monthly fraction of adjusting prices is very stable over time, after this large nominal exchange shock, an important part of the nominal exchange rate pass-through is due to the increase in how many prices are changing per period. Thus, these changes in pricing plans can explain an important part of the variation in the real exchange rate.[2]

A contribution of this chapter is that it covers a period with high inflation and the following disinflation from 1994 to 2002 (thus overlapping with the evidence provided by Gagnon (2009)) and a period with low and stable inflation (thus overlapping with Ysusi (2010) and Cortés Espada et al. (2012)).

Here I present two sets of facts for Mexico. The first one concerns aggregate prices indexes and exchange rates.

First, I show that the nominal and real exchange rates have a strong co-movement at short and medium run horizons and that this co-movement has became stronger as inflation has been lower and more stable. Also, the persistence of the real exchange rate has decreased. Second, I show that the role of relative price changes between retail tradable and non tradable goods in explaining changes in the real exchange rate has become smaller over over time, and that real exchange rate movements are mostly explained by changes in relative prices between 'at the dock' prices and retail prices. Third, I show that when there is a large nominal exchange rate shock, the reason behind the incomplete exchange rate pass-through and the increase in the real exchange rate is not a slow price adjustment of goods that are actually traded, but a less-than-proportional adjustment of retail prices.[3]

The second set of facts analyzes the behavior of individual prices used to compute the CPI. First, there is a positive correlation between the fraction of prices that adjust per period (i.e., the frequency of price adjustment) and the level of inflation, as found by

[2]After the 2008 depreciation, there was few changes in the fraction of adjusting prices, so in this case the change in pricing plans explains little of the real exchange rate changes.

[3]This is in line with the evidence provided by Burstein et al. (2005).

Gagnon (2009). Second, this correlation and the role of these changes in the fraction of adjusting prices in inflation is mostly explained by the exchange rate pass through after the 1994 large currency devaluation episode. While both the incomplete exchange rate pass-through in large depreciations and the elasticity of the frequency of price adjustment to the inflation environment have been documented in the literature, a contribution of this chapter is to study both phenomena together. There is a large and well developed literature comparing pricing models. While many papers use micro-data for periods during low aggregate volatility and low inflation (Klenow and Kryvtsov (2008), Nakamura and Steinsson (2008), Klenow and Malin (2010)), few papers analyze environments with high inflation or large shocks. Karadi and Reiff (2012) is a closely related paper as it studies the asymmetry of large positive and negative shocks when there is trend inflation while Alvarez et al. (2011) study the changing environment of Argentina's inflation in the 80s and 90s.

Several studies have documented the behavior of prices that underlie Mexico's CPI. Gagnon (2009) and Gagnon et al. (2012) study Mexico's high inflation period. Ysusi (2010) and Cortés Espada et al. (2012) study the period starting after 2002.

Regarding the relation exchange rates and prices, Burstein and Gopinath (2014) provides a comprehensive view on the state of the literature. Devereux and Engel (2003), Chari et al. (2002), Nakamura and Zerom (2010) study the degree and sources of incomplete pass through, while the role of relative price changes has been studied by Engel (1999), Mendoza (2000) and Burstein et al. (2006). Large devaluations are generally associated with large declines in the real exchange rate (RER). Burstein et al. (2002) and Burstein et al. (2005) study the empirical evidence on large devaluations and show that the primary force causing this declines is the slow adjustment in the price of non-tradable goods and services and not the slow adjustment in the price of tradable goods when these are measured at the border instead at the retail level. Capistrán et al. (2012) and Cortes Espada (2013) study the pass through from the exchange rate to price for Mexico and find that it has became smaller over time.

The paper is structured as follows. First, I describe the consumer prices' micro data. Second, I present three stylized facts that link Mexico's Real exchange rates and price indexes. Third, I introduce the methodology used to analyze the CPI micro data and

present two facts Fourth, I present conclusions.

1.2 Mexico's Consumer Price Index

Mexico's Consumer Price Index is constructed with a continuum collection of prices of specific items that belong to homogeneous product categories (*genéricos*). The number and classification of these categories varies from basket to basket. Gagnon (2009) Online Appendix summarizes those changes in the period of analysis.

Each month around 235000 individual prices are collected to calculate price variations in the categories. Each category has a different weight in the CPI and these weights are determined by expenditure shares in *Encuesta Nacional de Ingreso y Gasto de los Hogares (ENIGH)*, a household expenditure survey done by Mexican statistical agency (INEGI). The geographic representation of the index is ensured by including 46 cities. The ENIGH was updated in 2002 so the weights used for the 2002-2010 differ from the 1994-2010 period.

The micro data Mexico's Central Bank collects price quotes weekly or bi-weekly (depending on the product) and publishes monthly averages in *Diario Oficial de la Federación*. These are monthly averages of individual items' prices in a specific outlet, city, and good category. The price micro-data contains average monthly prices for more than 1,000 goods in a sample of 46 cities from April 1994 to December 2009. Each of these prices belongs to one group or 'Entry Level Item' (ELI) that corresponds to the highest disaggregation level used in the computation of the CPI. The data also contain the weights for each of these groups.

The data has certain important features that must be discussed. First, *Diario Oficial de la Federación* does not publish individual quotes, but only monthly averages of these prices. For the most volatile items (mostly agricultural goods), INEGI collects up to four prices per month. For other categories such as fresh food, it collects bi-weekly quotes. To account for the monthly averaging, individual price trajectories were filtered as in Gagnon (2009).[4]

[4]I refer the reader to Gagnon (2009) for more details about the treatment of the data.

Second, sales cannot be identified in the data set. Discounts are taken into account when recording prices, but these are not flagged in *Diario Oficial de la Federación*. This should be taken into account when interpreting results as the literature has documented that a significant fraction of price changes are temporary sales.[5]

Third, in order to reconcile the basket used before and after 1995, some ELIs are dropped. Several goods and services categories, prices are administered or they are recorded at each location at a very low frequency — i.e. they do not reflect market conditions. I follow the standard practice of removing these categories from the sample. For example, gasoline prices were prices administered by the Government, education is only adjusted twice a year when tuition is due, and rent is measured at each location every 6 months.Following Cortés Espada et al. (2012) and Gagnon (2009) I drop rent, homeowners' imputed rent, gasoline, education, utilities and other administered prices. This leaves 54.11% of the CPI basket between January 1994 and June 2002 and 65.9% of the basket between July 2002 and December 2010. Table 1.1 summarizes the sample coverage.

Aggregate prices Inflation is computed as

$$\pi_{r,t} = \sum_{i \in \Upsilon_{r,t}} \alpha_{i,r,t} \Delta p_{i,r,t},$$

where $\pi_{r,t}$ is the monthly inflation rate for month t and sector r, $\Upsilon_{r,t}$ is the set of prices observed in that month that belong to that sector, $\alpha_{i,r,t}$ is the CPI ELI's weight that corresponds to item i in sector r, and $\Delta p_{i,r,t}$ is the log change in item i's price relative to the previous month. These sector-specific inflation rates are compounded to calculate sector price indexes, from which cumulative inflation rates are computed.

Note that these computed price indexes are not strictly comparable with the Laspeyres price indexes reported by statistical agencies. Thus, the values that I report may differ from the official ones. This is the case for high inflation rates, for which I report smaller values than the ones implied by the official CPI index. For notational simplicity, if the sector r is not specified, π_t should be assumed to be the weighted average for all goods

[5]Nakamura and Steinsson (2008) show that this is an important feature of the CPI micro data for the US.

and services in the CPI basket considered here.

1.3 Exchange rates and price indexes: aggregate facts

In this section I present three stylized facts on the relation between aggregate price indexes and exchange rates. The CPI-based real exchange rate (RER^{cpi}) is defined as

$$RER_t^{cpi} = \frac{E_t P_t^*}{P_t},$$

where E_t is the nominal exchange rate, P_t^* is the trade partner's price index and P_t is the domestic price index.[6]

The change in the bilateral RER-CPI can be defined as the log change in the ratio of the CPI in the two countries (here, Mexico and the US) measured in a common currency:

$$\Delta rer_t^{cpi} = \Delta e_t + \Delta cpi_t^* - \Delta cpi_t,$$

where Δx_t represents log changes of variable $X_t = \{RER_t, E_t, P_t^*, P_t\}$ in time t relative to time $t-1$.

Aggregate RER, persistence and volatility

The first empirical finding is that the real exchange rate for consumer prices closely co-moves with the nominal exchange rate at short and medium horizons. This co-movement is stronger as inflation has been lower and more stable. Also, the persistence of the RER deviations from its trend has also decreased.

Figure 1.1 shows the cumulative log changes in NER and RER-CPI from 1981 to 2010. Visual inspection shows that both variables co-move and that this co-movement has become stronger in the latter years.

Table 1.2 presents summary statistics for the relationship between RER and NER.

[6] I will only focus on the bilateral exchange rate with the US -taking it as 'the rest of the World'- because it represents by far the most important trade partner for Mexico. Moreover, trade weighted nominal and real exchange rates have a correlation above 0.95 with the bilateral versions I will be referring to.

There I show the ratio of standard deviations and correlations between these variables based on for-quarter log changes.. As a benchmark, I present the same statistics for the US as calculated by Burstein and Gopinath (2014) for the period 1975-2013. Results show that changes in NER and RER are roughly as large and that their correlation is high. Compared to 1981-1994, both statistics have increased over time. Computing these statistics in the sub-sample 2002-2014 corroborates that this correlation has increased while the relative volatilities of RER and NER decreased over time. Table 1.2 also shows that RER and NER have become less volatile in the last period.

Following Steinsson (2008) and Burstein and Gopinath (2014), I estimate the persistence of the CPI-based RER with an AR(5) with constant and no time trend:

$$rer_t = \mu + \alpha rer_{t-1} + \sum_{j=1}^{p} \psi_j \Delta rer_{t-j} + \epsilon_t \tag{1.1}$$

Given that RER has a high persistence, I use the grid bootstrap procedure in Hansen (1999) to obtain a median unbiased estimate of α, which is the sum of the AR coefficients. The other parameters are estimated with OLS, conditional on the median unbiased estimate of α. Table 1.3 presents estimates and confidence intervals for the whole sample (1981Q1-2014Q4) and for the restricted sample (1996Q1-2014Q4). The statistics presented are the half-lives, defined as the larges time such that the impulse response function (IR) satisfies $IR(T-1) \geq 0.5$ and $IR(T) < 0.5$.

The half-life estimate is smaller than the US and UK and it becomes smaller after 1996. This could be explained by the fact that the exchange rate has become progressively more flexible. Given the stronger co-movement of NER and RER in this period, deviations in RER became less persistent. In other words, most of the variability of RER is increasingly explained by the variability of NER, which due to the combination of a flexible exchange rate regime and a low inflation environment in which Mexico's CPI reacts little to NER movements. While it is true that the flexible exchange rate regime implemented after 1995 and institutionalized with the adoption of an Inflation Targeting regime in 2002, could have lead to more variability in NER, this has not materialized because of a combination of less imbalances build up, smaller and less persistent domestic and external shocks.

The role of PPP failure and relative prices in Real Exchange Rate movements

Are RER^{cpi} changes a result of movements in the relative price of tradable goods across countries or a consequence of fluctuations in the relative price between non tradable and tradable goods? To answer this, a key empirical question is how is the price of tradable goods measured.

Burstein et al. (2002) and Burstein et al. (2005) argue that fluctuations in the relative price of non tradable to tradable goods are an important source of RER^{cpi} fluctuations between developing economies. Since retail prices are heavily contaminated by the cost of non tradable distribution services (retailing, wholesaling, transportation) their approach is to obtain the non tradable component as a residual, while measuring the relative price of tradable goods with the import and export price index at the dock. They show that there are many goods that are 'local goods' and that accounting for this increases the role of relative price changes in explaining RER^{cpi} movements for a middle income economy as Argentina. That is, taking into account that there are many goods that are neither imported nor exported matters to understand the source of RER movements. Here I investigate if this is also the case for Mexico.

While an alternative to this is to use the Producer Price Index (PPI) as a proxy for tradeable prices, this price index generally excludes import and export prices. To overcome this, Burstein et al. (2006) use pure-traded goods at the dock by constructing a geometric average of import and export prices at the dock.

A drawback of using the import price index (IPI) is that it includes intermediate inputs. In Mexico, between 1994 and 2013, the value of intermediate inputs constituted around 90% of total imports. Given this and by the fact that there is no import price index disaggregation by use of the imported goods, here I will first focus most of the analysis of the behavior of the RER^{cpi} using retail prices.

Using the CPI micro data, I construct CPI subindexes for 'tradables' and 'non-tradables' goods and services. To do so, I use entry level items in the CPI and classify them in tradables and non-tradables and appropriately weight them. In order to evaluate the role of local goods and imported inputs I rely on two approaches to what is a tradable price.

The first approach is to simply characterize what INEGI classify as 'goods and merchandises' as tradables and 'services' as non-tradables. The second approach takes into account whether some of these goods and merchandises are actually internationally traded or not. For this, all services are classified as non-tradables. For goods and merchandises, I use Vega (2012) procedure. This relies on identifying which of the goods in the consumer basket are traded and which are not (and thus, they are 'local goods').

Data on imports and exports for the U.S. is available at The Center for International Data at UC Davis at a 6-digit dissagregation in NAICS nomenclature. Using concordance tables for the CPI Entry Level Items and the NAICS nomenclature, I can define if a good is 'traded' or 'non-traded'. A good is traded if it is either imported or exported between the U.S. and Mexico. A good is non-traded if it is neither imported nor exported between these two countries. Hence, the non-traded categorization will include services and goods that have not recorded transactions with the US. When classifying CPI components into traded and non-traded, from the 202 groups of goods in the Manufacturing category (which are usually consider as traded), 41 groups were not traded between 2002 and 2006.[7]

Decomposing the RER Following Engel (1999), I decompose the RER movements to account for the the relative importance of tradable prices or relative prices. Assuming that the aggregate CPI indexes are geometric weighted averages of tradable and non tradable prices, the RER can be expressed as

$$RER_t = \frac{E_t P_t^*}{P_t} = \frac{E_t \left(P_t^{T*}\right)^{1-\omega*} \left(P_t^{N*}\right)^{\omega*}}{\left(P_t^T\right)^{1-\omega} \left(P_t^N\right)^{\omega}},$$

where ω and ω^* are the weight for non tradables in the home and foreign economy, respectively. Hence, I can define the log changes of the RER (rer_t) as

$$\Delta rer_t = \Delta rer_t^T + \Delta rer_t^N$$

[7]This is done for the period 2002-2010, which should be taken as a upper bound for the tradability. Mexico's economy has became much more open since the mid-1990s.

Where the first term measures the deviations from tradable prices 'law of one price'

$$\Delta rer_t^T = \Delta \log \left[E_t P_t^{T*} / P_t^T \right]$$

and the second term measures the changes in the tradable/non tradable prices

$$\Delta rer_t^N = \omega \Delta \log \left[P^N / P_t^T \right] - \omega^* \Delta \log \left[P^{N*} / P_t^{T*} \right],$$

Hence, the variance decomposition for the log changes in real exchange rate is given by

$$var\left(\Delta rer_t\right) = var\left(\Delta rer_t^T\right) + var\left(\Delta rer_t^N\right) + 2cov\left(\Delta rer_t^T, \Delta rer_t^N\right)$$

Table 1.4 shows the results for the decomposition when the tradables are measured at the retail level by 'goods and merchandises' (approach 1) or excluding 'local goods' (approach 2). First, results are not significantly affected by the approach taken to classify 'tradable' prices. As mentioned above, this is due to the fact that only a even imported goods' prices have a significant non tradable component at the retail level. Moreover, the share of imported goods in final consumption goods is small.

Second, while the size of the documented importance of the changes in the relative price component of the RER is debatable because of the measurement issues discussed above, it is relevant how the magnitudes change from the first to the second period of analysis. The fall in the importance of movements in relative prices suggests that the deviations from relative purchasing power parity hypothesis could be more important in understanding the movements of the RER in a low and stable inflation environment. In other words, nominal rigidities for tradable goods seem to matter more in the later period. It is also possible to conjecture that the more flexible exchange rate allowed the economy to generate less relative price misalignments.

Given the above mentioned limitations of using the goods' prices measured in retail level as tradable prices (including or not local goods), I construct an empirical measure of rer_t^T using both the (i) import price index, and (ii) CPI for goods and merchandises, and

compute rer_t^N as a residual. Following Burstein et al. (2006) I compute a lower bound L^N that measures the importance of movements in rer_t^N by imputing the covariance term to fluctuations in the price of non tradable (tradable) goods when the estimated covariance is negative (positive):

$$L^N = \begin{cases} \frac{var(rer_t^N)}{var(rer_t^{cpi})} & \text{if } cov(rer_t^T, rer_t^N) > 0, \\ \frac{var(rer_t^N)}{var(rer_t^{cpi})} + \frac{2cov(rer_t^T, rer_t^N)}{var(rer_t^{cpi})} & \text{if } cov(rer_t^T, rer_t^N) < 0. \end{cases}$$

$$U^N = \begin{cases} \frac{var(rer_t^N)}{var(rer_t^{cpi})} + \frac{2cov(rer_t^T, rer_t^N)}{var(rer_t^{cpi})} & \text{if } cov(rer_t^T, rer_t^N) > 0, \\ \frac{var(rer_t^N)}{var(rer_t^{cpi})} & \text{if } cov(rer_t^T, rer_t^N) < 0. \end{cases}$$

Table 1.5 shows that the importance of movements in relative prices between non-tradable and tradable was smaller between 2002-2010 relative to 1994-2002 for both measures of tradable prices. When measuring prices at the border, the importance of non-tradable prices increases to explain practically all the variance in RER for both periods. This is a result of import prices having full pass-through at the border.

As expected, when I measure tradable prices using retail prices for goods and merchandises, the importance of relative price movements falls. Also, the importance of relative price changes is smaller for the 2002-2010 period, suggesting that pass-through from the import prices to goods' retail prices was smaller in an environment with low and anchored inflation and flexible nominal exchange rate. This strengthens results from Table 1.4.

Large depreciations and incomplete exchange rate pass-through

One common characteristic of large currency depreciations in emerging economies is that while inflation in consumer prices is smaller than the change in the nominal exchange rate, this is not the result of incomplete exchange rate pass-through in import prices. The less-than-proportional adjustment of retail prices for goods and services —or incomplete exchange rate pass-through to prices (ERPT)- implies that the real exchange rate

depreciates as well. Burstein et al. (2005) document evidence for eight episodes of large increases in the nominal exchange rate for different emerging economies.

For Mexico, there are two episodes large depreciations in the period under analysis: November 1994 (the Tequila crisis) and October 2008 (the international financial crisis). While both happen under different monetary and exchange rate regimes, the interest here is to analyze the response of prices given the increase in the nominal exchange rate.

Table 1.6 shows aggregate prices' cumulative log-changes from one month prior to the depreciation for each of the two episodes considered here. Between November 1994 and May 1995 the Mexican Peso depreciated by 73%. While import prices at the dock (in pesos) rose by 80% and the CPI increased only by 26%. In late 2008, the nominal exchange rate shock (37%) import prices increased by 32% and the CPI increased by 3.5%. Therefore, both after November 1994 and after October 2008, the nominal exchange rate increased by a large amount while retail prices for goods and services increased but less-than-proportionally. However, in both episodes import prices increased almost as much as the nominal exchange rate.[8] This implies that that the 'law of one price' can be a reasonable approximation at the border, but not for retail prices.

The reason for this is that local components have an important share in retail prices (e.g. distribution costs, labor, etc.). Nominal wage movements are a good proxy for the behavior of local costs. In both episodes, wage inflation was below price inflation and the currency depreciation rate, implying lower real wages and even lower wages measured in dollars.

Figure 1.2 illustrates the response of the nominal exchange rate, import and export prices, CPI, and CPI sub-indexes for goods and for services during the 1994 episode. Figure 1.3 presents the same results for the 2008 episode.

Given the the muted response of retail prices, it is relevant to inquiry to what is the individual pricing patterns behind this. In the next section I present the methodology to analyze the micro data for consumer prices and show the role of changes in pricing plans in accounting for changes in the real exchange rate and the behavior of pricing patterns

[8] In 2008 the increase in the import price index is smaller than in 1994. This is related to the fact that prices in the US were falling. Gopinath et al. (2012) document this with US Customs data. In any case what matters here is that the CPI increased much less than the import price index

after the two large currency depreciation episodes.

1.4 Evidence from consumer prices' micro data

1.4.1 Frequency and average size of price adjustment

In order to analyze the price micro-data, I decompose total inflation (π_t) as follows.[9] The indicator function $I_{i,t}$ signals an observed price change in item i between period $t-1$ and t, so

$$I_{it} = \begin{cases} 1 & \text{if } p_{it} \neq p_{it-1} \\ 0 & \text{if } p_{it} = p_{it-1} \end{cases} .$$

The inflation rate can be decomposed into two multiplicative terms. The frequency of price adjustment (fr_t) measures the fraction of prices that were adjusted between periods $t-1$ and t and the average price change (dp_t) measures how much prices changed on average, conditional on changing.

$$\pi_t = \underbrace{\left(\sum_{i \in \Upsilon_t} \alpha_{it} I_{it} \right)}_{fr_t} \left(\underbrace{\frac{\sum_{i \in \Upsilon_t} \alpha_{it} I_{it} \Delta p_{it}}{\sum_{i \in \Upsilon_t} \alpha_{it} I_{it}}}_{dp_t} \right),$$

where α_{it} is the weight of item i in the CPI basket.

Figure 1.4 presents a scatter plot of the monthly frequency of price adjustment and annualized monthly inflation rates for the aggregate CPI. As shown in Gagnon (2009), between 1994 and 2002 high values of inflation typically coincide with higher values in the frequency of adjustment. Between 2002 and 2010, annualized monthly inflation rates were consistently below 10% and movements in frequency were smaller. Figure 1.5 shows the monthly frequency of price adjustment and (annualized) monthly inflation rates for goods and services. On average the frequencies for goods are higher than for services, although both increase for high inflation rates.[10] As these correlations decreases, by construction

[9] This follows Klenow and Kryvtsov (2008) closely.

[10] One of the salient features of the data is that there is a high degree of heterogeneity across sectors. Table 1.8 compares frequency of adjustment for the whole sample grouped in 9 sectors. For comparison,

the average size of price adjustment correlates more strongly with inflation.These facts are consistent with the findings for other emerging economies (see Alvarez et al. (2011)).

Figure 1.6 shows the time series for the frequency of price adjustment for the CPI, the CPI for Goods and Merchandises, and the CPI for Services. The most important change in the fraction of adjusting prices happened right after the 1994/1995 devaluation. This is true for the whole CPI, and for the two subindexes. After the 1995 episode, frequencies of price adjustment were much more stable.

To quantify the role of inflation in the frequency of adjustment, I regress frequency of price adjustment on inflation.[11] Table 1.9 shows that in the 1994-2002 period, the frequency of price adjustment was highly correlated with inflation. These results are close to Gagnon (2009) for the 1994-2002 period. However, when the 1995 observations are excluded from the sample ('restricted'), the correlation drops to values that are much closer to the corresponding with the 2002-2010 period. This is relevant because the literature that has studied episodes of high inflation in emerging economies[12] has interpreted the high correlation between frequency of adjustment and inflation as a 'steady state' correlation. However, as it was shown in Section 3, the spike in inflation in 1995 that is associated with the most important increase in the fraction of adjusting prices, was to a great extent the result of exchange rate pass-through after a large devaluation.[13]

Table 1.10 shows the results for the 2002-2010 sample. Relative to the 1994-2002 period and as inflation became lower and more stable, the correlation of frequency of price adjustment with inflation dropped significantly. Column 2 removes from the sample the months after the 2008 depreciation, showing that the change in results is mostly due to Goods and Merchandises, while the coefficient for Services is not very affected. This is the result of a smaller nominal exchange rate shock and a smaller exchange rate pass-through.

An Inflation Decomposition To quantify the role of changes in the frequency of adjustment in inflation, I follow Klenow and Kryvtsov (2008) and decompose inflation

the values found for the US by Nakamura and Steinsson (2008) are included.

[11] To account for the effects of changes in methodology, yearly dummies were included.

[12] In particular Alvarez et al. (2011) and Gagnon (2009)

[13] The high sensitivity of services' frequency of price adjustment seems to be driven by its strong seasonality. Given the number of estimated parameters, I can not include monthly dummies to remove this effect.

in two additive terms. Given that $\pi_t \equiv fr_t dp_t$, inflation can be expressed with a Taylor expansion around the median frequency of price adjustment ($\bar{fr}$) and the median average price change ($\bar{dp}$)

$$\pi_t = \underbrace{\bar{fr}dp_t}_{\text{IM}} + \underbrace{fr_t\bar{dp} + \left(dp_t - \bar{dp}\right)\left(fr_t - \bar{fr}\right) + O_t}_{\text{EM}}, \tag{1.2}$$

where O_t denotes higher order terms. The first term on the right hand side measures the 'intensive margin' (IM) of inflation. That is to say, it measures the part of inflation that is attributable to having a constant fraction of prices changing. The rest of the terms are associated with changes in the monthly fraction of prices that adjust and it is denoted as the 'extensive margin' (EM) of inflation. Hence, the inflation can be expressed as

$$\pi_t = \pi_t^{IM} + \pi_t^{EM}. \tag{1.3}$$

To further analyze the importance of each terms of inflation to explaining total inflation, we can apply a variance decomposition to get

$$var\left(\pi_t^{cpi}\right) = var\left(\pi_t^{IM}\right) + var\left(\pi_t^{EM}\right) + 2cov\left(\pi_t^{IM}, \pi_t^{EM}\right)$$

Table 1.11 presents the results. As it has been documented, as the monetary regime changed, the importance of the extensive margin of price adjustment decreased. The reason for this is that in an environment with anchored inflation expectations, individual pricing plans do not have to be changed and thus the fraction of adjusting prices is more stable over time.

The role of the extensive margin in RER

Above, I presented evidence that an important feature of the data is that the increase in the correlation between frequency of price adjustment and inflation is the response to nominal exchange rate shocks. Given the relation between nominal exchange rate fluctuations and inflation, it is of interest to analyze to what extent changes in frequency of price adjustment influence the real exchange rate.

To quantify the role of inflation and its margins in explaining RER across the two periods of analysis, I can further exploit the Klenow and Kryvtsov (2008) inflation decomposition. Given that the lot change in RER^{cpi} is given by

$$\Delta rer_t = \Delta e_t + \pi_t^* - \pi_t$$

After applying the covariance operator with respect to Δrer_t we get that

$$Cov(\Delta rer_t, \Delta rer_t) = Cov(\Delta e_t, \Delta rer_t) + Cov(\pi_t^*, \Delta rer_t) - Cov(\pi_t, \Delta rer_t)$$

Using the decomposition of inflation in intensive and extensive margins as it was presented above, I get the RER-inflation margins covariance decomposition

$$\begin{aligned} Var(\Delta rer_t) = Cov(\Delta e_t, \Delta rer_t) + Cov(\Delta p_t^*, \Delta rer_t) \\ -[Cov(\pi_t^{IM}, \Delta rer_t) + Cov(\pi_t^{EM}, \Delta rer_t)] \end{aligned}$$

$$1 = \frac{Cov(\Delta e_t, \Delta rer_t) + Cov(\pi_t^*, \Delta rer_t) - [Cov(\pi_t^{IM}, \Delta rer_t) + Cov(\pi_t^{EM}, \Delta rer_t)]}{Var(\Delta rer_t)}$$

Table 1.12 presents the results from this decomposition for 1994-2002.[14] The importance of domestic inflation is large and also the part of it that is attributable to the extensive margin is important.

Table 1.13 shows the results for the 2002-2010 period, showing that domestic inflation became less important and that the relative importance of the extensive margin was smaller as well. This suggests that not only the pass through became smaller but also pricing plans (i.e. *when* to adjust prices) were less affected during the low inflation and flexible exchange rate period. This pattern is even supported during a significant nominal shock as the 2008/2009 large depreciation of Mexico's peso.

[14]Note that the ratios of the covariances to variance of Δrer_t do not add up to one as the RER is computed using the aggregate CPI index and the importance of inflation is computed using only the subsample of entry level items described above.

Large devaluations and the extensive margin Given what was discussed above, it is of interest to analyze with more detail what was the response of individual prices to large monetary shocks as the ones that Mexico experienced in November 1994 and October 2008. Figure 1.9 shows the currency depreciation rate and inflation, together with the importance of the intensive and extensive margins of inflation. It is noticeable how the importance of the extensive margin is large immediately after the 1994 devaluation (more than 40%), while it is barely noticeable after 2008 (less than 8%)

Tables 1.14 and 1.15 reproduces Tables 1.6 adding the percentage of inflation that is attributable to the extensive margin associated with changes in the fraction of prices that are adjusted. In 1994/1995, not only pass through was higher in aggregate CPI, and CPI for tradable and non-tradables, but also the role of changes in the frequency of price adjustment in explaining inflation was very important. In the first six months after the shock, more than 40% of inflation is explained by changes in the frequency of price adjustment.

In 2008/2009, the depreciation was smaller -it peaked at 33%-, the response of consumer prices was smaller and also the role of the extensive margin was much less important -explaining less than 8% of inflation.[15]

1.5 Conclusions

In this chapter I presented evidence on the relationship between the nominal exchange rate, inflation and the changes in the pattern of prices' setting and connects this to the behavior of the real exchange rate.

I documented that two set of facts. A salient feature of the data is that there is a strong correlation between nominal and real exchange rates. This is relation is stronger as inflation is lower and more stable. As the nominal exchange rate regime became more flexible, the persistence of nominal and real exchange rates became smaller. Moreover, the most important explanation for movements in the real exchange rate are relative

[15]Figures 1.7 and 1.8 reinforce the message and show that the results are not driven by an aggregation bias across sectors. These figures show, for 1994 and 2008 respectively, how the frequency of price adjustment changed across CPI entry-level categories (ELIs) 3 months after the large depreciation, compared with the same month a year before. In 1994 there is a large change across all ELIs while in 2008 changes are idiosyncratic to the sector.

price movements between tradable goods at the border and tradable and non-tradable retail prices. This also holds during episodes of large currency depreciations like the ones experienced by Mexico in 1994 and 2008. These large movements in the real exchange rate are also associated to a less-than-proportional adjustment in retail prices, instead of a slow adjustment in traded goods 'at the dock'.

Using micro data for consumer prices, I show that the there is a positive relation between aggregate inflation and increases in the the frequency of price adjustment. Importantly, this correlation and the role of these changes in the fraction of adjusting prices in inflation is mostly explained by the exchange rate pass through after the 1994 large currency devaluation episode. While this partly holds in 2008, the facts that inflation expectations remained anchored in low values and given that the nominal exchange rate shock was smaller are associated to the much smaller change in pricing plans.

While both the incomplete exchange rate pass-through in large depreciations and the elasticity of the frequency of price adjustment to the inflation environment have been documented in the literature, a contribution of this chapter is to study both phenomena together.

In terms of modeling, these phenomena suggest the need of a model than can capture (i) endogenous decision of price adjustment at the individual level, (ii) aggregate shocks characteristic to small open economies like Mexico, and (iii) incomplete exchange rate pass-through as observed in the data. In the next chapter I analyze under what conditions can a menu cost model capture this response in the behavior of prices to large aggregate shocks.

Figures and Tables

Table 1.1: CPI Sample Coverage

	3/1994-7/2002	**9/2002-12/2010**
Full Sample		
CPI ELI	283	314
% CPI Basket	82.07%	100%
Sample without controlled prices		
CPI ELI	227	289
% CPI Basket	54.11%	65.9%

Source: Diario Oficial de la Federacion; INEGI; Gagnon (2009)

Table 1.2: Summary statistics for RER and NER

	$\frac{stdev(\Delta rer)}{stdev(\Delta ner)}$	$corr\left(\Delta rer, \Delta ner\right)$
1981-1994	0.538	0.717
1994-2002	0.814	0.9
2002-2014	0.843	0.907
US (1975-2013)	0.923	0.970

Table 1.3: Persistence for Mexico's RER

	81-14	**96-14**	**US**	**UK**
Half Life	2.13	1.33	4.46	2.02

Table 1.4: Role of relative price changes using consumer prices

	1994-2002		**2002-2010**	
Non tradables	**Services**	**Services and local goods**	**Services**	**Services and local goods**
$var\left(rer_t^N\right)/var\left(rer_t\right)$	0.089	0.123	0.063	0.054
$\frac{\left[var\left(rer_t^N\right)+2cov(.)\right]}{var(rer_t)}$	0.097	0.128	0.072	0.078

Table 1.5: Role of relative price changes using import prices

	1994-2002		**2002-2010**	
Tradeable:	**Imports**	**Goods**	**Imports**	**Goods**
L^N	0.973	0.115	0.929	0.046
U^N	1.202	0.132	0.983	0.101

Table 1.6: Cumulative Log Changes (%)

1994				
	t+3	**t+6**	**t+9**	**t+12**
E	50.17	54.93	58.69	80.04
Import Prices	52.54	59.06	62.94	84.05
Export Prices	51.60	57.86	56.99	79.66
CPI	11.07	22.47	27.06	34.22
CPI Goods	11.84	24.12	29.07	36.92
CPI Services	8.66	17.23	20.71	25.71
Wages	2.83	13.29	15.84	19.39
2008				
	t+3	**t+6**	**t+9**	**t+12**
E	23.48	33.21	23.26	23.40
Imports Prices	19.60	27.88	18.21	18.80
Exports Prices	8.63	22.67	17.58	22.46
CPI	2.16	3.22	4.51	5.70
CPI Goods	2.59	3.73	5.42	6.62
CPI Services	1.29	2.19	2.66	3.80
Wages	0.98	2.36	3.01	6.03

Source: Diario Oficial de la Federacion;INEGI

Table 1.7: Cumulative Log Changes (%)

1994				
	t+3	**t+6**	**t+9**	**t+12**
E	50.17	54.93	58.69	80.04
CPI	11.07	22.47	27.06	34.22
CPI Goods	11.84	24.12	29.07	36.92
CPI Services	8.66	17.23	20.71	25.71
CPI Tradables	11.55	25.23	30.18	37.49
CPI Non Tradables	10.50	18.99	23.14	30.11
Imports	52.54	59.06	62.94	84.05
Exports	51.60	57.86	56.99	79.66
2008				
	t+3	**t+6**	**t+9**	**t+12**
E	23.48	33.21	23.26	23.40
CPI	2.16	3.22	4.51	5.70
CPI Goods	2.59	3.73	5.42	6.62
CPI Services	1.29	2.19	2.66	3.80
CPI Tradables	2.38	3.21	5.12	6.40
CPI Non Tradables	1.92	3.22	3.83	4.91
Imports Prices	19.60	27.88	18.21	18.80
Exports Prices	8.63	22.67	17.58	22.46

Source: Diario Oficial de la Federacion;INEGI

Table 1.8: Monthly frequency of price adjustment by sector. Mexico and US

	Mexico			**US**	
	1994-2002	**1996-2002**	**2002-2010**	**1998-2005**	**1988-1997**
Processed Food	33.9	32.1	31.3	25.5	24.9
Unprocessed Food	50.0	50.9	60.1	39.5	43.2
Household Furnishing	22.9	21.7	28.6	20.6	23.0
Apparel	21.0	20.1	9.4	30.1	28.1
Transportation Goods	32.5	30.2	22.6	22.2	26.3
Recreation Goods	14.2	12.6	12.0	13.7	15.8
Other Goods	21.9	20.2	24.7	20.6	15.9
Utilities	64.2	66.7	71.9	49.4	50.5
Vehicle Fuel	57.5	58.0	53.1	87.5	65.0
Travel	16.4	15.4	11.5	44.4	35.4
Services (excl. Travel)	24.1	23.5	41.9	9.1	8.6

Table 1.9: Regression: frequency on monthly inflation (non-regulated goods and services)

	All	All	Goods	Goods	Services	Services
Sample	Full	Restricted	Full	Restricted	Full	Restricted
Constant	18.46**	21.01**	23.44***	27.52**	3.622**	3.83**
π	0.461**	0.132**	0.464**	0.134*	0.714**	0.633*

Note: regression includes yearly dummies. The restricted sample excludes VAT increases as well as the period after the 1994 devaluation event (Jan 1995 to Dec 1995). (*): significant to 90%; (**) significant to 95%; (***) significant to 99%.

Table 1.10: Regression: frequency on monthly inflation (non-regulated goods and services)

	All	All	Goods	Goods	Services	Services
Sample	Full	Restricted	Full	Restricted	Full	Restricted
Constant	19.64**	20.08**	28.5**	28.15**	2.79***	3.08**
π	0.201**	0.129**	0.116**	0.086**	0.597*	0.503*

Note: regression includes yearly dummies. The restricted sample excludes VAT increases as well as the period after the 2008 depreciation event (Nov 2008 to June 2009).(*): significant to 90%; (**) significant to 95%; (***) significant to 99%.

Table 1.11: Variance decomposition for inflation (IM: Intensive margin)

$var\left(\pi_t^{IM}\right)/var\left(\pi_t\right)$	All	G	S
1994-2002	0.407	0.314	0.093
2002-2010	0.829	0.801	0.483

Table 1.12: Variance decomposition for RER

	94-02	02-10
Δe	89.25%	104.9%
Δp^*	0.65%	-4.88%
Δp^{dof}	14.76%	0.16%

Table 1.13: Quantifying IM/EM margins and RER ($Cov(\Delta x_t, \Delta q_t)/Var(\Delta q_t)$

	94-02			**02-10**		
	All	**G**	**S**	**All**	**G**	**S**
IM	9.63	5.17	3.35	0.12	1.33	-0.81
EM	8.37	5.34	2.98	0.04	0.25	0.02

Table 1.14: Cumulative ERPT and inflation margins. November 1994

	E	IPI	CPI	$EM(\%)$	CPI^T	$EM(\%)$	CPI^N	$EM(\%)$
$t+3$	50.2	104.1	17.4	34.1	17.9	38.2	16.6	45.3
$t+6$	54.9	107.5	42	43.8	74.8	49.2	32.9	50.9
$t+12$	79.9	105	44.6	31.9	49.4	38.9	35	36.6

Table 1.15: Cumulative ERPT and inflation margins. October 2008

	E	IPI	CPI	$EM(\%)$	CPI^T	$EM(\%)$	CPI^N	$EM(\%)$
$t+3$	23.4	72.4	9.2	7.5	10.2	8.9	8.2	4.9
$t+6$	33.2	78.3	9.7	7.8	9.7	9.3	9.6	5.5
$t+12$	23.7	69.4	24.1	7.7	27.1	9.3	20.7	6.4

Figure 1.1: Real and nominal exchange rates

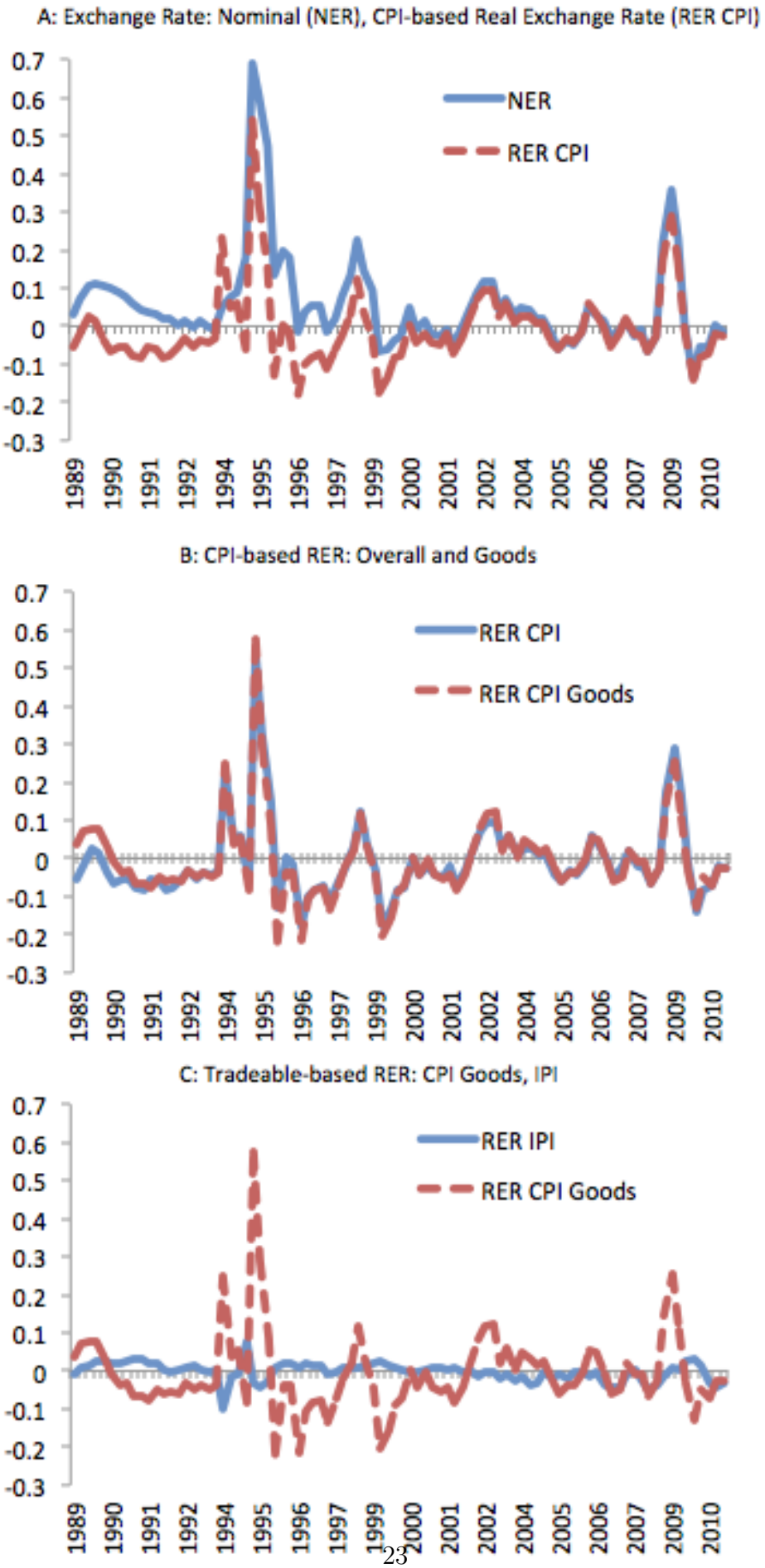
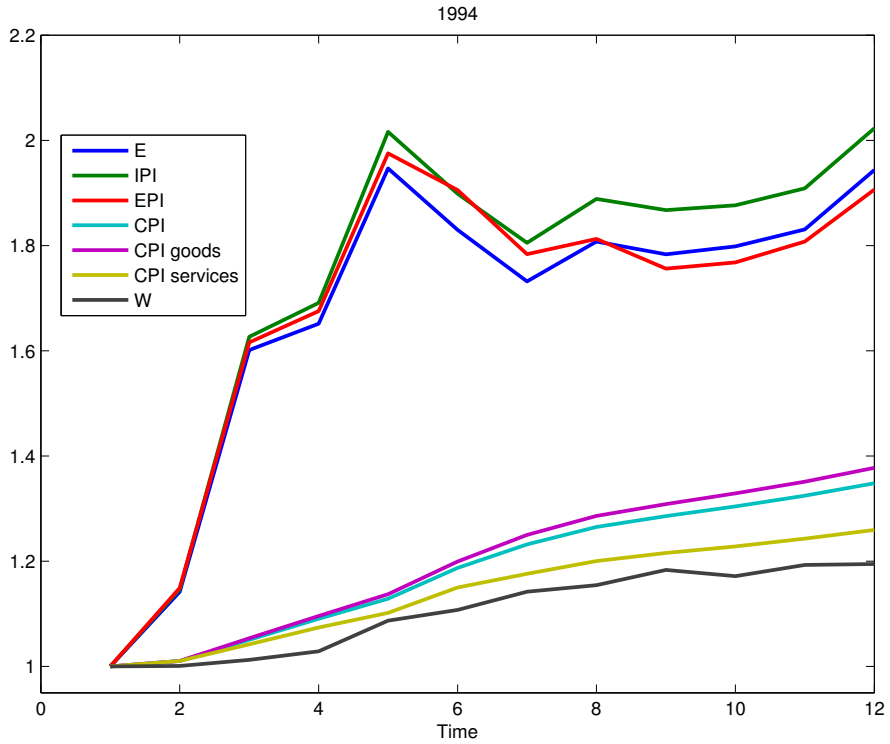
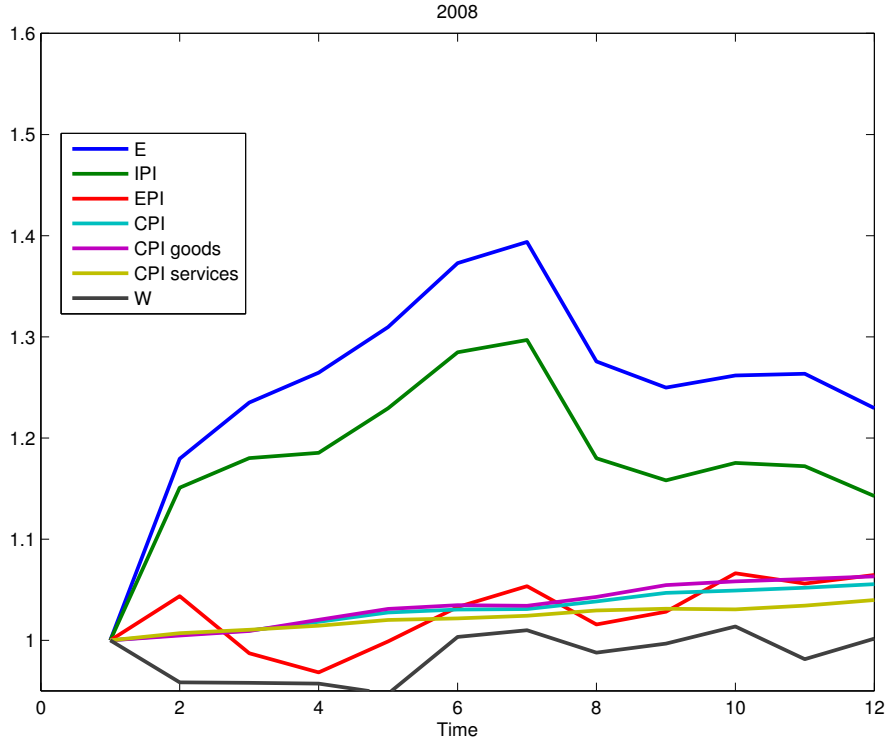


Figure 1.2: Price indexes (Nov 1994=1)



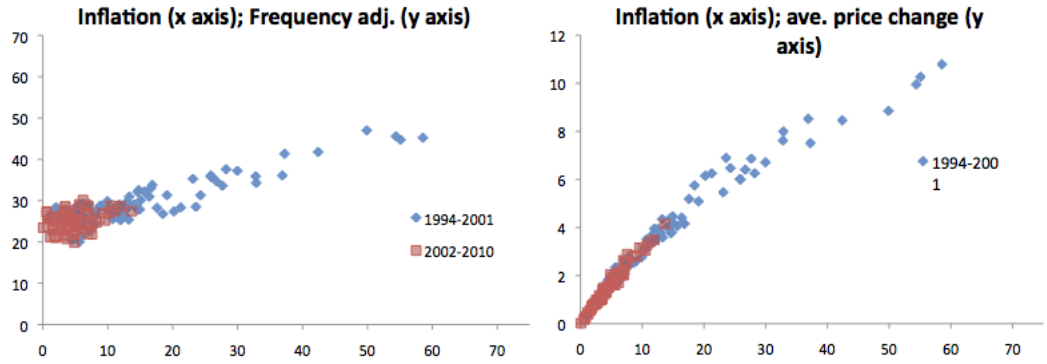
E: Nominal exchange rate; IPI: Import price index; EPI: Export price index; CPI: Consumer price index.

Figure 1.3: Price indexes (Oct 2008=1)



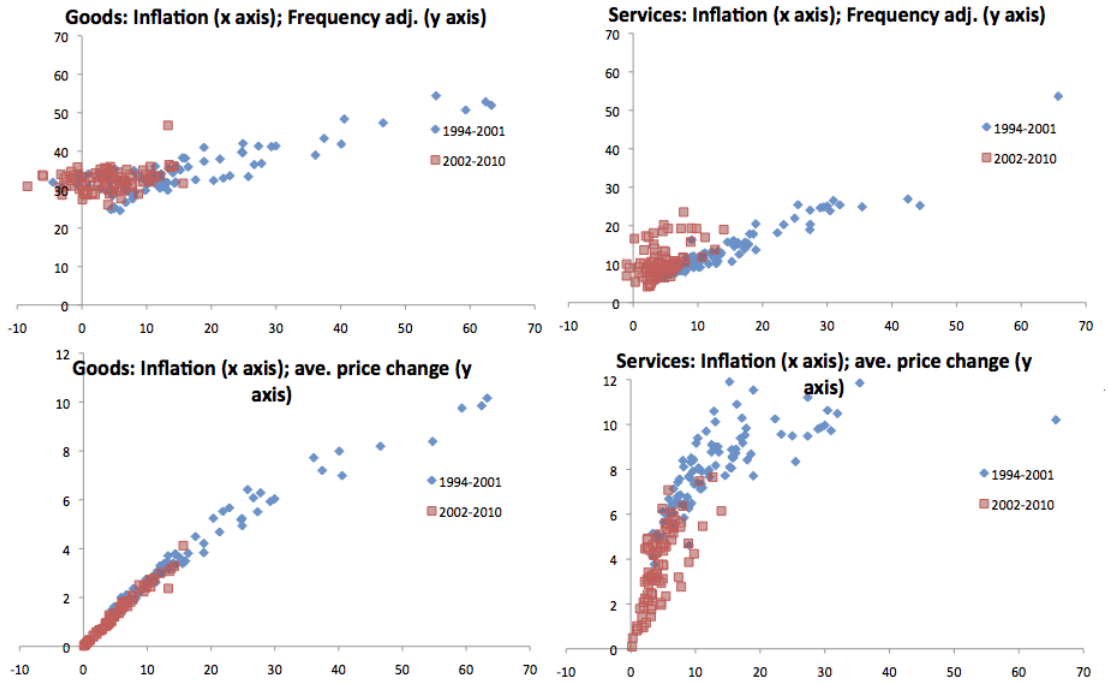
E: Nominal exchange rate; IPI: Import price index; EPI: Export price index; CPI: Consumer price index.

Figure 1.4: Monthly Inflation (annualized), frequency of price adjustment and average price change (CPI)



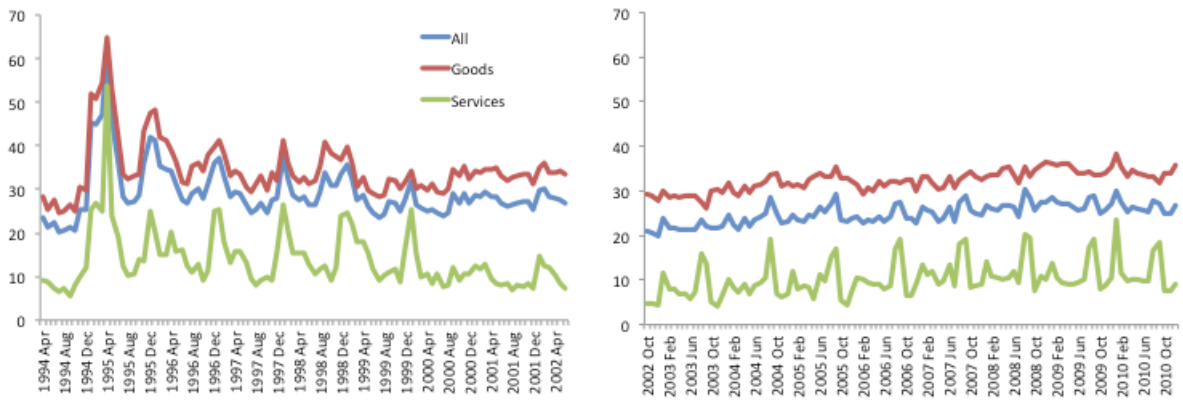
Sources: Diario Oficial de la Federacion, INEGI (Mexico).

Figure 1.5: Monthly Inflation (annualized), frequency of price adjustment and average price change (CPI Goods and Services)



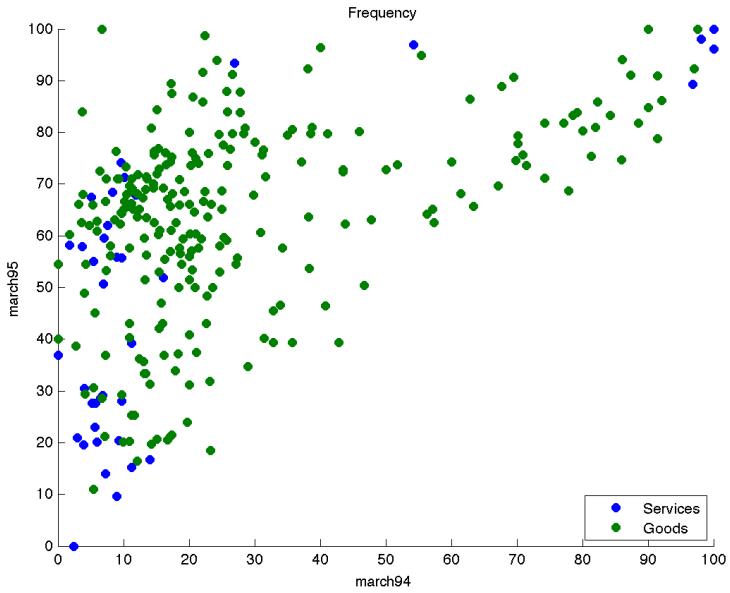
Sources: Diario Oficial de la Federacion, INEGI (Mexico).

Figure 1.6: Frequency of price adjustment (CPI, CPI Goods and CPI Services)



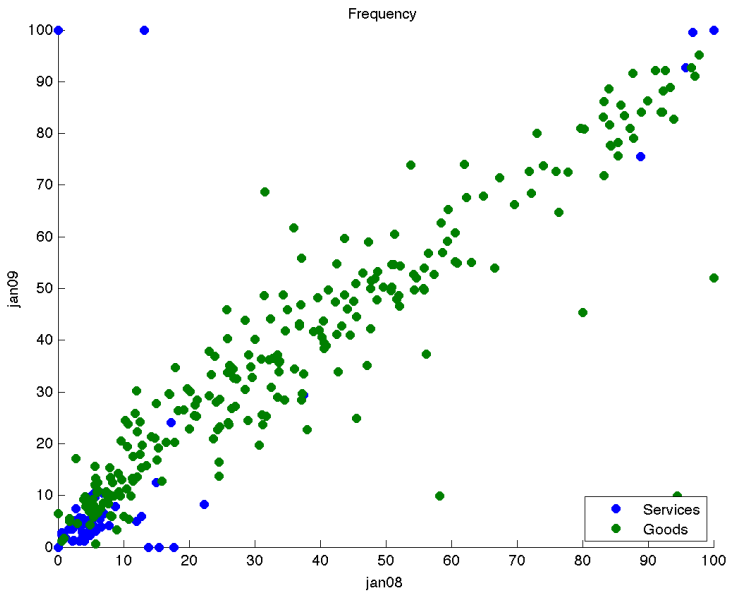
Sources: Diario Oficial de la Federacion, INEGI (Mexico).

Figure 1.7: Changes in monthly frequency of price adjustment between March 1994 and March 1995, for Entry-Level Categories in CPI



Sources: Banxico, INEGI (Mexico).

Figure 1.8: Changes in monthly frequency of price adjustment between Jan 2008 and Jan 2009, for Entry-Level Categories in CPI



Sources: Banxico, INEGI (Mexico).

Figure 1.9: Nominal Exchange Rate (NER), Inflation (CPI) and Inflation Margins (Extensive Margin (EM) and Intensive Margin (IM)

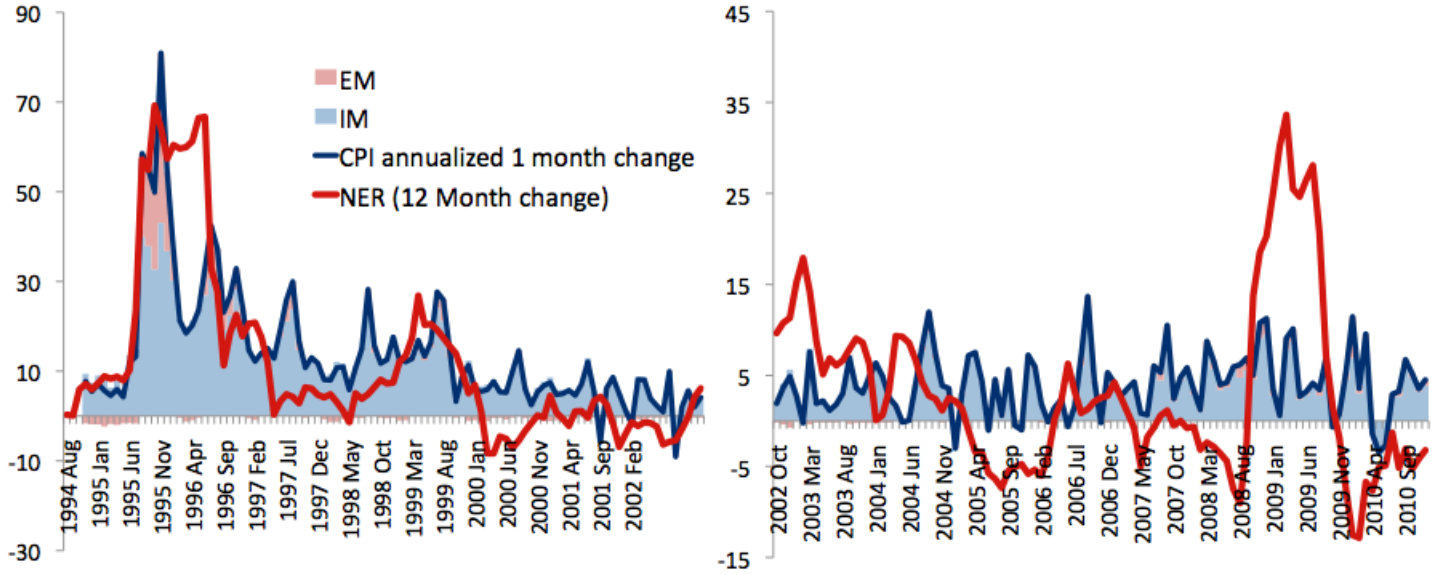


Figure 1.10: Nominal Exchange Rate (NER), Inflation (CPI) and Inflation Margins (Extensive Margin (EM) and Intensive Margin (IM)

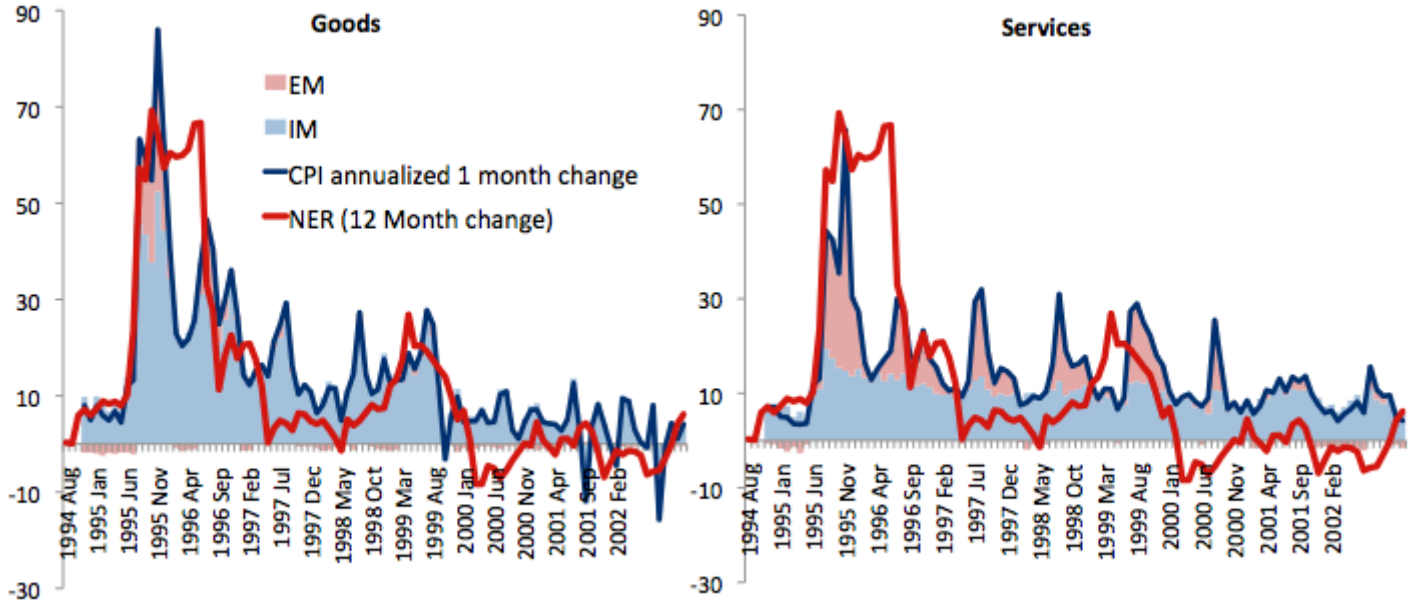
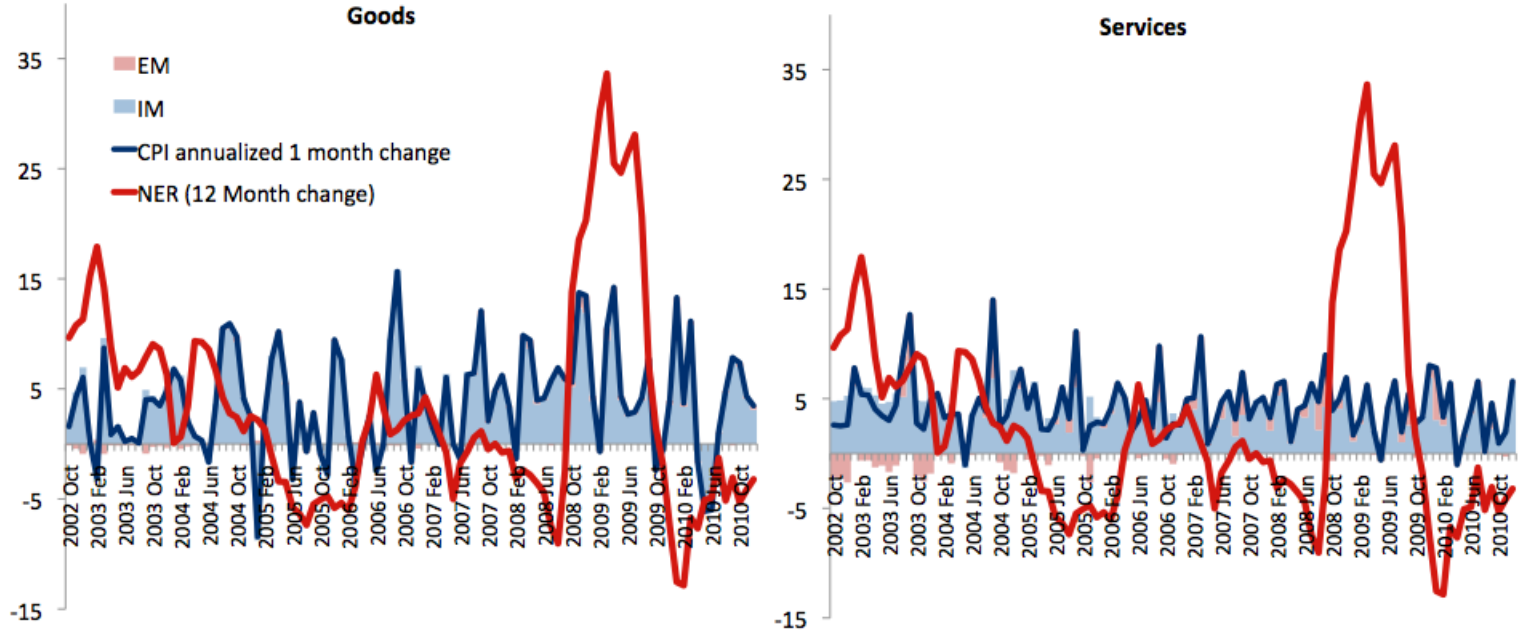


Figure 1.11: Nominal Exchange Rate (NER), Inflation (CPI) and Inflation Margins (Extensive Margin (EM) and Intensive Margin (IM)



CHAPTER 2

Large Currency Depreciations and Menu Costs.

2.1 Introduction

What role does price stickiness play in the response of prices after large nominal exchange rate shocks? Following large nominal exchange rate depreciations, there are large changes in real exchange rates —implying that retail prices respond only sluggishly to changes in the nominal exchange rate. These large deviations from the relative purchasing power parity at the aggregate level are typically accompanied by significant economic contractions. The aim of this chapter is to quantify the forces behind this less-than-proportional response of consumer prices when nominal exchange rate shocks are large.

Based on the evidence presented in Chapter 2, I focus on a large currency depreciation episode in Mexico, for which I observe the micro-data used to construct the Consumer Price Index (CPI). Between November 1994 and May 1995 the Mexican Peso depreciated by 73%. While import prices at the dock (in pesos) rose by 80%, the CPI increased only by 26%, and nominal wages increased by 15%. Importantly, during this period the monthly fraction of observed price changes nearly doubled relative to pre-depreciation months, increasing from 25% to 46%. While this margin of adjustment in prices accounts for almost half of the CPI inflation observed in this period,[1] it tends to be ignored in the sticky prices models that are used to evaluate monetary policy in small open economies.[2] Also, a model with flexible prices would not match this margin of adjustment as all prices would change after the depreciation.[3]

[1]This means that if the fraction of adjusting prices in the CPI micro data is held constant, the average price change in the micro data would imply a cumulative inflation rate of only 12.9% six months in after the depreciation.

[2]Standard open economy monetary models usually assume that nominal rigidities are given by 'Calvo' pricing. The prototypical model is presented in Gali and Monacelli (2005).

[3]As an additional benchmark I also consider the 2008 depreciation in which the currency depreciation was 39%, import prices increased by 32%, the CPI increased by 3.5% and the fraction of adjusting prices remained fairly stable.

In this chapter I study whether a menu cost model calibrated to the Mexican CPI micro data can account for the observed response of prices and quantities that follows a large depreciation. I build on the models considered by the closed economy literature that studies the aggregate implications of small monetary shocks when prices are sticky (see Nakamura and Steinsson (2013)). I use the model to determine which factors are instrumental in shaping the observed path of consumer prices in the aftermath of a large currency depreciation.

The model describes a small open economy similar to Gali and Monacelli (2005), with multiple heterogeneous sectors as in de Carvalho and Nechio (2011). I augment this standard framework in two important ways. First, I assume that the production of domestic goods requires both imported inputs and labor, so that firms' marginal costs of production depend on both the price of imported inputs and the nominal wage.[4] To the extent that the nominal wage moves less than the nominal exchange rate, firms' marginal costs do not move in proportion to the currency depreciation. In a context of constant markups, this implies that changes in consumer prices are smaller than changes in the nominal exchange rate (i.e. 'incomplete exchange rate pass-through' to prices), even if the law of one price holds for imported goods at the dock —as it is suggested by the above-mentioned evidence on dock prices.[5]

Second, I model nominal rigidities in consumer prices with a menu cost model calibrated to each sector's price micro-data as in Nakamura and Steinsson (2010). The calibration matches the observed fraction of adjusting prices and average size of these price adjustments in the price micro-data before the currency depreciation. The behavior of price indexes, the fraction of adjusting individual prices, and the size of these adjustments after the currency depreciation shock are outcomes of the model.

The purpose of the calibrated model is to quantify the ability of the desired price changes and nominal rigidities in prices to generate incomplete exchange rate pass-through to consumer prices. After the depreciation, *desired* price changes depend on

[4]This is similar to Hevia and Nicolini (2013) who study optimal monetary policy in a small open economy where imports are used to produce domestic goods.

[5]Importantly, the model is calibrated to account for the large proportion of labor —relative to imports— that is used in the production of final goods. Burstein et al. (2005) document that the local component of costs is an important driver of incomplete exchange rate pass-through at the retail level during large devaluations.

how much the exchange rate and nominal wages increase. Hence, for the desired price change to be smaller than the depreciation, nominal wages have to increase less than the exchange rate. The *actual* price change can differ from the desired one because of the nominal price rigidity. In the menu cost model, given an increase in unit input costs, firms' may find it optimal to not adjust their prices.

I simulate the response of prices to a variety of shocks (purely nominal depreciations and depreciations accompanied by negative real shocks that reduce economic activity) under assumptions on price stickiness (Menu costs, Calvo sticky prices, and flexible prices) and wage stickiness. I focus on the model's ability to match the data on exchange rate pass-through to desired prices (in the model this largely depends on the exchange-rate pass-through to wages and the share of wages in costs) and the increase in the fraction of goods whose prices change.

The chapter has three main conclusions. First, the menu cost model can match the fraction of adjusting prices and the behavior of sectoral and aggregate price indexes in the data after the depreciation *if* it includes a negative real shock and sticky wages.[6] Second, the role of the menu cost nominal rigidity in the incomplete exchange rate pass-through is small. While the same model with menu costs set to zero ('flexible prices') cannot match the change and size of adjusting prices in the micro data, it generates an increase in prices that is only 0.44 percentage points higher that in the baseline menu cost model.[7] Third, I show that assuming time-dependent nominal frictions in prices (e.g. Calvo prices) can substantially underestimate the response of prices to a large depreciation, implying large real effects of the nominal shock (i.e. large non-neutralities). This is a result of randomly choosing a constant fraction of firms to reset their prices, instead of letting firms choose when to adjust.[8]

To analyze the mechanisms at play and to isolate the role of consumer price nominal

[6]Burstein et al. (2007) also show that a dampened response of local costs is a key source of RER movements after large depreciations. As mentioned above, their results are restricted to an equilibrium with zero inflation and where the source of nominal rigidities is the endogeneity of markups.

[7]This implies that aggregate consumption is only 0.1 percentage points higher with the menu cost nominal rigidity.

[8]The assumption of a Calvo-type nominal rigidity in prices generates a large bias when the observed monthly fraction of adjusting prices increases as a response to the aggregate shocks . This effect is large in the 1994 episode. When shocks do not affect the monthly fraction of adjusting prices there is still a bias, as firms are *self-selected* into price changing instead of being randomly chosen (as in the Calvo model). This *selection effect* is present in the 2008 episode.

rigidities, I sequentially introduce the aggregate shocks and frictions needed for the model to match the response in prices 6 months after the currency depreciation.

First, I use the calibrated menu cost model with flexible wages to evaluate the behavior of consumer prices in response to a nominal shock that induces a depreciation of the nominal exchange rate of 73% —as observed in Mexico in 1994. The model predicts a counterfactual increase in prices and wages: both increase in the same proportion as the nominal exchange rate. The reason is that the nominal shock is large enough that all firms are willing to pay the menu cost and change their prices. In this sense, the model behaves as if prices were fully flexible. Since relative prices are unchanged, output, consumption and employment remain largely un-affected.[9] In contrast, in a Calvo sticky price-setting, the fraction of prices that is allowed to change is fixed and firms are randomly chosen to do so. In this case, the CPI increases less than the nominal exchange rate. The Calvo model does not allow for a change in the fraction of adjusting prices (as it is kept fixed by assumption), and it also generates a counterfactual expansion in activity and employment.[10] The data shows that in May 1995, private consumption in Mexico was 12.49% smaller than in October 1994, while hours worked fell 9.2%.

Second, given that the nominal rigidities in prices cannot account for either the observed behavior of prices or the sharp contraction in economic activity, I evaluate the role of real shocks in accounting for the behavior of prices and quantities. For that, I simulate a negative real shock that generates a large decline in consumption. I model the real shock as a *Sudden Stop* to capture the large current account reversal in 1994.[11] With this additional single shock, consumer prices increase less than the nominal exchange rate, which is qualitatively consistent with the data. The reason is that the contraction generated by the *Sudden Stop* causes labor demand to contract, and hence the real wage falls. Quantitatively, this less-than-proportional increase in nominal wages is still too large,

[9]These results hold for *large* nominal shocks. When the nominal shock is small enough—in the calibrated model, a depreciation of approximately 5%— the menu cost model generates real effects. These are still smaller than the ones in a Calvo setting.

[10]The mechanism through which this occurs is that in the model with Calvo prices, domestic goods are cheaper for the rest of the world, exports increase and so does labor demand and consumption.

[11]While part of the literature models Sudden Stops as an endogenous outcome (see Calvo (1998); Kaminsky and Reinhart (1999); Mendoza (2010)), in this chapter I take the Sudden Stop as an exogenous shock that constrains the economy's financial flows (see Kehoe and McGrattan (2005); Kehoe and Ruhl (2009); Meza (2008); Cook and Devereux (2006))

implying that the response in prices is still above the observed consumer price inflation.[12]

Third, given that nominal wage behavior is critical to matching the path of prices, I ask whether the menu cost model can account for the behavior in prices when I introduce nominal wage rigidities in the model, together with the *Sudden Stop*. I model wage stickiness as 'sticky plans' (see Mankiw and Reis (2002)). Each period, based on current information, there is a fixed probability of reseting the trajectory of current and future wages.[13]When the probability of reseting wage plans is chosen to match the aggregate data on wages, both the trajectory of aggregate and sectoral prices and the increase in the fraction of individual adjusting prices are very close to the data. However, the response of aggregate prices and quantities is very similar in the calibrated menu cost model or in a flexible price model with real shocks and sticky nominal wages. Thus, the frictions implied by price-setting rigidities do not influence the real variables in an significant degree, relative to the size of the shocks. While inflation is 26% and consumption is falling by 12.49%, the menu cost model generates an inflation rate 0.44 percentage points smaller and fall in consumption 0.01 percentage points lower than the model with flexible prices.

While consumer prices' rigidities do not generate important non-neutralities —as prices' frictions implied by the micro-data are shown to be small—, nominal wage stickiness can entail a large real effect of nominal depreciations. Assuming that wages can be adjusted only after a number of periods implies that there can be significant real effects of the nominal shock. For example, given the *Sudden Stop* and a 73% exchange rate depreciation, when wages are sticky consumption falls 10.85 percentage points less than when wages are flexible.

Fourth, motivated by the experiences of small open economies that keep an exchange rate peg while suffering negative real shocks,[14] I use the model to study how the economy adjusts to a negative real shock in the absence of a currency depreciation. In these

[12]To analyze the 2008 depreciation episode, where consumption contracted in 10.4%, I include a the negative demand shock to Mexico's exports that captures the 'Trade Collapse' associated with the international financial crisis.

[13]The approach taken to model the wage rigidity is pragmatic. While it would be desirable to base it in labor market micro data, in this chapter I restrict such analysis to consumer prices.

[14]Some examples are Argentina in the late 1990s or several European countries that were part of the Euro Zone—or kept an exchange rate peg with it— and suffered large contractions in economic activity since 2008. In almost all these cases, CPI and wage deflation was small relative to the contraction in economic activity.

episodes, the widespread belief is that nominal depreciations can help to ease the adjustment. For that to be true, there must be nominal rigidities in the economy. The model with menu costs and flexible wages does not agree with this 'folk wisdom': when a large real negative shock hits the economy, prices and wages fall significantly and almost in the same amount that they would in a model with flexible prices and wages.[15] However, when wages are sticky, the CPI remains roughly unchanged: as the exchange rate is constant and wages cannot fall much, firms have little incentive to pay the menu cost to reset their prices. Hence, a nominal depreciation would have implied a smaller contraction in economic activity. Therefore, sticky wages can justify the view that the exchange rate is 'overvalued' or that prices are 'too high'. Stickiness in consumer prices cannot account for this by itself.

Two final considerations are in order. First, Nakamura and Steinsson (2008) show that heterogeneity in price-setting is a feature of US CPI micro data, and models calibrated to it can exhibit more monetary non-neutralities.[16] I document that this is also a feature of the data in Mexico and show that calibrating my model to this heterogeneity generates a slight increase in the effect of the price rigidities. Second, Midrigan (2011) shows that the degree of price stickiness increases in menu cost models when firms' idiosyncratic productivity processes receive shocks from a 'fat-tailed' distribution. In my model, this feature increases the persistence of price stickiness, which is extremely short-lived otherwise (see Golosov and Lucas (2007)).

This chapter is related to the literature that studies the role of changes in the nominal exchange rate in small open economies. Typically, this has been done with sticky price models that either assume that only a fixed fraction of prices is allowed to change per period (see Gali and Monacelli (2005); Monacelli (2013); Hevia and Nicolini (2013)), or they restrict to a zero inflation equilibrium (see Burstein et al. (2007)). These approaches ignore the behavior of CPI micro data and they can be biased towards predicting very large real effects of large nominal shocks. This is relevant, as the degree to which prices are sticky imply different responses of the economy to real shocks and have different policy

[15] With menu costs, prices fall 4.69% and wages 5.56% for a real shock that contracts consumption in 4.53%. With flexible prices, the fall in prices is 5.31%, wages fall in 6.03% and consumption 3.96%.

[16] This is particularly true if prices have a time-dependent nominal rigidity, as in de Carvalho and Nechio (2011), but also for closed-economy menu cost models as in Nakamura and Steinsson (2010).

implications (see Calvo (2000); Lorenzoni (2014)). A contribution of this chapter is that I study an open economy and its response to shocks with a model that can account for the endogeneity of the fraction of price adjustment and self-selection in price adjustment.

This chapter is also related to the literature that studies the importance of changes in pricing patterns in emerging economies. Typically this literature has analyzed these pricing patterns in the CPI micro-data and compared them with one sector closed-economy menu cost models' steady states with different (and exogenous) inflation rates (see Gagnon (2009); Alvarez et al. (2011)).[17] A contribution of this chapter is that I analyze the observed prices and quantities in the aftermath of the large shock through the lens of a general equilibrium model that allows for sectoral heterogeneity.[18]

The chapter is structured as follows. First, I describe a model for a small open economy with state-dependent nominal rigidities that faces nominal and real shocks. Third, I use the model to analyze the role of the nominal rigidities determining prices and quantities in Mexico's episodes of large currency depreciations in 1994 and 2008. Lastly, I present conclusions.

2.2 The Model

In this Section I present a model in which the frequency of price adjustment —and hence the extensive margin of inflation— is endogenous and it can respond to aggregate shocks: prices adjust optimally to the environment, subject to a friction (menu costs). Incentives to change prices arise from changes in the marginal costs, so the response of these to the shocks will determine the desired price changes and the fraction of prices that adjust.

The model is a variant of the standard New Keynesian model for a small open economy. The economy has measure zero, so its policies do not affect the rest of the world. The structure of this economy is based on Gali and Monacelli (2005). I depart from the standard model in the following ways: (i) I add multiple sectors, (ii) in each sector,

[17] Gagnon (2009) studies how did the behavior of prices change in Mexico between the 'high inflation' regime in the mid-1990's and a 'low inflation regime' since the early 2000's, and finds that the frequency of price adjustment increases when inflation is high. Alvarez et al. (2011) provide an analysis of the more extreme monetary regimes in Argentina —that went from hyperinflation to very low and stable inflation— and also find that the frequency at which prices adjust responds to the nominal environment.

[18] In this respect, Karadi and Reiff (2012) is closer to this chapter. They study the effects of large VAT shocks in Hungary. However, they also analyze a closed-economy model with one sector.

monopolistically competitive firms produce differentiated varieties using labor and a homogeneous imported intermediate input with the relative importance of these production inputs being heterogeneous across sectors, and (iii) firms that wish to adjust their prices are subject to a menu cost nominal friction, which is also heterogeneous across sectors.

The economy is divided into a finite number of sectors indexed by $r \in 1, 2, ..., R$. In each sector there is a continuum of firms indexed by $j \in [0, 1]$. Each firm belongs to one of the R sectors and produces a differentiated good that is used to produce a sectoral output that is used for domestic consumption. Some sectors can face a demand from the rest of the world (this sector characteristic is set exogenously).

A superscript '$*$' denote variables that correspond to the rest of the world.

Time is discrete, there is no uncertainty over aggregate variables, and agents are infinitively-lived with perfect foresight over the whole future. I only consider unanticipated aggregate shocks, so that after agents are surprised by the realization of an aggregate shock, no further uncertainty remains and agents have perfect foresight.

There is no capital accumulation and the only asset in the economy is an non-contingent financial asset denominated in foreign currency.

2.2.1 Households

Households seek to maximize their lifetime utility of consumption and leisure

$$\sum_{t=0}^{\infty} \beta^t U\left(C_t, L_t\right).$$

Households have Greenwood-Hercowitz-Huffman preferences over each period's consumption and leisure represented by the utility function (see Greenwood et al. (1988))

$$U\left(C_t, L_t\right) = \frac{1}{1-\sigma}\left[C_t - \psi_0 \frac{\left(L_t\right)^{1+\psi}}{1+\psi}\right]^{1-\sigma}, \tag{2.1}$$

where L_t is labor, and C_t is aggregate consumption.

These preferences are convenient as they isolate the labor supply from wealth effects.

Households maximize their life-time utility subject to a sequence of budget constraints

$$P_t C_t + E_t B_{t+1} = W_t L_t + \Pi_t + E_t P^*_{x,t} X_t + (1 + i^*_{t-1}) E_t B_t$$

for $t = 0, 1, 2, \ldots,$

where E_t is the nominal exchange rate (domestic currency per dollar), W_t is the nominal wage, Π_t denotes aggregate nominal profits; $P^*_{x,t} X_t$ denotes the value in foreign currency of an endowment of an exported non-consumed good (e.g. a commodity endowment). In the case of Mexico, exports of this commodity endowment correspond to oil exports. B_t are foreign bond holdings (in foreign currency) paying the interest rate i^*_t. In order to abstract from steady-state trends in consumption, I will assume that $(1 + i^*)\,\beta = 1$ in steady state..

Taking first order conditions with respect to bond holdings and consumption yields the Euler equation for B_{t+1} given by

$$\left(\frac{C_t - \psi_0 \frac{(L_t)^{1+\psi}}{1+\psi}}{C_{t+1} - \psi_0 \frac{(L_{t+1})^{1+\psi}}{1+\psi}} \right)^{-\sigma} = \beta \frac{P_t}{P_{t+1}} (1 + i^*_t) \frac{E_{t+1}}{E_t}. \tag{2.2}$$

Households' labor supply is given by

$$\frac{W_t}{P_t} = \psi_0 L_t^{\psi}.$$

As it will be discussed later, agents may also be unexpectedly subject to an exogenously imposed borrowing constraint $B_{t+1} \geq \bar{B}_{t+1}$ for some exogenous sequence $\{\bar{B}_s\}_{s=\tau}^{S}$. If that is the case, the exogenous constraint will hold and the Euler equation will not bind. This constraint will capture the salient characteristics of a *Sudden Stop* in a mechanical and simplified way. When this happens, the economy becomes unexpectedly closed to financial flows (see Lorenzoni (2014); Burstein et al. (2007); Kehoe and Ruhl (2009).

2.2.2 Firms

2.2.2.1 Competitive aggregators

The aggregate consumption bundle C_t is a composite consumption index defined by

$$C_t = \left[\sum_{r}^{R} \gamma_r{}^{\frac{1}{\lambda}} C_{r,t}^{\frac{\lambda-1}{\lambda}} \right]^{\frac{\lambda}{\lambda-1}}, \tag{2.3}$$

where γ_r are the shares of each sector in aggregate consumption. The first order condition of the cost minimization of the aggregator firms yields optimality conditions between sectors r and $r-1$

$$\left(\frac{1-\gamma_{r-1}}{\gamma_r} \right) \left(\frac{C_{r,t}}{C_{r-1,t}} \right) = \left(\frac{P_{r,t}}{P_{r-1,t}} \right)^{-\rho}. \tag{2.4}$$

The other source of sectors' demand are exports

$$C_{r,t}^{*} = \chi_r \left(\frac{P_{r,t}}{E_t} + \phi^{*} \right)^{-\theta} Y_t^{*}. \tag{2.5}$$

The indicator χ_r is exogenously set to one if the sector exports (*e.g.* manufactures) and zero if it does not (*e.g.* services). Export prices are set with *producer currency pricing*, so the demand for sector r depends negatively on its dollar price $P_{r,t}/E_t$. To generate a response of exports consistent with the data, I introduce foreign distribution costs (ϕ^{*} are the distribution costs in the foreign market), so that the price paid by the foreigner consumers of sector r exports has a fixed component of goods produced in the foreign country (see Corsetti and Dedola (2005) and Cravino (2012)). The rationale is that this will reduce the elasticity of exports to movement in the sector price expressed in foreign currency, thus mechanically capturing the fact that exports are constrained by other factors that limit their response to price incentives (financial constraints, fixed costs of accessing to new markets, etc).

The market equilibrium condition in each of these R sectors is

$$Y_{r,t} = C_{r,t} + C_{r,t}^{*}, \tag{2.6}$$

where $Y_{r,t}$ is the total output of sector r. In each of the R sectors, this output is produced by a competitive industry that aggregates differentiated varieties from firms with a technology featuring constant elasticity of substitution across varieties that belong to the sector

$$Y_{r,t} = \left[\int_0^1 y_{r,t}(j)^{\frac{\epsilon-1}{\epsilon}} dj\right]^{\frac{\epsilon}{\epsilon-1}}. \tag{2.7}$$

Hence, each sector aggregator has a demand for variety j given by

$$y_{r,t}(j) = \left(\frac{P_{r,t}(j')}{P_{r,t}}\right)^{-\epsilon} Y_{r,t}. \tag{2.8}$$

2.2.2.2 Differentiated Goods Producers

In any sector r, there is a continuum of monopolistic competitors. Firm j will produce with technology

$$y_{r,t}(j) = Z_{r,t}(j) L_{r,t}(j)^{1-s_r} M_{r,t}(j)^{s_r}, \tag{2.9}$$

where $Z_{r,t}(j)$ is firm's j idiosyncratic productivity, $L_r(j)$ is its use of labor and $M_r(j)$ is its use of imported inputs. Given that the law of one price holds for imports, there will be full pass-through at the border. Normalizing the price of imports to one: $P_{M,t} = P^*_{M,t} E_t = E_t$

From the firm's cost minimization problem the unit input cost is

$$MC_{r,t} = \Phi_r W_t^{1-s_r} E_t^{s_r},$$

with $\Phi_r = s_r^{-s_r} (1-s_r)^{s_r-1}$. The firm's demands for labor and imports are given by

$$M_{r,t}(j) = \left(\frac{s_r}{1-s_r}\frac{W}{E_t}\right)^{1-s_r} \frac{1}{Z_{r,t}(j)} Y_{r,t}(j)$$
$$L_{r,t}(j) = \left(\frac{s_r}{1-s_r}\frac{W_t}{E_t}\right)^{-s_r} \frac{1}{Z_{r,t}(j)} Y_{r,t}(j).$$

The idiosyncratic productivities follow a log autoregressive process given by

$$\log Z_{r,t}(j) = \rho_Z \log Z_{r,t-1}(j) + \epsilon_{r,t}. \tag{2.10}$$

To allow for flexibility in the specification of the process, I will allow for the independent idiosyncratic shocks follow a Poisson process with rate q, where this arrival rate is independent of the innovation process ϵ_r

$$\epsilon_r = \begin{cases} 0 & \text{with probability } q \\ N(0, \sigma_{r,\epsilon}) & \text{with probability } 1-q \end{cases}. \tag{2.11}$$

Thus, the idiosyncratic shocks $\epsilon_{r,t}$ have a Normal distribution with zero mean and standard deviation $\sigma_{\epsilon,r}$ and arrive at rate $1-q$. The literature for closed economies has found that the introduction of 'fat-tailed' shocks' distributions can generate greater price stickiness and capture the fact that many price changes are smaller than those generated by a standard menu cost model with a log normal productivity process (see Midrigan (2011)). Here, I follow Karadi and Reiff (2012) in the specification of the process to generate the fat-tails in the distribution of productivities. In my results, the main difference will be that the slower arrival of idiosyncratic shocks will generate more persistence in the response of prices relative to the log-normal case (where $q = 0$). This is discussed in greater detail in Section 2.5.

Menu Costs In every period, firms producing the differentiated varieties observe their own idiosyncratic states (the price they had the previous period $p_{r,t-1}(j)$ and their productivity this period $Z_{r,t}(j)$) and the aggregate states of the economy and choose between keeping their past price or choosing the optimal reset price subject to a menu cost $\kappa_r MC_{r,t}$.[19]

Firms' exogenous state variables are $\Omega(j) = Z(j), W, P_r, P_{-r}, E$, where P_r, P_{-r} are the price index for the sector and a vector of all other sectors' price indexes, respectively.

[19]In menu cost models, production is usually linear in labor and the menu cost is usually proportional to the wage, hence κW_t. The modification that I introduce is irrelevant for the computation of the steady state without aggregate shocks but greatly simplifies the computation of the transition when there is an unexpected aggregate shock.

Dropping notation for sectoral heterogeneity for expositional convenience, a firm's recursive problem is described by the following Bellman equations. The value of not changing the price is

$$V^{NC}\left(p_{-1}(j),\Omega(j)\right)=\Pi\left(p_{-1}(j),\Omega(j)\right)+\beta EV\left(\frac{p_{-1}(j)}{1+\pi},\Omega'(j)\right). \tag{2.12}$$

The value of paying the menu cost and choosing the optimal price is

$$V^{C}\left(p_{-1}(j),\Omega(j)\right)=\max_{p(j)}\Pi\left(p(j),\Omega(j)\right)-\kappa MC+\beta EV\left(\frac{p_(j)}{1+\pi}\Omega'(j)\right). \tag{2.13}$$

So the firm's value functions will be given by

$$V\left(p_{-1}(j),\Omega(j)\right)=\max_{C,NC}\left\{V^{NC}\left(p_{-1}(j),\Omega(j)\right),V^{C}\left(p_{-1}(j),\Omega(j)\right)\right\}. \tag{2.14}$$

The solution for this problem is described by 'Ss rules': given the aggregate states, each combination of idiosyncratic states $(p_{-1}(j),Z(j))$ will be either in the 'inaction area', in which it is more profitable for the firm to keep their price, or it will be outside the inaction area, so that the firm will incur the menu cost and reset its price to the optimal new level. In Appendix 2.7 I provide details of the solution method.

2.2.3 Balance of Payments

Given the assumption that the law of one price holds for imports, $P_{M,t}=E_t$ and that the foreign price of the imported input $P^*_{M,t}$ is normalized to one, the dollar value of imports is M_t (the sum of all firms' imported inputs).

$$M_t=\sum_{r=1}^{R}\int_0^1 M_{r,t}(j)dj.$$

The Balance of Payments is

$$M_t=P^*_{x,t}X_t+\sum_{r=N+1}^{R}\frac{P_{r,t}}{E_t}C^*_{r,t}+(1+i^*)B_{t+1}-B_t, \tag{2.15}$$

where B_t are domestic net holdings of foreign assets, i_t^* is the international interest rate, $P_{x,t}^* X_t$ is the value of the commodity endowment, and $\sum_{r=N+1}^{R} \frac{P_{r,t}}{E_t} C_{r,t}^*$ is the dollar value of differentiated exports.

Price indexes and RER

Each sector r has a price index given by

$$P_{r,t} = \left(\int_0^1 P_{r,t}(j)^{1-\epsilon} \, dj \right)^{\frac{1}{1-\epsilon}}. \tag{2.16}$$

Consumer price index (CPI) is

$$P_t = \left(\sum_r^R \gamma_r P_{r,t}^{1-\rho} \right)^{\frac{1}{1-\rho}}. \tag{2.17}$$

The import price is $P_{M,t} = E_t$.

Given the normalization imposed on foreign prices in foreign currency ($P_t^* = 1$), the CPI-based real exchange rate is given by $RER_t = \frac{E_t}{P_t}$.

Given the above assumption of producer currency pricing, the export price for each sector is $\frac{P_{r,t}}{E_t}$.

Equilibrium

A perfect-foresight competitive equilibrium for this economy is a set of paths for quantities $(\left\{ C_t, \left\{ C_{r,t}, C_{r,t}^*, Y_{r,t} \right\}_{r=1}^{R}, B_{t+1}, L_t, M_t \right\}_{t=0}^{\infty})$ and prices $(\left\{ P_t, \left\{ P_{r,t} \right\}_{r=1}^{R}, W_t \right\}_{t=0}^{\infty})$ such that, given a path of the exogenous variables $\left\{ E_t, Y_t^*, P_{x,t} X_t, \bar{B}, i_t^* \right\}$, households maximize their utility and firms maximize profits, the aggregate, sectoral and differentiated goods, and labor markets clear and the balance of payments holds.

After the unanticipated aggregate shocks hit the economy, agents maximize their objective functions under perfect foresight.

2.3 Calibration

2.3.1 Firms

There are five parameters to be chosen in the monopolistically competitive firm's problem in each sector r. These are the share of imported inputs (s_r), the menu cost (κ_r), the idiosyncratic shock's standard error ($\sigma_{\epsilon,r}$), the autoregressive process coefficient for the idiosyncratic productivity process (ρ), and the idiosyncratic shocks' Poisson arrival rate (q). The calibration is performed in the following manner:

Input shares The value of the share of imported inputs s_r is taken from Mexico's Input Output Table for 2003.[20] I take the revenue share of imported inputs by sector and compute cost shares by multiplying the revenue share by the the gross markup.[21] [22]

Menu costs As it is usual in the menu cost literature, the values of the menu cost parameter K_r and the standard error of the idiosyncratic shock $\sigma_{\epsilon,r}$ are jointly calibrated to target the frequency of price adjustment (fr_r) and the average size of price adjustment (dp_r) by sector before the depreciation.

In the exercises I present in the next section I also consider two variations of the model. First, a 'Calvo' specification in which firms are randomly allowed to change their price. I calibrate the probability with which they receive that opportunity to the frequency of price adjustment in each sector. Second, I also consider a 'Flexible price' specification in which K_r is set to zero for all sectors.

The last two parameters are common across sectors. I set the autoregressive coefficient in the idiosyncratic productivity process (ρ_r) to be 0.7 as in Nakamura and Steinsson (2010) and Golosov and Lucas (2007). The idiosyncratic shock Poisson arrival rate q is

[20] I use this year as it has separate measurements for the *Maquila* industry, which I leave out of the calibration. The 2010 publication of the Input Output Table does not allow to separate inputs use and production between the 'domestic economy' and the *Maquila* sector.

[21] This cannot be done directly as sectors in the I-O matrix are different than the ones in CPI. I matched the 215 sub-categories in my subsample of the CPI and matched them to the SCIAN nomenclature used in the I-O matrix. With this, I re-aggregated the sectors using CPI weights and computed the imported input use.

[22] Nakamura and Steinsson (2010) have the same approach for the US but they do not discriminate between domestic and imported inputs.

set to 0.7 in the baseline specification. This value will generate a higher kurtosis than the log normal case, where $q = 0$.

Table 2.1 summarizes the calibration for the baseline specification for a two sector economy (goods and services).

2.3.2 Macro parameters

I summarize the parameter values for the baseline specification of the model in Table 2.2. First, the elasticity of substitution between varieties (ϵ) is chosen to imply a gross markup of 1.3. This is similar to what Nakamura and Steinsson (2010) use in their closed economy monetary model. I set the domestic elasticity of substitution between sectors (ρ) to 0.4. This is consistent with estimates in the literature.[23] The share parameters in the domestic aggregate good (γ_r) are taken from the CPI basket weights (computed over the restricted sample of categories described in Section 2).

I assume $\psi = 0.25$, which implies a Frisch labor supply elasticity of 4. I choose this value to be consistent with the literature (see Stockman and Tesar (1995)). In particular, it makes results comparable Burstein et al. (2007), who also use this value for the Frisch elasticity. The level parameter in the disutility of labor (ψ_0) is set so that in steady state the nominal wage is normalized to 1. The value of the foreign distribution cost (ϕ^*) is chosen so that the pre-devaluation margin is 50% in foreign markets.[24] The level parameter for export demand is set to one if the sector exports (e.g. goods) and zero otherwise (e.g. services). The elasticity of exports (θ) is chosen so that the model can capture the relatively inelastic response of exports to the change in relative prices after the depreciation.

The steady state net foreign asset position is chosen to match the ratio of the current account to consumption the year before the depreciation. In order to pin down the share of exports in the economy, I choose the value of commodity exports in steady state to target the share of exports in GDP.

[23] See Burstein et al. (2007); Kehoe and Ruhl (2009)

[24] This is consistent with the evidence in Burstein et al. (2005).

2.3.3 Shocks

There were large contractions in aggregate economic activity in each of the two episodes that I study. Figures 2.1 and 2.2 illustrate this. Six months after the depreciation private consumption was 12.49% smaller (in May 1995), and 10.4% smaller (in April 2009).

In the 1994 depreciation episode, I generate a recession by assuming that the borrowing constraint becomes binding at a level $i_0^* \bar{B}$ at the time of the depreciation. This experiment is similar to the Sudden Stop modeled by Kehoe and Ruhl (2009). I calibrate the borrowing constraint to match the fall in real consumption six months after the shock. The assumed fall in $\bar{B}$ coincides with a 55% unanticipated and permanent increase in the nominal exchange rate. This depreciation rate coincides with the change in the nominal exchange rate six months after the depreciation.

The 2008 depreciation coincided with a large fall in demand from Mexico's main trade partner (the US) and a fall in the price of commodities that Mexico exports.[25] I assume that there is a fall in Y_0^*, the demand from the rest of the world, and a fall in $P_{x,t}X_0$, the commodity endowment, that coincides with a depreciation of 33% (the cumulative depreciation of the Peso between October 2008 and April 2008). The size of the fall in $P_{x,t}X_0$ is taken from the data (the fall in commodity exports) and the size of the fall in Y_0^* is chosen to match the observed fall in real consumption.

At time zero, there is an unanticipated one-time permanent exchange-rate depreciation, so E_t increases. In both examples I assume that agents did not anticipate either a change in the nominal exchange rate, in the binding asset constraint, or in export demand, so the economy is initially in a steady state with constant prices and quantities.

2.4 Basic Results

In this section, I first present the results of a pure depreciation without negative real shocks. Then I show the results of introducing negative real shocks for the 1994 large depreciation episode. I also extend the model to use sticky nominal wages to match the data and repeat the exercise to evaluate the potential non-neutralities arising from labor

[25] Exports to the US correspond 85% of total Mexico's non-oil exports

market nominal rigidities. In all cases the role of the menu cost in consumer prices is small in explaining the behavior of prices. Most firms pay the menu cost to readjust their prices and the aggregate outcomes of the model are similar to the outcomes of the model with flexible prices.

I then repeat the exercises for 2008 to show an episode in which the frequency of price adjustment barely moves in the data. I show how the model can match the data and how much does the price nominal rigidity matter.

All the reported results are expressed in percentage log-changes to be consistent with the facts shown in Section 2.

2.4.1 The 1994 Episode

2.4.1.1 Pure Depreciation

Absent any real shock or wage rigidity, a large currency depreciation creates large incentives to adjust prices. When the source of prices' nominal rigidities are menu costs, currency depreciation will not affect the real economy. The intuition is the following: assuming that firms chose not to reset their prices, the fall in the dollar price of exports will imply a large increase in exports and hence, in labor demand. Moreover, imports will be more expensive, causing firms to substitute imports for labor. Thus, the nominal wage must increase to incentivize workers to supply more labor. The increase in nominal wages and import costs makes all firms willing to pay the menu cost and reset their prices to their optimal levels.

Columns 1 to 3 in Table 2.3 correspond to the model without real shocks for the baseline model (*Menu*), one in which the menu costs κ_r are set to zero for all sectors (*Flexible*), and one in which there firms receive a random opportunity to adjust their price that arrives with a probability equal to the steady state frequency of price adjustment (*Calvo*). Column 4 reports the values from the data for the 1994 depreciation.[26]

For the menu cost model and the flexible price model there is no difference whatsoever.[27] The responses of prices and wages are both proportional to the currency depre-

[26]Results for the 2008 episode would be analogous, so they are omitted.

[27]The only difference is the 'waste' of resources used to pay for the menu costs and readjust prices.

ciation. The log change in the exchange rate and nominal wages is 55%, so all firms' marginal costs increase in that amount as well. Given the calibration of the menu costs, all firms are willing to pay the menu costs and reset their prices. Therefore, the equilibrium for large 'pure' nominal shocks features complete exchange rate pass-through to prices in the model with menu costs.[28]

At this point, it is helpful to relate the predictions of the model to those of a 'Calvo' sticky price model. Column 3 shows the result of only allowing a random 9% of service-producing firms and 33% of goods-producing firms to adjust per month.[29] As the price index of the exporting sector is now lower in foreign currency terms, exports grow. This expansion generates an increase in labor demand, so real and nominal wages must increase to incentivize workers to sell their labor. Therefore, under Calvo pricing, a large nominal shock generates a large expansion. This expansion comes at the expense of firms' markups over marginal costs. As shown in Figures 2.1 and 2.2, this expansion in employment, imports, and consumption is counterfactual.

2.4.1.2 Negative Real Shocks with Flexible wages

Table 2.4 show the results of a 55% log change in the nominal exchange rate together with a *Sudden Stop* that forces the economy to repay $i_t^* \bar{B}$ every period and causes consumption to fall by 12.49% six months after the shock. Column 4 summarizes the data observed in Mexico between November 1994 and May 1995.

Column 1 presents the results of the model with menu costs. The fall in consumption is exactly matched in the Menu cost specification since it is a target of the real shock calibration (i.e. the value of $i_t^* \bar{B}$). Nominal wages increase almost 25%, which is higher than in the data. While employment falls as the economy produces less, imported inputs fall even more, as firms substitute toward labor —the cheapest input. As prices in foreign currency are lower (the RER increases by 19.2%), exports increase, partially compensating for the fall in domestic consumption.

[28]Note that this result depends critically on the size of the shock. When nominal shocks are small enough, not all firms will want to adjust their prices. Next section explores the effect of different shock sizes.

[29]Note that these frequencies of adjustment are larger than the ones found in the standard open economy New Keynesian model. Gali and Monacelli (2005) uses a quarterly value of 0.25, that corresponds to a 0.07 in the monthly calibration.

Column 2 shows the results of the flexible price model, where menu costs are set to zero. Given that in the menu cost model all firms choose to adjust their prices, the results of these two models are almost identical. In this case, the menu cost nominal rigidity is too small to generate significative aggregate effects.

Column 3 shows the results of the Calvo model. Under this assumption, prices adjust much less, as only a constant and random fraction of firms is allowed to reset their prices. The real effect of this is very large: given the same negative real shock, consumption does not fall. The reason for this is that exports grow much more because their price in dollars is even lower (compared to Column 1 and 2). While imports still fall, the demand for labor increases and so does the real wage.

A summary statistic of the cumulative effect of the changes in the fraction of price adjustment is the proportion of cumulative inflation explained by the 'extensive margin' of price adjustment ($\frac{\pi_t^{EM}}{\pi_t}$). As shown in Section 2, this term is positive only if there is a change in the fraction of prices that adjust, compared to the pre-shock steady state.

In the data the extensive margin of inflation is very important to account for inflation in the 1994 episode. Only the menu cost model can capture the fact that there is a change in the fraction of adjusting firms. In the flexible price model, this margin is zero as all firms change their prices every period, even before the shock.[30] In the 'Calvo' model, this margin is shut down by assumption and firms are forced to have prices much lower than the one they want (i.e. they have very low 'effective' markups) and this is the source of the large non-neutralities that this model generates.

One of the conclusions drawn from this exercise is that, under the calibration of the macro parameters, the response in nominal wages is too strong with respect to the data even with the addition of the negative real shock. Therefore the baseline menu cost model cannot fully account for the aggregate behavior of prices. In the next sub-section I introduce *sticky wages* to allow the model to be closer to the data in this case and analyze its implications.

[30]Given that firms receive idiosyncratic shocks and face a trend inflation, the fraction of adjusting nominal prices is one before and after the shock.

2.4.1.3 Sticky wages

The approach to modeling sticky wages follows Erceg et al. (2000). There is a continuum of *unions* ($k \in [0,1]$) that buy the representative household's labor supply and use it to produce and sell a differentiated variety of labor. There is monopolistic competition among the different types of labor. These varieties are sold to a competitive labor aggregator sector with CES technology and elasticity of substitution ϵ_W . The labor composite is given by

$$L_t = \left[\int_0^1 L_t(k)^{\frac{\epsilon_W - 1}{\epsilon_W}} dk\right]^{\frac{\epsilon_W}{\epsilon_W - 1}}. \tag{2.18}$$

These unions are subject to the 'sticky plans' formulation of Mankiw and Reis (2002). Wage plans are set in advance and can only be revised slowly after new information arrives. This setup is chosen to model wage rigidities because it is a simple way to allow for inertia in wages. Moreover, this formulation is very tractable and does not add another layer of complexity to the numerical solution. The results are insensitive to other forms of time-dependent wage rigidities.[31]

A union k inherits a wage plan $\{W_{t_0+s}(h)\}_s$ that was last set at time t_0. The opportunity to revise this plan arrives stochastically. If such an opportunity arises at time t and there has been a shock, the union makes a new plan for the current wage and future price path. Given that I only consider unanticipated shocks, this implies that after any such shock no further uncertainty remains. As a result, unions maximize under apparent perfect foresight. Hence, union k optimally sets its wage $W_t(k)$ to maximize

$$\max_{W_t(k)} (W(j) - MC_t) W_t(k)^{-\varepsilon_w} W_t^W L_t. \tag{2.19}$$

The parameter that governs the frequency at which wages adjust is calibrated so that wage plans are consistent with the behavior of prices in the monthly data.

[31] A richer version of the model could include a labor market more suitable to take to the labor market micro data. A promising alternative would be to have a search model with nominal wage rigidities as in Gertler et al. (2008) so that wages do not violate the restriction on the efficiency of matches.

2.4.1.4 The 1994 Episode with Negative Real shock and Sticky Wages

Table 2.5 shows the results for the 1994 episode when wages are sticky. Column 1 presents the results of the model with menu costs and sticky wages. The *Sudden Stop* is recalibrated to match the contraction in consumption under wage stickiness.

The role of price stickiness The menu cost model with sticky wages matches the data quite closely: the response of prices is almost equal to the data. The nominal wage increase for this seems to be above the observed increase in the data. Also, the fraction of the price change that is explained by the 'extensive margin' of price adjustment is also close to the data: the frequency of adjustment increases significantly and it explains 50.3% of cumulative inflation in the data and 55.8% in the model with sticky wages. This is due to the fact that, despite the real wage is falling, in the model the nominal wage is increases by 20.2%, which gives incentives to most firms to reset their prices.

To evaluate the role of the menu cost nominal rigidity in prices, it is useful to compare Column 1 (menu costs) with Column 2 (flexible prices). The increase in prices is very similar in both cases. This is explained by the generalized readjustment of prices under menu costs.

This is one of the main results of the chapter. Menu cost nominal rigidities are *small* relative to the size of the real shock. The fact that the menu cost model is so close to the flexible price model is evidence that the role of price rigidities is small relative to the size of the shocks this economy experiences.

Column 3 shows the results of Calvo pricing under sticky wages. Because the desired price changes are large, the Calvo price rigidity has a large effect on prices and consumption, relative to the menu cost and flexible price models. The reason is, again, that most firms would want to change their prices and they cannot under this assumption. Thus, shutting down the extensive margin of price adjustment by holding the *fraction* of firms adjusting generates a fall in consumption of 9.85% (instead of 12.49%) for the same combination of nominal and real shocks.

The role of wage stickiness The second benchmark to compare these results with is Column 4, where I present the results of the same nominal and real shocks, under menu

costs and frictionless wage adjustment.[32]

The effects of wage rigidities are noticeable for the menu cost model. With flexible wages, wages increase by 31.67%, and the response in prices is larger than in the data. This generates a smaller increase in exports and a larger fall in employment. While real wages fall, they fall less than when wages are sticky. Therefore, labor demand is weaker with flexible wages. The effect on consumption is also large: flexible wages imply that consumption falls by 23.34% relative to 12.49% (the calibrated value for sticky wages).

It is illustrative to note that the Calvo model with flexible wages (Column 6) is observationally similar to the menu cost model with sticky wages (Column 1). The CPI micro data is what provides identification of the source of nominal rigidities. In Column 6, the model is unable to match the role of the extensive margin of price adjustment in explaining the response of prices to the depreciation.

2.4.2 The 2008 Episode

Here I present the results for the 2008 episode. In the data there are three salient differences with respect to the 1994 episode. While the nominal exchange rate shock was large, it was roughly half of the one in 1994. Also, nominal wages barely increased and the frequency of price adjustment did not change significantly.

For expositional purposes, in the 2008 episode I only present the cases of a negative real shock paired with flexible wages and with sticky wages. The results of the pure depreciation exercise are similar to the ones shown above for the 1994 depreciation episode.

2.4.2.1 Negative real shock and flexible wages

Table 2.6 shows the results for a 33% log change in the nominal exchange rate and a fall in export demand such that consumption falls by 10.4% in the space of 6 months. Column 4 shows the data for Mexico between October 2008 and April 2009.

Column 1 presents the results from the menu cost model, which is again very close to the flexible price model (Column 2). In both these cases, nominal wages and prices

[32]Notice that results differ relative to Table 2.4 —where wages are also flexible— as the *Sudden Stop* has been re-calibrated to match consumption under the sticky wage assumption.

increase more than they do in the data. Under the assumption of Calvo pricing (Column 3), prices increase by less, so the fall in exports is smaller and the economy faces a smaller contraction in consumption and labor. Because labor demand does not fall as much as in the first two cases, real wages experience a smaller decrease less as well. As before, I introduce nominal wage rigidities to match the behavior of the CPI.

2.4.2.2 Negative real shock under sticky wages

Table 2.7 shows the results for the 2008 episode when wages are sticky. The fall in export demand is recalibrated to match the contraction in consumption under menu costs and wage stickiness. Column 1 presents the results of the model with menu costs and sticky wages. This model can again match the data, both for prices and nominal wages. Moreover, the extensive margin is close to the data. In this episode, the frequency of adjustment changed very little so this margin is not relevant to explain cumulative inflation. This is due to the fact that nominal wages are barely adjusting. Given the relatively small share of imported inputs in firms' unit input cost, this implies that the fraction of firms that will want to reset their price barely increases.

The role of price stickiness To evaluate the role of the menu cost nominal rigidity in prices, Column 2 shows the output of the model with flexible prices and sticky wages. Relative to the data, prices increase slightly more, and consumption decreases slightly more.

Importantly, these results are very close to the menu cost model in Column 1. This stresses again one of the messages of the chapter: menu cost nominal rigidities are *small* relative to the size of the real shock. While consumption falls 10.4% in the menu cost model, it falls 10.47% when prices are fully flexible. Put differently, the non-neutrality that the menu cost model generates only accounts for a difference of 0.07 percentage points of consumption. The small differences in the rest of the variables show the same result. The fact that the menu cost model is so close to the flexible price model is again evidence that the role of price rigidities is small relative to the size of the shocks this economy experiences.

The small effect of the change in the frequency of adjustment is summarized by the

percentage of inflation explained by the 'extensive margin' ($\frac{\pi_t^{EM}}{\pi_t}$). Clearly, an important feature of the flexible price version of the model is that all firms will choose to reset their prices. As shown in Column 7, in the data only 7.5% of cumulative inflation can be explained by changes in the fraction of adjusting firms. The menu cost model matches this margin quite closely

Column 3 shows the results of Calvo pricing under sticky wages. Because wages adjusted little —due to the rigidity imposed on them— desired price changes are small and the Calvo price rigidity has a small effect on prices and consumption, relative to the menu cost and flexible price models.

Given that in the menu cost model the fraction of adjusting firms changes very little after the shock, the difference with the Calvo model is only explained by which firms adjust. In the menu cost model, the adjusting firms are the ones whose prices are farther from their desired levels: firms that had very low prices may want to readjust them to keep pace with the higher unit input costs they face.

In the Calvo model, firms that adjust are chosen randomly, so a firm that already had a high price may have an opportunity to change its price, but it will increase it by a much smaller amount. Firms with low prices may not get the random opportunity to increase their prices. Thus, shutting down the selection of adjusting firms keeps prices from fully adjusting to their desired prices. However, in this case it is not the fact that the *fraction* of firms adjusting is constant —which barely changes in the Menu cost model— but the *identity* of which firms are adjusting. Since wage increases are dampened by wage stickiness, the desired increase in prices is relatively small —as shown in the other two cases— and the extent to which consumption differs in the Calvo specification is smaller when wages are sticky relative to when wages are fully flexible. Given that the frequency of price adjustment in the changes very little in the data and in the menu cost model, the only relevant margin is *which* firms adjust prices.

The role of wage stickiness The second benchmark to compare the menu cost with sticky wages is the same model and shocks but letting wages to freely adjust. Results for this are presented in Column 4.

The effects of wage stickiness are noticeable for the menu cost model. With flexible

wages, wages increase by 4.31%, and the response in prices is larger than when wages are sticky. This generates a larger fall in exports (given the same exogenous fall in foreign demand), and importantly, in employment. While real wages fall, they fall less than when wages are sticky. Therefore, labor demand is weaker. The effect of this in consumption is also large: sticky wages imply that consumption falls 4.38% less than with flexible wages.

Again, an interesting result of this experiment is that the specification of the model with Calvo prices and flexible wages (Column 6) is close to having the same prices and consumption than the menu cost model with sticky wages (Column 1). The comparison of these two models is also of interest: it shows that without disciplining the price rigidity with micro data, one could assume that the source of non-neutralities comes from the final goods markets.

Given that the frequency of adjustment barely changes in the data and in these two models, the sources of the real effects of the nominal depreciation —in the presence of a real shock— could be misidentified. One of the findings of this chapter is that once the nominal rigidity is disciplined with the menu cost model calibrated to micro data, it must be the case that the labor market is the main source of nominal rigidities, and not prices.

2.5 Key mechanisms

Here I first analyze the role of three characteristics of the model that affect outcomes through the pricing problem of the firm: the size of the nominal shock, the characteristics of the idiosyncratic productivity process, and the heterogeneity in menu costs across sectors. Then I analyze the role of macro parameters for the baseline menu cost model with two sectors.

2.5.1 Firms' pricing

Size of the nominal depreciation To analyze the role of the size of the nominal shock, here I show results with only pure depreciation (and no real shock). Figure 2.3 compares the exchange rate pass-through to prices ($\frac{d \log P_t}{d \log E_t}$) for the menu cost, Calvo and flexible prices specifications of the model in the period that the shock hits ('on-

impact'). With flexible prices, the pass-through is always equal to one. With Calvo, it is approximately linear on the size of the shock. As anticipated above, the pass-through is highly non-linear for the menu cost model: for small shocks it is closer to the Calvo model (although the pass-through is larger) and for large shocks it is similar to the flexible price model. As discussed in the next subsection, the ability of nominal rigidities to generate incomplete pass-through to prices is much less 6 months after the shock.

Figure 2.4 shows the effects of different depreciation rates in the menu cost model. The results show that there are real effects for depreciations below 15%. In particular, for a 5% depreciation, consumption increases by almost 2% on impact (Panel A). For shocks that are small enough, the counterpart of increase in consumption is the incomplete response of prices on impact (Panel B). When there are nominal rigidities, labor demand increases and the real wage increases as well (Panel C). When the depreciation is 15% or more, the fraction of adjusting firms goes to 1 (see Panel D), so there are no real effects of the nominal shock.

This illustrates how the role of the size of the shock matters when menu costs are the source of nominal rigidities in prices. When the nominal depreciation increases above 5%, the non-neutralities begin to diminish as more firms have incentives to pay the menu cost and increase their price. The effect of the depreciation on prices is reinforced as nominal wages increase. Absent any real shock or wage rigidity, a large currency depreciation will create large incentives to reset prices, so in equilibrium the nominal exchange rate shock will not generate real effects.

Persistence of price stickiness Figure 2.5 shows that the real effects of a small depreciation die-off very quickly as more firms receive idiosyncratic shocks that make them reset their prices, so the exchange rate pass-through quickly increases. The fact that there are still non-neutralities present a few months after the shock is due to the idiosyncratic shock specification. The fact that firms 'rarely' (i.e. only 30% of the time) receive shocks to their productivity makes them more willing to keep their prices un-adjusted.

The distribution of idiosyncratic shocks is critical in determining the real effects of nominal shocks. For example, Midrigan (2011), Kehoe and Midrigan (2010) and Karadi

and Reiff (2012) show that if the innovations are drawn from a 'fat-tailed' distribution, aggregate nominal shocks can have larger real effects than when idiosyncratic shocks are normally distributed (as in Golosov and Lucas (2007)). The intuition behind this is that as the kurtosis of the distribution of the productivity shock increases, more firms will be far from the threshold that makes them want to pay the menu cost and reset their price.[33]

I introduced 'fat-tails' in idiosyncratic shock distribution assuming that the arrival of a shock is governed by a Poisson process with probability $1 - q$. When $q = 0$, the idiosyncratic productivity is an AR(1) process with log normal shocks and it coincides with the standard menu cost model as in Golosov and Lucas (2007).[34]

The 'fat tails' have the effect of increasing the persistence of the nominal shock. When firms receive productivity shocks every period ($q = 0$), firms that did not adjust to the nominal depreciation will be willing to do so in the next few periods. When the shock follows a Poisson arrival process ($q > 0$), this process is delayed as fewer firms receive a productivity shock per period. Figure 2.5 illustrates this for a small depreciation: when $q = 0$ the effect is short-lived, whereas when $q = 0.7$ (my baseline specification) there is more persistence.

Sector heterogeneity de Carvalho and Nechio (2011) show that in a Calvo model, heterogeneity in the frequency of price adjustment generates more price stickiness and that the degree of monetary non-neutrality is convex in the frequency of price change. The reason is that in a Calvo model, if some firms change their prices several times before others can even change their price once, the effect of a monetary shock on output will be inversely proportional to the fraction of firms that have changed their price at least once since the shock occurred.

In the menu cost model, firms are not selected at random to change their prices. Therefore, the relationship between the frequency of price change and the degree of monetary non-neutrality in different sectors is more complicated in a menu cost model.

[33] Alvarez and Lippi (2014) show analytically that kurtosis is a key moment of the data in order to explain non-neutralities.

[34] For the log-normal case ($q = 0$), I re-calibrated the menu cost by sector and the variance of the idiosyncratic process to match the monthly frequency of price adjustment and the average size of price adjustment.

It depends crucially on the nature of the differences between the sectors that give rise to the differences in the frequency of price change. Nakamura and Steinsson (2010) show that the introduction of sectoral heterogeneity in pricing generates a higher degree of non-neutralities if (i) the model is calibrated to a low trend inflation rate, (ii) the average size of price changes is large, and (iii) there is no strong correlation between the size and frequency of price changes and the relatively low average of frequency of price changes.

In Figure 2.8 I show the response of the model to a 5% depreciation when it is calibrated to a one, two, or five sector economy using Mexico's CPI micro data and import content from the Input Output tables. The figure shows that there is an increase in the degree of stickiness when the model has two sectors instead of only one, but there is no significant effect of adding more sectors. The reason for this is that the biggest effect of heterogeneity comes from the differences between goods and services, and not between the subcategories within them.[35]

2.5.2 Macro parameters

Figure 2.6 shows the effect of a trend (yearly) inflation of 3% and 20%. Consistent with the steady-state analysis in Alvarez et al. (2011), as inflation increases, the same nominal shock generates much more price adjustment. The intuition is that as trend inflation rises, firms will care less about the idiosyncratic productivity shocks and more about aggregate shocks . Hence their 'inaction area' — the maximum-allowed deviations in their prices from their desired level— will be reduced as their prices have to be readjusted more often because of the underlying monetary regime they face. In the limiting case of high inflation and very small idiosyncratic shocks, the economy will converge to the one in Caplin and Spulber (1987), where nominal shocks are neutral.[36]

Figure 2.7 and Table 2.9 present the results of a depreciation of 5%. In all columns the pricing rigidity is given by the menu cost model with flexible wages and without real shocks. In all cases, this small depreciation is expansionary, there is incomplete pass-through to prices, and there is also an increase in the frequency of adjustment. Column

[35]The result still holds -although it is slightly weaker- if all sectors are homogeneous in the share of labor and imported inputs.

[36]See Caballero and Engel (2007)

1 shows the outcome in the baseline model.

Column 2 shows that when the labor supply elasticity is lower ($1/\psi = 2$, half of the value in the baseline calibration) real wages increase by more, prices increase by more, and consumption does not increase as much, as export growth is smaller because of a higher increase in domestic prices. The intuition is that for the same increase in labor demand and a given price level, nominal wages have to increase by more. Hence, more firms will have incentives to reset their prices, which dampens the real effect of the depreciation and increases the price level.

In Column 3, the import share in production is doubled in each sector (relative to the baseline). Prices increase by more and exports grow less than in the baseline. The reason is that for a higher imported input content, the same depreciation generates a bigger increase in firms' input costs so more firms will increase their prices.

Column 4 and 5 show what happens when the the export elasticity is high ($\theta = 4$) and when the export share is doubled (20%), respectively. In both cases, the expansionary mechanism driven by exports is now more powerful. In this case the additional labor demand generates a higher pass-through than in the baseline, and the increase in consumption is also larger.

2.6 Large Appreciations

In the previous sections I showed that nominal rigidities in consumer prices do not appear to play a large role in determining the nominal or real outcomes of a large nominal depreciation. In this section I use the model to analyze how the economy adjusts to a negative real shock in the absence of a currency depreciation.

Here I analyze mechanisms through prices be 'too high' after a negative real shock hits. That is, I analyze what mechanisms of the model can be responsible for the exchange rate to be 'overvalued'. I assume that the economy is in a steady state and the nominal exchange rate does not change. In $t = 0$, the economy receives a negative real shock. While the experiment is purely illustrative and is not calibrated to data, the spirit of the exercise is based on the experiences of countries that maintained an exchange rate peg

while suffering external shocks.[37] In this context, nominal rigidities can exacerbate the real shock, as relative prices are not able to adjust sufficiently.

Table 2.8 presents the result of an export demand shock that contracts consumption by 4.6% when wages are flexible and prices are subject to menu costs (Column 1). There is a significant deflation in prices (-4.6%) and wages (-5.6%). The fall in the relative price of labor vis-a-vis the imported input is consistent with the larger fall in imports compared with employment. The differences with the flexible price model (Column 2) account for a change in consumption and CPI of -0.57% and 0.62%, respectively. While these effects are not negligible, the price rigidity cannot generate large real effects. Put differently, in the absence of a currency depreciation, the nominal rigidities captured by the CPI micro data do not prevent the 'internal devaluation' that this economy generates: the results are very close to the model with flexible prices. When price rigidities are Calvo (Column 3), the effect of the real shock is much larger. As prices fall less, the contraction in exports, in employment and consumption is larger, and real wages also fall more.

Columns 4-6 present the results of introducing the same wage stickiness as in subsection 2.4.1.3 to the menu cost, flexible and Calvo pricing models. The most significant result is that now wages move much less, so the deflation in CPI is much weaker. The same real shock now causes a much bigger drop in consumption. In the menu cost model with wage rigidity (Column 4) there is only partial adjustment in wages, retail prices, and the real exchange rate and the fraction of adjusting prices does not change at all. Given that prices do not fall, exports now fall much more than when wages are flexible. Given that the relative price between imports and labor does not change, there is no substitution in production towards labor, so imports and employment fall in the same amount. This generates an even bigger fall in exports and employment. In the flexible prices-sticky wages specification this is mitigated by the frictionless adjustment in prices.

An interesting result that arises in this exercise is that consumption falls more in the menu cost model with sticky wages (Column 4) than Calvo with sticky wages (Column 6). The reason is that in the menu cost model, the change in unit input cost is negligible

[37]Some examples are Argentina in 1995 and during the late 1990's, and countries in Europe that suffered a combination of negative shocks in 2008-2009 and maintained the currency union (Greece, Ireland, Spain, Portugal) or the exchange rate peg with the Euro (Latvia, Lithuania).

(wages fall only by 0.16%), so firms are not willing to pay the cost to lower their prices.[38] Since the price indexes are close to constant, the real effects of the shock are amplified further. In contrast, with Calvo pricing, a fraction of firms receive the opportunity to reset their price 'for free'. This makes the prices slightly more flexible than with menu costs, so the effects of the real shock are partially mitigated.

This is the effect of menu cost non-linearities: for very small shocks to input costs, firms will be reluctant to adjust, while for very large shocks they will all reset their prices. This type of effect is ignored when the nominal rigidity in prices is modeled with Calvo pricing.

More generally, the model with sticky wages is consistent with the widely held view that, when the nominal exchange rate is held constant, the main source of rigidities that prevents the adjustment in the Real Exchange Rate is in the labor market and not in final goods prices.

2.7 Conclusion

In this chapter I quantify the role of consumer price stickiness in the response of prices after large nominal exchange rate depreciations. To do so, I use a model of a small open economy where the nominal rigidity is calibrated to CPI micro data. This allows me to analyze two large currency depreciations experienced in Mexico: the 'Tequila' crisis in 1994 and the international financial crisis and trade collapse in 2008.

One of the main findings is that both negative real shocks and nominal wage rigidities must be present in the model in order for it to match the observed response of prices to the exchange rate depreciations.

Moreover, the role of rigidities in prices is small, generating small real effects in the two depreciation episodes studied here. While the menu cost frictions allow the model to endogenously match the behavior of the fraction of adjusting prices, the paths of aggregate prices and quantities are very similar in a model with flexible prices. I also find that a model with time-dependent price rigidities would overestimate the real effects from the nominal depreciation.

[38] Except for idiosyncratic reasons. This has no aggregate implications in this context.

Furthermore, the model permits the construction and analysis of an 'overvaluation' scenario for the exchange rate. When the economy receives a negative real shock and the exchange rate is kept fixed, the exchange rate can become 'overvalued' if nominal frictions are large enough to prevent adjustment of prices and wages. Nominal wage rigidities would be powerful enough to generate such an 'overvaluation.'

One limitation of the analysis is the treatment of the labor market. The role of nominal wage rigidities is particularly sensitive to the parametrization of the labor supply. The principal objective of this chapter is to provide a quantitative answer to the role of consumer price rigidities. Bringing the same level of discipline to the determination of wages is not a trivial task, as labor contracts involve long-term relationships and contracts.

Another qualification of the model is the exogeneity of the nominal exchange rate shock. While this does not affect the main findings, it would be desirable to allow for the nominal exchange rate to be the endogenous response of a policy decision (the exchange rate regime) and the response of financial markets to the real shocks that the economy experiences. This is left for further research.

Tables and Figures

Table 2.1: Firms' problem calibration (Baseline)

		Services	**Goods**
	Production Function		
s_r	Imported input cost share	0.054	0.159
	Menu Costs		
	Parameters		
κ_r	Menu cost (% Revenue)	6.71	1.07
$\sigma_{r,\epsilon}$	Idiosyncr. shock std. dev. (%)	2.97	5.95
	Targets		
fr	Freq. price adjustment (%)	9.8	33.1
dp	Average price adjustment (%)	5.2	8.1

Table 2.2: Macro parameters calibration (Baseline)

Parameter	Value	Target/Source
	Chosen	
Discount factor	$\beta = 0.997$	$r^* = 4.1\%$
Coef. relative risk aversion	$\sigma = 0.99$	
Varieties' elasticity of substitution	$\varepsilon = 4.33$	$Markup = 1.3$
Sector domestic elasticities	$\rho = 0.5$	Kehoe-Ruhl (2009)
Exports' distrib. cost	ϕ^*	Distr. Margin=50%
Frisch Elasticity	$1/\psi = 4$	
	Data	
Trend inflation	$\pi = 0.04$	Data
Export demand elasticity	$\theta = 2.8$	Δ Export Value 1995
Steady state asset holding	B_0	$CA/C = -5\%$
Commodity endowment	PX	Diff Exports/GDP=15%

Table 2.3: Large Depreciation with no real shocks. Cumulative Log Changes 6 months after the shock

	1	**2**	**3**	**4**
		Model		**Data**
Prices	Menu Costs	Flexible	Calvo	
Wages	Flexible	Flexible	Flexible	
Targets ($\Delta \log \%$)				
E	55	55	55	55
C	0	0	17.8	-12.5
Prices ($\Delta \log \%$)				
RER	0	0	28.2	28.7
P	55	55	26.8	26.3
π^{EM}/π	85	0	0	50.3
W	55	55	32.3	15.3
Quantities ($\Delta \log \%$)				
L	-0.02	0	21.9	-9.21
X	0	0	6.2	11
M	-0.01	0	5.6	-21.5

Table 2.4: Large Depreciation with Sudden Stop (1994). Cumulative Log Changes 6 months after the shock

	1	**2**	**3**	**4**
	Model			**Data**
Prices	Menu Costs	Flexible	Calvo	
Wages	Flexible	Flexible	Flexible	
Targets ($\Delta \log \%$)				
E	55	55	55	55
C	-12.49	-12.5	-0.1	-12.5
Prices ($\Delta \log \%$)				
RER	19.2	19.2	44.1	28.7
P	35.8	35.8	10.9	26.3
π^{EM}/π	61.2	0	0	20.3
W	23.1	23.1	12.7	15.3
Quantities ($\Delta \log \%$)				
L	-6.8	-6.7	7.8	-9.21
X	4.1	4.1	7.9	11
M	-19.9	-19.8	-15.7	-21.5

Table 2.5: Large Depreciation with Sudden Stop with Sticky Wages (1994). Cumulative Log Changes 6 months after the shock

	1	**2**	**3**	**4**	**5**	**6**	**7**
	Model						**Data**
Prices:	Menu Cost	Flexible	Calvo	Menu Cost	Flexible	Calvo	
Wages:	Sticky	Sticky	Sticky	Flexible	Flexible	Flexible	
Targets ($\Delta \log \%$)							
E	55	55	55	55	55	55	55
C	-12.49	-12.49	-9.85	-23.34	-22.61	-13.54	-12.5
Prices ($\Delta \log \%$)							
RER	29.82	29.38	33.53	19.25	19.83	31.52	28.7
P	25.18	25.62	21.47	35.75	35.17	23.48	26.3
π^{EM}/π	60.6	0	0	64.1	0	0	50.3
W	20.20	20.45	18.47	31.67	31.29	22.32	15.3
Quantities ($\Delta \log \%$)							
L	-3.74	-3.82	-0.84	-16.31	-15.55	-4.66	-9.21
X	9.96	9.74	10.80	8.22	8.05	10.82	11
M	-45.56	-45.37	-44.56	-46.73	-46.42	-44.69	-21.5

Table 2.6: Large Depreciation with Trade Collapse (2008). Cumulative Log Changes 6 months after the shock

	1	**2**	**3**	7
	Model			**Data**
Prices	Menu Costs	Flexible	Calvo	
Wages	Flexible	Flexible	Flexible	
Targets ($\Delta \log \%$)				
E	33	33	33	33
C	-10.4	-10.76	-7.43	-10.4
Prices ($\Delta \log \%$)				
RER	28.3	28.91	30.6	29.1
P	5.35	5.76	2.60	3.9
π^{EM}/π	11	0	0	7.5
W	2.44	2.65	0.94	0.8
Quantities ($\Delta \log \%$)				
L	-5.83	-6.2	-3.33	-13.1
X	-20.32	-20.53	-19.54	-24.1
M	-31.19	-31.33	-29.71	-25.2

Note: The fall in export demand is calibrated for Column 1.

Table 2.7: Large Depreciation with Trade Collapse (2008). Cumulative Log Changes 6 months after the shock

	1	**2**	**3**	**4**	**5**	**6**	**7**
	Model						**Data**
Prices:	Menu Cost	Flexible	Calvo	Menu Cost	Flexible	Calvo	
Wages:	Sticky	Sticky	Sticky	Flexible	Flexible	Flexible	
	Targets ($\Delta \log \%$)						
E	33	33	33	33	33	33	33
C	-10.40	-10.47	-10.46	-14.78	-15.38	-11.90	-10.4
	Prices ($\Delta \log \%$)						
RER	29.51	29.39	29.93	25.99	25.43	29.14	29.1
P	3.49	3.61	3.07	7.01	7.57	3.86	3.9
π^{EM}/π	10.4	0	0	32.2	0	0	7.5
W	0.21	0.22	0.22	4.31	4.71	2.00	0.8
	Quantities ($\Delta \log \%$)						
L	-5.95	-6.02	-5.90	-10.82	-11.46	-7.46	-13.1
X	-22.55	-22.67	-21.82	-23.36	-23.68	-22.17	-24.5
M	-33.49	-33.56	-33.46	-34.34	-34.56	-33.31	-25.2

Note: The fall in export demand is calibrated for Column 1.

Table 2.8: No Nominal Depreciation with Trade Collapse.

(Cumulative Log Changes, 6 months after the shock)

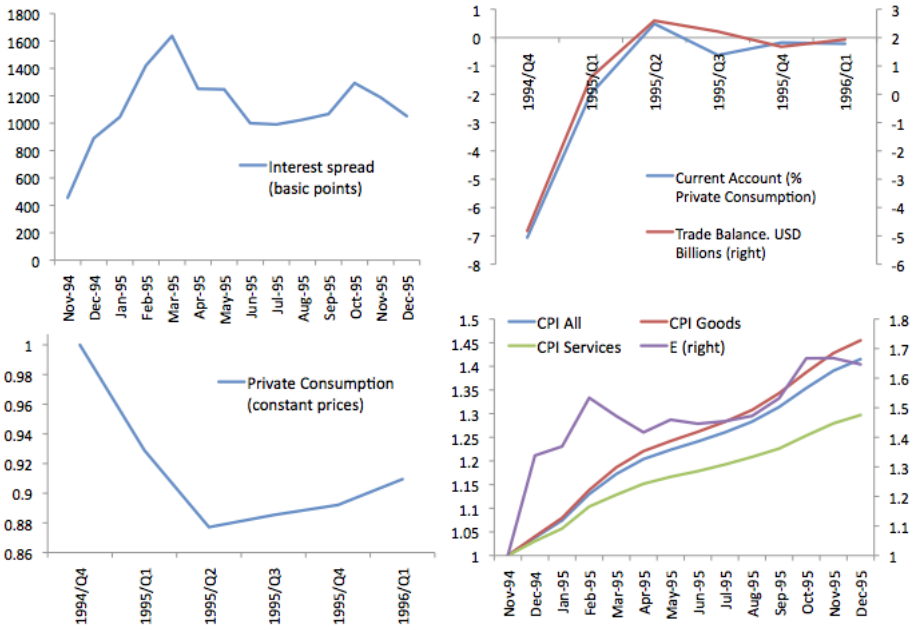
	1	**2**	**3**	**4**	**5**	**6**
	Model					
Prices	Menu Costs	Flexible	Calvo	Menu Cost	Flexible	Calvo
Wages	Flexible	Flexible	Flexible	Sticky	Sticky	Sticky
	Targets ($\Delta \log \%$)					
E	0	0	0	0	0	0
C	-4.53	-3.96	-6.89	-10.83	-8.04	-9.81
	Prices ($\Delta \log \%$)					
RER	-4.69	-5.31	-2.20	-0.14	-1.70	-0.76
P	-4.69	-5.31	-2.20	-0.14	-1.70	-1.26
π^{EM}/π	10.2	0	0	2.1	0	0
W	-5.56	-6.03	-3.72	-0.16	-2.66	-1.72
	Quantities ($\Delta \log \%$)					
L	-3.50	-2.87	-6.10	-10.46	-7.38	-8.70
X	-5.79	-5.68	-6.49	-7.53	-6.75	-7.10
M	-8.84	-8.72	-9.57	-10.51	-9.81	-10.23

Table 2.9: Menu cost model. Different parametrizations; Depreciation (no real shock).

(Cumulative Log Changes, 6 months after the shock)

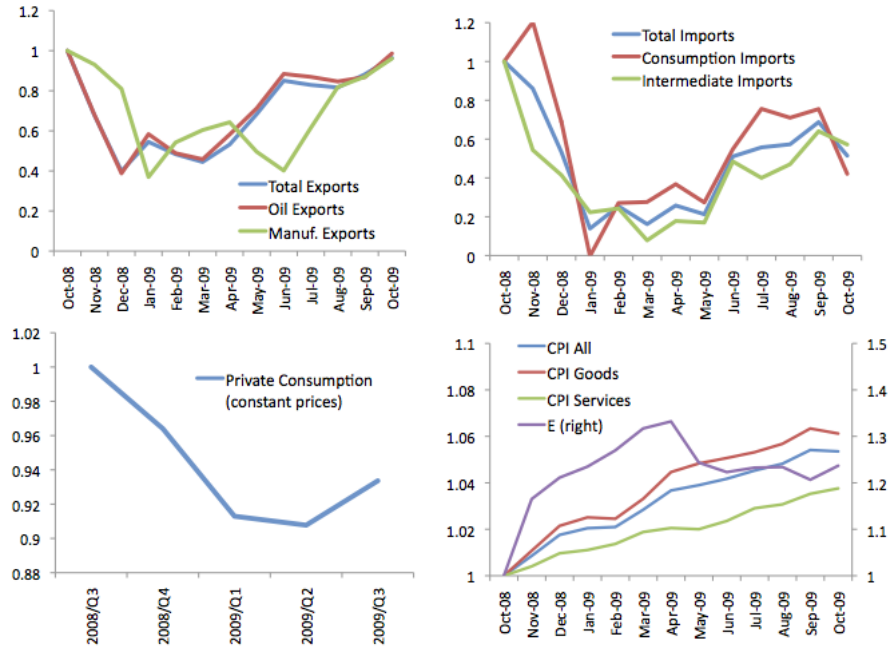
	1	**2**	**3**	**4**	**5**
	Baseline	Low Labor elasticity $1/\psi = 2$	High import share (2x baseline)	High export elasticity $\theta = 4$	High Export Share 20%
Targets ($\Delta \log \%$)					
E	5	5	5	5	5
C	0.612	0.405	0.371	0.690	0.668
Prices ($\Delta \log \%$)					
RER	0.740	0.573	0.654	0.617	0.630
P	4.260	4.427	4.346	4.383	4.370
π^{EM}/π	32.3	34.1	36.8	35.7	36.65
W	4.426	4.628	4.469	4.563	4.536
Quantities ($\Delta \log \%$)					
L	0.661	0.409	0.483	0.719	0.671
X	0.214	0.156	0.165	0.422	0.171
M	0.198	0.145	0.071	0.391	0.307

Figure 2.1: Shock Calibration. Sudden Stop (1994)



Sources: Banxico, INEGI (Mexico).

Figure 2.2: Shock Calibration. Trade Collapse (2008)



Sources: Banxico, INEGI (Mexico).

Figure 2.3: Effects of Depreciation size in Exchange rate Pass-through (without real shocks)

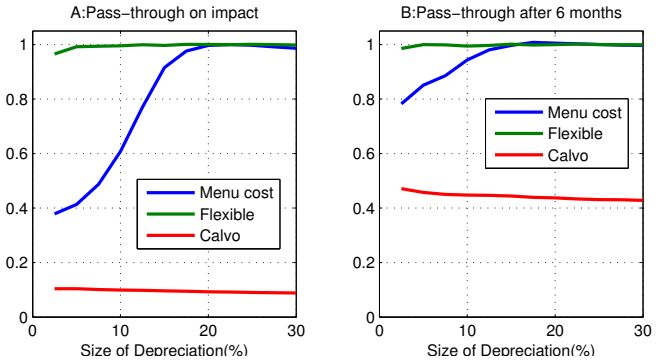


Figure 2.4: Effects of Depreciation size (without real shocks)

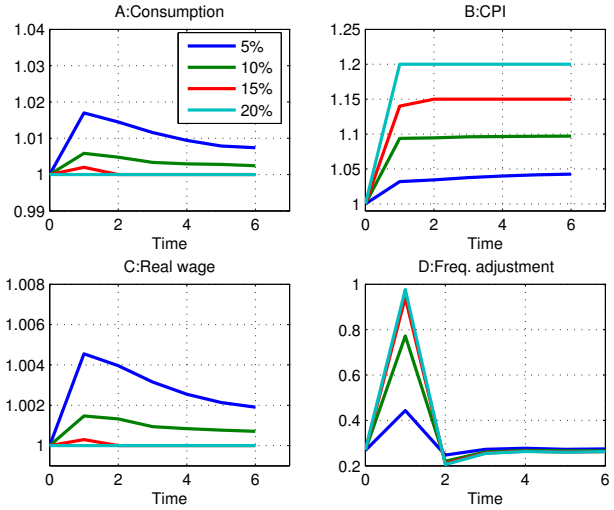


Figure 2.5: Effects of fat-tailed shocks in a 5% depreciation (without real shocks)

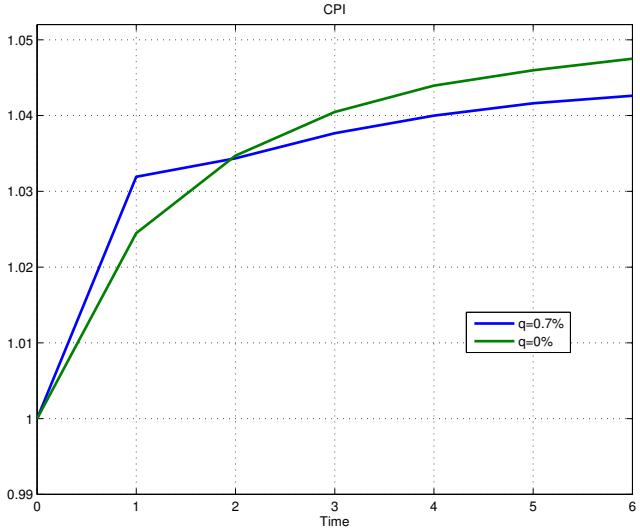


Figure 2.6: Effects of Trend inflation in a 5% depreciation (without real shocks)

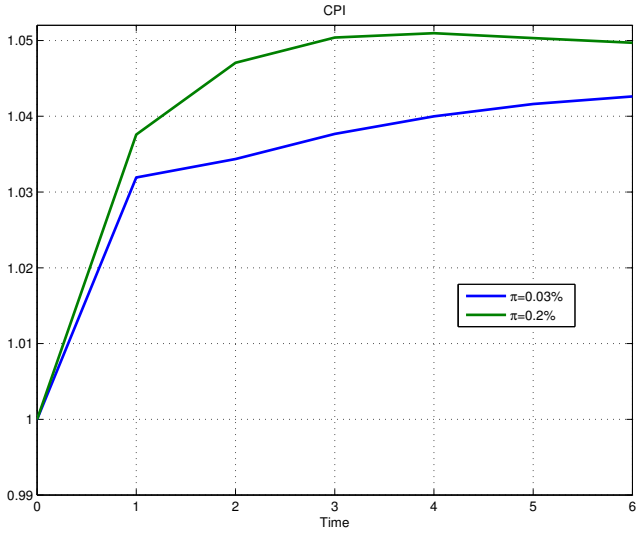


Figure 2.7: Effects of macro parameters in a 5% depreciation (without real shocks)

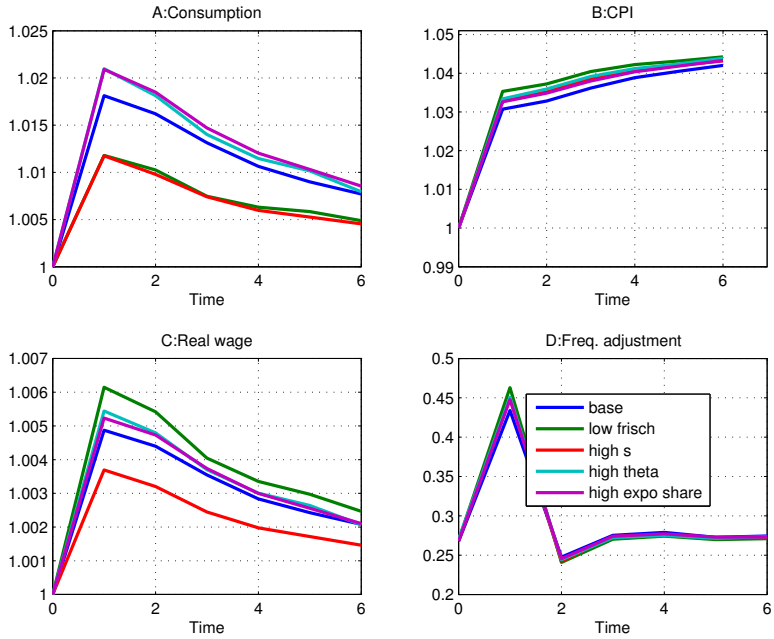
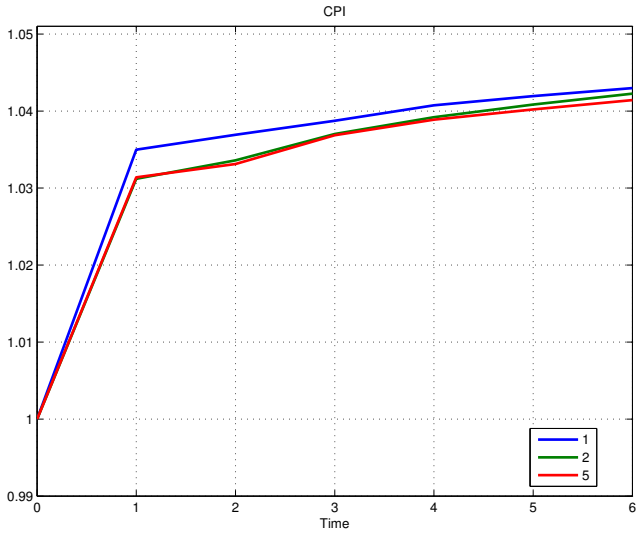


Figure 2.8: Effects of sector heterogeneity in a 5% depreciation (without real shocks)



Appendix A: Model Solution

An Approximation for Policy Rules

Given the solution for the Ss bands in steady state, I will compute the transition using the following approximation (following Burstein Hellwig 2007, see their appendix for more details).

Omitting notation for sectors for simplicity, first define the following steady state variables:

The steady-state front-loading factor and the Ss-bands, in terms of deviation from targets are given by

$$\begin{aligned}\rho^* &= \log p^*(s) - \log \hat{p}^f(s; MC^{ss}) \\ \bar{K}(s) &= \log \bar{p}(s) - \log p^*(s) \\ \underline{K}(s) &= \log \underline{p}(s) - \log p^*(s)\end{aligned}$$

The optimal pricing strategies can be approximated by

$$\begin{aligned}\log p_t^*(s) &= \rho^* + \log \hat{p^f}(s_t; MC_t) \\ \log \bar{p}_t(s) &\approx \bar{K}(s) + \log p_t^*(s) \\ \log \underline{p_t^*}(s) &\approx \underline{K}(s) + \log p_t^*(s)\end{aligned}$$

Following this approximation, the ideal flexible price $\log \hat{p^f}\left(s, \hat{P}\right)$ and the approximate target price $\log p_t^*(s)$ and the Ss-bands all increase by the same magnitude δ , in the initial period of imact of the a shock to nominal spending (relative to the counterfactual with steady-state inflation). As a function of δ , the response of prices on impact (net of steady-state inflation) $\Delta \log P$ is approximated by $\Delta \tilde{\log} P$

$$\begin{aligned}\Delta \log P \approx \Delta \tilde{\log} P = &\int_s \int_{\hat{p} \leq \underline{p_t}(s)} (\log p_t^*(s) - \log \hat{p}_t)\, \phi(\hat{p}; s)\, d\hat{p} ds + \\ &\int_s \int_{\hat{p} > \overline{p_t}(s)} (\log p_t^*(s) - \log \hat{p}_t)\, \phi(\hat{p}; s)\, d\hat{p} ds - \mu\end{aligned}$$

Where

$$\mu \approx \int_s \int_{\hat{p} \leq \underline{p_t}(s)} \left(\log p^*(s) - \log \hat{p}\right) \phi\left(\hat{p}; s\right) d\hat{p} ds + \int_s \int_{\hat{p} > \overline{p}_t(s)} \left(\log p^*(s) - \log \hat{p}\right) \phi\left(\hat{p}; s\right) d\hat{p} ds$$

CHAPTER 3

Pegs, Overborrowing and Pain.

3.1 Introduction

In this chapter I present a model of a small open economy that can suffer both unemployment and insufficient consumption smoothing. The channels through which this happens are the presence of a downward nominal rigidity on wages and a collateral constraint on external debt.

Small open economies are known for being prone to experience high volatility in consumption and crises. These crises are related to policy regimes and, in particular, to the exchange rate policy regime. When a negative shock occurs, it is uncommon to see fast and sizable deflations that allow these economies to gain competitiveness and to induce a domestic expenditure switching from tradable goods to non-tradable goods. This is one of the reasons that explains why economies that choose currency pegs seem to experience higher and more persistent unemployment rates than countries that use their exchange rate as a policy tool to smooth negative external shocks.[1]

While it seems that nominal rigidities five incentives to pursue a flexible exchange rate regime, it also true that many countries choose to keep their nominal exchange rate fixed and not use it as a policy tool. Typically, these countries had a history of high monetary instability and are said to exhibit *fear of floating*[2]. The common interpretation for is is that lack of commitment abilities from monetary authorities and poor institutional quality are often 'solved with a rule that may be even passed as a law.

Fixed exchange rate regimes typically generate financial dollarization which increases significantly the exit costs of the exchange rate regime as the contractionary 'balance

[1] Argentina in the'90s and the current financial turmoil in UE are clear examples of this. The different experiences in the 30s are explained by Eichengreen and Temin (1997) and Bernanke (1983).

[2] See Calvo and Reinhart (2000)

sheet' effects might out-weight the expected gains of a devaluation.[3] This type of dilemma has been experienced by Latin American and Asian countries in the 90s and early 2000s and, more recently, by the Euro Zone peripheral countries.

Here I propose a model that exhibits both unemployment and balance sheet effects. It relies in two market incompleteness. First, nominal wages are rigid downwards: when a negative external demand shock occurs, labor market will not clear, generating *involuntary* unemployment. This means that labor supplied will be "rationed" or the labor market will be "incomplete". In this context, a depreciation of the nominal exchange rate will have a real effect because this would lower wages in terms of tradable goods increase labor demand.

Second, this economy will be subject to a collateral constraint in its external debt. The only asset agents can use to smooth their tradable consumption is denominated in tradable goods and the value of their stock of debt can not be higher than a fraction of the GDP expressed in tradable goods. That is to say, financial markets also are "incomplete".

In this context, a nominal exchange rate depreciation that is used as a substitute of wage flexibility will decrease the value of the non-tradable production lowering the amount of possible indebtedness. Then, the optimal exchange rate policy will have to deal with two constraints that respond in opposite ways. An depreciation of the nominal exchange rate can potentially alleviate unemployment at the cost of generating a "sudden stop" in capital flows and forcing an adjustment in the trade balance.

The contributions of this chapter are twofold. First, I show how financial amplification effects caused by "over borrowing" can generate high unemployment rates without resorting to extreme wage rigidity as in Schmitt-Grohé and Uribe (2011). Second, it shows that the exchange rate policy faces a tradeoff between unemployment and tradable consumption when the collateral constraint binds.[4]. Putting two insights together are just reflecting the tradeoff of maintaining a currency peg during a crises: higher unemployment or a bigger financial crisis.[5].

[3] See Yeyati and Sturzenegger (2003)

[4] Put in other words, maintaining a currency peg during a negative shock, by smoothing the real exchange rate adjustment, it loosens the endogenous financial constraint of the economy

[5] An alternative interpretation of above is that the endogenous borrowing constraint generates *fear of floating*: when the nominal exchange rate is a policy instrument and both constraints are binding, the optimal depreciation rate will be smaller than in the case when the borrowing constraint does not bind

I follow Schmitt-Grohé and Uribe (2011) who analyze a small open economy with two good and quantitative effects of choosing an exchange rate peg or an optimal exchange in the presence of downward rigidity of nominal wages. In particular, negative shocks will generate unemployment when the nominal exchange rate is not used to compensate the nominal rigidity. The policy recommendation that this implies is to have an active exchange rate regime that responds to external shocks.

I also follow Bianchi (2011), who introduces an endogenous borrowing constraint: the maximum level of debt that can be taken is a proportion of the tradable value of GDP. Since part of it is composed of non-tradable goods, this generates agents to have higher leverage. This type of mechanism generates a feedback loop as shocks may have amplified effects. Korinek (2011) associates these type of episodes to financial crises. In this environment, Bianchi (2011) carries on a quantitative assessment of the externality created by a borrowing constraint and leverage when agents do not internalize the effect of there indebtedness on the adjustment to negative shocks. Its policy recommendation is to introduce taxes on debt on "good" times to neutralize that externality. Without this tax, the negative shock will be amplified as agents reduce their consumption of tradable good, lowering the relative price of the non-tradable good and then reducing even further the value of the collateral. This is why this model is said to have "financial amplification".

Financial amplifications effects due to debt-deflation are know since Fisher (1933) analyzed the Great Depression through this lens. The mechanism was reincorporated to the literature on crises as it played an important role in magnifying shocks and policy distortions in the East Asian crises: in the presence of debt-dollarization a relatively small shock led to a self-reinforcing decline of exchange rates and asset prices, deteriorating balance sheets even further and making the macroeconomic conditions to worsen.

As Korinek (2011) states, the key ingredient is a relative price (exchange rate, asset prices, the interest rate) that moves in such a way that hurts the financial position of domestic agents. The models that present balance sheet effects that generate financial amplification can have the collateral constraint specified on a current relative price (as in this paper) or in future prices. Among the first class is Mendoza (2010), Jeanne and Korinek (2010) and this paper. The second class, as in Lorenzoni (2008) or Schneider and Tornell (2004) generate income and wealth effects that may cause inefficient bubbles

and booms.

The potentially perverse interaction between this two market failures and a currency peg has recently gained much more attention since the external, banking and fiscal crises that several Euro Zone are suffering. Interesting examples of this are Carlin (2012) and Farhi et al. (2011).

The paper is structured as follows. First, I introduce the general setup of the model and labor and financial markets constraints. Second, I present some analytic results in a simplified version to illustrate the basic mechanisms. Third, I will briefly discuss how to solve recursive problems with occasionally binding constraints and present the solution algorithm. Fourth, I present some preliminary quantitative results to illustrate the amplification effect on unemployment under currency peg and the fear of floating effect on the exchange rate policy when this is available. Fifth, I conclude and discuss further research that this paper motivates.

3.2 The model

Households

The economy is populated by a representative household that has preferences on the consumption of aggregate consumption (c) that is an aggregate of a tradable consumption good (c^T) and a non-tradable consumption good (c^N).

$$max \sum_{t=0}^{\infty} \beta^t U(c_t), \tag{3.1}$$

where

$$c_t = A(c_t^T, c_t^N), \tag{3.2}$$

The household inelastically supplies labor ($\bar{h}$) and sells a number of hours h_t for which receives a real wage w. It can sell/buy non-contingent debt (d) for which it pays/receives an the risk free interest rate (r). It also receives an endowment of tradable good (y_t) and profits from the firms (ϕ) and pays p units of tradable good for one non-tradable good.

So its budget constraint is given by

$$c_t^T + p_t c_t^N + b_{t+1} \leq y_t^T + w_t h_t + b_t(1 + r_t) + \phi_t, \tag{3.3}$$

The household also faces a borrowing constraint that allows them to be indebted up to a a fraction κ of the economy's GDP expressed in tradable goods

$$b_{t+1} \leq -\kappa \left(p_t c_t^N + y_t \right). \tag{3.4}$$

Then, its optimization problem is defined by the following set of equations:

$$\frac{A_2(c_t^T, c_t^N)}{A_1(c_t^T, c_t^N)} = p_t, \tag{3.5}$$

$$\lambda_t = U'(c_t) A_1(c_t^T, c_t^N), \tag{3.6}$$

$$\lambda_t = \beta E_t \lambda_{t+1} + \mu_t, \tag{3.7}$$

$$\mu_t \geq 0, \tag{3.8}$$

$$b_{t+1} \leq -\kappa \left(p_t c_t^N + y_t \right), \tag{3.9}$$

where λ and μ are the Lagrange multipliers of constraints 3.3 and 3.4

Firms

Firms are competitive, produce the non-tradable good using a production technology F and maximize their profits $\phi_t = p_t F(h_t) - w_t h_t$. Hence, their optimality condition is given by

$$p_t F'(h_t) = w_t \tag{3.10}$$

Labor market

The real wage can be expressed as $w_t \equiv W_t/E_t$, where W_t is the nominal wage and E_t the nominal exchange rate. As noted above, the key assumption made by Schmitt-Grohé and Uribe (2011) is that nominal wages are downwardly rigid. That is,

$$W_t \geq \gamma W_{t-1}$$

Re writing, we get a constraint on the dynamics of the real wages

$$w_t \geq \gamma \frac{w_{t-1}}{\epsilon_t} \tag{3.11}$$

where $\epsilon_t = E_t/E_{t-1}$.

When the constraint binds, it will mean that the labor market will no clear at the inelastically supplied number of hours ($\bar{h}$). Hence, employment must satisfy

$$h_t \leq \bar{h} \tag{3.12}$$

The associated slackness condition for the labor market is

$$(h_t - \bar{h})(w_t - \gamma \frac{w_{t-1}}{\epsilon_t}) \tag{3.13}$$

Goods markets

The market clearing condition for the non tradable good is

$$c_t^N = F(h_t) \tag{3.14}$$

This, together with households' budget constraint and definition of profits yields an inter temporal budget constraint for tradable good

$$c_t^T + b_{t+1} = y_t^T + b_t * (1 + r_t) \tag{3.15}$$

General Disequilibrium Dynamics

The general disequilibrium dynamics are given by stochastic processes $c_t, c_t^T, c_t^N, h_t, p_t, w_t$, b_{t+1}, λ_t *and* μ_t *satisfying (3.2) and (3.4)-(3.15) given the exogenous stochastic processes* y_t^T *and* r_t*, an exchange rate policy* ϵ_t *and initial conditions* w_{-1} *and* b_0*.*

This model nests Bianchi (2011) and Schmitt-Grohé and Uribe (2011). When wages are fully flexible ($\gamma = 0$), the model is identical to Bianchi's and when debt is only constrained by the No-Ponzi condition (that is, the constraint on debt is the natural debt limit), the model is identical to Schmitt-Grohé and Uribe (2011).

The intuition between the two inequality constraints is summarized in Figure 3.1.[6] With out the collateral constraint, when a negative realization of y_T occurs, the relative demand for non-tradable goods will shift to the left: in order to be market clearing, excess supply of labor should push nominal wages down which would shift firms' non-tradable supply to the right. But if wages are downward rigid this will not happen, generating an unemployment rate described by the distance $\bar{h} - h_a$. As discussed above, the role of a nominal devaluation would be to substitute the nominal adjustment of wages and putting the non-tradable supply at the full employment level (point B).

Without the wage constraint and if the shock and initial asset position is such that the collateral constraint binds, there will be an "amplification" process: decentralized reductions in tradable consumption will lower the relative price p, lowering the value of the collateralizable output and making the collateral constraint to be tighter. This is an example of the externality generated by a Fisherian deflation[7]: agents do not internalize the negative effect of their individual deleverage on others' collateral. In equilibrium, instead of going from point E to B, the economy will go to D, where c_T and p are lower.

However, if the two constraints bind, the economy will go to point C: now the Fisherian amplification effect implies also an amplification in the quantity adjustment. As before, individual reductions of tradable consumption generate a reduction in the value of non-tradable production, but now this is decomposed in a fall in p (given by the slope of firms' non-tradable supply) and an increase in unemployment because of the downward wage

[6] To simplify the exposition, the figure assumes $\gamma = 1$, that is, there is none nominal adjustment over time.

[7] See Fisher (1933)

rigidity. Without a devaluation, the economy will stay in point C, where unemployment $\bar{h} - h_c$ is bigger than $\bar{h} - h_b$.

Now, for a given nominal rigidity, the unemployment that a shock can generate should be bigger and the required devaluation to alleviate it should be bigger. [8]

In the next section I present a simplified version of the model to show some analytical results that supports these intuitions.

3.3 A simple model

In order to show the the mechanisms that underly the general version of the model, in this section I present a simple two period model with no uncertainty.

In the first period, the representative household will consume both a tradable and a non-tradable goods. In the second period it will only the tradable good. Households' maximization program is:

$$max \quad \log(c_1) + c_2$$

where given that here I assume $\beta = \frac{1}{1+r}$, the time discount factor can be normalized to one. The consumption bundle in the first period is given by $c_1 = (c_{T,1})^{\omega} (c_{N,1})^{1-\omega}$, where $c_{T,1}$ and $c_{N,1}$ are the consumption of the tradable and non-tradable good in the first period, respectively.[9]

The period budget constraints are given by

$$c_{T,1} + pc_{N,1} = y_{T,1} + w_1 h_1 + \phi + b_0 - b_1 \qquad [\lambda]//c_{T,2} + b_1 = y_{T,2}$$

where p is the price of the non-tradable good and w is the wage, both in terms of the tradable good. The household receives a tradable endowment in each period ($y_{T,1}, y_{T,2}$ and has asset holdings at beginning of period 1 and 2 are given by b_0 and b_1.

[8] Note that in this simple model without regime changes I can not discussed the extra amplification effect that a non-fully anticipated devaluation would generate in c_T as the exchange rate policy here is exactly the same as if $\gamma = 0$.

[9] As will be discussed below, the assumption of a Cobb-Douglas aggregator will mute the effect of higher unemployment into relaxing the collateral constraint.

The collateral constraint for period 1 is given by

$$b_1 \leq -\kappa \left(y_{T,1} + p y_{N,1} \right) \qquad [\mu]$$

where μ is the associated Lagrange multiplier. The relative demand for period 1 goods will be given by

$$p = \frac{1-\omega}{\omega} \frac{c_{T,1}}{c_{N,1}}$$

The Euler equation is given by $1 + \mu = \lambda$, where the discount factor is equal to 1, μ is the Lagrange multiplier for the collateral constraint and *lambda* is the marginal utility of consumption. The constrained labor market and firms' problem is identical as it is explained in the general model above. With out loss of generality I can normalize ω to be one and the total labor supply to $\bar{h} = (1-\omega)^{1/\alpha} = 1$

Loose financial constraint

If $\kappa \leq d_0$ the collateral constraint will not bind and $\mu = 0$. Then, $c_{T,1} = \omega$ and $b_0 = b_1$. Using(3.16), firms' FOC (3.10) and non-tradable good market clearing, the relative price of period one goods is

$$p = \frac{1-\omega}{\omega} = \frac{w_1 h_1}{\alpha}$$

So, the value of hired labor will be constant:[10] $w_1 h_1 = \alpha(1-\omega)$.

If the downward wage constraint does not bind ($w_1 \geq w_0$), the first best allocation is

[10]This is depends on the Cobb-Douglas aggregator assumption and will greatly simplify the following.

attained

$$c_{T,1}^{FB} = \omega$$
$$c_{N,1}^{FB} = 1 - \omega$$
$$d_1^{FB} = d_0$$
$$p^{FB} = 1$$
$$h_1^{FB} = (1-\omega)^{1/\alpha}$$

If the wage constraint does bind, employment will be rationed: $h_1^{w.con} = \frac{\alpha(1-\omega)}{w_0}$. Then, non-tradable consumption will be $c_{N,1}^{w.con} = \left(\frac{\alpha\omega}{w_0}\right)^{\alpha}$. It is easy to see that $c_{N,1}^{FB} > c_{N,1}^{w.con}$. Then, the relative price of period 1 goods will have to be bigger under the wage constraint: $p^{w.con} > p^{FB}$. This is just reflecting the downward wage rigidity on the real exchange rate. Note that in both cases the value of non-tradable production is constant: $p_N y_N = 1-\omega$.[11]

Binding collateral constraint

If $\kappa > d_0$, then $\mu > 0$. Demand for assets will be given by $b_1 = -\kappa\left(y_{T,1} + p y_{N,1}\right)$. Let $m = y_{T,1} + b_0$.[12] Then, the collateral constraint can be written as

$$b_1 = -\kappa\left(y_{T,1} + p_1 c_{N,1}\right) \tag{3.16}$$

(3.17)

$$c_{T,1} = m - b_1 \tag{3.18}$$

Equation (3.17) capture the effect of a lower real exchange rate reducing how much each individual can borrow. Equation (3.18) shows how lower borrowing reduces tradable consumption of agents.

[11] With a general CES aggregator, $p_N y_N$ will be a decreasing function of h_1.

[12] Using the current account, this allows me to express tradable consumption as $c_{T,1} = m - b_1$

In general equilibrium can express (3.17) as

$$b_1 = -\kappa \left(y_{T,1} + \frac{1-\omega}{\omega}(m - b_1) \right)$$

Which can be simplified to solve for $c_{T,1}$ under the collateral constraint.[13]

$$c_{T,1}^{fin.con} = \frac{m\omega - \kappa\omega y_{T,1}}{\omega - (1-\omega)\kappa}$$

From which I can find the relative price

$$p^{fin.con} = \frac{1-\omega}{\omega} c_{T,1}^{fin.con} = \frac{w_1 h_1}{\alpha}$$

Proposition 1. *When the collateral constraint binds, the full employment wage is increasing in net wealth.*

Proof. The value of employed labor can then be expressed as $w_1 h_1 = \frac{1-\omega}{\omega} \alpha c^{fin.con}$. Then, the 'full employment' wage derivative with respect to m is:

$$\frac{dw_1^{full}}{dm} = \frac{1-\omega}{\omega} \frac{\alpha}{\bar{h}} \frac{dc_{T,1}^{fin.con}}{dm}$$

Since, financial constrained tradable consumption is increasing in net wealth of the economy (m), the full employment wage will be increasing as well. □

An alternative view of this is that, under a binding collateral constraint, the bigger the negative shock to $y_{T,1}$, the bigger the required fall in $c_{T,1}$ and hence the lower the full employment real wage. Then, the cutoff previous wage w_0 that generates unemployment will be smaller as well and the required devaluation to restore unemployment will be higher.[14]

[13] As stated above, the value of the non-tradables is not affected by the wage constraint, so this is true whether it binds or not.

[14] See Korinek (2011) for an insightful discussion on how agents undervalue their liquidity in this type of environment.

Devaluation trade-offs

In the simple case shown above, the collateral constraint has an additional impact on the labor market as it generates higher unemployment by amplifying the fall of $c_{T,1}$. Thus, in this case, a bigger devaluation would be needed to restore full employment.

Allowing for a more general constant elasticity of substitution (CES) aggregator than the Cobb-Douglas aggregator used above, the value of non-tradable goods will change when employment changes. This will generate a trade-off: when the collateral and wage constraints bind, a more flexible exchange rate policy will lower the relative price of non-tradables and lower unemployment, but it that will reduce the collaterallizable value of non-tradable production making the collateral constraint to be tighter. Then, tradable consumption will have to be lower. This is summarized in the following proposition.

Proposition 2. *With a general CES aggregator and if the collateral constraint binds, there will be a trade off between tradable and non-tradable consumption.*

Proof. Since the collateral constraint binds, we can right the choice of assets as

$$\begin{aligned} b_1 &= -\kappa \left(y_{T,1} + \frac{1-\omega}{\omega} (\frac{m - b_1}{c_{N,1}})^{\eta+1} c_{N,1} \right) \\ &= -\kappa \left(y_{T,1} + \frac{1-\omega}{\omega} (m - b_1)^{\eta+1} h_1^{-\alpha\eta} \right) \end{aligned}$$

So the derivative of b_1 with respect to h_1 is positive:

$$\frac{db_1}{dh} = \frac{\kappa \frac{1-\omega}{\omega} (y_1 + b_0 - b_1)^{1+\eta} h^{-\alpha\eta-1}}{1 + \kappa \frac{1-\omega}{\omega} (y_1 + b_0 - b_1)^{\eta} h^{-\alpha\eta)}}$$

Then, for the states in which the constraint binds, its multiplier will be increasing in h, and then also increasing in the devaluation rate ϵ (as the wage constraint also binds). From the Euler equation, a higher multiplier for the collateral constraint reduces the consumption of current tradable consumption. □

This means that a devaluation will force the agents to accumulate more assets (or reduce their debt) for which they need to reduce their consumption of tradable goods. Note that this has the same qualitative effect than a devaluation when the wage constraint

binds and the collateral constraint does not (i.e. reduce the current account deficit when there is a negative shock to tradables) but now it entails a trade off in terms of welfare.

The implication of this is that the optimal exchange rate policy has to internalize the effect that it causes on the collateral constraint. In Bianchi (2011), the (constrained) Planner can get collateral constrained if asset levels are low enough. So even when there are "optimal capital controls" (i.e. Pigouvian taxes), the optimal exchange rate policy will have to depend on the country's balance sheet. The policy design implications of this are non-trivial and are left for further research.

3.4 Quantitative analysis

Calibration

The calibration values are taken from Schmitt-Grohé and Uribe (2011) for preference and technology parameters and from Bianchi (2011) for κ (the financial constraint).[15] Table 1 summarizes the baseline calibration.

3.4.1 Solution method

The non-linearities of the model and the occasionally binding constraints forces to use non-linear methods. More over, since this model characteristics violate the Second Welfare Theorem, it can not be represented by a Social Planner, making the Value function iteration method much more cumbersome.

The chosen approach rests on Coleman (1991). He provides a numerical algorithm to approximate and find policy functions by iterations, which relies on a proof of existence and uniqueness of equilibria that uses monotone operators. This method is particularly useful in non-Pareto environments as the one that the model describes.

Rendahl (2006) shows that an iterative procedure on the Euler equation (i.e. *time iteration*) is convergent. This is very convenient from a computational perspective because it provides theoretical insights that allow dynamic economic problems with inequality constraints to be reliably and efficiently solved. For instance, the recently popularized

[15]Both papers match moments from aggregate data for Argentina

endogenous grid method (EGM) developed by Carroll (2006) is actually nested by time iteration.

As Hintermaier and Koeniger (2010) I exploit the differentiability of the value function iteration at iteration step n in the problem with inequality constraints as in Proposition 1 in Rendahl (2006). Also, the value function is strictly concave at each iteration step (see Stokey et al. (1989)). By proposition 2 in Rendahl (2006), the time iteration will converge to true policy function. At each iteration for given state variables, the unique maximizers are contiunous policy functions.

The MATLAB implementation of this algorithm builds on the Richter Throckmorton Toolbox (see Richter et al. (2011)). In order to gain robustness (see Floden (2008)) I added the option to discretize the process for y_T and integrate the expectations in the Euler equation using Tauchen (1986) Markov method. More importantly, I introduced the intermediate steps in the iterative process to deal with the occasionally binding inequality constraints. The algorithm is summarized in the appendix.

Quantitative results

Figure 3.2 shows the policy function for bond holdings for different values of the current wage w. Note that as in Bianchi (2011), the presence of the collateral constraint generates a "kink" in the policy function when the asset holding is low enough. As expected from the discussion above, as w gets lower, the collateral constraint becomes "tighter".

Figure 3.3 show unemployment as a function of the endogenous states (bond holdings and past wages). Moving to the "southeast" of the state space shows how low asset holding and high past wages generate lower employment levels.

As discussed above, the endogenous collateral constraint and the fact that $\beta(1+r)$ is less than one, makes the asset holding to converge to a stochastic steady state. The intuition behind this is that there is an "endogenous" real return on the asset holding since the competitive equilibrium outcome can make more or less likely for the collateral constraint to bind in the future. This relates to Schmitt-Grohé and Uribe (2002), as they present different ways to avoid the asset holding to be a random walk. Also, Chamberlain and Wilson (2000) proof that $\beta(1+r)$ less than one is a necessary condition for the

convergence.

Figure 3.4 shows the stationary asset distribution when only the collateral constraint is present and wages are fully flexible (or there is an exchange rate policy that replicates that). In Figure 3.5 the wage constraint is introduced. From the two figures and the first and second moments presented in Table 3.2, we can see that there does not to seem to be a significant effect on the stationary asset holding distribution.

Nonetheless, the excepted effects from the above discussion are noticeable when we analyze a "crisis" event. Figures 3.6 to 3.9 show the impulse responses to a sizable negative one time innovation (-20% relative to the steady state) to tradable endowment AR(1) process for different values of the constraints parameters (κ and γ).

By comparing Figure 3.6 with 3.7 we can see that downward sticky wages generate tradable consumption to fall less than when wages are flexible. The other side of the same effect is that the asset adjustment has to be bigger in the latter case.

From Figures 3.6 and 3.8 we see that the decreases in adjustment in consumption is much slower when the collateral constraint parameter κ is lower (the constraint is "harder" in this case). This makes unemployment to be higher over the whole adjustment period.

Last, in Figure 3.9 we see that doubling κ and leaving wages flexible does not seem to have a significant impact on the dynamics of the economy.

3.5 Conclusion

In this paper I presented a model that displays financial amplification of shocks and unemployment. This tractable framework includes to relevant market distortions for small open economies with currency peg regimes: downward nominal rigidity of wages and an endogenous collateral constraint. The two constraints interact with each other, generating a potential policy trade offs when there are no enough independent policy instruments.

From the quantitative point of view, the main finding is that the collateral constraint will generate higher unemployment as it magnifies the shock to the labor market.

There is a number of issues that have not been discussed here and deserve more

attention. The most straight forward is that the interest rate could be made stochastic to have a better representation of a Sudden Stop episode. If a working capital constraint as in Neumeyer and Perri (2005) is introduced, there would be even more amplification and richer dynamics.

More importantly, a constrained efficiency analysis should be conducted to allow to design optimal policy interventions in this framework. With flexible wages, the second best policy is shown to be a Pigouvian tax (Bianchi (2011) and that partially alleviates the financial constraint. Without the collateral constraint, the optimal exchange rate policy is a devaluation that is a perfect substitute of wage flexibility.

One important question that the model I present in this chapter could answer is whether what policy instruments can deal with the inefficiencies caused by over borrowing and wage rigidity. This *prudential* (or ex ante) perspective and the ex post exchange rate policy responses entail interesting questions that are left for further research. Nonetheless, this simple environment strongly points to the fact that monetary and financial stability policies should be coordinated. Since an exchange rate policy that targets employment could potentially 'tighten' the borrowing constraint, and thus interact with the Pigouvian taxes on debt that Bianchi (2011) advocates for.

3.6 Appendix

3.6.1 Appendix A: The algorithm

The following algorithm describes the routine implemented to find the policy functions

1. Set grids for asset holdings b and past wages w_{-1} and discretize the tradable endowment autoregressive process approximating it with a Markov process.[16] [17]

2. Generate (feasible) guesses for the policy functions c_T, b', h, p, w. Even though there is probably some guess closer to the fixed point, I use just assume full employment and $b' = b_{grid}$, it correcting with $c_T = \epsilon$ when c_T is not positive.

3. Set iteration count $j = 1$.

4. For each node in the state space b, w_{-1}, y_T, assume the collateral constraint binds and compute the implied asset holdings and tradable consumption, taking p_{k+j-1}, w_{k+j-1} and h_{k+j-1} from the previous iteration.

$$b'^{con}_{k+j} = \kappa \left(p_{k+j-1} h^{\alpha}_{k+j-1} + y_T \right)$$
$$c^{con}_{T,k+j} = b(1+r) + y - b'^{con}_{k+j}$$

5. With $b'^{con}_{k+j}, c^{con}_{T,k+j}$ and h_{k+j-1} compute the value of the multiplier that corresponds to the collateral constraint

$$\mu = \lambda - \beta E \lambda'$$

   If $\mu > 0$, go to (). If not, go to ()

6. Find $b'_{k+j}, c_{T,k+j}$ that solve the Euler equation and the current account.

7. Compute the relative price p and wage w given $c_{T,k+j}$ and h_{k+j-1}. Check if the wage constraint binds for that w_{-1}. If it does not, there is "full employment",

[16] Because of time constraints, the preliminary results I present here are computed with grids of 50 equally spaced for each of the endogenous states. Clearly the nonlinearity of the problem requires much finer grids.

[17] I also experimented using Gauss-Hermite quadrature method to integrate the expectation in the Euler equation. There does not seem to be significant differences in results or computation times.

so set $h_{j+k=1}$ and update w_{k+j} and p_{k+j}. If the wage constraint does bind, set $w = \gamma w_{-1}$ and update h_{j+k} and p_{k+j}.

8. Compute the euclidean distances of elements of the tensors that describe each policy function and check if $\|x_{k+j}(b, w_{-1}, y) - x_{k+j}(b, w_{-1}, y)\| \leq \epsilon$ for $x = c_T, b', w, h, p$, the policy functions reached the fixed point. If not, use the update as new guess by setting $x_{k+j}(b, w_{-1}, y) = \delta x_{k+j}(b, w_{-1}, y) + (1 - \delta)\, x_{k+j-1}(b, w_{-1}, y)$ and repeat the procedure . I found that to insure the stability of the contraction mapping, δ should be close to 0.3.[18]. If not, the policy functions converged to their fixed point: stop the algorithm and save the policy functions.

[18]With a finer grid it is possible that this discount could be lowered to speed up the convergence to the fixed point

3.7 Tables and Figures

Table 3.1: Calibration values

Parameter	Value	Concept	Source
γ	0.99	Degree of downward nominal rigidity	Schmitt-Grohé and Uribe (2011)
σ	5	Risk aversion	idem
$\bar{y^T}$	1	Steady state tradable output	idem
$\bar{h}$	1	Labor endowment	idem
r	0.04	World interest rate	Bianchi (2011)
ω	0.31	Share of tradables	idem
$1/(1+\eta)$	0.83	Elasticity of substitution between goods	idem
α	0.75	Labor share in nontraded sector	idem
β	0.91	Discount factor	idem
κ	0.302	Collateral parameter	idem
ρ	0.95	AR(1) autocorrelation coefficient	Baseline
σ_ϵ	0.004	AR(1) shock std. dev.	Baseline

Table 3.2: Data statistics from the model

	$\kappa = 0.302$ $\gamma = 0.99$	$\kappa = 0.2$ $\gamma = 0.99$	$\kappa = 0.302$ $\gamma = 0$
Tradable consumption			
Mean			0.9627
Standard deviation			0.0214
Asset holdings			
Mean	-0.93	-0.6212	-0.9362
Standard deviation	0.0092	0.0144	0.0160
Correlation with c_T	-0.8485	-0.8819	-0.8655
Employment			
Mean	0.9992	0.9982	1
Standard deviation	0.0062	0.076	0
Correlation with c_T	0.2313	0.3775	0

Figure 3.1: General disequilibrium with collateral constraint

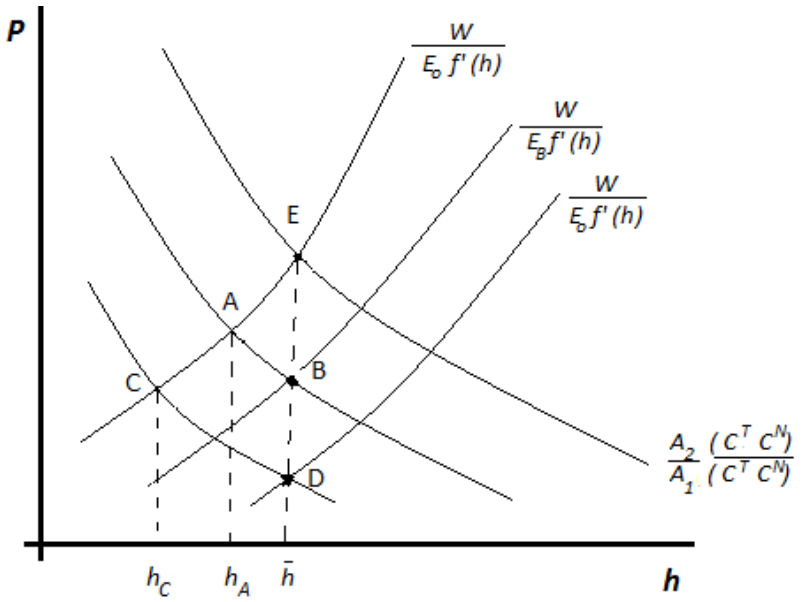


Figure 3.2: Asset policy function

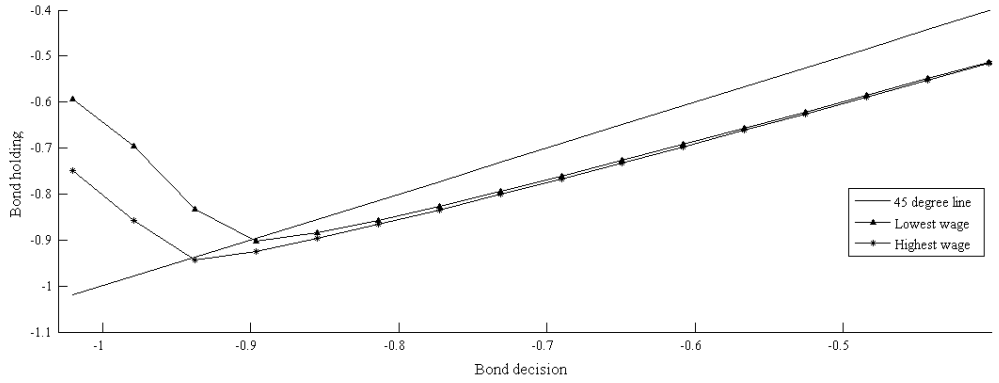


Figure 3.3: Employment as function of endogenous states

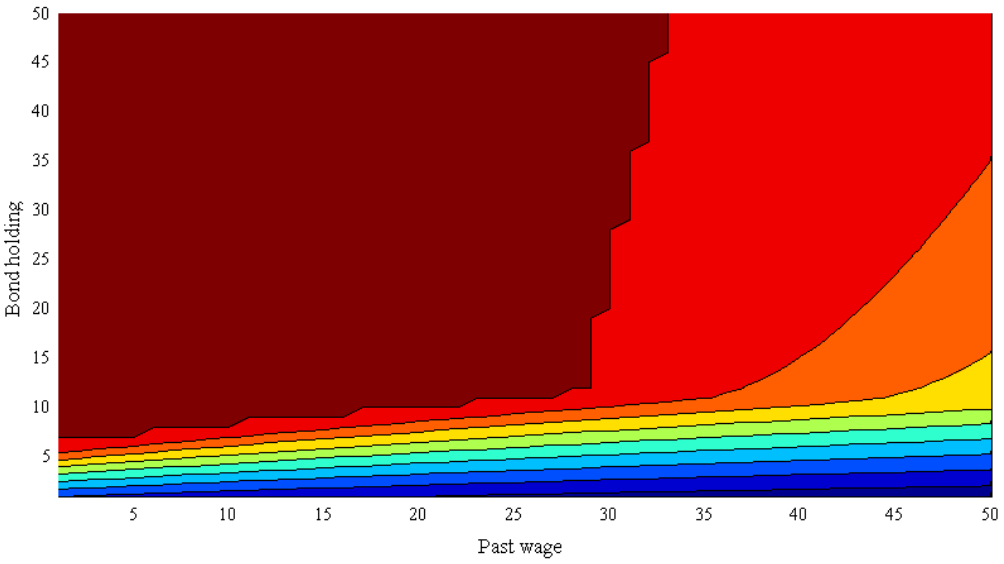


Figure 3.4: Asset distribution with flexible wages

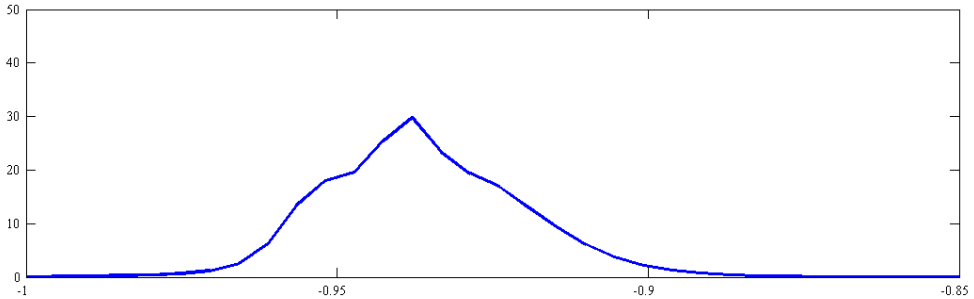


Figure 3.5: Asset policy with downward rigid wages

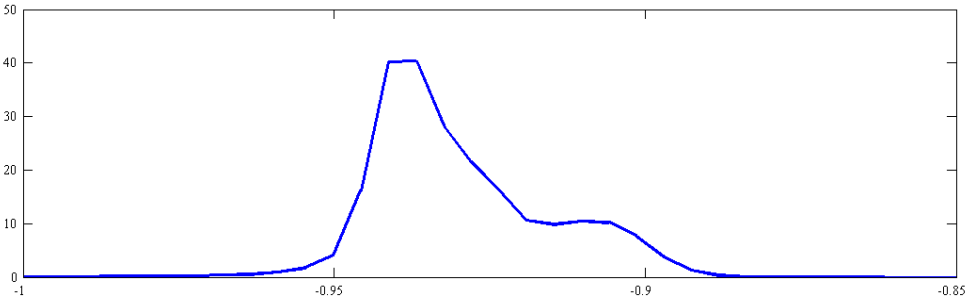


Figure 3.6: Baseline ($\kappa = .302$; $\gamma = 0.99$)

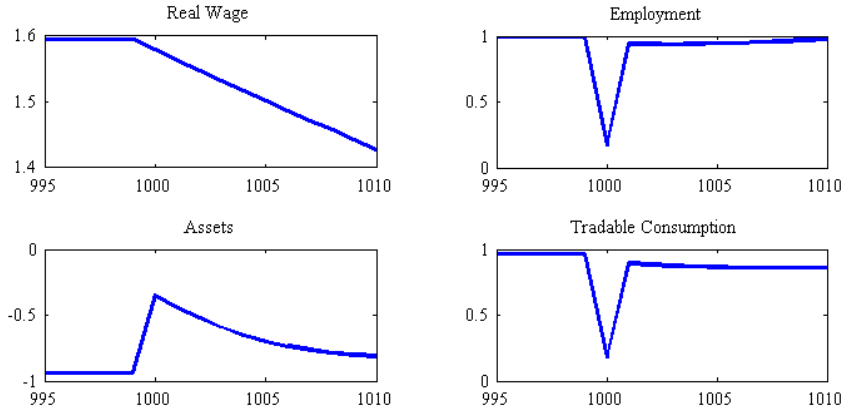


Figure 3.7: Baseline collateral constraint, flexible wages ($\kappa = .302$; $\gamma = 0$)

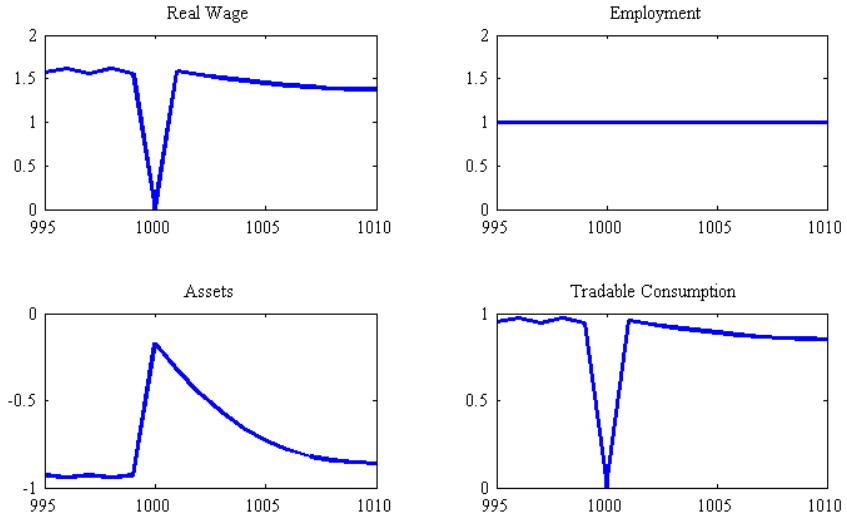
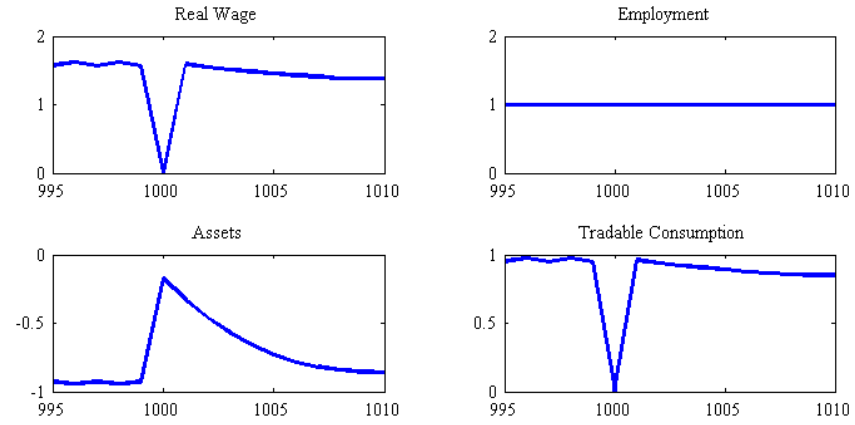


Figure 3.8: High collateral constraint, sticky wages ($\kappa = .2$; $\gamma = 0.99$)



Figure 3.9: Low collateral constraint, flexible wages ($\kappa = .604$; $\gamma = 0$)



CHAPTER 4

References

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