Large Currency Depreciations and Menu Costs

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Abstract

This paper studies why inflation in consumer prices is so low after episodes of large currency depreciations in emerging economies, and to what extent this is a consequence of nominal rigidities. Using a small open economy model with menu-cost nominal frictions that is calibrated to micro data from Mexico's Consumer Price Index, I find that in episodes of large depreciations, the effect 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 explained by negative real shocks and nominal stickiness in wages.

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1 Introduction

What role does price stickiness play in the response of prices after large nominal exchange rate shocks? In episodes of large currency depreciations, real exchange rates closely follow nominal rates—implying that retail prices respond only sluggishly to changes in the nominal exchange rate. The aim of this paper is to quantify the forces behind this less-than-proportional response of consumer prices the nominal exchange rate shocks are large.

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 individual prices that adjusted nearly doubled relative to the pre-depreciation months, increasing from 25% to 46%.[1] This margin of adjustment in prices is ignored in the usual sticky prices monetary models for small open economies and it explains about half of CPI inflation in this period.[2] Also, a model with flexible prices would not match this margin of adjustment as all prices would change after the depreciation.

In this paper I study if a menu cost model calibrated to sectoral and CPI micro data can reproduce the response of prices and quantities after a large depreciation. I build on the models considered in a large literature on the aggregate implications of sticky price models in response to small monetary shocks in closed economies – see e.g. Nakamura and Steinsson (2013)—. I use the model to analyze what ingredients are key to account for the observed path of consumer prices in the aftermath of a large currency depreciation.

The model describes a small open economy with a similar structure as in Gali and Monacelli (2005), with heterogeneity across sectors as in de Carvalho and Nechio (2011). I depart from the literature for small open economies in two ways. First, I model firms' production function of domestic goods as using imported inputs and labor. Assuming that the law of one price holds for imports —as suggested by the above mentioned evidence on dock prices— the nominal exchange rate and the nominal wage are the two prices determining firms' nominal input costs.[3] Importantly, the model is calibrated to account

[1] 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.

[2] This means that if the fraction of adjusting prices in the CPI micro data is held constant, the average price changes in the micro data would imply a cumulative inflation rate of only 12.9% 6 months in after the depreciation.

[3] 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.

for the large proportion of labor —relative to imports— that is used in the production of final goods. Relative price changes between the nominal exchange rate and labor are one source of the less-than-proportional response of prices to the exchange rate (i.e. 'incomplete exchange rate pass-through'). Burstein et al. (2005) document that the incidence of local costs are an important driver of incomplete exchange rate pass-through at the retail level during large devaluations.

Second, I model nominal rigidities in 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 strength of the desired price changes and nominal rigidities in prices in generating incomplete exchange rate pass-through to prices. After the depreciation, *desired* price changes are a result of 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 optimal to not adjust their prices.

The paper 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.[4] Second, the role of the menu cost nominal rigidity in the incomplete exchange rate pass-through is small. Relative to the same model with menu costs set to zero ('flexible prices') that cannot match the change and size of adjusting prices in the micro data, the calibrated menu cost model generates an increase in prices that is only 0.44 percentage points lower.[5] 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 a 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

[4] 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 mark-ups.

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

to choose when to adjust.

To analyze the mechanisms at play and to isolate the role of consumer price nominal rigidities, I sequentially introduce the aggregate components 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 to the nominal exchange rate. The reason is that the nominal shock is large enough so 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 the relative prices remain unchanged, output, consumption and employment remain largely un-affected.[6] 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.[7] The data shows that in May 1995 private consumption in Mexico was 12.49% smaller than in October 1994, while hours worked fell 8%.

Second, given that the nominal rigidities in prices cannot account for either the observed behavior in prices or the sharp contraction in economic activity, I ask if prices and quantities can be driven by a real shock. For that, I include 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.[8] With this additional single shock, consumer prices increase less than the nominal exchange rate. The reason is that the contraction generated by the *Sudden Stop* causes labor demand to contract, and hence the real wage falls. This less-than-proportional increase in nominal wages is still too large, implying that the response in prices is still above the observed consumer prices' inflation.[9]

[6] 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.

[7] 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.

[8] While part of the literature models Sudden Stops as an endogenous outcome (see Calvo (1998); Kaminsky and Reinhart (1999); Mendoza (2010)), in this paper 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))

[9] To analyze the 2008 depreciation episode, where consumption contracted in 10.4%, I

Third, given that the 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*. When wage stickiness is chosen to match the aggregate data on wages, both the behavior 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 wages. Thus, the frictions implied by price setting rigidities do not alter the real variables in an important amount, relative to the size of the shocks. While inflation is 26% and consumption is falling in 12.5%, the menu cost model generates an inflation rate 0.2% smaller and fall in consumption 0.1% smaller 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 imply 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, if wages are assumed to last one year on average, for the same combination of depreciation and real shock, employment would fall 13% less and consumption would fall 10% less than if wages were assumed to be fully flexible.

Finally, motivated by the experiences of small open economies that keep an exchange rate peg while suffering negative real shocks,[10] I use the model to study how the economy adjusts to a negative real shock in the absence of a currency depreciation. In these episodes, the widespread belief is that the nominal depreciations can help to ease the adjustment, but for that to be true, some nominal rigidity must be at play. The model with menu costs and flexible wages cannot account for 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.[11] With 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 generated a smaller contraction in economic activity.

include a the negative demand shock to Mexico's exports that captures the 'Trade Collapse' associated with the international financial crisis.

[10]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.

[11]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%.

Therefore, the view that the exchange rate is 'overvalued' or that prices are 'too high' can be accounted by sticky wages, but not by stickiness in consumer prices.

The model incorporates two features that generates more price stickiness in closed economy menu cost models. The first one is heterogeneity across sectors. 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.[12] I document that this is also a feature of the data in Mexico and show that calibrating my model to this generates a slight increase in the effect of the price rigidities. The second feature is that firms' idiosyncratic productivity processes receive shocks from a 'fat-tailed' distribution. Midrigan (2011) shows this also increases how sticky prices are. In my model, this feature generates additional persistence to the price stickiness, which is extremely short lived otherwise (see Golosov and Lucas Jr (2007)).

Previous research that studied the role of change in the nominal exchange rate in small open economies questions have done so in 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 implications (see Calvo (2000); Lorenzoni (2014)).

The importance of changes in pricing patterns has been shown to be relevant in emerging economies. Typically this literature has analyzed the pricing patterns in the data and compared them with steady states of one sector closed-economy menu cost model with different (exogenous) inflation rates (see Gagnon (2009); Alvarez et al. (2011)).[13] A contribution of this paper is that I model the observed aggregate prices and quantities, and the microeconomic evidence on prices in the aftermath of the large shock through the lens of a general equilibrium model that allows for sector heterogeneity.[14]

[12] 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).

[13] 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.

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

The paper is structured as follows. First, I present evidence for Mexico's prices around the episodes of large currency depreciations in 1994 and 2008. Second, 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. Last, I present conclusions.

2 Empirical Motivation

This section documents two facts. The first one focuses on aggregate prices and the CPI-based Real Exchange Rate (RER). The RER is defined as

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

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.[15] After large currency depreciations, the response in P_t is less than proportional to the exchange rate shock. This is true for all subcategories within the CPI index.

The second set of facts is related to the behavior of individual prices used to compute the CPI. The fraction of prices that adjust per period (i.e., the frequency of price adjustment) changes when the nominal shocks are large enough. This is particularly true for the 1994 large currency depreciation episode and goes in line with findings in Gagnon (2009). Moreover, price setting is highly heterogeneous across sectors. In general the frequency at which prices adjust is higher for goods than services.

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, one contribution of this paper is to study both phenomena together.

Before giving more details about these motivating facts, I describe the micro-data used to compute the prices indexes.

one sector.

[15] 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.

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 1000 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 correspond to the highest disaggregation level used in the computation of the CPI. The data also contain the weights for each of these groups.

In order to reconcile the basket used before and after 1995 some ELIs are dropped. Given that for 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 them from the sample.[16] Also, the ELIs are matched to the 6-digit NAICS nomenclature to extract sector characteristics for the model calibration, as explained later.

This leaves 54.11% of CPI basket between January 1994 and June 2002 and 65.9% of basket between July 2002 and December 2010. Table 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.[17] For notational simplicity, if the sector r is not specified, π_t should be assumed to be the weighted average for all goods and services in the CPI basket considered here.

[16]Following Cortés Espada et al. (2012) and Gagnon (2009) I drop rent, homeowners' imputed rent, gasoline, education, utilities and other administered prices. 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.

[17]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.

2.1 Incomplete exchange rate pass-through to CPI

As found by Burstein et al. (2005), when there is a large nominal exchange rate shock, the main force that induces the low rates of inflation is a less-than-proportional adjustment of retail prices for goods and services —or incomplete 'exchange rate pass-through' to prices (ERPT)— and not the slow adjustment of prices that are actually traded.

Table 2 shows the cumulative log-changes from one month prior the depreciation for the two episodes considered here. 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 by much less.[18]

Import prices, however, increased almost as much as the nominal exchange rate.[19] This implies that that the 'law of one price' can be a reasonable approximation at the border, but not in retail prices.

The reason for this is that retail prices include a great deal of local components, as distribution costs, labor, etc. A good indicator of the behavior of local costs is nominal wages. In both episodes, wage inflation was below price inflation and the depreciation rate, implying lower real wages and even lower wages in dollars.

Figure 1 shows the response of the nominal exchange rate, import and exports prices, CPI, and CPI sub-indexes for goods and for services for the 1994 episode. Figure 2 presents the same results for the 2008 episode.

2.2 Evidence from Micro Data

In order to analyze the price micro data, I decompose total inflation (π_t) as follows.[20] The indicator function $I_{i,t}$ signals an observed price change in item i between period $t-1$ and

[18] To simplify the analysis here I will focus on the standard categorization between goods and services. Given that Burstein et al. (2005) document the importance of local goods and services and goods that are actually internationally traded, in the Appendix I extend Vega (2012) methodology to classify goods ELIs as they were actually traded or not. The main results are not affected by this. See Table 13 in the Appendix for methodology and results.

[19] 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

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

t, so

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

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) that 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.

The main motivating empirical finding from the micro data is summarized in Figure 5. Months of high inflation and frequency of adjustment in Figure 4 are the ones that associated with the large exchange rate shock (73%) in late 1994 and the incomplete, but still positive, exchange rate pass-through to prices: 6 months after the depreciation, cumulative inflation was 26%. In late 2008, the nominal exchange rate shock (33%) was accompanied a cumulative inflation rates of 3.4%. With this low inflation (relative to the cumulative exchange rate depreciation), the frequency of price adjustment did not change significantly.[21]

Also, there is a great deal of heterogeneity across sectors. Table 3 compares frequency of adjustment for the whole sample grouped in 9 sectors. For comparison, the values found for the US by Nakamura and Steinsson (2008) are included.[22]

Figure 4 shows the monthly frequency of price adjustment and (annualized) monthly inflation rates for goods and services. As it is shown in Gagnon (2009), on average the

[21] Figures 6 and 7 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 much more idiosyncratic to the sector.

[22] For consistency, and given that the Mexican data does not include a ‘flag’ for sales and discounts, the value shown for the US correspond to prices that do not net out of sales’ prices.

frequencies for goods are higher than for services. Between 1994 and 2002, high values of inflation are correlated with increases in the frequency of adjustment. Between 2002 and 2010, annualized monthly inflation rates were consistently below 20% and movements in frequency where not so extreme, but there is still a positive correlation. The average size of price adjustment correlates very strongly with inflation. By construction, this correlation is weaker when the frequency also co-moves with inflation.

To summarize the role of the change in the frequency of adjustment in inflation, I follow Klenow and Kryvtsov (2008) and decompose inflation in two additive terms. This decomposition will be used when comparing the model outcomes to the data. 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 ($\bar{dp}$)

$$\pi_t = \underbrace{\bar{fr} dp_t}_{\text{IM}} + \underbrace{fr_t \bar{dp} + \left(dp_t - \bar{dp}\right)\left(fr_t - \bar{fr}\right) + O_t}_{\text{EM}}, \tag{1}$$

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 proportion of prices that change over time and it is referred as the 'extensive margin' (EM) of inflation. Hence, the inflation can be expressed as

$$\pi_t = \pi_t^{IM} + \pi_t^{EM}. \tag{2}$$

Using this decomposition for inflation, Figure 10 shows the depreciation rate and inflation, together with the importance of the intensive and extensive margins of inflation. The importance of the extensive margin (i.e. the changes in re pricing plans) is large right after the 1994 devaluation (more than 40%), while it is barely noticeable after 2008 (less than 8%).[23]

The fact that a there is larger change in the fraction of prices that change when the inflation rate is higher is consistent with the findings for emerging economies (see Gagnon (2009); Alvarez et al. (2011)). This suggests that the modeling of the nominal price friction should allow for this margin of price adjustment to be endogenous.

The model I propose in the next Section 3 accounts for the patterns found in the micro data. Prices adjust optimally, with some friction (menu costs), to the environment. When nominal marginal costs change in a large amount, the fraction of adjusting prices

[23]Figure 11 shows the results for goods' and services' CPI sub-indexes.

can change as well. The model also can account for incomplete exchange rate pass-through when wages react less than proportionally to the currency depreciation. c

3 The Model

The model is a variant of the standard New Keynesian model for small open economy with measure zero, so its policies do not affect the rest of the world. The structure of this economy is based in Gali and Monacelli (2005). I take the following departures from the standard model: (i) I add multiple sectors, (ii) in each sector, competitive monopolistic 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 are subject to a menu cost nominal friction to adjust their prices, 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 food that is used to produce a sectoral output. This output is used for domestic consumption. Depending on the sector, it can face a demand from the rest of the world (this sector characteristic is set exogenously).

Variables without superscript '$*$' correspond to the domestic economy, while the ones with it 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 the after agents are surprised and an aggregate shock is realized, no further uncertainty remains and agents have perfect foresight.

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

3.1 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))

$$U\left(C_t, L_t\right)=\frac{1}{1-\sigma}\left[C_t-\psi_0 \frac{\left(L_t\right)^{1+\psi}}{1+\psi}\right]^{1-\sigma}, \tag{3}$$

where L_t is labor, and C_t is a 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

$$P_t C_t+E_t B_{t+1}=W_t L_t+\Pi_t+E_t P_{x, t}^* X_t+\left(1+i_{t-1}^*\right) E_t B_t$$

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 corresponds 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, in steady state, $\left(1+i^*\right) \beta=1$.

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

$$\left(\frac{C_t-\psi_0 \frac{\left(L_t\right)^{1+\psi}}{1+\psi}}{C_{t+1}-\psi_0 \frac{\left(L_{t+1}\right)^{1+\psi}}{1+\psi}}\right)^{-\sigma}=\beta \frac{P_t}{P_{t+1}}\left(1+i_t^*\right) \frac{E_{t+1}}{E_t}. \tag{4}$$

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 were the case, the exogenous constraint would hold and the Euler equation would not bind. This constraint will capture in a mechanical and simplified way an episode of *Sudden Stop*, in which the economy becomes unexpectedly closed to financial flows (see Lorenzoni (2014); Burstein et al. (2007); Kehoe and Ruhl (2009).

3.2 Firms

3.2.1 Competitive aggregators

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

$$C_t = \left[\sum_r^R \gamma_r{}^{\frac{1}{\lambda}} C_{r,t}^{\frac{\lambda-1}{\lambda}}\right]^{\frac{\lambda}{\lambda-1}}, \tag{5}$$

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 $r-1$

$$\left(\frac{1-\gamma_{r-1}}{\gamma_r}\right)\left(\frac{C_{r,t}}{C_{r-1,t}}\right) = \left(\frac{P_{r,t}}{P_{r-1,t}}\right)^{-\rho}. \tag{6}$$

The other source of sectors' demand are exports

$$C^*_{r,t} = \chi_r \left(\frac{P_{r,t}}{E_t} + \phi^*\right)^{-\theta} Y^*_t. \tag{7}$$

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 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

$$Y_{r,t} = C_{r,t} + C^*_{r,t}, \tag{8}$$

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

$$Y_{r,t} = \left[\int_0^1 y_{r,t}(j)^{\frac{\epsilon-1}{\epsilon}} dj \right]^{\frac{\epsilon}{\epsilon-1}}. \tag{9}$$

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

$$y_{r,t}(j) = \left(\frac{P_{r,t}(j')}{P_{r,t}} \right)^{-\epsilon} Y_{r,t}. \tag{10}$$

3.2.2 Differentiated Goods Producers

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

$$y_{r,t}(j) = Z_{r,t}(j) L_{r,t}(j)^{1-s_r} M_{r,t}(j)^{s_r}, \tag{11}$$

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

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

The idiosyncratic productivities follow a log autoregressive process given by

$$\log Z_{r,t}(j) = \rho_Z \log Z_{r,t-1}(j) + \epsilon_{r,t}. \tag{12}$$

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

$$\epsilon_r = \begin{cases} 0 & \text{with probability } q \\ N(0, \sigma_{r,\epsilon}) & \text{with probability } 1-q \end{cases}. \tag{13}$$

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 larger price stickiness and capture the fact that many price changes are smaller than 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 with more detail in Section 6

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 pay a menu cost $\kappa_r MC_{r,t}$ and choose the optimal reset price.[24]

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 all the other sectors price indexes. Dropping notation for sectoral heterogeneity for expositional convenience, firms' recursive problem is described by the following Bellman equations. The value of not changing the price is

$$V^{NC}\left(p_{-1}(j), \Omega(j)\right) = \Pi\left(p_{-1}(j), \Omega(j)\right) + \beta EV\left(\frac{p_{-1}(j)}{1+\pi}, \Omega'(j)\right). \tag{14}$$

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

$$V^{C}\left(p_{-1}(j), \Omega(j)\right) = \max_{p(j)} \Pi\left(p(j), \Omega(j)\right) - \kappa MC + \beta EV\left(\frac{p_(j)}{1+\pi}\Omega'(j)\right). \tag{15}$$

So firms' value functions will be given by

$$V\left(p_{-1}(j), \Omega(j)\right) = \max_{C,NC}\left\{V^{NC}\left(p_{-1}(j), \Omega(j)\right), V^{C}\left(p_{-1}(j), \Omega(j)\right)\right\}. \tag{16}$$

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',

[24]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.

in which is more profitable for the firm to keep their price, or it will be outside the inaction area, so the firm will incur the menu cost and reset its price to the optimal new level. In Appendix 8 I provide details of the solution method.

3.3 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 as 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

$$M_t = P^*_{x,t} X_t + \sum_{r=N+1}^{R} \frac{P_{r,t}}{E_t} C^*_{r,t} + (1+i^*)B_{t+1} - B_t. \tag{17}$$

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

$$P_{r,t} = \left(\int_0^1 P_{r,t}(j)^{1-\epsilon} \, dj \right)^{\frac{1}{1-\epsilon}}. \tag{18}$$

Consumer price index (CPI) is

$$P_t = \left(\sum_{r}^{R} \gamma_r P_{r,t}^{1-\rho} \right)^{\frac{1}{1-\rho}}. \tag{19}$$

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

Given the normalization imposed to 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 are $\frac{P_{r,t}}{E_t}$.

Equilibrium

An perfect-foresight competitive equilibrium for this economy is a set of paths for quantities $(\left\{C_t, \{C_{r,t}, C^*_{r,t}, Y_{r,t}\}_{r=1}^{R}, B_{t+1}, L_t, M_t\right\}_{t=0}^{\infty})$ and prices $(\left\{P_t, \{P_{r,t}\}_{r=1}^{R}, W_t\right\}_{t=0}^{\infty})$ 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, 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.

4 Calibration

4.1 Firms

There are five parameters to be chosen in the monopolist 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.[25] I take the revenue share of imported inputs by sector and compute cost shares multiplying them by the gross mark-up.[26] [27]

[25] 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.

[26] 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.

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

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 get that opportunity to the frequency of price adjustment in each sector. Second, I also consider a 'Flexible price' specification, 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 Nakamura and Steinsson (2010) and Golosov and Lucas Jr (2007). The idiosyncratic shock Poisson arrival rate q is set to 0.7 in the baseline specification. This value will generate a higher kurtosis than the log normal case, where $q = 0$.

Table 4 summarizes the calibration for the baseline specification for a two sector economy (goods and services).

4.2 Macro parameters

I summarize the parameter values for the baseline specification of the model in Table 5. First, the elasticity of substitution between varieties (ϵ) is chosen to imply a gross mark-up 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.[28] 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)), and in particular, to have results comparable with the ones in 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.[29] 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

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

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

the model can capture the response of exports to the change in relative prices after the depreciation. The implied value yields a relatively inelastic demand.

The steady state net foreign asset position is chosen to match the ratio of 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.

4.3 Shocks

In the two episodes of large depreciations that I study there were large contractions in aggregate economic activity. Figures 8 and 9 illustrate this. Relative to the pre-depreciation months, 6 months after the depreciation private consumption fell 12.5% in May 1995, and 10.4% 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 Mexico's main trade partner demand (the US) and a fall in the price of commodities that Mexico exports.[30] 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 anticipated either a change in the nominal exchange rate, in the binding asset constraint or in the export demand, so the economy is initially in a steady state with constant prices and quantities.

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

5 Basic Results

In this section, first I 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 allow for sticky nominal wages to match the data and repeat the exercise to evaluate the potential non-neutralities arising from labor market nominal rigidities. In all cases the rigidity in consumer prices is too small for the shocks the economy experiences. Therefore, 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 the how much does the price nominal rigidity matter in this case.

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

5.1 The 1994 Episode

5.1.1 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 would imply a large increase in exports and hence, in labor demand. Moreover, imports would be more expensive, causing firms to substitute imports for labor. Thus, the nominal wage has to go up to incentivize workers to increase their labor supply. The increase in nominal wages and import costs makes all firms to be willing to pay the menu cost and reset their prices to their optimal levels.

Columns 1 to 3 in Table 6 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.[31]

For the menu cost model and the flexible price model there is no difference whatso-

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

ever.[32] Both the response of prices and wages is proportional to the currency depreciation. The log change in the exchange rate and nominal wages is 55%, so all firms' marginal costs increase in that amount too. Given the calibration of the menu costs, all firms would be 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 when in the model with menu costs.[33]

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.[34] As the price index of the exporting sector is now lower in foreign currency, exports grow. This expansion generates an increase in labor demand, so real and nominal wages must increase to incentivize workers to sell their labor force. Therefore, under Calvo pricing, a large nominal shock generates a large expansion. At the expense of firms' effective mark-ups over marginal costs, the economy would experience a boom. As shown in Figures 8 and 9, this expansion in employment, imports, and consumption is counterfactual.

5.1.2 Negative Real Shocks with Flexible wages

Table 7 show the results of a 55% log change in the nominal exchange rate together with a *Sudden Stop* that forces the economy to repay every period $i_t^*\bar{B}$ and causes consumption to fall in 12.5% 6 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 as 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 for labor —the cheapest input. As prices in foreign currency are lower (the RER increased by 19.2%), exports increase, partially compensating the fall in domestic consumption.

Column 2 shows the results of the flexible price model, where menu costs are set to

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

[33] 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.

[34] 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.

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 ($\frac{\pi_t^E M}{\pi_t}$). 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.[35] In the 'Calvo' model, this margin is shut down by assumption and firms are forced to have prices much lower than the ones they would want (i.e. they have very low 'effective' mark ups) and this is the source of the large non-neutralities that this model generates.

One of the conclusions of this exercise is that, under the chosen 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 analyze the allow the model to be closer to the data in this case and analyze its implications.

5.1.3 Sticky wages

The approach to model 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

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

given by

$$L_t = \left[\int_0^1 L_t(k)^{\frac{\epsilon_W - 1}{\epsilon_W}} dk \right]^{\frac{\epsilon_W}{\epsilon_W - 1}}. \tag{20}$$

These unions are subject to the 'sticky plans' formulation of Mankiw and Reis (2002). Wage plans are set in advance and can only 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 so it does not add another layer of complexity to the the numerical solution. The results are insensitive to other forms of introducing time-dependent wage rigidities.[36]

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

$$\max_{W_t(k)} (W(j) - MC_t) W_t\,(k)^{-\varepsilon_w}\, W_t^W L_t. \tag{21}$$

The calibration for the parameter that governs the frequency at which wages adjust is chosen so that the duration of an average wage plan lasts a certain amount of time. Hence, the frequency at which wages adjust is set to match the behavior of prices in the monthly calibration.

5.1.4 The 1994 Episode with Negative Real shock and Sticky Wages

Table 8 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 re-calibrated to match the contraction in consumption under wage stickiness.

[36] 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.

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 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, while the real wage is falling, in the model the nominal wage is still increasing in 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 paper. 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 an evidence that the role of prices' 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 can't under this assumption. Thus, shutting down the extensive margin of price adjustment by assuming the *fraction* of firms adjusting generates a fall in consumption of 9.85% (instead of 12.5%) 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 letting wages to freely adjust.[37]

The effects of this are noticeable for the menu cost model. With flexible wages, wages increase in 315.67%, 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 of this in consumption is also large: flexible wages imply that consumption falls a 23.34% relative to the 12.5% (the calibrated value for sticky wages).

[37] Notice that results differ relative to Table 7 —where wages are also flexible— as the *Sudden Stop* has been re-calibrated to match consumption under the sticky wage assumption.

It is illustrative to note that the Calvo model with flexible wages (Column 6) is observationally very 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.

5.2 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 changed significantly.

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

5.2.1 Negative Real shock and flexible wages

Table 9 shows the results for a 33% log change in the nominal exchange rate and a fall in export demand such that consumption falls in 10.4% after 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 increase more than they do in the data. Under the assumption of Calvo pricing (Column 3), prices increase less, so exports fall less 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 fall less as well. As before, I introduce nominal wage rigidities to match the behavior of the CPI.

5.2.2 Negative Real shock under Sticky Wages

Table 10 shows the results for the 2008 episode when wages are sticky. The fall in export demand is re-calibrated 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 can match the data, both for prices and nominal wages. Again, 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 paper: 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 account for a differential of 0.07% 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 prices' rigidities is small relative to the size of the shocks this economy experiences.

The small importance of the change in the frequency of adjustment is summarized by the percentage of inflation explained by the 'extensive margin' ($\frac{\pi_t^{EM}}{\pi_t}$) or how much of inflation is associated to a change in the fraction of adjusting firms. 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 a 7.5% of cumulative inflation can be explained by changes in the fraction of adjusting firms. The menu cost model can account quite closely for this margin.

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 accounted by which firms adjust. In the menu cost model, the adjusting firms are the one that had their prices farther from their desired levels: firms that had very low prices may want to readjust them to 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 in 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. As wage increase is dampened by the 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 than when wages were set to be fully flexible. Given that the frequency of price adjustment in the data changes very little in the data and in the menu cost model, the only relevant margins is *which* firms adjust prices.

The role of wage stickiness Again, the second benchmark to compare the menu cost with sticky wages is given by Column 4, where I present the results of the same shocks, under menu costs and letting wages to freely adjust.

The effects of this are noticeable for the menu cost model. With flexible wages, wages increase in 4.31%, and the response in prices is larger. This generates a larger drop in exports, 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 a 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 presence of a real shock— could be misguided. One of the findings of this paper is that once the nominal rigidity is disciplined with the menu cost model calibrated to micro data, it has to be the case that the labor market is the main source of nominal rigidities, and not prices.

6 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.

6.1 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 13 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 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 it discussed in the next subsection, the effect of the nominal rigidities generating incomplete pass-through to prices is much smaller 6 months after the shock.

Figure 14 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 small enough, the counterpart of this 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 start to decrease 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 15 shows that the real effects of a small depreciation very quickly die-off as more firms receive idiosyncratic shocks that makes them reset their prices, and 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 Jr (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 then want to pay the menu cost and reset their price.[38]

I introduced 'fat-tails' in idiosyncratic shocks' 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 Jr (2007).[39]

The main effect this generates is that the persistence of the nominal shock is increased. When firms receive productivity shocks every period ($q = 0$), firms that did not adjusted to the nominal depreciation will be willing to do so in the next periods. When the shock arrives with the Poisson process ($q > 0$), this process is delayed as fewer firms receive a productivity shocks per period. Figure 15 illustrates this for a small depreciation: when $q = 0$ the effect is very short lived, while when $q = 0.7$ (my baseline specification) there is more persistence.

Sector heterogeneity I explore this effect in the context of my model by exploring the effects of the heterogeneity across sectors.

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 other 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 therefore more complicated in a menu cost model. It depends crucially on the nature of the differences between the sectors that give rise to

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

[39] 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.

the differences in the frequency of price change. Nakamura and Steinsson (2010) show that the introduction of sectoral heterogeneity in pricing can generate different patterns of non-neutralities and that this generates more non-neutralities if the model is calibrated to a low trend inflation rate, the average size of price changes is large and that 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 18 I show the response of the model to a 5% depreciation when it is calibrated to a one, two or five sector economy with Mexico's CPI micro data and import use 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 those.[40]

6.2 Macro parameters

Figure 16 shows the effect of a trend annualize 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 is higher, firms' will care less about the idiosyncratic productivity shocks and more about aggregate shocks . Hence their 'inaction area' — the 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.[41]

Figure 17 and Table 12 present the results of a depreciation of 5%. In all columns the pricing rigidity is given by the menu cost model with flex 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 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

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

[41] See Caballero and Engel (2007)

demand and a price level, nominal wages have to increase by more. Hence, more firms will have incentives to reset their prices, dampening the real effect of the depreciation, and increasing the price level.

In Column 3, 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 lead by exports is now more powerful. In this case is the additional labor demand that generates a higher pass-through than in the baseline, and the increase in consumption is also larger.

7 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 which the exchange rate can prices be 'too high' after a negative real shock hits. That is, I ask the model what does it take 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 it is not calibrated to data, the spirit of it is based on the experiences of countries that maintained an exchange rate peg while suffering external shocks.[42] In this context, nominal rigidities can exacerbate the real shock, as relative prices are not able to adjust enough.

Table 11 presents the result of an export demand shock that contracts consumption 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 bigger fall in imports than employment. The differences with the flexible price model (Column 2) account for

[42] 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).

a change in consumption of -0.57% and 0.62% in the CPI. While these effects are not negligible, the price rigidity cannot account for 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 —that is also 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 fall in exports is larger and so is the contraction in employment and consumption, the fall in real wages is then also larger.

Columns 4-6 presents the results of introducing the same wage stickiness as in the subsection 5.1.3 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 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 practically nil (wages fall in only 0.16%), so firms are not willing to pay the cost to lower their prices.[43] Since the price indexes are practically constant, the real effects of the shock are amplified further. In contrast, with Calvo pricing, a fraction of firms gets 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.

In more general terms, the model with sticky wages is consistent with the widely held view that, when the nominal exchange rate is hold constant, what main source of rigidities that prevent the adjustment in the Real Exchange Rate are in the labor market and not in final goods prices.

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

8 Conclusion

In this paper I studied the role of consumer price stickiness in the response of prices after large nominal exchange rate depreciations. To do so, I used a model of a small open economy where the nominal rigidity is calibrated to CPI micro data. This allowed me analyze two large currency depreciations experienced in Mexico: the 'Tequila' crisis in 1994 and the International Financial crisis in 2008.

One of the main findings is that, in order for the model to match the observed response of prices to the exchange rate depreciation, this has to be the result of a fall in real wages caused by negative real shocks and nominal wage rigidities.

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

Furthermore, the model allows to analyze a counterfactual exercise of a 'overvaluation' of 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 in prices and wages. While the calibrated rigidity in prices cannot account for this, nominal wage rigidities can be a powerful mechanism to do so.

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 objective of this paper was to provide a quantitative answer to the role of consumer price rigidities. Putting the same discipline the wages is not a trivial task, as labor contracts involve long term relationships and contracts. Nonetheless, studying the same question using richer models for the labor market calibrated to labor market and firm micro data.

Another qualification of the model is the exogeneity of the nominal exchange rate shock. While it would be straight forward to add a monetary market and a monetary policy shock that generates the observed movement —as it is typically done in the literature—, 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.

References

Alvarez, F., Gonzalez-Rozada, M., Neumeyer, A., and Beraja, M. (2011). From hyperinflation to stable prices: Argentina: evidence on menu cost models. *manuscript, University of Chicago*.

Alvarez, F. and Lippi, F. (2014). Price setting with menu cost for multiproduct firms. *Econometrica*, 82(1):89–135.

Burstein, A., Eichembaum, M., and Rebelo, S. (2005). Large devaluations and the real exchange rate. *Journal of Political Economy*, 113(4):742–784.

Burstein, A., Eichenbaum, M., and Rebelo, S. (2007). Modeling exchange rate passthrough after large devaluations. *Journal of Monetary Economics*, 54(2):346–368.

Caballero, R. J. and Engel, E. M. (2007). Price stickiness in ss models: New interpretations of old results. *Journal of monetary economics*, 54:100–121.

Calvo, G. A. (1998). Capital flows and capital-market crises: the simple economics of sudden stops.

Calvo, G. A. (2000). Notes on price stickiness: with special reference to liability dollarization and credibility.

Caplin, A. S. and Spulber, D. F. (1987). Menu costs and the neutrality of money. *The Quarterly Journal of Economics*, pages 703–726.

Cook, D. and Devereux, M. B. (2006). External currency pricing and the east asian crisis. *Journal of International Economics*, 69(1):37–63.

Corsetti, G. and Dedola, L. (2005). A macroeconomic model of international price discrimination. *Journal of International Economics*, 67(1):129–155.

Cortés Espada, J., Murillo, J. A., Francia, M. R., and de México, B. (2012). Evidencia de los micro datos del inpc respecto al proceso de formación de precios.

Cravino, J. (2012). Exchange rates, aggregate productivity and the currency of invoicing of international trade.

de Carvalho, C. V. and Nechio, F. (2011). Aggregation and the ppp puzzle in a sticky-price model. *American Economic Review*, 101(6):2391–2424.

Erceg, C. J., Henderson, D. W., and Levin, A. T. (2000). Optimal monetary policy with staggered wage and price contracts. *Journal of monetary Economics*, 46(2):281–313.

Gagnon, E. (2009). Price setting during low and high inflation: Evidence from mexico. *The Quarterly Journal of Economics*, 124(3):1221–1263.

Gali, J. and Monacelli, T. (2005). Monetary policy and exchange rate volatility in a small open economy. *The Review of Economic Studies*, 72(3):707–734.

Gertler, M., Sala, L., and Trigari, A. (2008). An estimated monetary dsge model with unemployment and staggered nominal wage bargaining. *Journal of Money, Credit and Banking*, 40(8):1713–1764.

Golosov, M. and Lucas Jr, R. E. (2007). Menu costs and phillips curves. *Journal of Political Economy*, 115(2).

Gopinath, G., Itskhoki, O., and Neiman, B. (2012). Trade prices and the global trade collapse of 2008–09. *IMF Economic Review*, 60(3):303–328.

Greenwood, J., Hercowitz, Z., and Huffman, G. W. (1988). Investment, capacity utilization, and the real business cycle. *The American Economic Review*, pages 402–417.

Hevia, C. and Nicolini, J. P. (2013). Optimal devaluations. *IMF Economic Review*, 61(1):22–51.

Kaminsky, G. L. and Reinhart, C. M. (1999). The twin crises: the causes of banking and balance-of-payments problems. *American economic review*, pages 473–500.

Karadi, P. and Reiff, A. (2012). Large shocks in menu cost models. Technical report, European Central Bank.

Kehoe, P. J. and McGrattan, E. R. (2005). Sudden stops and output drops. *American Economic Review*, 95(2):381–387.

Kehoe, P. J. and Midrigan, V. (2010). Prices are sticky after all. Technical report, National Bureau of Economic Research.

Kehoe, T. J. and Ruhl, K. J. (2009). Sudden stops, sectoral reallocations, and the real exchange rate. *Journal of Development Economics*, 89(2):235–249.

Klenow, P. J. and Kryvtsov, O. (2008). State-dependent or time-dependent pricing: Does it matter for recent us inflation? *The Quarterly Journal of Economics*, 123(3):863–904.

Lorenzoni, G. (2014). International financial crises. *Handbook of International Economics*, 4:689–740.

Mankiw, N. and Reis, R. (2002). Sticky information versus sticky prices: A proposal to replace the new keynesian phillips curve. *Quarterly Journal of Economics*, 117(4):1295–1328.

Mendoza, E. G. (2010). Sudden stops, financial crises, and leverage. *The American Economic Review*, 100(5):1941–1966.

Meza, F. (2008). Financial crisis, fiscal policy, and the 1995 gdp contraction in mexico. *Journal of Money, Credit and Banking*, 40(6):1239–1261.

Midrigan, V. (2011). Menu costs, multiproduct firms, and aggregate fluctuations. *Econometrica*, 79(4):1139–1180.

Monacelli, T. (2013). Is monetary policy in an open economy fundamentally different&quest. *IMF Economic Review*, 61(1):6–21.

Nakamura, E. and Steinsson, J. (2008). Five facts about prices: A reevaluation of menu cost models. *The Quarterly Journal of Economics*, 123(4):1415–1464.

Nakamura, E. and Steinsson, J. (2010). Monetary non-neutrality in a multisector menu cost model*. *The Quarterly journal of economics*, 125(3):961–1013.

Nakamura, E. and Steinsson, J. (2013). Price rigidity: Microeconomic evidence and macroeconomic implications. *Annual Review of Economics*, 5:133–163.

Stockman, A. C. and Tesar, L. L. (1995). Tastes and technology in a two-country model of the business cycle: Explaining international comovements. *The American Economic Review*, 85(1):168–185.

Vega, M. A. H. (2012). Real exchange rate variations, nontraded goods and disaggregated cpi data. Technical report, Banco de México.

Tables and Figures

Table 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 2: 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 3: 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

Sources: Diario Oficial de la Federacion (Mexico); Nakamura and Steinsson (2008) (US)

Table 4: 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 5: 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	$1/\psi = 2$	
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 6: 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 7: 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 8: 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 9: 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 10: 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 11: No Nominal Depreciation with Trade Collapse.

(Cumulative Log Changes, 6 months after the shock)

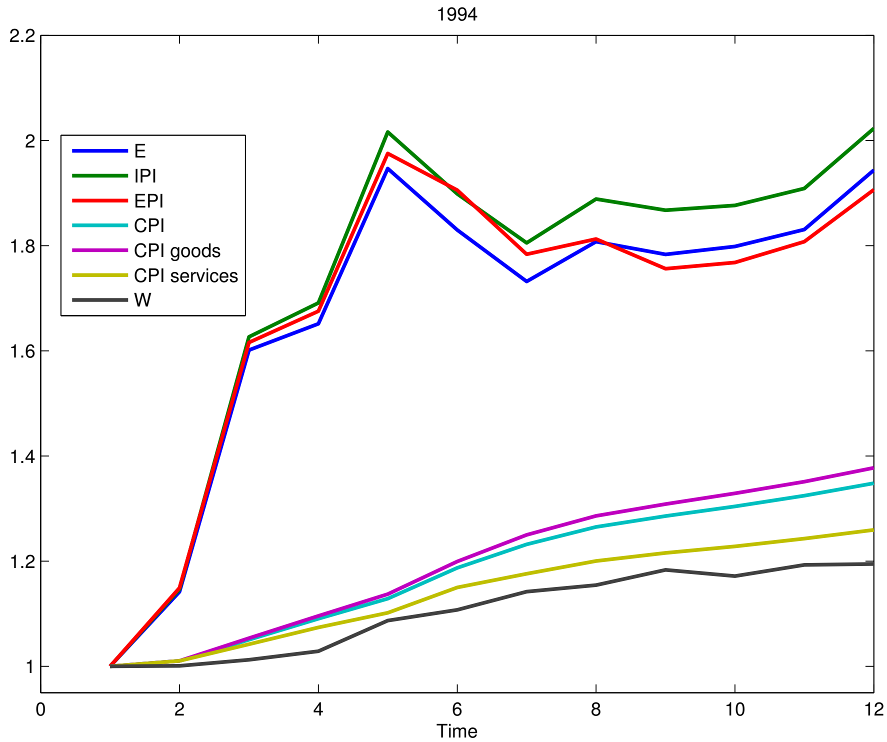
	1	**2**	**3**	**4**	**5**	**6**
	Model					
Prices	Menu Costs	Flexible	Calvo	Menu Cost	Flexible	Calvo
Wages	Flexible	Flexible	Flexible	Sticky	Sticky	Sticky
Targets ($\Delta \log \%$)						
E	0	0	0	0	0	0
C	-4.53	-3.96	-6.89	-10.83	-8.04	-9.81
Prices ($\Delta \log \%$)						
RER	-4.69	-5.31	-2.20	-0.14	-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 12: Menu cost model. Different parametrizations; Depreciation (no real shock).

(Cumulative Log Changes, 6 months after the shock)

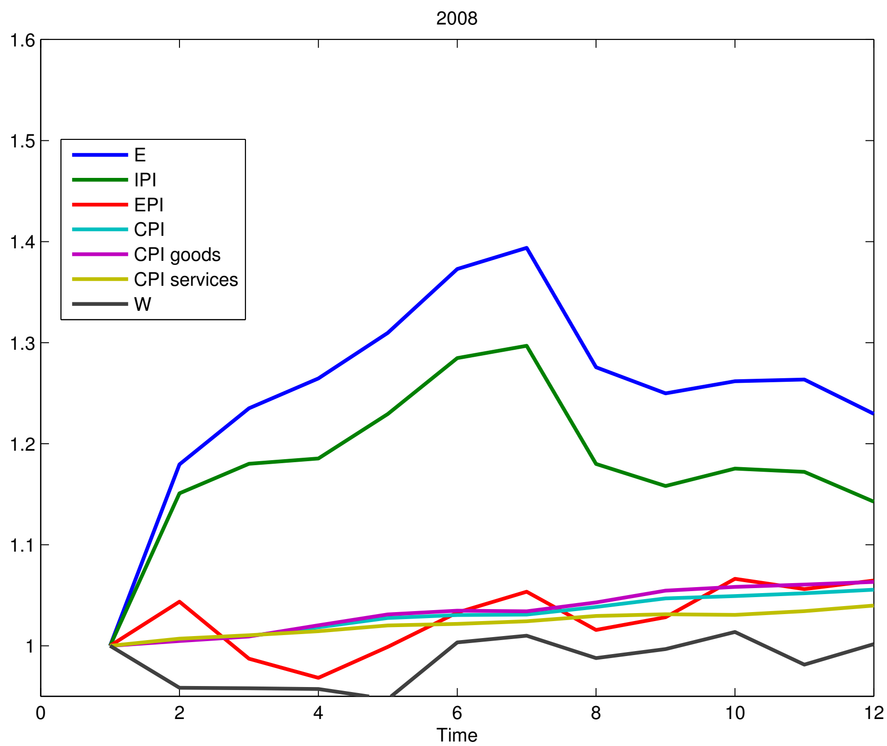
	1	**2**	**3**	**4**	**5**
	Baseline	Low Labor elasticity $1/\psi = 2$	High import share (2x baseline)	High export elasticity $\theta = 4$	High Export Share 20%
Targets ($\Delta \log \%$)					
E	5	5	5	5	5
C	0.612	0.405	0.371	0.690	0.668
Prices ($\Delta \log \%$)					
RER	0.740	0.573	0.654	0.617	0.630
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 1: Price indexes (Nov 1004=1)



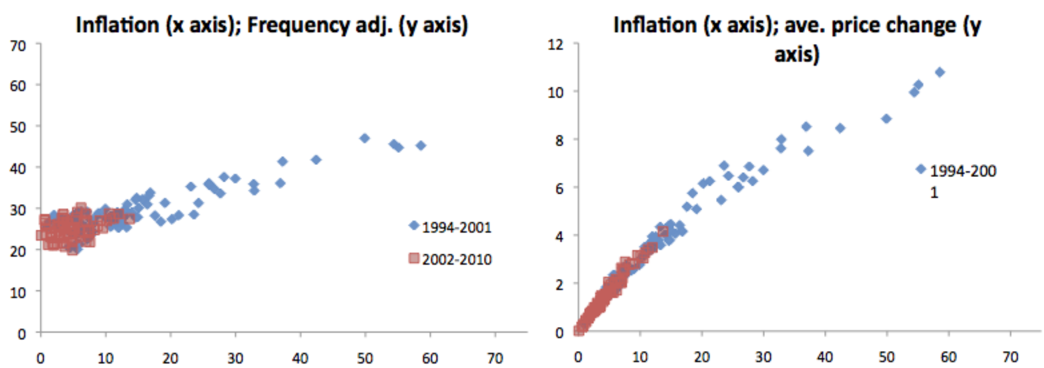
E: Nominal exchange rate; IPI: Import price index; EPI: Export price index; CPI: Consumer price index.

Figure 2: Price indexes (Oct 2008=1)



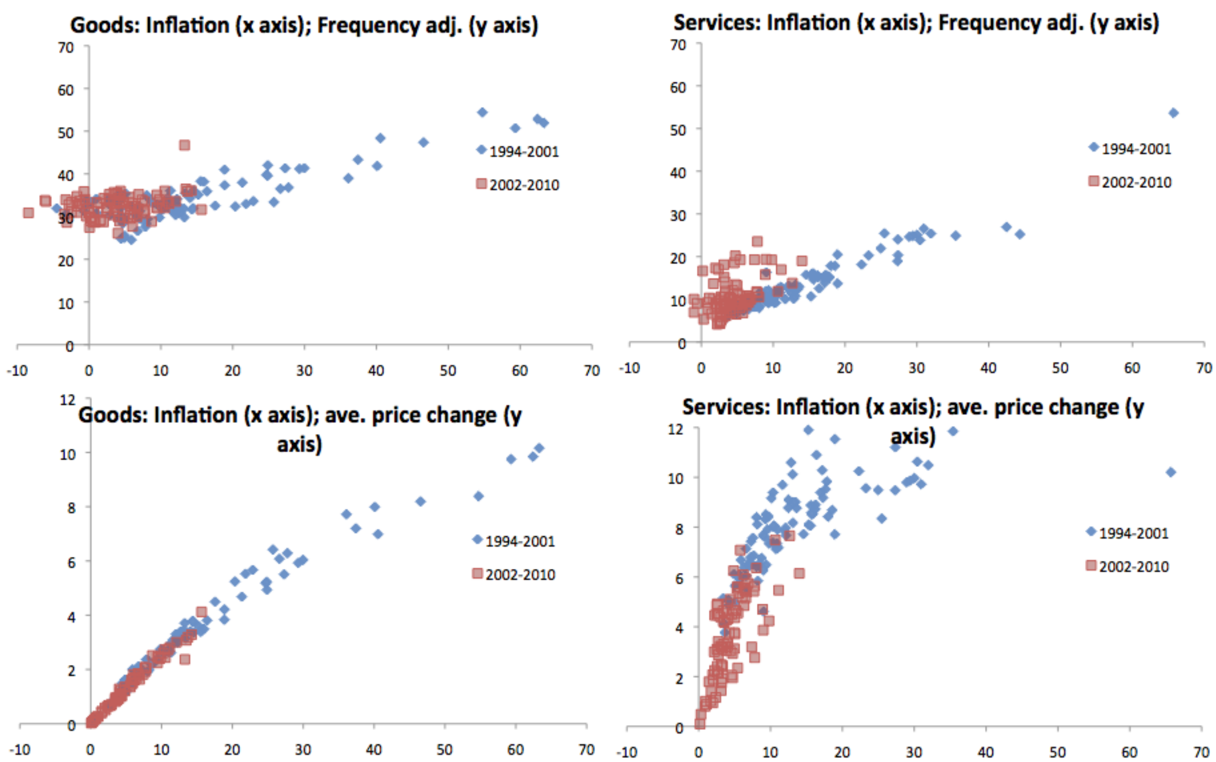
E: Nominal exchange rate; IPI: Import price index; EPI: Export price index; CPI: Consumer price index.

Figure 3: Monthly Inflation (annualized), frequency of price adjustment and average price change (CPI)



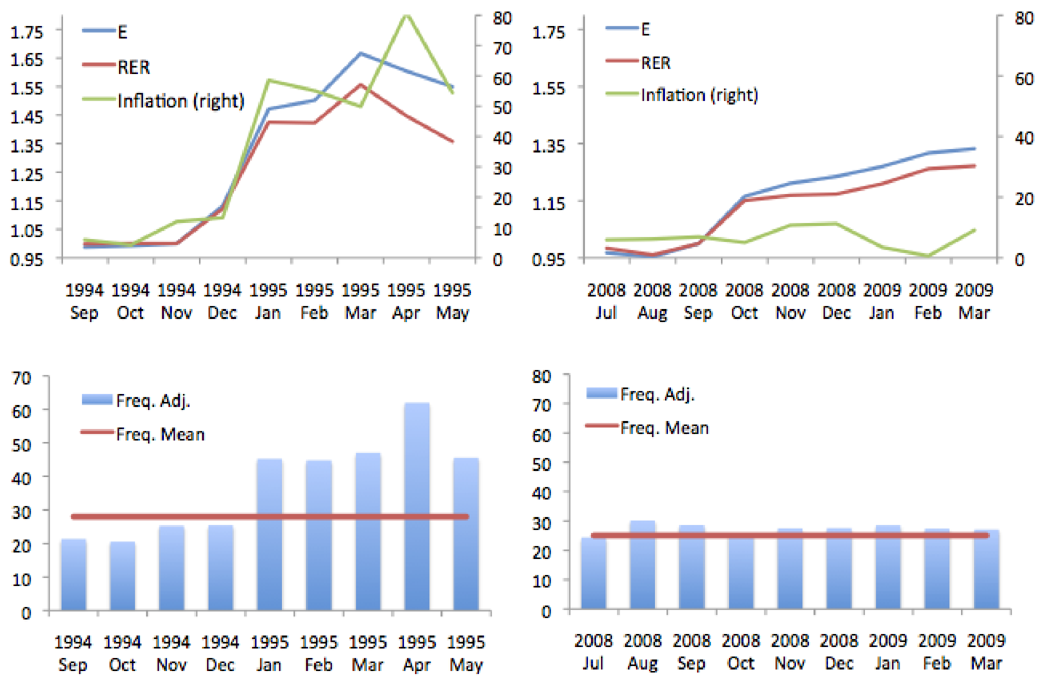
Sources: Diario Oficial de la Federacion, INEGI (Mexico).

Figure 4: Monthly Inflation (annualized), frequency of price adjustment and average price change (CPI Goods and Services)



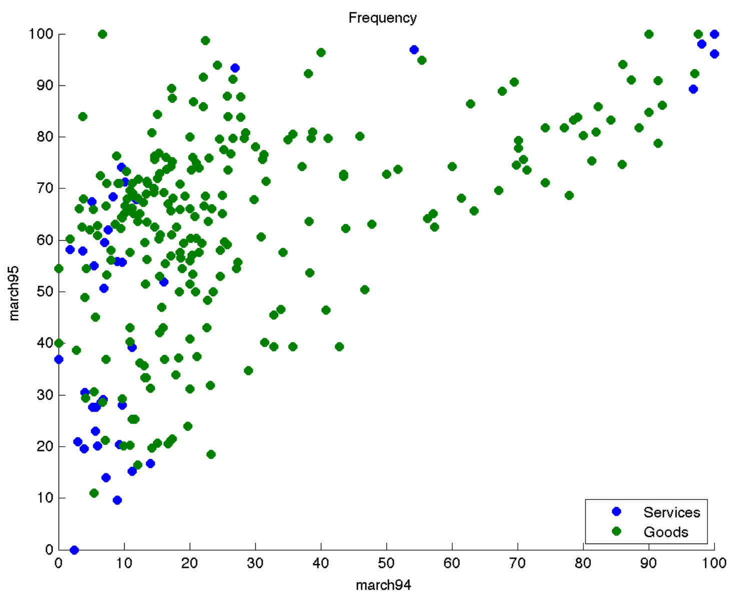
Sources: Diario Oficial de la Federacion, INEGI (Mexico).

Figure 5: Nominal exchange rate, RER, Inflation (above) and Frequency of price adj. (below)



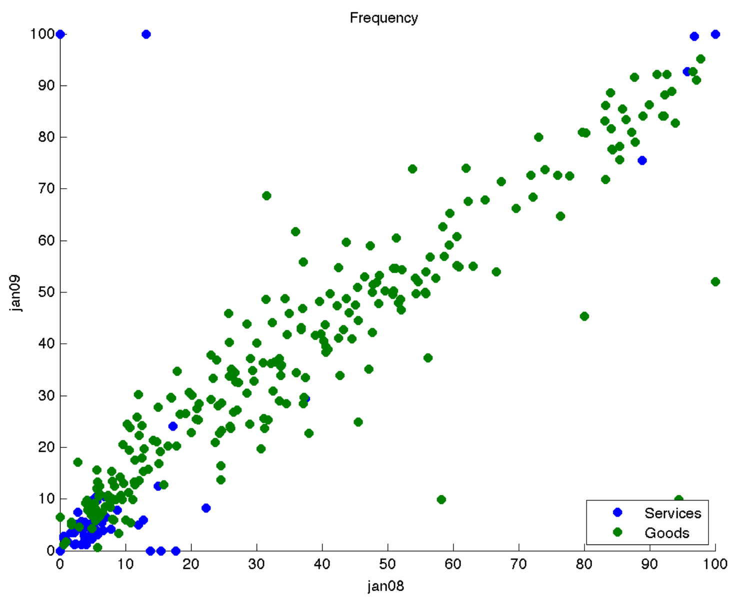
Sources: Diario Oficial de la Federación, INEGI; International Financial Statistics.

Figure 6: Changes in monthly frequency of price adjustment between March 1994 and March 1995, for Entry-Level Categories in CPI



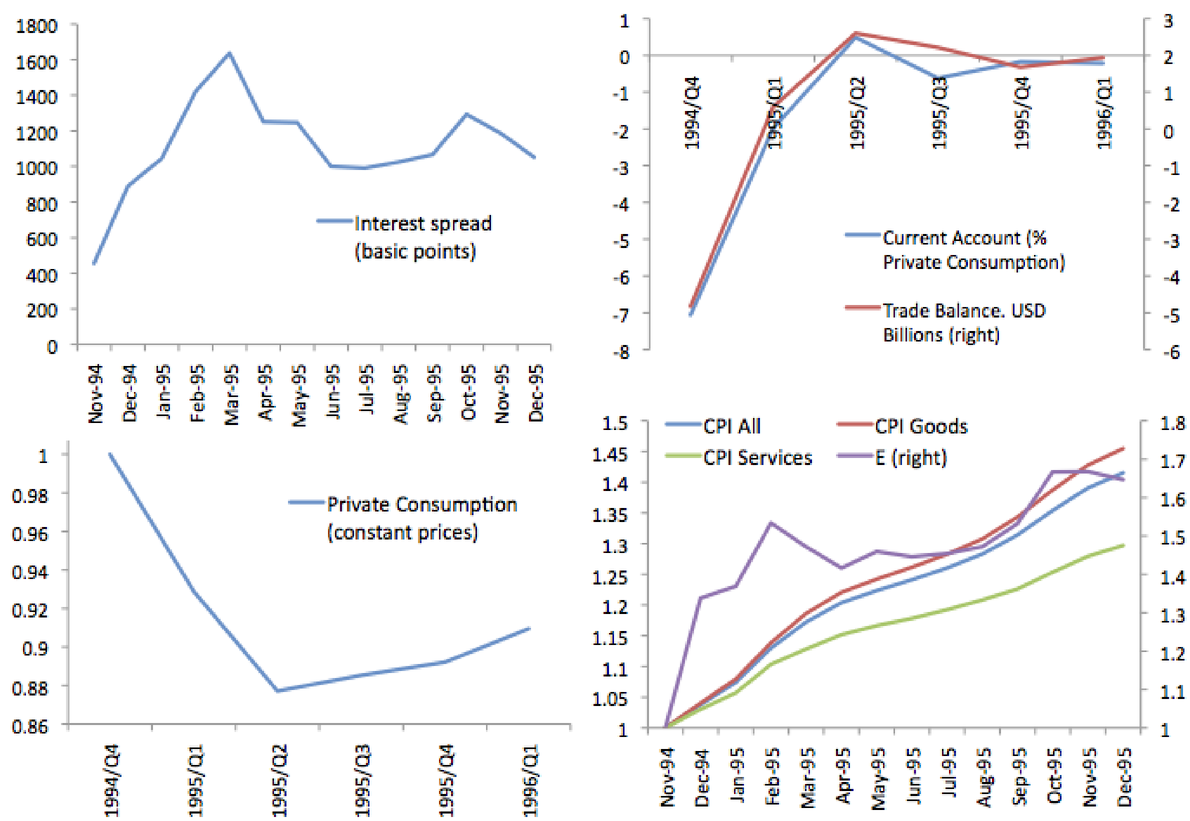
Sources: Banxico, INEGI (Mexico).

Figure 7: Changes in monthly frequency of price adjustment between Jan 2008 and Jan 2009, for Entry-Level Categories in CPI



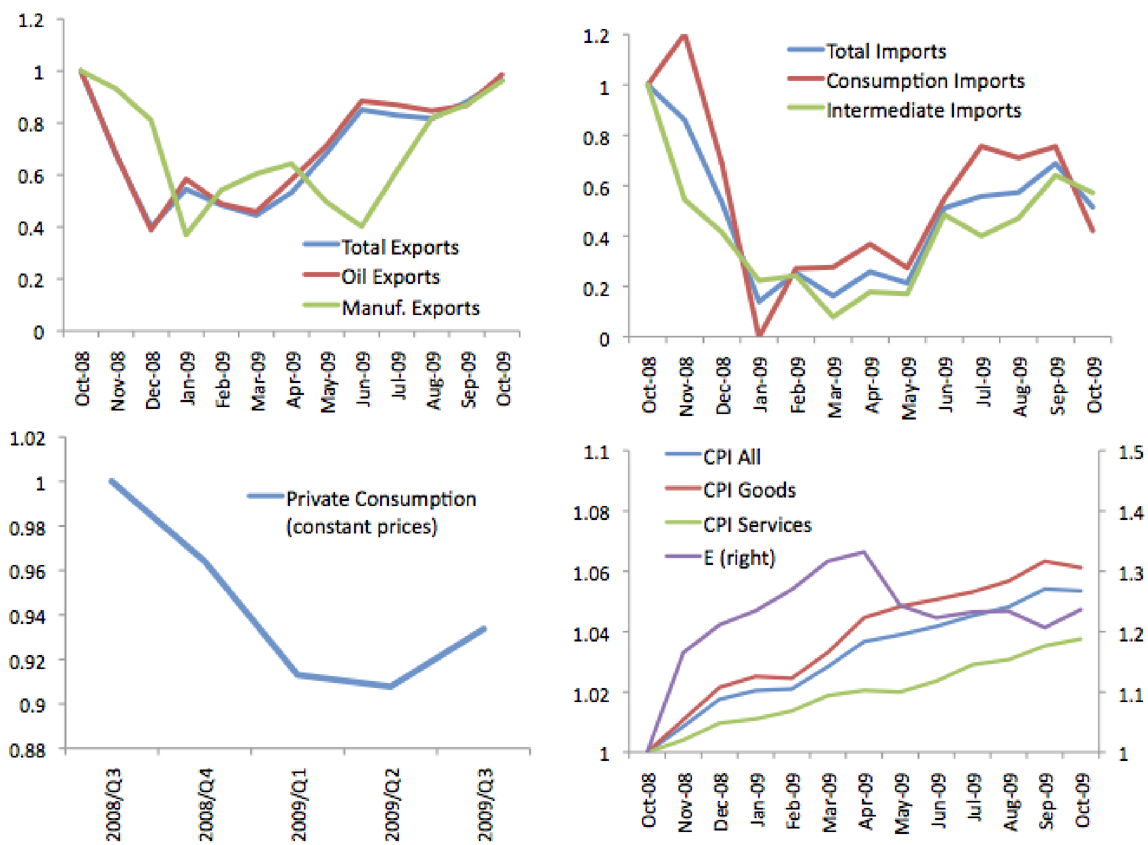
Sources: Banxico, INEGI (Mexico).

Figure 8: Shock Calibration. Sudden Stop (1994)



Sources: Banxico, INEGI (Mexico).

Figure 9: Shock Calibration. Trade Collapse (2008)



Sources: Banxico, INEGI (Mexico).

Figure 10: Nominal Exchange Rate, Inflation and Inflation Margins

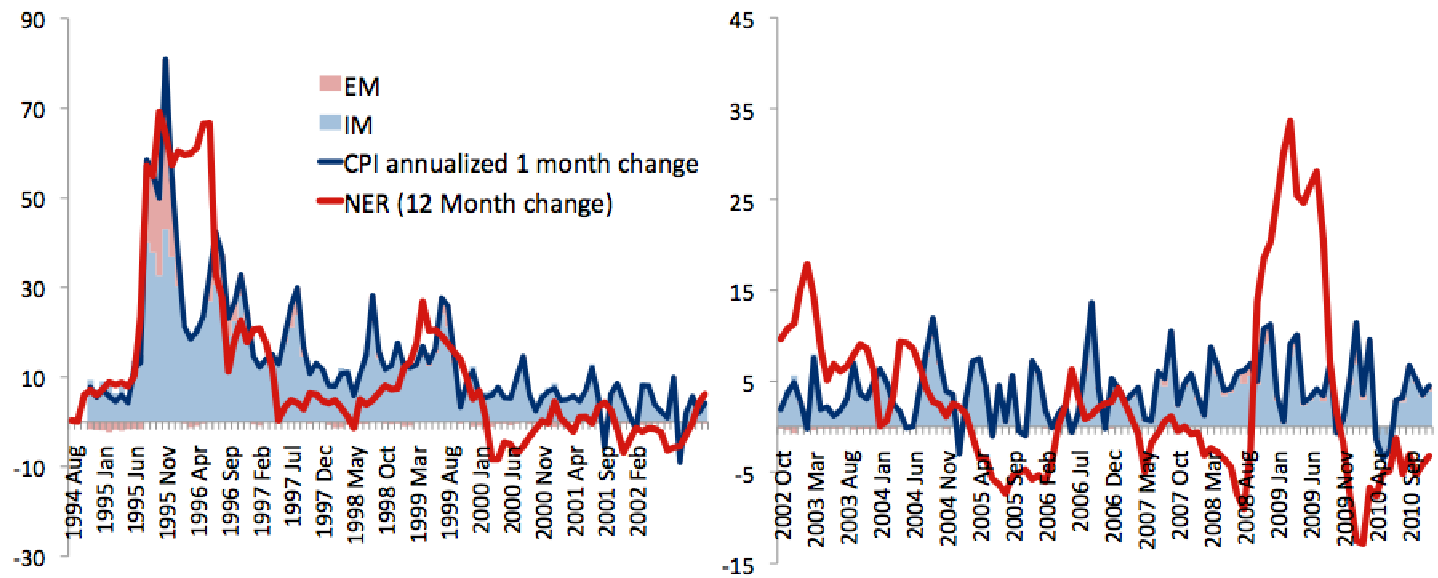


Figure 11: Nominal Exchange Rate, Inflation and Inflation Margins

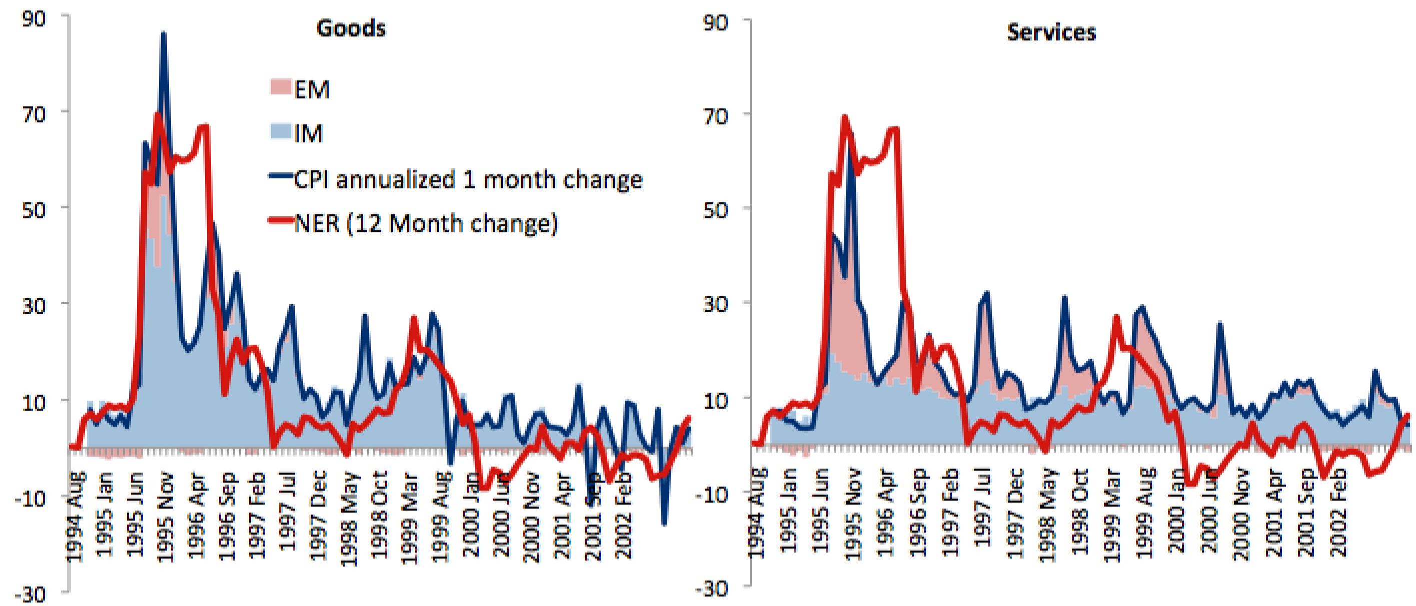


Figure 12: NER, Inflation and Inflation Margins

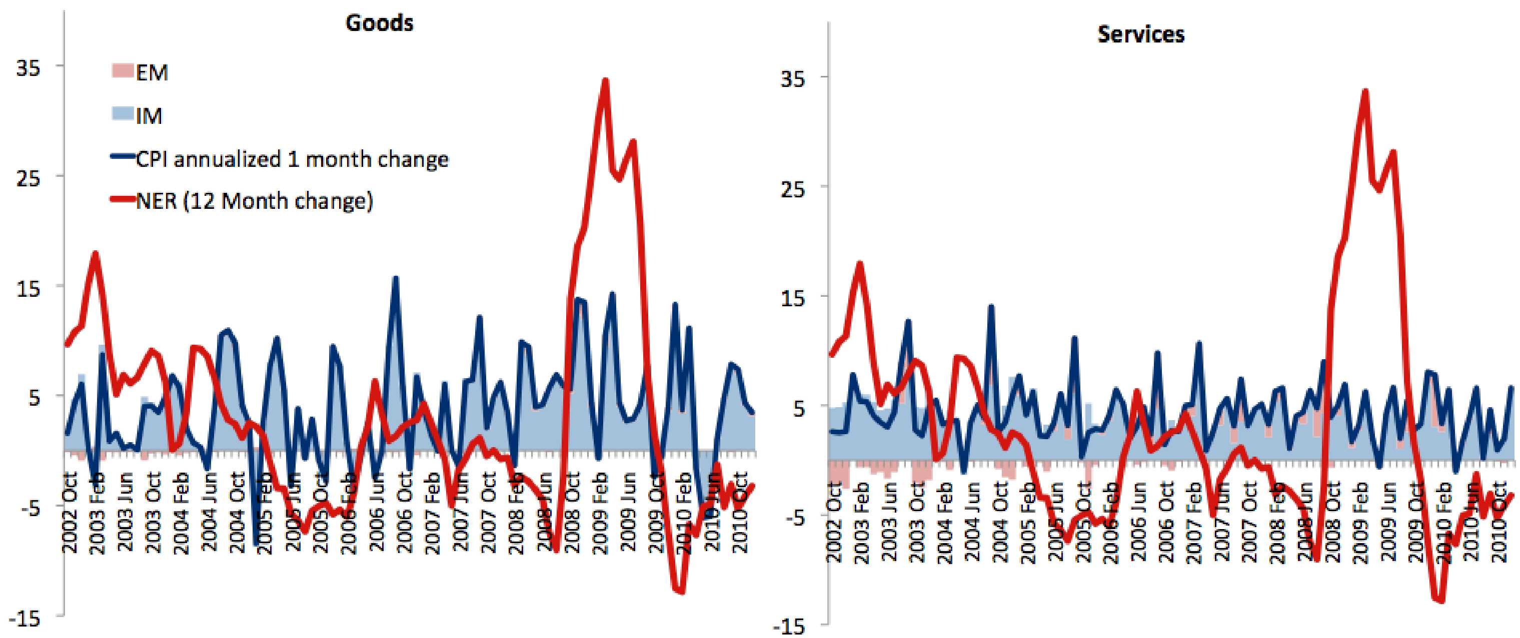


Figure 13: Effects of Depreciation size in Exchange rate Pass-through (without real shocks)

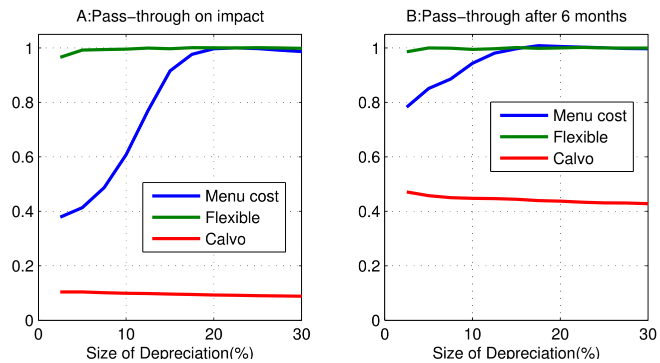


Figure 14: Effects of Depreciation size (without real shocks)

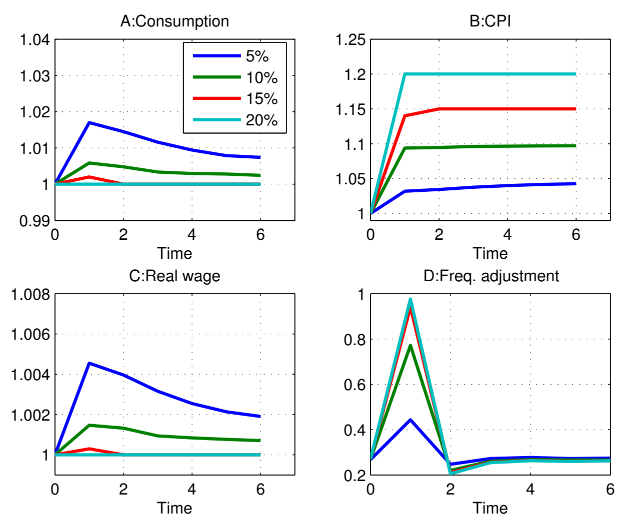


Figure 15: Effects of fat-tailed shocks in a 5% depreciation (without real shocks)

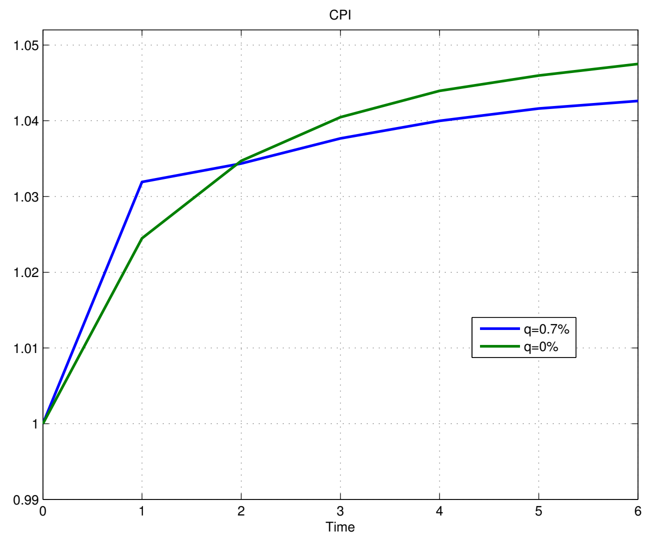


Figure 16: Effects of Trend inflation in a 5% depreciation (without real shocks)

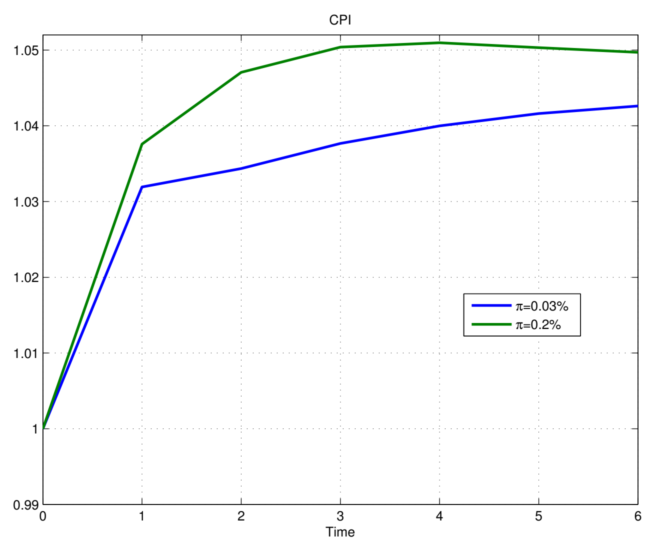


Figure 17: Effects of macro parameters in a 5% depreciation (without real shocks)

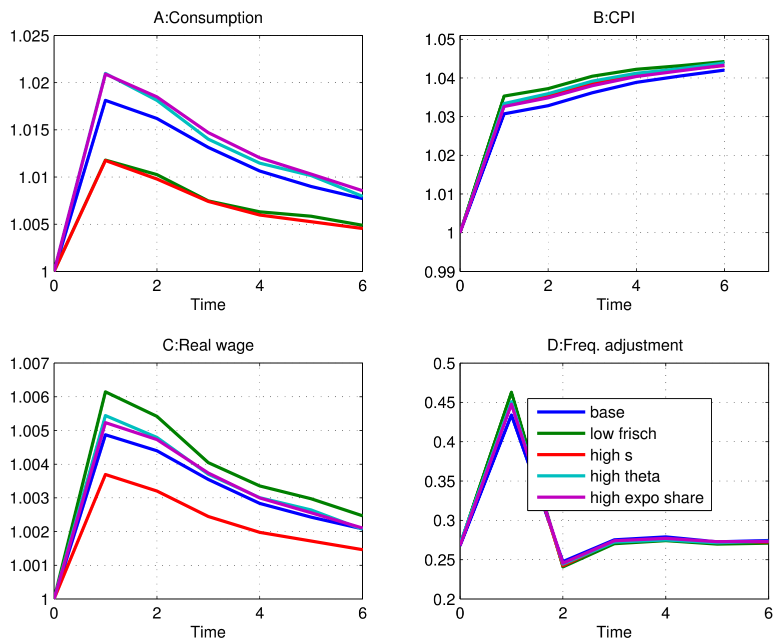
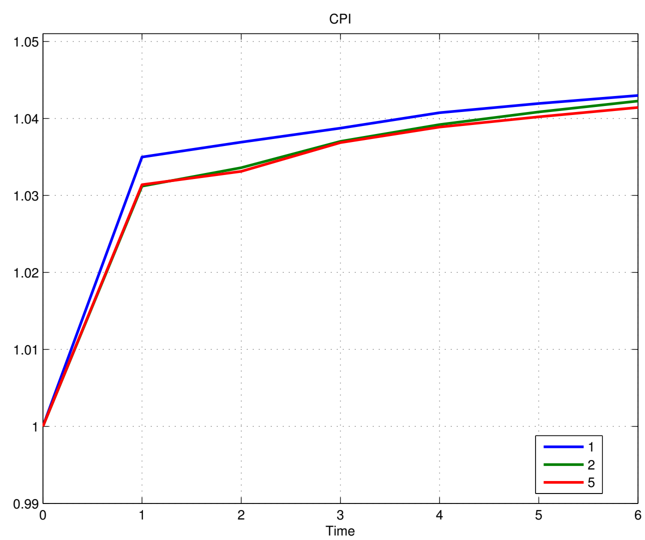


Figure 18: Effects of sector heterogeneity in a 5% depreciation (without real shocks)



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

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

The optimal pricing strategies can be approximated by

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

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 $\Delta \tilde{\log} P$

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

Where

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

Appendix B: Local and traded goods

Following closely Vega (2012), here I classify CPI ELIs in 'tradables' and 'non-tradables'. Using concordance tables for the CPI ELIs to the NAICS nomenclature, he uses data on imports and exports for the U.S. are available from The Center for International Data at UC Davis at a 6-digit dissagregation in NAICS nomenclature. A good is traded if it is either imported or exported between the U.S. and Mexico. A good is then called 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.

For the case of Mexico, when classifying CPI components into traded and non-traded, it is found that 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.[44]

Table 13 add these categorizations to 2 and **??**. As it is can be seen there results are not affected by removing goods that are non-traded and adding them to the non-tradeable category. ,

[44] 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.

Table 13: 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