On What States Do Prices Depend?

Answers From Ecuador *

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January 1, 2014

Abstract

An important challenge for macroeconomics is to understand the reasons that retail prices change infrequently and the implications of this pricing behavior for economic welfare and allocative efficiency. This paper develops a menu cost model of pricing in which retail firms intermediate trade between manufacturers of goods and final consumers. In particular, retail firms purchase manufactured goods in a competitive global market and employ workers to sell the goods in retail outlets at a markup over marginal cost. An important facet of our analysis is that the labor-cost share of retail production differs across goods in the consumption basket. Consequently, firms with different cost structures will change prices by different amounts and at different frequencies despite facing a common menu cost. This allows us to account for some of the cross-sectional differences observed in the frequency of price changes across goods. We apply this model to Ecuador to take advantage of a rich database of monthly retail prices of more than 200 goods and services across 12 Ecuadorian cities. Ecuador is also an interesting case study for menu cost pricing because it underwent a number of dramatic changes in inflation and exchange rate regimes, with a currency crisis and hyperinflation followed by adoption of the US dollar as the unit of account.

*This paper was written while Mario Crucini was a visiting senior fellow at the Globalization and Monetary Policy Institute at the Federal Research Bank of Dallas. Mario Crucini gratefully acknowledges the financial support of the National Science Foundation. The views in this paper are our responsibility and should not be interpreted as reflecting the views of the Federal Reserve Bank of Dallas or the Federal Reserve System.

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1 Introduction

This paper contributes to the menu cost literature, an economic environment where firms pay a fixed cost to adjust their nominal prices. In the presence of these fixed costs, firms find it optimal to adjust their prices only when the benefit of doing so exceeds the fixed cost. Consequently, the optimal price includes a band of inaction, a range of states of nature over which the cost of a price change exceeds the benefit in terms of increased profits and the price remains nominally rigid.

Our model deviates from the existing literature somewhat by allowing for both a distribution margin and a markup. The distribution margin captures the real frictions associated with intermediating trade between manufacturers and final consumers. These frictions naturally included trade costs since manufacturers and consumers are not often in the same location. More quantitatively important are the labor and capital associated with traditional brick-and-mortar retailing. We model this second friction as involving only labor to keep our model tractable. Moreover we lack data on retail rental prices that would allow us to explicitly incorporate distribution capital. What we do allow for is the fact that the amount of labor needed to intermediate trade between manufacturers and consumers differs significantly across goods. Crucini and Landry (2013) report that the distribution share for gasoline is about 0.20 while that for haircuts is 0.85. the mean across goods in the micro-data used here is about 0.5. Thus, the markup plus real frictions associated with retail trade are predicted to be 50% of the final retail price.

The model is applied to Ecuador over the period January 1997 to April 2003 to take advantage of a rich micro-price database as well as a rich stochastic environment. Ecuador started the period of study with monthly inflation of 2.2% in the first couple of years. The inflation doubled to 4.5 in the middle of the sample in which a currency crises developed. Inflation fell to 1.2% after Ecuador adopted the US dollar as its official currency. Both the frequency and average absolute size of micro-price changes are strongly positively correlated with the rate of aggregate inflation. Because Ecuador is a small open economy, heavily dependent on crude petroleum exports, we model the unit cost of retail goods as composites of Ecuadorian wages (retail labor) and the local currency import price of item (when import unit values are available). Our benchmark model emphasizes common shocks to import prices as might be due to nominal exchange rate shocks.

2 The model

The model is a partial equilibrium model in which a continuum of firms belongs to a sector that combines labor (i.e., retail services) and a wholesale good purchased on world markets to produce a differentiated final good:

$$y_t(i) = l_t(i)^{\alpha_i} m_t(i)^{(1-\alpha_i)}$$

where $y_t(i)$ is the final good the consumer purchases, $l_t(i)$ denotes retail services involved in making the good available to the final consumer and $m_t(i)$ is the good itself. The use of a Cobb-Douglass production function is consistent with a literature that models final goods with round-about production, but contrasts with Burstein, Eichenbaum and Rebelo (2007) who assume distribution services and goods are Leontief inputs into the production of final goods. In contrast, Crucini and Yilmazkuday (2013) find the CD function a useful approximation in accounting for long-run price international dispersion. As little work has been done to actually estimate the retail production function, we leave this issue aside for the time being and adopt the CD form due to is tractability.

Consumers have CES preferences over goods and thus the demand for the good i is:

$$y_t(i) = y \left(\frac{\widetilde{p}_t(i)}{\widetilde{p}_t} \right)^{-\theta}$$

where $\widetilde{p}_t(i)/\widetilde{p}_t$ is the nominal price of good i relative to the CPI price index (all nominal variables are denoted with a $\widetilde{}$, to avoid confusion between real and nominal variables. Real aggregate demand (and income) is y and θ is the elasticity of demand. We normalize output to unity in what follows.

Firm i maximizes the expected discounted value of its profits:

$$E_t \sum_{s=t}^{\infty} d_{t,s} \pi_s(i)$$

where $d_{t,s}$ is the discount factor between period t and future period s and $\pi_s(i)$ is the flow level of *real profits* (nominal profits divided by the CPI price level) for the firm in period s. Flow profits in real terms equals,

$$\pi_s(i) = p_t(i)y_t(i) - w_t l_t(i) - p_t^m m_t(i) - \chi w_t I_t(i)$$

where $I_t(i) = 1$ if the firm adjusts its price, $p_t(i)$, and 0 otherwise. Note we are assuming for now that the import prices are equal, p_t^m, which in a abstract sense is meant to emphasize common shocks to the import prices of goods the populate the consumption basket.

Following Nakamura and Steinsson (NS, 2008), the real wage, $w = \widetilde{w}_t/\widetilde{p}_t = (\theta - 1)/\theta$.[1] The indexation of the nominal wage means that as firm leave their nominal prices constant, demand for their products increases and real profits also rise provided $\theta > 1$ (when the demand elasticity is unitary, the increase in demand is offset by the decline in real revenues are unchanged). To see this, substitute the demand function into the profit function to arrive at:

$$\pi_s(i) = (p_t(i))^{1-\theta} - w l_t(i) - w\chi I_t(i) - p_t^m m_t(i)$$

where the first term is real revenue.

In making pricing decisions, the firm takes the aggregate price level, the real wage and the relative price of imports as given. Before calibrating and simulating the model, we provide some basic facts about micro-price behavior and aggregate inflation in Ecuador over the period of our analysis.

3 The frequency of retail price changes

The Ecuadorian retail price data is from INEC, the official national statistical agency of Ecuador. In particular these data are the universe of items used to construct the official CPI and consist of 223 goods price is 12 different Ecuadorian cities (including the capital, Quito). The frequency of the data is

[1]In a general equilibrium model with linear disutility of labor and constant aggregate consumption, the real wage would be equal to $Wt/Pt = \alpha U_C(C)$, where α is the marginal disutility of labor. Under the additional assumption that prices are flexible,$Wt/Pt = (\theta - 1)/\theta$. More generally, if the degree of monetary nonneutrality is small, variation in Ct will be small and the real wage will be approximately constant.

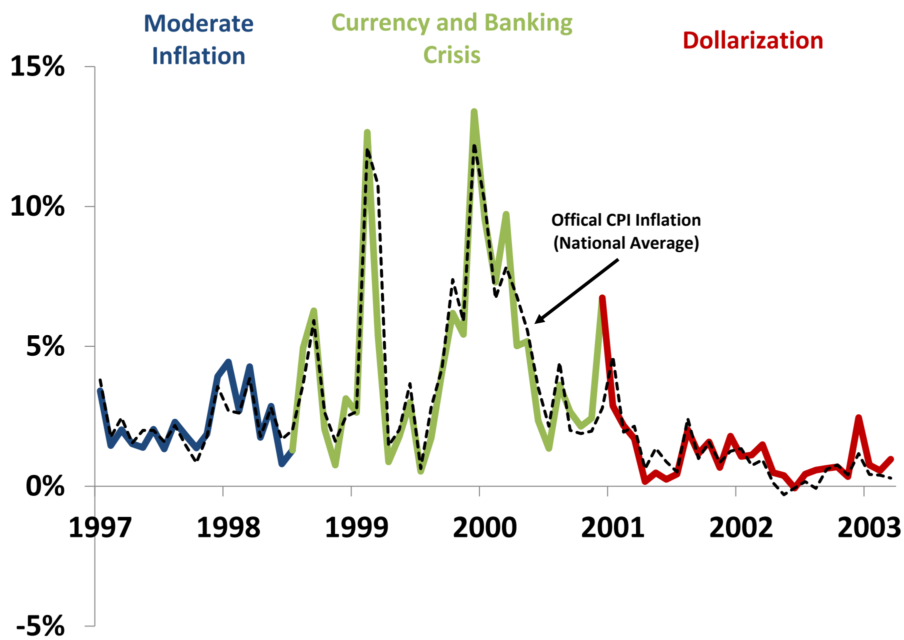

Figure 1: CPI inflation rates by era

monthly, the first observation is January 1997 and the last is April 2003. The data is described in detail in Penaloza (2005).[2]

Figure 1 plots monthly inflation constructed as an equally weighted average of inflation across all goods and cities. We have verified that this is almost exactly what the official CPI looks like. The inflation rate is displayed in tricolor, blue for the pre-crisis regime, green for the period of financial and exchange rate crisis and red starting when Ecuador officially adopted the US dollar as its currency.

Table 1 reports key statistics describing the time series properties of ag-

[2]The Ecuadorian micro-price panel was obtained from INEC (the national statistical agency of Ecuador) by Penaloza (2005) who studied Ecuadorian real exchange rates with respect to the United States in his Ph.D. dissertation.

gregate price inflation and micro-prices.

Table 1. Price Facts

	Full sample	Era 1	Era 2	Era 3
	1997:01-2003:04	1997:01-1998:07	1998:08-2000:12	2001:01-2003:04
Inflation	2.7%	2.2%	4.5%	1.2%
Price change frequency	57.7%	54.1%	67.8%	50.0%
Price increases	43.2%	42.8%	54.7%	31.8%
Price declines	14.4%	11.3%	13.1%	18.2%
Size of price changes	7.1%	5.9%	9.8%	3.9%

Notes: Size of price changes are average absolute values across goods and time periods.

The facts are presented for the sample overall and three eras to convey the narrative history of inflation in Ecuador. Inflation is very high compared to industrial countries even before the financial and exchange rate crisis, averaging 2.2% per month. Inflation reaches hyperinflationary levels during the financial and exchange rate crisis (Era 2). The average is a bit deceptive in the sense that some inflationary spikes extended to more than 10% per month (again, see Figure 1). The inflationary situation moderated in Era 3, with inflation partly stabilizing presumably as a consequence of Ecuador adopting the US dollar as its official currency combined with a commitment to open trade and integration with international capital markets. In Era 3 Ecuador achieves a historical low inflation of 1.2% per month.

The first answer to the question about what states price adjustment depends is evident in the table. Consistent with the state dependent or menu cost theory of price adjustment, when inflation is the only state upon which prices depend, higher inflation should induce more frequent price changes. We see this general tendency across the three eras of our sample with the frequency of price changes increasing from 50%, to 54.1% and then to 67.8% as we move from the lowest to highest inflation regime. These frequencies are about twice as high as those reported in Nakamura and Steinsson (NS, 2008) for the United States, even with sales included. The difference is partly accounted for by the fact that inflation is much higher in Ecuador than in the US, even during the recent period of dollarization. A more appropriate comparison may be Gagnon (2009), who studies the frequency of price changes in Mexico from 1994 to 2002. Over this nine-year period, the CPI inflation rose from 2.2% in 1994 to peak of 12.3% in 1995, before falling to 1.6% in the last year. The frequencies price changes were 22.1%, 61.9% and about 27.4% in these three periods. While not exactly matching Ecuador, the frequencies conditional on inflation are in a similar range to what we find.

Another important feature of the micro-data attracts our attention. As other authors have pointed out, the frequency of price changes differs substantially across items in the consumption basket. This heterogeneity of frequencies across goods is a universal feature of micro-price data, not requiring qualification. An important question to ask is whether the cross-sectional variance in frequencies reflects economic structure that macroeconomists should be building into their models or uninteresting noise. We suspect that structure underlies these patterns. As an informal metric to elucidate such structure we ask if the frequency of price changes maintains its cross-sectional pattern as we move from one regime to another.

Figure 2 accomplishes this by plotting the frequency of price change by good in our micro-sample as individual data points. The x-coordinates of this figure are the frequencies of price change in Era 1, the sample with the inflation rate closer to the historical mean. The y-coordinates for the blue (red) dots are frequencies in the Era 2 the crisis period (Era 3, the dollarization period). The higher (lower) average frequencies in Era 2 (Era 3) are evident with the blue (red) scatter lying above (below) the 45-degree line.

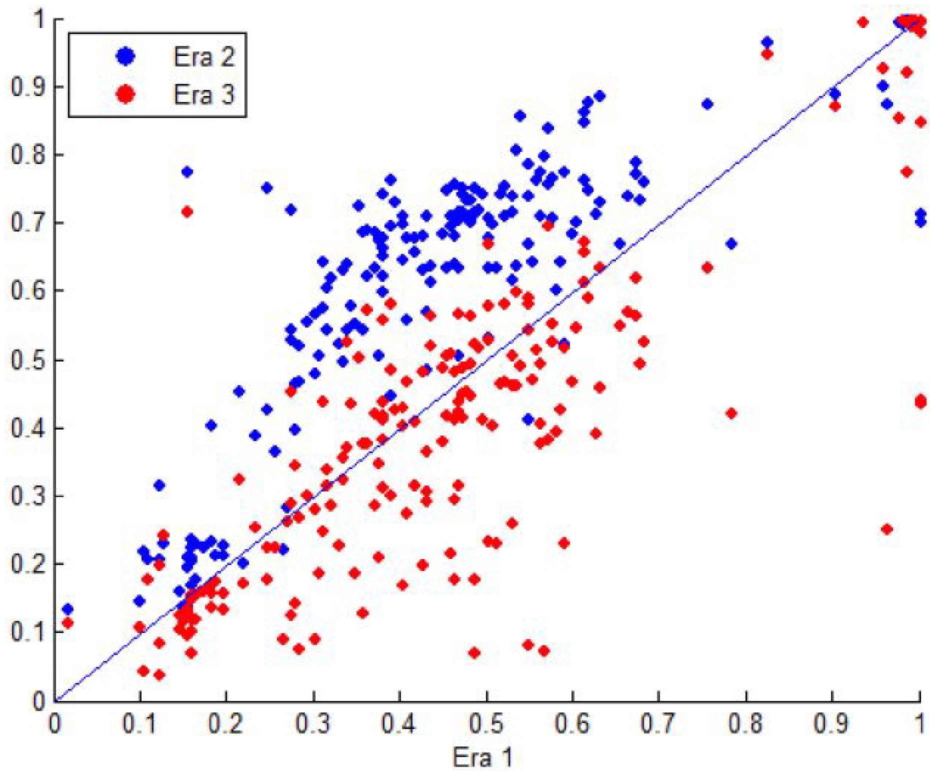

Figure 2. Goods-by-goods frequencies of price changes in the data

Evidence of a structural relationship is the fact the cross-sectional distribution of frequencies is preserved across eras. That is, the correlation of frequencies of price changes across goods is strongly positive across regimes (i.e.,the blue and red scatter diagrams show strong positive correlation with each other). What this suggests to us is that there is some factor specific to an individual good that induces more frequent price changes or less frequent price changes with has little to do with the inflation regime. These are the additional states upon which prices depend. What are these additional states.

In our view, a vital one is the import price index. Consider a log-linearized version of the nominal cost function implied by our model:

$$c_t(i) = \alpha_i w_t + (1 - \alpha_i) p_t^m$$

That two state variables are the market wage in Ecuador, w_t, and the import price index, p_t^m. While we plan to allow for good specific import unit values, for now we emphasize this two-state stochastic structure. This would effectively capture common shocks to import unit values as might arise when nominal exchange rates shift the entire distribution of import prices.

Clearly the variance of the marginal cost function depends on the variance of wages, the variance of import prices and their covariance. It also depends on the cost share of the two inputs, α_i. In Goloslov and Lucas (2007) the frequency of price changes is increasing in the variance of the microeconomic productivity shocks experienced by firms because this translates into higher variance in marginal cost. In our setting, the frequency of price changes will depend on the variance of these two aggregate states and the distribution cost share.

It should also be kept in mind that the assumption of wage indexation creates an asymmetry in the cost function across these two state variables. To see this, consider what indexation of the import cost component would mean. Effectively it would imply complete exchange rate pass-through of nominal shocks as might be the case when exchange rates are flexible and international prices obey the LOP. When pass-through is incomplete, as it usually is, the import price in local currency will move differently than the aggregate price level and thus also differently than the nominal wage when wages are assumed to be indexed to the aggregate price level.

Consider, now, adding real shocks to the productivity of foreign firms who produce Ecuadorian imports; these would move the import price index relative to the wage level and moreso the more complete is pass-through of foreign prices into domestic import prices. A similar point was made in Crucini, Shintani and Tsuruga (2013). Namely that flexible prices amplify the transmission of real shocks across locations while sticky prices amplify the transmission of nominal shocks.

With this empirical discussion as background we return to the calibration of a more stylized stochastic structure in our benchmark parameterization.

4 Results

Following NS, the log price level follows a random walk with drift:

$$\log P_t = \mu_r + \log P_{t-1} + \eta_t$$

where $\eta_t \sim N(0, \sigma_\eta^2)$ and the subscripted, μ_r, allows for regime changes in the average rate of inflation.

Import prices are assumed also to follow a random walk with drift that share the same drift rate, but has an independent innovation:

$$\log P_t^m = \mu_r + \log P_{t-1}^m + \nu_t$$

where $\nu_t \sim N(0, \sigma_\nu^2)$. At the present time, we calibrate this using a trade-weighted real exchange rate (that is, a traded-weighted average of foreign CPI converted to domestic currency units). While standard in the macroeconomics literature to use such real exchange rates as measures of relative price (home to foreign), the intent of our model is to measure import unit values. We are currently assembling micro-data on imports of items found in the Ecuadorian CPI to construct much improved measures of this component of marginal cost.

Table 2 contains our benchmark calibration. We measure the variance of the inflation and import price shock as the variance of the inflation rate and the log-change in the trade-weighted real exchange rate, respectively. The values are 0.027 and 0.002, respectively. The order of magnitude dominance of the CPI inflation innovation variance relative to the import price innovation variance is surprising and given the lack of indexation of this variable in our model, will be an important source real marginal cost volatility.

Table 2: Calibration

	Full sample	Era 1	Era 2	Era 3
	1997:01-2003:04	1997:01-1998:07	1998:08-2000:12	2001:01-2003:04
Inflation	2.7%	2.2%	4.5%	1.2%
$\sigma_\eta = \sigma_\nu$	0.027	0.008	0.033	0.010
α_i	Haircut	0.85	Menu cost	0.7%
	Gasoline	0.19	λ	0.60
	Median	0.52	E(Menu)	0.42%

We allow the mean inflation as well as the standard deviation of the innovations to the CPI price level and import price level to change across the three eras. We hold the distribution cost shares and the menu costs fixed. The former are taken from US NIPA estimates by sector and matched to the Ecuadorian sample by placing each retail item into the sectors defined by the US NIPA structure. The values range from 0.19 for gasoline to 0.85 for haircuts. The mean across the 223 goods in the Ecuadorian micro-panel is 0.52. The menu costs are 0.7% of labor income when they accrue and given the mean frequency of price changes is 0.6, roughly 0.42% of aggregate labor income is assumed to be spent on price adjustment by retail firms.

The first facet of the model we examine is its ability to match the mean frequency of prices changes across regimes. Here we restrict the model to have only aggregate price level shocks and no heterogeneity in the labor shares across goods. That is, the labor share of retail production is set at 0.52, the mean across goods. Figure 3 presents the mean frequencies of price changes by regime for each city in the Ecuadorian micro-panel as well as the predictions of the baseline calibration of the model. The black dots are the predictions from the model while the red, blue and green dots are those from the micro-data. For example, the cluster of red dots are the mean frequencies of price changes across goods, city-by-city for the dollarization era (Era 3). With inflation of about 3% per quarter, the frequency of price changes is about 50% per month. Inflation during the financial crisis is above 14% per quarter and the mean frequencies are between 60 and 70%. The menu cost is parameterized to match the overall average frequency, which is the third black dot from the bottom left. We see that the model also fits the high inflation regime, but underestimates the frequency of price changes in Era 3, the dollarization regime. That menu cost models fits to high inflation regimes underestimate frequencies of price changes at low level of inflation was a motivation for Golosov and Lucas (2007) to add idiosyncratic productivity shocks to elevate the frequency of price changes at low inflation levels. In our model there are no productivity shocks, but the variation in the import price index serves a similar purpose, shifting the firms' cost function. An important difference is that our production function exhibit diminishing marginal productivity in each factor and constant returns in total.

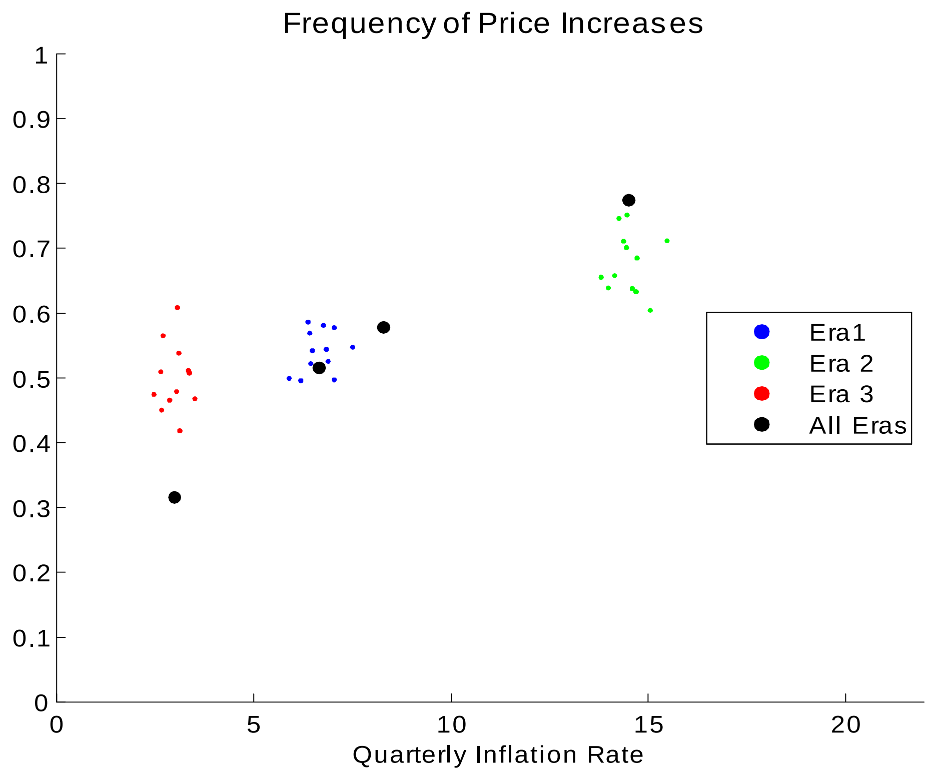

Figure 3. Median Price Change Frequency by Regime, Data and Model

In particular, the decision rule of a firm in our model is two dimensional in the sense that the decision to change price is a function of the aggregate price level as well as a function of the import price level. Moreover, the size of the inaction region and magnitude of price jumps is different for each component of marginal cost and also depends on the cost share of labor and traded inputs into production.

Figure 4 presents the baseline calibration for four different values of the labor cost share. Notice that the inaction region falls from about 4% (1.02-0.98) to about 1% (1.005-0.995) as the labor share falls from 0.589 to 0.167. The reason the inaction region is rising in the labor share is that nominal wages are indexed to the aggregate price level while imports are not. Consequently profits become less sensitive to the aggregate price level as the labor share rises. Note that demand for the firm's product is always rising in the aggregate price level because the relative price of the firm's good is reduced.

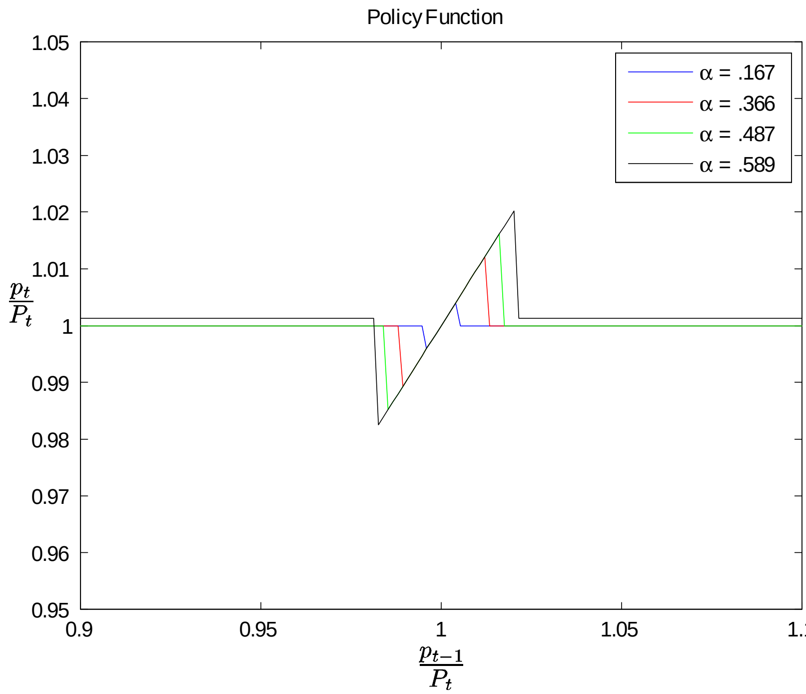

Figure 4. Firm's decision to change price as a function of the price level

As a very preliminary calibration we treat the inflation and import price index symmetrically in the sense that they are both random walks and have the same innovation variance. Our next exercise is to see how the model fares in accounting for the heterogeneity of frequencies of price changes when the only heterogeneity that exists is the labor share. Figure 5 reports the results in the same fashion as the data were presented in Figure 3. Era 1 simulations are on the x-axis and Era 2 and 3 are y-coordinates. It should be kept in mind that we have fewer distribution shares than goods, which limits to some extent the cross-section variance that results. That said, the variation is much less than we saw in Figure 3 earlier. We suspect that this is partly due to our adherence to a common variance of import price shocks across goods. Currently we are reconciling micro-data on unit values of imports with the retail goods and the stochastic properties of these goods will be used to more accurately map the theory into the data. Given that much idiosyncratic variance is likely to aggregate out at the import price index level and inflation level, it would be expected the shocks to unit values will be much larger than inflation and thus play a more significant role, particularly for goods that do not use retail labor intensively.

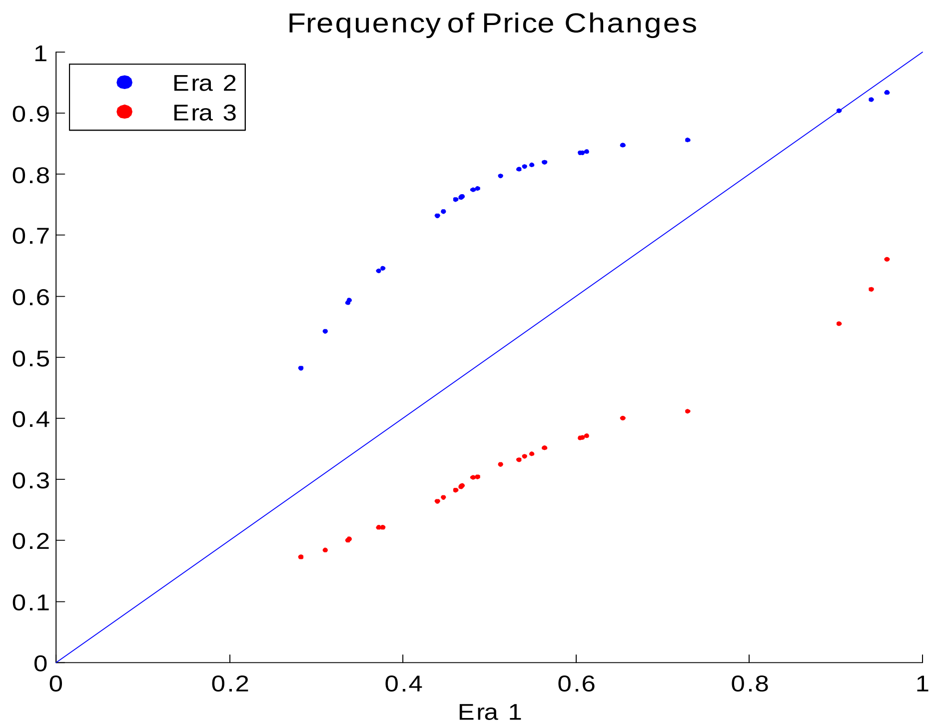

Figure 5. Frequency of price changes by sector and regime (model)

5 Future work

Our preliminary works indicates the conceptually, the menu cost model has the structure necessary to account for both the average frequencies of price change across regimes and the differences in frequencies by good within a regime. However, our we currently lack the micro-data at the import stage to incorporate the heterogeneity of cost shocks across retail items originating from fluctuations in prices at the dock. This represents an important empirical extension to our work. Moreover, it will provide more direct evidence on the hypothesis put forward by Golosov and Lucas (2007) that firm-level productivity shocks are responsible for a health fraction of the observed price changes in micro-data. GL did not have firm-level productivity data to verify their conjecture and the import unit values will serve this purpose effectively in the case of Ecuador.

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