

**Manuscript version: Author's Accepted Manuscript**

The version presented in WRAP is the author's accepted manuscript and may differ from the published version or Version of Record.

**Persistent WRAP URL:**

<http://wrap.warwick.ac.uk/136770>

**How to cite:**

Please refer to published version for the most recent bibliographic citation information. If a published version is known of, the repository item page linked to above, will contain details on accessing it.

**Copyright and reuse:**

The Warwick Research Archive Portal (WRAP) makes this work by researchers of the University of Warwick available open access under the following conditions.

© 2020 Elsevier. Licensed under the Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International <http://creativecommons.org/licenses/by-nc-nd/4.0/>.



**Publisher's statement:**

Please refer to the repository item page, publisher's statement section, for further information.

For more information, please contact the WRAP Team at: [wrap@warwick.ac.uk](mailto:wrap@warwick.ac.uk).

# Rigidities and adjustments of daily prices to costs: Evidence from supermarket data\*

Monica Giulietti

School of Business and Economics  
Loughborough University  
United Kingdom

Jesús Otero

Facultad de Economía  
Universidad del Rosario  
Colombia

Michael Waterson

Department of Economics  
University of Warwick  
United Kingdom

March 2020

## Abstract

We assess the extent of inertia in grocery retail prices using data on prices and costs from a large supermarket chain in Colombia. Relative to previous work our analysis benefits from encompassing a wide variety of products, availability of reliable replacement cost data, and the daily frequency of the data. We confirm the existence of significant nominal rigidities in reference prices (three months) and even more so in reference costs (about six months), but differing depending on the type of product, being on average smaller in the case of perishable goods. Using a non-linear autoregressive distributed lag (NARDL) approach to cointegration, we examine the path of prices relative to costs and determine the speed of adjustment of prices to shocks. We find significant mean reversion but also uncover asymmetries in response to positive and negative changes in costs. As a novel finding, we uncover evidence of the effect of market concentration, input price volatility, along with own labels and the perishable nature of products, on the likelihood of price asymmetry in response to costs changes.

JEL Classification: C32, E31, L11, L81

Keywords: nominal rigidities, prices, costs, retail trade, non-linear error correction.

---

\*This is a substantially revised version of an earlier working paper by the same authors, which is available under the same title in the Warwick Economics Research Papers series No: 1187. We thank Anindya Banerjee, Francesco Lippi, Jeremy Smith, participants at the 13th International Conference on Computational and Financial Econometrics (London, UK), and seminar participants at Universidad ICESI (Cali, Colombia) for their suggestions. We also thank two anonymous reviewers for their thoughtful and constructive comments. This paper has been written over the course of several visits by J. Otero to the Department of Economics at the University of Warwick. He would like to express his gratitude to the department for always providing a welcoming and supportive environment for this research. Financial support by the Universidad del Rosario is also gratefully acknowledged. The usual disclaimer applies. E-mail addresses: m.giulietti@lboro.ac.uk (M.Giulietti); jesus.otero@urosario.edu.co (J. Otero); michael.waterson@warwick.ac.uk (M. Waterson; corresponding author).

# 1 Introduction

This paper contributes to the extensive macroeconomic literature on nominal rigidities by providing evidence on relative movements of price and cost changes for a wide variety of items, based on a detailed and unique micro data set of daily prices and costs from a major supermarket chain in Colombia, a developing country with relatively low levels of inflation.

According to the macroeconomic literature, nominal rigidities play an important role in explaining key economic processes, such as the dynamic relationship between money, real output and prices, and the evolution of retail price inflation over time; see e.g. Taylor (1999). Traditionally, nominal rigidities have been modelled in the macroeconomic literature as “sticky” prices, that is prices that respond slowly to exogenous shocks, such as unanticipated economic policy interventions or international events. In turn, a wide range of papers have debated the question of whether final goods prices are sticky or not.<sup>1</sup>

In fact, there are two literatures concerning price flexibility that have been the subject of significant debate. One is the long-standing debate on flexibility of prices and its importance in macroeconomics to the presence of full employment, leading from Keynes’ (1936) criticism of the classicists. The other, also with a significant literature, is the debate regarding asymmetry of price changes to cost movements, surveyed in Meyer and von Cramon-Taubadel (2004). As the latter authors point out, there are at least three reasons to be concerned about possible asymmetry in this context. First, there may be gaps in economic theory (Peltzman, 2000), second there are potential welfare implications, and third, they may indicate market failures arising from monopoly power. However, the differences between these two literatures is arguably more apparent than real, since the effect of Keynesian price inflexibility is related to wage (i.e. in part cost) inflexibility and thus to the linkage between prices and costs. Given this context, we aim to contribute both to the literature on price

---

<sup>1</sup>See inter alia, Carlton (1986), Cecchetti (1986), Kashyap (1995), Eden (2001), Baharad and Eden (2004), Bils and Klenow (2004), Chakraborty et al. (2015), Wulfsberg (2016), Berger and Vavra (2018) and Cavallo (2018) and the surveys by Klenow and Malin (2010), Greenslade and Parker (2012) and Nakamura and Steinsson (2013). Existing literature has focused primarily on the study of developed countries, using data from sources as diverse as store-level hand collection, mail-order catalogues, national statistical agencies, scanner data from stores, and the internet. Several contributions have considered the importance of sale prices in limiting the analyst’s ability to measure correctly the extent of price dynamics, by generating errors in the measurement of the frequency of price changes; e.g. see Hendel and Nevo (2006), Nakamura (2008) and Nakamura and Steinsson (2008). These studies have also highlighted the problems that arise when trying to reconcile observed price dynamics with either flexible price models or menu costs models, as discussed in Chevalier and Kashyap (2011). In response to these concerns Kehoe and Midrigan (2008) and Eichenbaum et al. (2011) among others introduced modifications to the standard menu cost model to accommodate observed periods of temporary price changes, or sales.

flexibility or inflexibility in the longer term as well as the literature on the relationship of prices to costs. In doing this, we take account of the findings of Kehoe and Midrigan (2015) who show that although there is significant high frequency price flexibility, this is accompanied by substantial low frequency price stickiness. We do so by examining regularised prices (in the form of reference prices, as in Eichenbaum et al., 2011) as well as actual prices.

The context of our paper is a major supermarket chain in Colombia, a country that has experienced significant periods of inflation in the past but over the period we are considering was under a strict central bank-imposed regime targeting control of inflation. Although we characterise the retailer as a supermarket, in fact the range of goods sold is extremely wide and our sample, while capturing only a small number of products, takes full advantage of this. A (probably different) supermarket chain was the target of a price-scraping exercise by Cavallo (2018). Price-scraping enables the capture of a very large number of prices but is not able to capture cost information.

There is a small previous literature on nominal price rigidities in Colombia. To our knowledge the first paper in this area is Jaramillo and Cerquera (1999), which provides evidence in support of the menu costs hypothesis during the years 1991-94, a period characterised by double digit inflation between about 20% and 30%. In 1991 a new political constitution radically modified the structure and functions of the central bank in Colombia (Banco de la República), with the purpose of creating an institution independent from the central government. Since the 1991 constitutional reform, inflation has been exhibiting a declining path to one-digit levels.<sup>2</sup>

Studies that have been able to utilise cost information in examining price rigidity are very much in the minority. Salient exceptions are Eichenbaum et al. (2011), where an approximation to the replacement cost of an item by the retailer is constructed using data on sales and adjusted gross profit, and Anderson et al. (2017) who have data on “base wholesale costs” in their scanner-based analysis of price movements in response to cost

---

<sup>2</sup>In the recent economic history of Colombia the lowest inflation rate was recorded in November 2013 with 1.8%. During the 2015/6 years the country witnessed a new episode of inflationary pressures, with the annual inflation rate reaching 9% in July 2016. This recent episode appears to have been short-lived, though. In subsequent work, Julio et al. (2011) and Julio and Zárate (2011) studied nominal rigidities based on the microdata collected by the Colombian statistical agency (DANE) to construct the consumer and producer price indexes, respectively. Julio et al. (2011) find that the implicit duration of runs (or spells) of consecutive constant consumer prices amounts to approximately 8.4 months including house rental charges (6.4 months, when these are excluded), while Julio and Zárate (2011) indicate that the average duration of runs of constant producer prices is approximately 5.5 months. In both studies, the authors report a large degree of heterogeneity in their findings depending on the product under consideration.

movements, which they use to see whether prices or “regular prices” move with costs.<sup>3</sup> Earlier, the famous paper by Peltzman (2000) discovered asymmetries in the movement on prices dependent on whether they were rising or falling. Nakamura and Zerom (2010) engage in a detailed investigation of the coffee market, in particular examining the relationship between commodity prices and wholesale prices and finding a role for local costs as well as markup adjustment. Our investigation, by contrast, has a wide range of products but is cleaner, or more limited, in examining only local cost movements. Sherman and Weiss (2015) look at competition in the small, between stallholders in a Jerusalem market, some of whom have nearby competitors whilst others do not. Chevalier et al. (2003) are also able to back out cost data in their study on Dominick’s food stores in the US but have a different research question in mind, understanding pricing behaviour in relation to public holidays.<sup>4</sup>

The distinctive aspect of our sample is that we have scanner data on grocery prices and also on replacement costs from a broad-range major supermarket chain in Colombia. The data at our disposal are observed with daily frequency over a 2007-2010 study period, enabling us to see whether temporal aggregation conceals important movements. Although the sample period is not recent, a secondary benefit is that it nonetheless allows us to fill a gap in the existing literature through the examination of a developing country over a period of low and stable inflation (5.3% on average during the period under consideration). This is in marked contrast to most existing studies on developing countries which have focused on episodes of high inflation; see e.g. Ahlin and Shintani (2007) and Gagnon (2009).

On the one hand, one might expect to observe more prevalent price rigidities in the country as a result of the dominance of cash transactions.<sup>5</sup> Indeed, Knotek (2011) finds evidence in support of the view that in economies where the use of cash is prevalent, prices which facilitate rapid transactions because they require few monetary units or little change in return help to generate price rigidity, as these prices are easier to remember. On the other hand, Colombian supermarket chains contribute to the development of new business formats

---

<sup>3</sup>See also Dutta et al. (2002) and Levy et al. (2002)’s papers which use the costs dataset available in Dominick’s data in their analyses on orange juice.

<sup>4</sup>In related literature, Gopinath and Rigobon (2008), Gopinath and Itskhoki (2010) and Gopinath et al. (2010) exploit exchange rate variations to infer cost shifts.

<sup>5</sup>The dominance of cash transactions in Colombia is largely due to the size of the so-called underground (or shadow) economy. Rogoff (2002) observes that the anonymity that cash guarantees to the holder is appreciated not only by gangsters and drug dealers, but also by small businesses and entrepreneurs (and their customers) who are interested in avoiding various forms of taxation; see also Rogoff (2015). Loayza (1996) provides estimates of the size of the underground economy in Colombia of around 35% of GDP, while posterior estimates by Schneider and Hametner (2014) put this figure between 27 and 56% of GDP.

by providing credit alternatives to customers for the acquisition of durable consumption goods, opening super-stores and express stores in low- and middle-income cities across the Colombian territory, and fostering the marketing of their own products. The introduction of these new business practices might be expected to change pricing structures through increased competition in the supermarket sector.

Following data description in section 2, in section 3 we carry out a range of investigations to establish the character of our data, in particular in terms of pricing patterns. Most studies of supermarket pricing, such as Nakamura (2008), Kehoe and Midrigan (2008), and Eichenbaum et al. (2011), hereafter EJR, have used filtering techniques to remove what appear to be short-lived price fluctuations creating excessive noise in the data. We choose to filter prices using the approach implemented in EJR, defining a reference price (cost) as the most frequently observed (modal) price (cost) within a given time period. In our case this period is one month, given the daily frequency of our data. We also examine the nature of price endings, heterogeneity in price movements and the consequences of aggregation.<sup>6</sup> This examination confirms a general pattern of behaviour similar to that observed in existing studies on other countries.

In our subsequent analysis, in section 4 we use time series methods to investigate the tracking of prices to costs through the framework of a conditional asymmetric error correction model reminiscent of the modelling strategy adopted by Peltzman (2000), Nakamura and Zerom (2010) and Sherman and Weiss (2015). After finding support for the presence of stable long-run equilibrium relationships between prices and costs in the majority of products, and uncovering evidence of a long-run asymmetric response of prices to costs in several instances, in section 5 we investigate potential explanations of asymmetry based on imperfect competition models where measures of market structure play a key role. Section 6 concludes.

## 2 Data description

Our empirical analysis is based on scanner data from a major supermarket retailer in Colombia, and the sample period spans 37 consecutive months between 2007 and 2010.<sup>7</sup> We have

---

<sup>6</sup>EJR have weekly data and choose the quarter as the period over which their reference prices are evaluated. We also perform a direct comparison with their work below.

<sup>7</sup>Strictly speaking the retailer is a hypermarket given the wide range of sold products. To put the results that follow in context, in 2008 and 2009 the value share of the two largest hypermarkets, namely Exito and Carrefour, amounted to 38% and 32%, respectively, with the remaining 30% share for this format being distributed among Olímpica, Alkosto and Cacharrería La 14 (see Euromonitor International, 2010, p.550).

observations on daily quantities and the daily price (net of discounts) recorded at the check-out counter of 49 stores belonging to the retailer. We also have daily information on the total cost of each specific product bought by the retailer and quantities purchased. On investigation of the cost data, it is apparent in every case that the wholesale cost of each product is a linear function of quantity purchased (with origin at zero), meaning that observed average cost is an excellent approximation to marginal replacement cost.<sup>8</sup> The maximum number of time series observations for each store and product is 1,127. The information was collected directly from the supermarket retailer, and confidentiality agreements prevent us from providing any specific information that may help identify the retailer, such as the exact location of the stores or the day of the week during which price discounts are applied.<sup>9</sup>

We consider a total of 33 products (the unit of analysis is the bar code) grouped into two broadly defined categories, namely, 20 perishable products and 13 non-perishable ones. Perishable products (P) are all fresh foods, while within the non-perishable (NP) category we include groceries, household goods and other products. Fresh foods include meat, poultry, fish, fruit, milk and eggs. Groceries include ambient human and pet foods. Household items include bedroom, bathroom and cooking essentials. Other items include car accessories and stationery. The products in our analysis are all major selling items and include the top-selling item (by revenue) in each category of the supermarket’s sales over the time period under consideration. It might be argued that by selecting high sales items we risk picking up loss-leaders, whose price is kept low even in the presence of rising cost in order to bring customers into the store and purchase other, higher margin products. This does not apply for our chosen products, since there are only three that exhibit average markups of less than 5%.

In terms of the presentation of the results, it is worth clarifying two aspects related to the specific name of some of the products in the detailed tables. The first is “assisted sale” (*asa*) which means that the product is purchased from a counter assistant in the store as opposed to being taken from the shelves. The second is “own brand” (*own*), which refers

---

<sup>8</sup>This markedly contrasts with the situation in many countries, where there are substantial non-linearities in the cost structure as a result of bargaining at the wholesale level

<sup>9</sup>Given the confidentiality agreements, to avoid disclosure of the store chain’s name through its precise discount policy related to a day of the week, for purposes of third-party replication we have masked the database by dropping five observations from each product and store, and deliberately modifying the start of the study period to July 1, 2007. The results based on the masked version of the database are very similar to those reported in the paper. The masked data file and replication script (designed for Stata 14) are available from the authors upon request.

to a product that is produced/labelled by the supermarket, as opposed to brand 1, brand 2 and brand 3 (*br1*, *br2* and *br3*, being disguised brand names) which indicates that the product can be found in other supermarket chains or grocery stores. The total number of observations available for the empirical analysis is over 1.5 million.

Although a wider selection of products (94) and a larger number of stores (67) were available in the original database, some of these products (such as some brands of motorcycles, televisions and laptop computers) had to be excluded due to the low number of sales in individual stores. As for the selected stores, they represent all those operated by the supermarket chain in Colombia, with the exception of outlets that had been opened for less than a year.<sup>10</sup> In sum, we end up analysing the dynamics of prices and costs of 33 products for 49 stores owned by the supermarket chain and located across the Colombian territory.

The price information used in the paper is based on scanner data recorded at the checkout counter that day. Therefore we avoid the measurement problems in some other papers, e.g. EJR's, due to their imputing prices from the ratio of sales value to quantities sold, hence including the effect of discounts associated with promotions. We examine prices and costs in their raw state as well as after smoothing, for which we adopt the reference price approach of EJR.<sup>11</sup> Following the literature (e.g. Nakamura and Steinsson, 2008; Cavallo, 2018), if a product is not sold on a particular day we set the associated price (cost) equal to the value observed in the previous day, except for the final observation in our data where we assume that the series ends. This approach implies that our estimates are conservative when measuring stickiness.<sup>12</sup>

---

<sup>10</sup>These latter shops would provide only a few observations for the analysis and the sales patterns might have been affected by the novelty of having a new store in a particular area.

<sup>11</sup>As part of its business practice, during the study period the retailer implemented strategies of anticipated and unanticipated price reductions. Anticipated reductions took the form of the so-called "day of special prices" based on the application of price discounts on a particular day of the week, which was always the same day throughout the sample period. The range of products comprised beef, poultry and fruits, whose prices were reduced by up to 20%, (or 30% if purchasing with the retailer's credit card); this discount did not apply to prepared foods though. Any smoothing algorithm removes the effect of these events. In turn, unanticipated reductions took the form of price reductions where neither the day(s) of occurrence nor the magnitude of the discount was known in advance by consumers. It is possible that different algorithms would treat these slightly differently. The products covered typically encompassed groceries, home and other products categories. It is worth noting that, to the best of our knowledge, other temporary or individual specific discounts in the form of coupons, which according to Eichenbaum et al. (2014) and Alvarez et al. (2016) generate small price changes that are spurious, were not part of the business strategy of the retailer.

<sup>12</sup>One inevitable difficulty with the use of scanner data is that we only observe the price of a product for days when at least one customer buys the product. This might induce selection in the prices observed, with price increases less likely to be registered as they decrease the likelihood of the product being bought. To assess robustness of our findings to this selection problem, we alternatively assigned missing values by carrying backward the last recorded price (cost) until one was available, finding largely similar results.



Another advantage of our dataset, compared to that used in some other studies, is the high frequency of observations for prices and costs. This allows us to evaluate the price dynamics (or alternatively their inertia) more precisely. Inevitably though, our sample frame limits our ability to generalise our results to a wider range of goods and to other supermarket chains. In effect, we treat price-setting as a response to the general competitive framework facing the store rather than specific moves by other firms. However, this same limitation also applies to studies based on other scanner data such as the Dominicks dataset.

In order to assess the possibility that different levels of price competition might be observed across different areas of the country we calculated descriptive statistics which allow us to compare the extent of price competition in the largest urban areas with that of other areas of the country. These are presented in Table 1 where we report summary statistics for all products in all stores in the country, all stores outside Bogotá, as well as all stores in Bogotá, Medellín, Barranquilla and Cali (detailed results for the stores in Bogotá are presented in Appendix A). Across different measures of price and cost variation we observe a similar behaviour in the four main urban areas in Colombia, although it is worth noting that Bogotá has the lowest fraction of months when prices are constant for the whole month. In Bogotá we also observe low implied duration of price and cost changes, a sign of more dynamic price setting than in other areas. Medellín on the other hand displays the highest actual and reference mark-ups and the highest standard deviations in these mark-ups. It is likely that there is more intense competition with other supermarket chains in Bogotá, but these summary statistics suggest that the potentially more intensive price competition has a relatively small effect, and essentially none outside Bogotá.

Figure 1 shows the time path of prices and costs for all 33 products averaged across stores. It is clear from these plots that raw prices tend to exhibit significantly greater variability/noise over time than costs, although there are non-perishable products (such as pillows and towels) whose prices remain constant over extended periods of time. We also see that for some fresh foods and groceries price discounts occur very frequently, and that there are limited episodes where prices fall even below costs (i.e. loss-leaders). Costs, on the other hand, exhibit a greater degree of constancy over time. The plots also reveal the presence of potential outliers, whose treatment is important in order to be able to link microeconomic evidence to macroeconomic models; Alvarez et al. (2016), for example, argue in favour of dropping them (see also Cavallo, 2018). To assess the robustness of our findings to the

presence of outliers, we have replaced price (cost) observations lying outside three standard deviations around the corresponding mean by carrying forward the last recorded price (cost). Accounting for outliers in this manner yields qualitatively similar findings though. For this reason in what follows we shall report the results obtained without adjustment for these atypical observations.

### 3 Initial empirical analysis of pricing behaviour

In this section, we describe a range of features of our data relating it to the existing literature in terms of the character of price rigidity and exploring the special features that add to its novelty. To gain a sense of underlying trends, we first examine reference prices ( $p^r$ ) and reference costs ( $c^r$ ), as in EJR, defined as the most frequently observed values within a month. In order to avoid recording aberrant observations as a result of the cut-off points chosen for the start and end of the month, we carried out an additional exercise which involved calculating reference prices as the modal price using a moving window of 7 days over a period of 28 days, and similarly for reference costs. This can be viewed as a robustness check to assess the potential effect on our results of special discounts associated with specific holidays and subsequent price adjustments in the following periods. Although the results obtained using this second approach suggest (perhaps not surprisingly) that reference prices and reference costs are slightly less persistent, all other findings are qualitatively similar to those obtained using the actual calendar dates as cut off points for individual months, confirming that our results are robust to the choice of start and end points for a monthly period. In what follows, we present the results based on the first approach to be consistent with previous work.

Table 2 draws a comparison between raw and reference prices and costs. It presents the fraction of days spent at, above or below reference price and cost. It shows that actual prices spend 72% of the time on average at the same level as the reference price, whilst the corresponding value for costs is 91%; on average, prices (costs) spend 9% (4%) of the time above the reference price (cost).<sup>13</sup> Interestingly, these data exhibit a large degree of heterogeneity across different products, which on casual inspection is related to their

---

<sup>13</sup>Computing reference prices over a quarterly window, in a similar fashion to EJR, we find that in Colombia daily prices spend about 12% of the time on average at the same level as the reference price. This value is smaller than the 24% obtained by Sudo et al. (2014) in their analysis of micro daily price (but not cost) dynamics for Japan.

perishability, something we investigate later. We see that the prices and costs of perishable goods, such as meats, tend to spend a lower proportion of time at the same level as reference price.

Regarding price and cost variations/ rigidity over time, Table 3 lists the fraction of months in which price and costs are constant for the whole month for all products. Daily prices are constant for the whole month 16% of the time, compared to 69% for costs. Table 4 presents the conditional probabilities of changes in actual and reference prices. It shows that actual prices change 18% of the time when costs do not change, while the probability of reference prices changing when reference costs do not change is miniscule. It also shows higher probabilities for the change in prices (reference prices) when costs (reference costs) do change. Table 5 describes in more detail the analysis of the movements from non-reference (NR) to reference (R) price and vice versa, and similarly for cost movements. Perishable goods tend to remain at reference price for approximately 86% of the time, while non-perishable goods tend to remain at reference price for about 92%. On the other hand reference costs for all products tend to remain static.

One type of nominal rigidity worth examining is the existence and treatment of price endings, as identified by Levy et al. (2011) and Levy et al. (2019) who find evidence of differentiated behaviour in 9-ending prices compared to non 9-ending prices. To draw comparisons with our Colombian retailer, we compute the relative frequency of 900-ending prices and costs, since Colombian prices and costs are expressed in thousands of pesos. Figures 2 and 3 display the frequency distributions of the last three digits in prices and costs for all products and stores respectively, illustrating notable differences in the frequency of 3-digit endings in prices and costs. Prices ending 900 and above are the most popular, with some secondary peaks of importance occurring at 200-, 400-, 500-, 600-, 700- and 800-ending. This pattern is similar to that observed for the Dominick’s data in the United States (see Levy et al., 2011). As for costs, 000- and 500-ending tend to be the most popular but not by much. A related topic has to do with the transition probability for prices and costs when focusing on the last three digits. Table 6 contains the transition matrices for changes in prices and cost across different blocks of price endings. In the case of prices the highest probability is observed in the transition from 900-999 to 900-999 at 0.89, others being much lower. Turning to costs, the transition probabilities along the main diagonal are all much higher, ranging between 0.94 and 0.97, which reflects the greater degree of persistence of this variable (once

more, qualitatively similar results are obtained for the stores in Bogotá; see Table A.5)

To examine the behaviour of gross profitability of the retail chain across the range of products under consideration, we calculate the daily actual and reference markups. The actual markup is calculated using actual prices and actual costs, while the reference markup is calculated using reference prices and reference costs (both markups are measured in percentage terms). The resulting means and standard deviations are listed in Table 7. Markups vary widely across products, as expected, with an average daily markup of 29% based on actual prices and costs, and of 32% when reference prices and reference costs are considered. The results of our analysis of the daily actual mark-ups as calculated for the products sold in Bogotá are reported in Table A.6. Perishable goods in general seem to have rather low markups averaging approximately 22% compared to all other products, and particularly compared with non-perishable goods.

Results not reported here for brevity indicate that, as would be expected, in the whole country the probability of a daily price change is much higher (0.189) than the probability of a change in reference price (0.013), by a factor of approximately fifteen times on average. Supermarkets in the Bogotá area exhibit similar ratios between these two probabilities. Table 8 contains the implied duration of price and costs, using the average of the inverse of the product-level probabilities of a price change. The implied duration of price stability is 7.7 days, that is approximately one week. Based on the corresponding daily frequency of price changes for Japan reported in Sudo et al. (2014), which is around 0.162, actual prices in Colombia exhibit about the same average flexibility as those in Japan. Reference prices are stable for nearly a year in EJR compared to only about three months in our study (that is, 93.4 days). For the supermarkets in Bogotá (Table A.7) the implied persistence of price and reference price is somewhat smaller, namely 6.9 and 89.7 days, respectively. As for costs, the probability of a daily cost change is higher than that of a change in reference cost, both in the whole of the country (2.4% against 0.9%) and in Bogotá (2.9% against 0.9%). Significant variations in persistence can be observed among products.

Our data-set enables us to examine heterogeneity of price changes along the lines employed by Midrigan (2011) and so to evaluate the degree of concordance with his approach to menu costs against others. Figures 4 and 5 show distributions akin to Midrigan’s Figure 2, looking at both raw and reference prices. Since we know that many perishable products have a “special price” day, we separate the sample into perishable and non-perishable subsets. The

former clearly show the masses at -0.2 and the resultant increase by around 0.25 that follows, which of course is ironed out in the corresponding figure for reference prices. But what is apparent in both figures is significant heterogeneity in the range of price changes, which evidences against a simple menu cost approach and in favour of a more nuanced model along the lines proposed by Midrigan. Figure 6 shows the corresponding plot for markup changes, which again illustrates considerable heterogeneity. An additional investigation uses the fact that during the 2007-2010 period in Colombia the monthly inflation rate fluctuated between a peak of 7.94% (October 2008) and a trough of 1.84% (March 2010).<sup>14</sup> Our corresponding Figure 7 however, shows markedly little difference in the frequency of positive price changes with inflation, again consistent with Midrigan’s framework but seemingly inconsistent with Alvarez et al. (2019). Indeed, the evidence suggests that as inflation increases the frequency of the retailer’s positive price changes if anything falls, although the estimated regression slope coefficient is statistically insignificantly different from zero. Of course, Alvarez et al.’s data encompasses a markedly wider range of inflation for Argentina and in their paper there is indeed little relationship at the modest levels of inflation observed in our data-set.

We end the section by providing some evidence on the consequences of our choice of temporal aggregation. Specifically, we consider by how much we would over/under estimate the response of the economy to nominal shocks by using data at weekly and monthly frequency, since most macroeconomic analyses of price rigidities are done at the monthly frequency (e.g. Nakamura and Steinsson, 2008; Wulfsberg, 2016). First we aggregate our daily data over a period of one week and calculate the reference prices and costs over a period of one quarter. Then we aggregate our daily data over a period of one month and calculate the reference prices and costs over a period of one quarter. Finally, to provide meaningful comparisons, we use the daily prices and costs to compute reference prices and reference costs also using a quarterly window. Using the weekly and monthly aggregation we find that the percentage of time prices spend at their corresponding reference level is smaller, that is 43% and 40%, respectively, compared to 61% with the daily data. Making direct comparisons with allowance for different numbers of observations, it is approximately 0.7 (0.6) times less likely that prices measured on a weekly (monthly) basis remain at the same level than daily prices.<sup>15</sup> When using weekly and monthly data, larger values are observed for the unconditional probability

<sup>14</sup>Figures from the Colombian National Department of Statistics (DANE).

<sup>15</sup>Prices remaining constant over 43% of 161 weeks implies constancy over 485 days; prices remaining constant over 40% of 37 months implies constancy over 444 days; lastly, prices remaining constant for 61% of 1127 days implies constancy over a total of 687 days.

of price change (65% and 92% respectively, compared to 19% for daily data), the conditional probability of price change when cost does not change (61% and 87% respectively, compared to 18% for daily), and the conditional probability of price change when cost does actually change (80% and 98% respectively, compared to 44% for daily). Similar results are observed for reference price changes. These findings suggest that the loss of information due to a different temporal aggregation implies more flexible and less persistent prices and costs, leading to the conclusion that the macroeconomic effects of shocks are shorter.

These analyses of reference prices and costs and temporal aggregation confirm that the Colombian grocery trade data has many similar features to, but also some contrasts with, data obtained from other countries, such as the US or other Latin American countries (e.g. Cavallo, 2018).

## 4 Analysis of price persistence relative to costs

Because our data-set has the advantage of a large number of daily observations, we are able to assess price persistence, interpreted here as the way in which prices adjust after deviations (whether positive or negative) from the long term level of the mark-up of prices over costs. To this end, we start by considering that the relationship between prices and costs can be modelled through by an autoregressive distributed lag (ARDL) model which, after some rearranging and re-parameterising, can be reformulated as an error correction model (ECM), similar to the pass-through regressions used by Peltzman (2000), Nakamura and Zerom (2010) and Sherman and Weiss (2015), among others. Within this framework, we go on to evaluate whether daily prices react differently to positive and negative deviations from the long term relationship between prices and costs. We aim to investigate whether there is a long term relationship between price and cost, forming an equilibrium mark-up for each particular product, and then assess the extent to which prices adjust in response to deviations from this long term steady state relationship. We also investigate whether responses are asymmetric, depending on whether changes in costs are positive or negative.

Our econometric modelling strategy adopts the so-called non-linear ARDL (NARDL) model considered by Shin et al. (2014), who extend the ARDL approach of Pesaran and Shin (1998) and Pesaran et al. (2001) to the modelling of asymmetries in long-run relationships and short-run adjustments. Following Shin et al., and adapting their econometric framework and notation to our purposes, let us consider the NARDL model for prices,  $p_t$ , and costs,  $c_t$

(both variables measured in logarithms):

$$p_t = \sum_{j=1}^l \phi_j p_{t-j} + \sum_{j=0}^q (\theta_j^+ c_{t-j}^+ + \theta_j^- c_{t-j}^-) + \varepsilon_t, \quad (1)$$

where the independent variable is defined as  $c_t = c_0 + c_t^+ + c_t^-$ , and  $c_t^+$  and  $c_t^-$  denote partial sum processes:

$$c_t^+ = \sum_{j=1}^t \Delta c_j^+ = \sum_{j=1}^t \max(\Delta c_j, 0),$$

and

$$c_t^- = \sum_{j=1}^t \Delta c_j^- = \sum_{j=1}^t \min(\Delta c_j, 0).$$

$\phi_j$  are the parameters in the autoregressive part,  $\theta_j^+$  and  $\theta_j^-$  are the parameters in the asymmetric distributed lag part,  $\varepsilon_t$  is the error term which is assumed to have zero mean and constant variance,  $\sigma_\varepsilon^2$ , and  $t = 1, \dots, T$  is the number of time observations. There are differential lag lengths  $l$  and  $q$  on the lagged variables  $p_{t-j}$ ,  $c_{t-j}^+$  and  $c_{t-j}^-$ . Although authors such as Cook (1999) and Cook et al. (1999b,a) have shown that asymmetry tests in the error correction framework may suffer from low power, the decomposition of  $c_t$  into its positive and negative changes is useful for our purposes since our cost data do not exhibit predominantly positive or negative growth rates.

The model in (1) can be rewritten in non-linear error correction form as:

$$\Delta p_t = \rho p_{t-1} + \theta^+ c_{t-1}^+ + \theta^- c_{t-1}^- + \sum_{j=1}^{l-1} \gamma_j \Delta p_{t-j} + \sum_{j=0}^{q-1} (\varphi_j^+ \Delta c_{t-j}^+ + \varphi_j^- \Delta c_{t-j}^-) + \varepsilon_t, \quad (2)$$

where  $\rho = \sum_{j=1}^l \phi_j - 1$ ,  $\gamma_j = -\sum_{i=j+1}^l \phi_i$  for  $j = 1, \dots, l-1$ ,  $\theta^+ = \sum_{j=0}^q \theta_j^+$ ,  $\theta^- = \sum_{j=0}^q \theta_j^-$ ,  $\varphi_0^+ = \theta_0^+$ ,  $\varphi_j^+ = -\sum_{i=j+1}^q \theta_i^+$  for  $j = 1, \dots, q-1$ , and  $\varphi_0^- = \theta_0^-$ ,  $\varphi_j^- = -\sum_{i=j+1}^q \theta_i^-$  also for  $j = 1, \dots, q-1$ . Defining  $\beta^+ = -\theta^+/\rho$  and  $\beta^- = -\theta^-/\rho$ , the non-linear error correction term can be written as  $\xi_t = p_t - \beta^+ c_t^+ - \beta^- c_t^-$ , and so that error correction model becomes:

$$\Delta p_t = \rho \xi_{t-1} + \sum_{j=1}^{l-1} \gamma_j \Delta p_{t-j} + \sum_{j=0}^{q-1} (\varphi_j^+ \Delta c_{t-j}^+ + \varphi_j^- \Delta c_{t-j}^-) + \varepsilon_t. \quad (3)$$

To allow for potential non-zero contemporaneous correlation between  $c_t$  and  $\varepsilon_t$  in (3), Shin et al. consider the following reduced-form model for  $\Delta c_t$ :

$$\Delta c_t = \sum_{j=1}^{q-1} \lambda_j \Delta c_{t-j} + v_t, \quad (4)$$

where  $v_t \sim iid(0, \sigma_v^2)$ . The conditional model of  $\varepsilon_t$  in terms of  $v_t$  can be written as:

$$\varepsilon_t = \omega v_t + e_t = \omega \left( \Delta c_t - \sum_{j=1}^{q-1} \lambda_j \Delta c_{t-j} \right) + e_t, \quad (5)$$

where, by construction,  $e_t$  is not correlated with  $v_t$ . Substituting (5) into (3) Shin et al. obtain the following conditional non-linear ECM:

$$\Delta p_t = \rho \xi_{t-1} + \sum_{j=1}^{l-1} \gamma_j \Delta p_{t-j} + \sum_{j=0}^{q-1} (\pi_j^+ \Delta c_{t-j}^+ + \pi_j^- \Delta c_{t-j}^-) + e_t, \quad (6)$$

where  $\pi_0^+ = \theta_0^+ + \omega$ ,  $\pi_0^- = \theta_0^- + \omega$ ,  $\pi_j^+ = \varphi_j^+ - \omega \lambda_j$ ,  $\pi_j^- = \varphi_j^- - \omega \lambda_j$  for  $j = 1, \dots, q-1$ .

Implicit in our NARDL analysis is the assumption that costs can be treated as an exogenous variable; but if this assumption is false then the resulting estimates will suffer from endogeneity bias. However, in the context of our data and econometric method, we argue that we can reasonably treat costs as exogenous. Indeed following our preliminary investigation of the price, cost and quantity data, showing that the wholesale cost of each product is a linear function of quantity purchased, we consider the assumption of exogeneity appropriate. The same does not apply to total revenue against quantity purchased. Furthermore, from an econometric viewpoint, Shin et al. (2014) indicate that appropriate specification of the lag orders in the NARDL model is sufficient to correct for the problems of residual serial correlation and endogenous regressors.<sup>16</sup>

Our estimation strategy takes advantage of the fact that the number of observations  $T$  is large, so that we do not need to use a panel data approach to generate the number of observations which will allow us to estimate the required number of parameters. Therefore we estimate each product's regression separately, thus accounting for the potential heterogeneity across products. With this purpose in mind, prices and costs for each product are averaged across stores. Shin et al. (2014) indicate that since the model in (6) is linear in all its parameters, ordinary least squares (OLS) can be used for estimation. We estimate (6) for

---

<sup>16</sup>See also Bewley (1979) and Pesaran and Shin (1998) for the ARDL model.



up to  $l = q = 7$  lags (i.e. a week), where the appropriate lag lengths are determined using the Schwarz information criterion (SIC); qualitatively similar findings are obtained when the optimal lag lengths are selected using the Akaike information criterion (AIC). To ensure comparability of the models for different choices of  $l$  and  $q$ , all estimations are carried out over the same sample period.<sup>17</sup>

Shin et al. (2014) use this analytical framework to develop a bounds testing approach for asymmetric cointegration, and in doing so extend the work of Pesaran et al. (2001) for the case of symmetric cointegration. In particular, these authors propose two tests for the null of no asymmetric cointegration based on equation (2). First, following Banerjee et al. (1998), one can use the  $t$ -statistic to test the restriction  $\rho = 0$ , denoted  $t_{BDM}$ . Second, following Pesaran et al. (2001), one can use the  $F$  statistic to test the restrictions:  $\rho = \theta^+ = \theta^- = 0$ , denoted  $F_{PSS}$ . The bounds testing approach involves computing two sets of asymptotic critical values, which provide upper and lower bounds for two extreme cases, namely, one in which all the regressors are  $I(1)$  and one in which they all are  $I(0)$ . If the proposed  $t_{BDM}$  and  $F_{PSS}$  statistics fall outside these bounds, then conclusive inference can be performed without establishing the order of integration of the series. If, on the other hand, they fall inside, then inference is not conclusive and knowledge of the order of integration of the variables is required. As indicated by Pesaran et al. (2001), the bounds testing approach to cointegration provides a useful modelling strategy to test for the existence of a (single) long-run equilibrium relation between  $p_t$  and  $c_t$  when there is no certainty regarding the variables' order of integration. This turns out to be advantageous in the case of our data, as some of the price and cost series reveal (sometimes prolonged) periods with constant observations (or exhibiting little variation), limiting the usefulness of established univariate time series methodologies.

The main results of the NARDL analysis are reported in Tables 9 and A.8 for Colombia and Bogotá, respectively. Similar to the modelling of symmetric cointegration, the critical value bounds for the  $t_{BDM}$  and  $F_{PSS}$  test statistics depend upon the number of regressors in the long-run cointegration equation, let us say  $k$ . On this point, Shin et al. observe that when dealing with asymmetric cointegration it is not clear what the appropriate value of  $k$  should be, because when  $c_t$  is partitioned into  $c_t^+$  and  $c_t^-$  the last two terms are dependent.

---

<sup>17</sup>Additionally, we also experimented with longer lag structures, for example by setting  $l = q = 30$  lags (that is, a month), and the results were largely the same, except that (not surprisingly) in some cases we observed slightly larger standard errors due to multicollinearity among the explanatory variables.

Accordingly, here we follow the “conservative” approach advocated by these authors and treat the pair of partial sums as a single  $I(1)$  regressor, that is  $k = 1$  in our case. Using the  $t_{BDM}$  statistic and a 5% significance level, we find that for all stores in the country there are 29 out of 33 products which support the presence of stable long-run equilibrium relationships between prices and costs; in the case of Bogotá the number of such instances is 30. The few products where there is no evidence of cointegration are dropped in the subsequent analysis.<sup>18</sup> The third and fourth columns in Tables 9 and A.8 report the long-run response of prices following a permanent change in costs by 1 and -1, denoted  $\mathcal{LR}^{(+)}$  and  $\mathcal{LR}^{(-)}$ , respectively. As can be seen, in the overwhelming majority of cases these long-run effects are statistically different from zero at the 5% significance level. Lastly, the fifth and sixth columns present the results of the test for the presence of short- and long-run symmetry, where the former is given by  $\sum_{i=0}^{q-1} \pi_i^+ = \sum_{i=0}^{q-1} \pi_i^-$  for all  $i = 0, \dots, q-1$ , while the latter is given by  $\beta^+ = \beta^-$ . Using a 5% significance level, our findings offer a mixed picture with all possible combinations of (a)symmetric behaviour occurring: there are products with short- and long-run symmetry, short- and long-run asymmetry, short-run asymmetry only and long-run asymmetry only. All in all, in the Colombia stores there are seven products which exhibit the presence of long-run price asymmetry, while in the case of Bogotá stores there are six products where a long-run asymmetric price response is observed.

## 5 Determinants of long-run price asymmetry

Taking advantage of a wider variety of products and stores relative to other papers, albeit with a limited set of products, we can shed some light on the sources of the likelihood of the existence of long-run price asymmetry documented above. To this end, we follow Peltzman (2000) who considers two main sets of explanation for the extent of the asymmetric response of prices to costs. The first comes from industrial organisation, and is related to models of imperfect competition where conventional measures of market structure occupy a central place. The second is based on macroeconomic models, specifically those that focus on menu-cost explanations of price rigidities. Among the several potential candidate variables examined by Peltzman (2000), there are two that stand out as significant explanations:

---

<sup>18</sup>The excluded products are beef (sirloin), chicken breast with skin own brand, set of two towels branded, and printer paper 75gr for all Colombian stores; and beef (sirloin), set of two towels branded, and printer paper 75gr for Bogotá. Qualitatively similar findings (not reported here) are obtained when inference is based on the  $F_{PSS}$  statistic.

the extent of supply chain fragmentation, in the sense that when retailers obtain supplies directly from one manufacturer, or from a small number of them, there is less evidence of price asymmetry; and input price volatility, which takes the view that greater cost volatility is associated with lesser price asymmetry.

Within this framework, our empirical exploration of the drivers of long-run price asymmetry takes place in a cross-sectional setup, where we aim to explain the probability that the price of a product exhibits such behaviour. For this, we construct a dependent variable that takes the value of 1 if there is asymmetry at the 5% significance level and 0 otherwise.<sup>19</sup> The analysis here concerns only the products where we uncovered evidence in favour of stable long-run equilibrium relationships between prices and costs, that is 29 for Colombia stores and 30 for Bogotá stores. In terms of the explanatory variables, we use an additional piece of information available in the database, namely the number of distinct suppliers of a specific product to the supermarket retailer. We assume that this variable provides a reasonable measure of both (inverse) market concentration in supply and retailer-supplier contractual relations. In addition, as in Peltzman (2000), we measure each product's input price volatility through the standard deviation of the daily change in (the logarithm of)  $c_t$ . Lastly, we also consider two indicator variables, one for own brand products, and the other for perishable products.

Since the dependent variable is binomial, we estimate a probit model using maximum likelihood. Table 10 reports the resulting marginal effects along with their corresponding heteroskedasticity robust standard errors. The motivation for using robust standard errors is that the dependent variable is constructed using estimated coefficients from the conditional asymmetric ECM in (6), and so it appears useful in reporting the precision of the estimates. Albeit with a small number of observations, the results are satisfactory. In the models for Colombia and Bogotá stores the marginal effects for the number of suppliers and cost volatility have the expected negative sign and are statistically different from zero, supporting the view that an increase in the number of suppliers and in cost volatility reduces the probability of finding asymmetry. Furthermore, the estimated coefficient on own brand is also negative and statistically significant in both models, suggesting that the likelihood of finding long-run price asymmetries is smaller for products with the retailer brand. In the case of perishable products, there is a larger probability of finding asymmetric behaviour in

---

<sup>19</sup>See the last column in Tables 9 and A.8 for Colombia and Bogotá stores, respectively.

the case of Colombia stores; in the case of Bogotá stores the coefficient is also positive but not statistically different from zero.

## 6 Concluding remarks

This paper investigated the extent of price inertia in retail grocery prices and costs using a detailed dataset for a large supermarket chain in Colombia with daily data over 2007-2010. Compared to other work in this area, our dataset contains a large number of daily observations, and a wide range of product types, although the number of products is more limited than in several other studies. We analysed 33 products sold in 49 stores in the whole of Colombia, but also provide results for the capital city of Bogotá, where one would expect to observe more intense competition among supermarkets compared with less populated areas in the remainder of the country.

Our data validation analysis shows that price dynamics in Colombia over the period observed are comparable to those of other countries previously studied in the literature, although we find less persistence in the Colombian prices compared with the US. In particular, even after accounting for different data frequency and for different forms of temporary price changes by our retailers, the results on price inertia in Colombia reveal less price persistence compared with other studies which rely on scanner data from US retailers, such as Eichenbaum et al. (2011), Midrigan (2011), Eichenbaum et al. (2014) and Anderson et al. (2017). Our results however exhibit a wide range of price and cost persistence across the different products in our sample.

We also investigated the sign and size of price adjustments which occur in response to positive and negative changes in costs. This was accomplished within a conditional non-linear error correction model framework. We find that for the overwhelming majority of products there is evidence of stable long-run equilibrium relationships between the prices and costs of the products under consideration; this is indicative that short-run deviations from equilibrium are corrected.

These findings contribute to the literature on nominal rigidities, defined as inertia in reference prices and costs, by providing microeconomic evidence concerning the extent of such inertia in the grocery retail sector, and about the nature of the price adjustments to deviations from long term equilibrium levels for the mark-ups of prices over costs. Our results reveal significantly less variation in references prices (costs) than in raw prices (costs) and are

consistent with those of Kehoe and Midrigan (2015) and therefore with the view that despite microeconomic variation in prices, prices are sticky at the macroeconomic level. Kehoe and Midrigan (2015) state that this evidence is consistent with the menu cost hypothesis of infrequent changes in prices at the retail level. Our attempts to evaluate the validity of the menu cost hypothesis in the context of our data led us to conclude that the data is consistent with Midrigan (2011)'s menu cost approach, as we observe heterogeneity in price variation, particularly between perishable and non-perishable goods. Furthermore, in line with the menu cost literature we find that in our sample low price volatility is associated with high levels of asymmetric reactions.

What are the wider implications of our results? To put them in context, they come from a country that, at the time, was experiencing a period of economic stability, with low inflation. On the one hand, price movements follow cost movements relatively closely, with variable lags but without much delay, which suggests that shocks to the economy would be played out fairly rapidly. However, there are significant timing differences across products, which temper that conclusion. Also, competition matters- the more intense competition in Bogotá and other highly populated cities, compared with more rural areas of the country, leads to swifter reactions to cost shocks. This at least partly explains why costs are more stable than prices, assuming the supermarket buys on a national basis. Moreover, our paper provides further evidence that the speed at which prices follow costs differs significantly depending on whether costs are rising or falling for several products. Finally, a concentrated supplier market increases the asymmetry of price reactions to cost variation.

## References

- Ahlin, C. and M. Shintani (2007). Menu costs and Markov inflation: A theoretical revision with new evidence. *Journal of Monetary Economics* 54(3), 753–784.
- Alvarez, F., M. Beraja, M. Gonzalez-Rozada, and P. A. Neumeyer (2019). From hyperinflation to stable prices: Argentina’s evidence on menu cost models. *Quarterly Journal of Economics* 134(1), 451–505.
- Alvarez, F., H. L. Bihan, and F. Lippi (2016). The real effects of monetary shocks in sticky price models: A sufficient statistic approach. *American Economic Review* 106(10), 2817–2851.
- Anderson, E., B. A. Malin, E. Nakamura, D. Simester, and J. Steinsson (2017). Informational rigidities and the stickiness of temporary sales. *Journal of Monetary Economics* 90(C), 64–83.
- Baharad, E. and B. Eden (2004). Price rigidity and price dispersion: evidence from micro data. *Review of Economics Dynamics* 7(3), 613–641.
- Banerjee, A., J. Dolado, and R. Mestre (1998). Error-correction mechanism tests for cointegration in a single-equation framework. *Journal of Time Series Analysis* 19, 267–283.
- Berger, D. and J. Vavra (2018). Dynamics of the U.S. price distribution. *European Economic Review* 103(C), 60–82.
- Bewley, R. A. (1979). The direct estimation of the equilibrium response in a linear dynamic model. *Economics Letters* 3(4), 357–361.
- Bils, M. and P. J. Klenow (2004). Some evidence on the importance of sticky prices. *Journal of Political Economy* 112(5), 947–985.
- Carlton, D. W. (1986). The rigidity of prices. *American Economic Review* 76(4), 637–658.
- Cavallo, A. (2018). Scraped data and sticky prices. *The Review of Economics and Statistics* 100(1), 105–199.
- Cecchetti, S. G. (1986). The frequency of price adjustment : A study of the newsstand prices of magazines. *Journal of Econometrics* 31(3), 255–274.

- Chakraborty, R., P. W. Dobson, J. S. Seaton, and M. Waterson (2015). Pricing in inflationary times: The penny drops. *Journal of Monetary Economics* 76(C), 71–86.
- Chevalier, J. A. and A. K. Kashyap (2011). Best prices. NBER Working Papers 16680, National Bureau of Economic Research.
- Chevalier, J. A., A. K. Kashyap, and P. E. Rossi (2003). Why don’t prices rise during periods of peak demand? evidence from scanner data. *American Economic Review* 93(1), 15–37.
- Cook, S. (1999). Nonsymmetric error correction revisited. *Applied Economics Letters* 6(7), 467–470.
- Cook, S., S. Holly, and P. Turner (1999a). DHSY revisited: The role of asymmetries. *Applied Economics* 31(7), 775–778.
- Cook, S., S. Holly, and P. Turner (1999b). The power of tests for non-linearity: The case of Granger-Lee asymmetry. *Economics Letters* 62(2), 155–159.
- Dutta, S., M. Bergen, and D. Levy (2002). Price flexibility in channels of distribution: Evidence from scanner data. *Journal of Economic Dynamics and Control* 26(11), 1845–1900.
- Eden, B. (2001). Inflation and price adjustment: An analysis of microdata benjamin eden. *Review of Economic Dynamics* 4(3), 607–636.
- Eichenbaum, M., N. Jaimovich, and S. Rebelo (2011). Reference prices, costs, and nominal rigidities. *American Economic Review* 101(1), 234–262.
- Eichenbaum, M., N. Jaimovich, S. Rebelo, and J. Smith (2014). How frequent are small price changes? *American Economic Journal. Macroeconomics* 6(2), 137–155.
- Euromonitor International (2010). *Retail Trade International* (17 ed.). London: Euromonitor.
- Gagnon, E. (2009). Price setting during low and high inflation: Evidence from Mexico. *The Quarterly Journal of Economics* 124(3), 1221–1263.
- Gopinath, G. and O. Itskhoki (2010). Frequency of price adjustment and pass-through. *Quarterly Journal of Economics* 125(2), 675–727.

- Gopinath, G., O. Itskhoki, and R. Rigobon (2010). Currency choice and exchange rate pass-through. *American Economic Review* 100(1), 304–336.
- Gopinath, G. and R. Rigobon (2008). Sticky borders. *Quarterly Journal of Economics* 123(2), 531–575.
- Greenslade, J. V. and M. Parker (2012). New insights into price-setting behaviour in the UK: Introduction and survey results. *Economic Journal* 122(558), F1–F15.
- Hendel, I. and A. Nevo (2006). Measuring the implications of sales and consumer inventory behavior. *Econometrica* 74(6), 1637–1673.
- Jaramillo, C. F. and D. Cerquera (1999). Price behavior in an inflationary environment: Evidence from supermarket data. Borradores de Economía 138, Banco de la Republica de Colombia.
- Julio, J. M. and H. M. Zárate (2011). ¿Cómo se fijan los precios en Colombia? Evidencia de los microdatos del PPI. In E. López Enciso and M. T. Ramírez (Eds.), *Formación de precios y salarios en Colombia*, Volume 1, pp. 154–187. Bogotá: Banco de la República.
- Julio, J. M., H. M. Zárate, and M. D. Hernández (2011). Rigideces de precios al consumidor en Colombia. In E. López Enciso and M. T. Ramírez (Eds.), *Formación de precios y salarios en Colombia*, Volume 1, pp. 102–151. Bogotá: Banco de la República.
- Kashyap, A. K. (1995). Sticky prices: New evidence from retail catalogs. *Quarterly Journal of Economics* 110(1), 245–274.
- Kehoe, P. and V. Midrigan (2015). Prices are sticky after all. *Journal of Monetary Economics* 75(C), 35–53.
- Kehoe, P. J. and V. Midrigan (2008). Temporary price changes and the real effects of monetary policy. NBER Working Papers 14392, National Bureau of Economic Research.
- Keynes, J. M. (1936). *The General Theory of Employment, Interest and Money*. London: Macmillan.
- Klenow, P. J. and B. A. Malin (2010). Microeconomic evidence on price-setting. In B. M. Friedman and M. Woodford (Eds.), *Handbook of Monetary Economics*, Volume 3, pp. 231–284. Elsevier.



- Knotek, E. S. I. (2011). Convenient prices and price rigidity: Cross-sectional evidence. *The Review of Economics and Statistics* 93(3), 1076–1086.
- Levy, D., S. Dutta, and M. Bergen (2002). Heterogeneity in price rigidity: Evidence from a case study using microlevel data. *Journal of Money, Credit and Banking* 34(1), 197–220.
- Levy, D., D. Lee, H. Chen, R. J. Kauffman, and M. Bergen (2011). Price points and price rigidity. *The Review of Economics and Statistics* 93(4), 1417–1431.
- Levy, D., A. Snir, A. Gotler, and H. Chen (2019). Not all price endings are created equal: Price points and asymmetric price rigidity. *Journal of Monetary Economics* forthcoming.
- Loayza, N. V. (1996). The economics of the informal sector: a simple model and some empirical evidence from Latin America. *Carnegie-Rochester Conference Series on Public Policy* 45(C), 129–162.
- Meyer, J. and S. von Cramon-Taubadel (2004). Asymmetric price transmission: A survey. *Journal of Agricultural Economics* 55(3), 581–611.
- Midrigan, V. (2011). Menu costs, multiproduct firms, and aggregate fluctuations. *Econometrica* 79(4), 1139–1180.
- Nakamura, E. (2008). Pass-through in retail and wholesale. *American Economic Review* 98(2), 430–437.
- Nakamura, E. and J. Steinsson (2008). Five facts about prices: A reevaluation of menu cost models. *Quarterly Journal of Economics* 123(4), 1415–1464.
- Nakamura, E. and J. Steinsson (2013). Price rigidity: Microeconomic evidence and macroeconomic implications. *Annual Review of Economics* 5(C), 133–163.
- Nakamura, E. and D. Zerom (2010). Accounting for incomplete pass-through. *Review of Economic Studies* 77(3), 1192–1230.
- Peltzman, S. (2000). Prices rise faster than they fall. *Journal of Political Economy* 108(3), 466–502.
- Pesaran, M. H. and Y. Shin (1998). An autoregressive distributed-lag modelling approach to cointegration analysis. In S. Strøm (Ed.), *Econometrics and Economic Theory in the 20th*

- Century: The Ragnar Frisch Centennial Symposium*, pp. 371–413. Cambridge: Cambridge University Press.
- Pesaran, M. H., Y. Shin, and R. J. Smith (2001). Bounds testing approaches to the analysis of level relationships. *Journal of Applied Econometrics* 16(3), 289–326.
- Rogoff, K. S. (2002). The surprising popularity of paper currency. *Finance and Development* 39(1), March.
- Rogoff, K. S. (2015). Costs and benefits to phasing out paper currency. *NBER Macroeconomics Annual* 29(1), 445–456.
- Schneider, F. and B. Hametner (2014). The shadow economy in Colombia: Size and effects on economic growth. *Peace Economics, Peace Science, and Public Policy* 20(2), 1–33.
- Sherman, J. and A. Weiss (2015). Price response, asymmetric information and competition. *Economic Journal* 125(589), 2077–2115.
- Shin, Y., B. Yu, and M. Greenwood-Nimmo (2014). Modelling asymmetric cointegration and dynamic multipliers in a nonlinear ARDL framework. In R. C. Sickles and W. C. Horrace (Eds.), *Festschrift in Honor of Peter Schmidt. Econometric Methods and Applications*, pp. 281–314. New York, NY: Springer.
- Sudo, N., K. Ueda, and K. Watanabe (2014). Micro price dynamics during Japan’s lost decades. *Asian Economic Policy Review* 9(1), 44–64.
- Taylor, J. B. (1999). Staggered price and wage setting in macroeconomics. In J. B. Taylor and M. Woodford (Eds.), *Handbook of Macroeconomics*, Volume 1, pp. 1009–1050. Amsterdam: Elsevier.
- White, H. (1980). A heteroskedasticity-consistent covariance matrix estimator and a direct test for heteroskedasticity. *Econometrica* 48, 817–838.
- Wulfsberg, F. (2016). Inflation and price adjustments: Micro evidence from Norwegian consumer prices 1975–2004. *American Economic Journal: Macroeconomics* 8(3), 175–194.

Figure 1: Prices (grey line) and costs (black line) of all products. Thousands of pesos

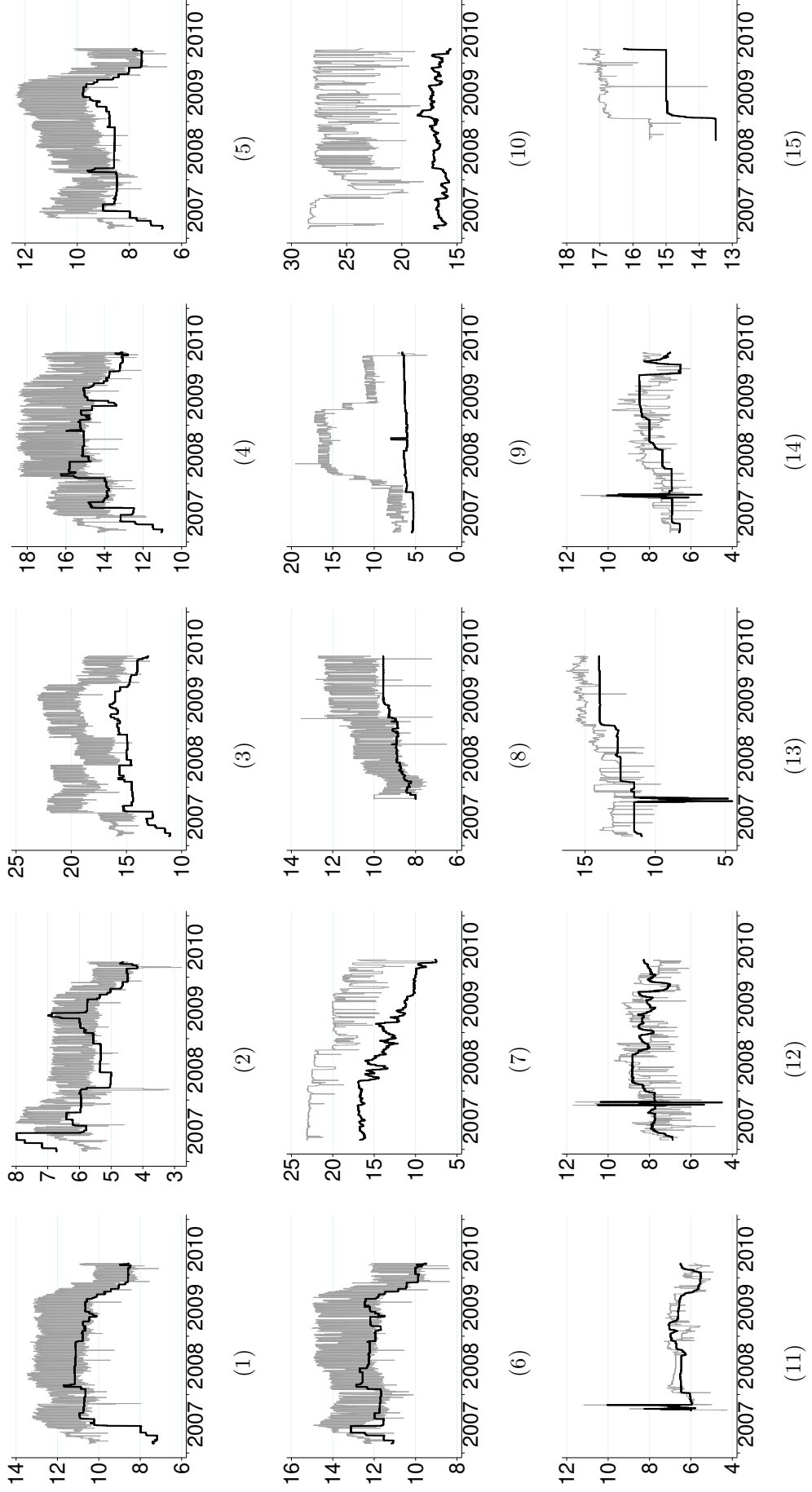


Figure 1: *Continued from previous page*

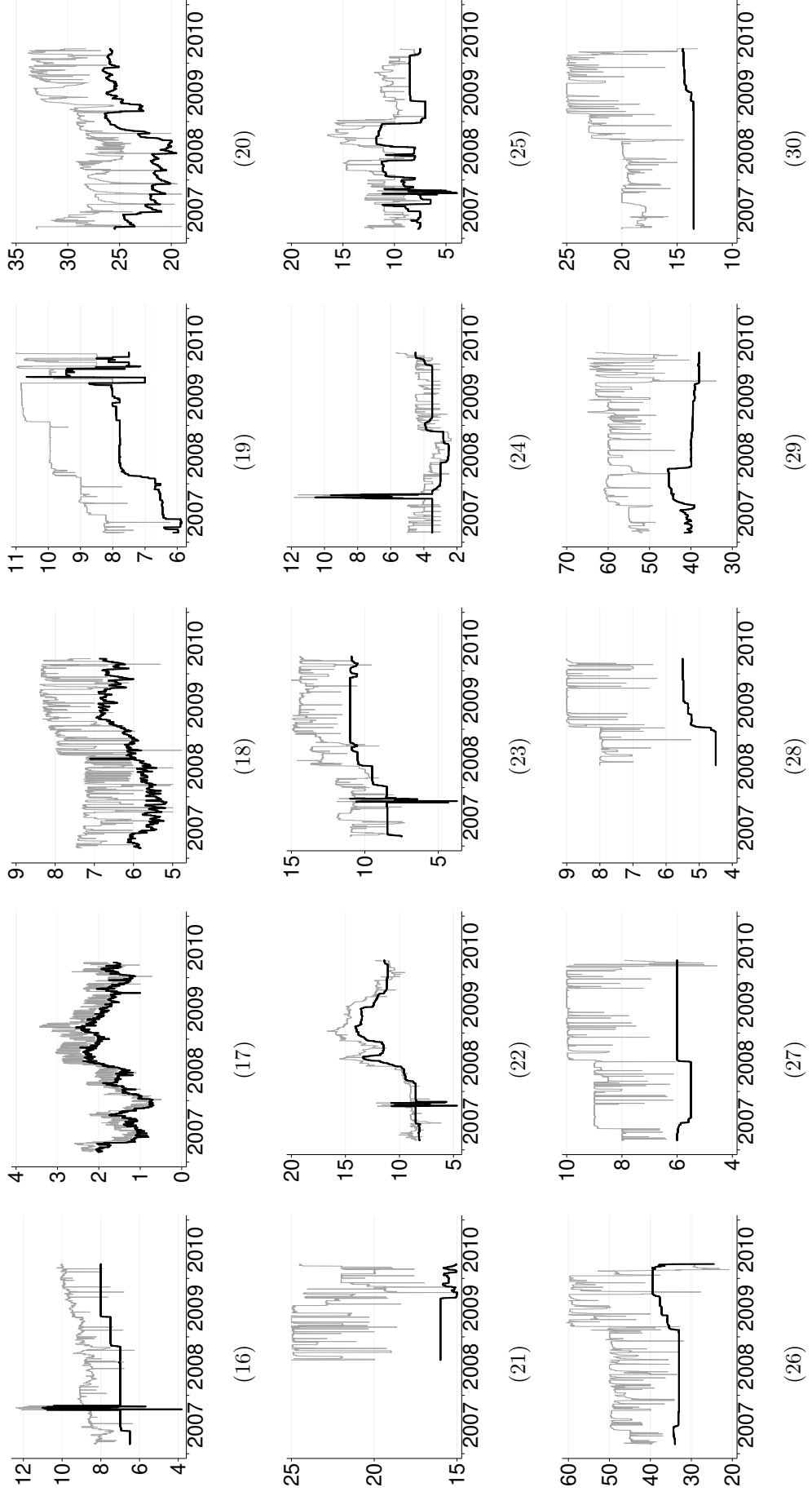
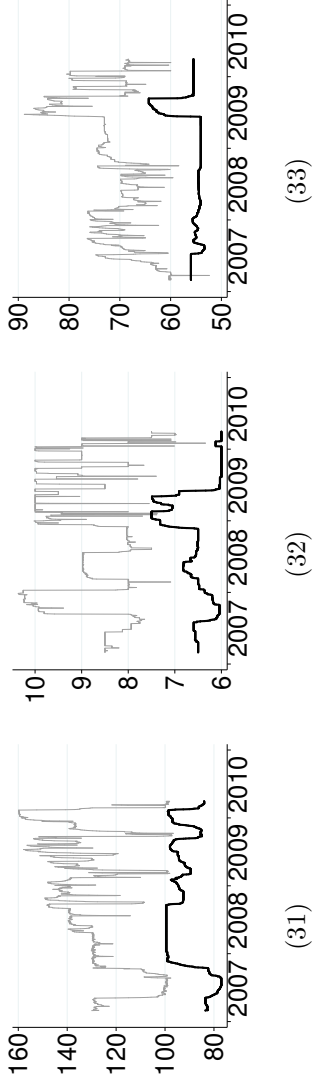


Figure 1: Continued from previous page



Note: (1) Beef (minute steak *own*); (2) Beef (ribs *own*); (3) Beef (rump steak *asa own*); (4) Beef (rump steak *own*); (5) Beef (sirloin *own*); (6) Beef (thick flank *own*); (7) Catfish fillets (imported); (8) Chicken breast; (9) Chicken breast with skin *own*; (10) Cooked prawn *asa*; (11) Eggs 30 units red *br1*; (12) Full fat milk (6X900ml) *own*; (13) Lactose-free milk (6X1100ml) *br1*; (14) Lactose-free milk UHT (4X946ml) *br2*; (15) Lactose-free milk (6X1300ml) *br3*; (16) Packet of sausages 500gr *br1*; (17) Papaya melona; (18) Red mojarra fish; (19) Roast chicken *br1*; (20) Salmon fillets; (21) Dog food *own*; (22) Rice 5kg *br1*; (23) Soya oil X 3000cm3 *own*; (24) Sugar 2.5kg *own*; (25) Toilet paper 12 rolls *own*; (26) Bedspread; (27) Pillow 50X70 *br1*; (28) Pillow 65X45 *br1*; (29) Pressure cooker 6lt *br1*; (30) Set of two towels *br1*. (31) Car battery *own*; (32) Printer paper 75gr; (33) Tyres R13.

Figure 2: Distribution of the last three digits in prices

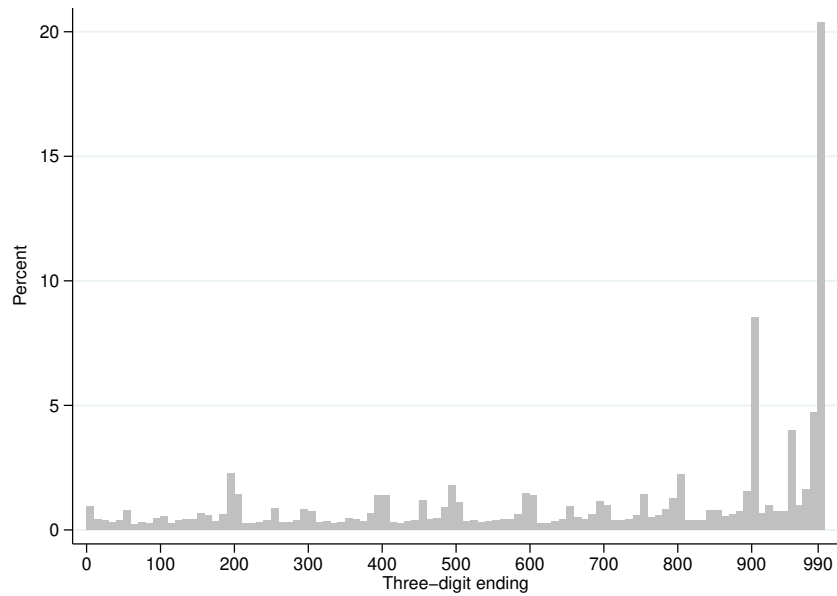


Figure 3: Distribution of the last three digits in costs

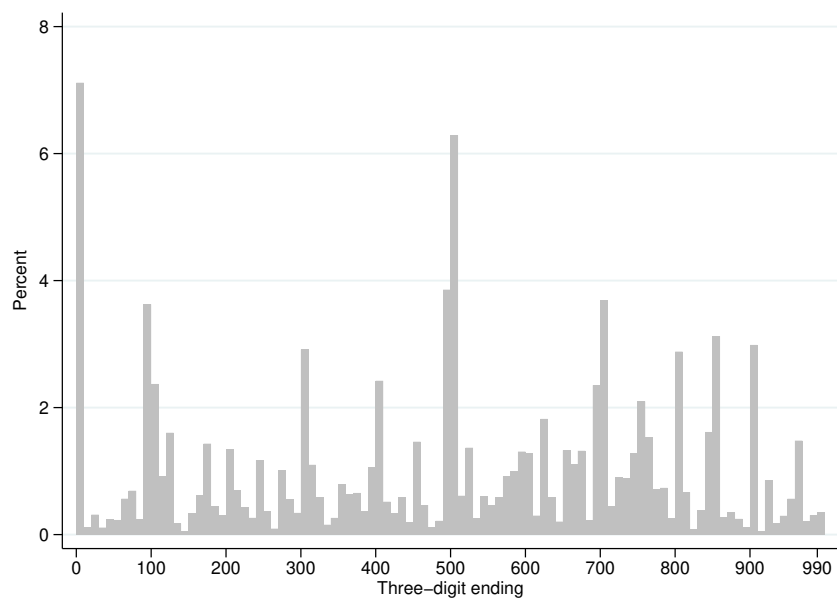


Figure 4: Distribution of non-zero price changes ( $\Delta p_t/p_{t-1}$ ) by type of good

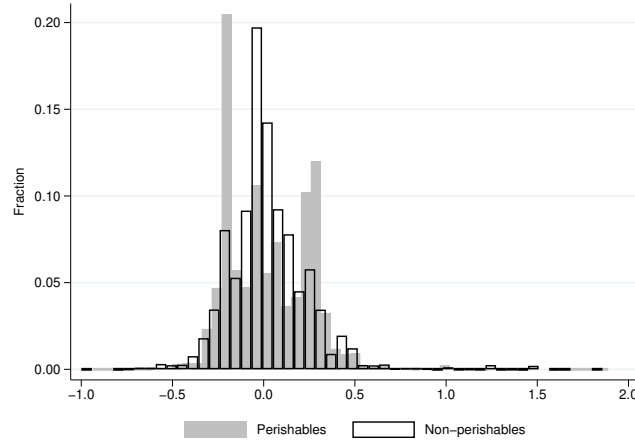


Figure 5: Distribution of non-zero reference price changes ( $\Delta p_t^r/p_{t-1}^r$ ) by type of good

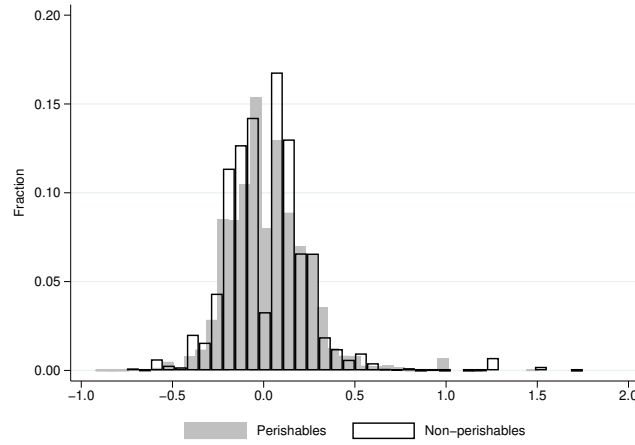


Figure 6: Distribution of non-zero markup changes ( $\Delta m_t$ ) by type of good

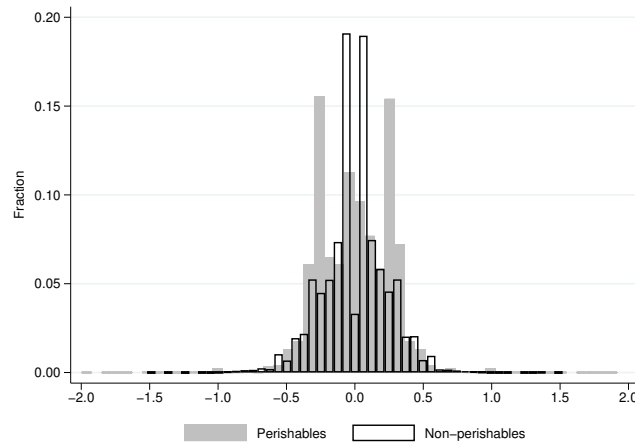


Figure 7: Average absolute frequency of positive price changes and inflation

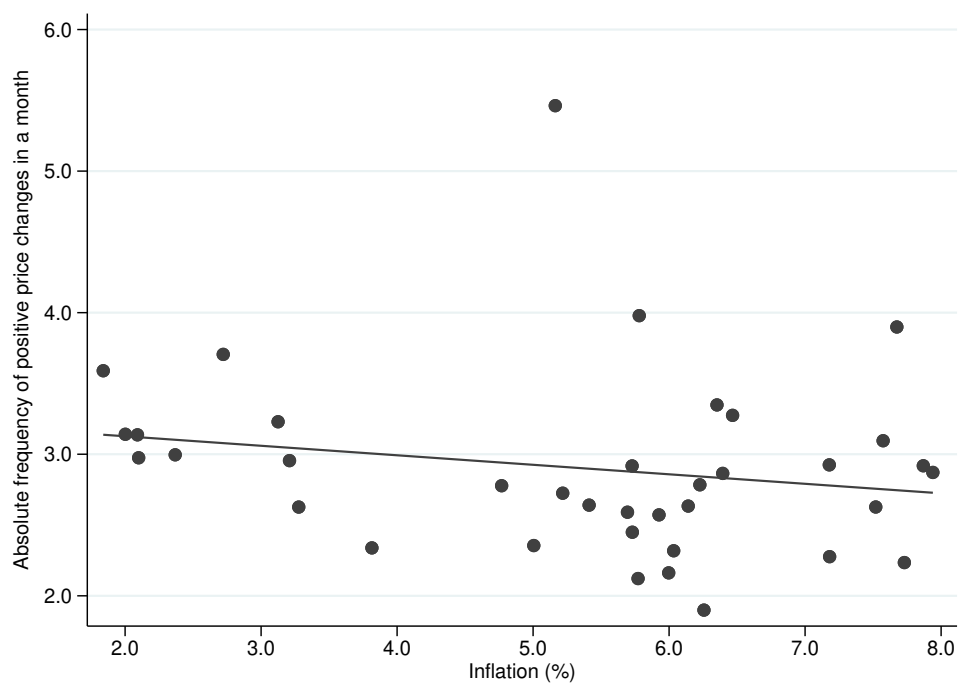




Table 1: Summary statistics for all products in selected cities

Indicator	Cities					
	All	All but Bog	Bog	Med	Bar	Cal
Number of stores	49	36	13	5	4	3
Number of observations	1,501,233	1,077,586	423,647	159,457	119,426	100,113
Fraction of days price spent at $p^r$	0.72	0.73	0.71	0.73	0.73	0.72
Fraction of days price spent below $p^r$	0.19	0.19	0.20	0.19	0.18	0.20
Fraction of days price spent above $p^r$	0.09	0.09	0.09	0.08	0.09	0.09
Fraction of days cost spent at $c^r$	0.91	0.91	0.90	0.91	0.92	0.91
Fraction of days cost spent below $c^r$	0.05	0.05	0.05	0.05	0.04	0.05
Fraction of days cost spent above $c^r$	0.04	0.04	0.05	0.04	0.04	0.04
Fraction of months in which						
$p$ is constant for the whole month	0.16	0.17	0.12	0.17	0.19	0.15
$c$ is constant for the whole month	0.69	0.70	0.66	0.69	0.72	0.68
Probability of $\Delta p$   no $\Delta c$	0.18	0.18	0.19	0.19	0.16	0.20
Probability of $\Delta p^r$   no $\Delta c^r$	0.01	0.01	0.01	0.01	0.01	0.01
Probability of $\Delta p$   $\Delta c$	0.44	0.44	0.43	0.42	0.45	0.46
Probability of $\Delta p^r$   $\Delta c^r$	0.57	0.57	0.56	0.54	0.60	0.56
Transition from $p^{nr}$ to $p^{nr}$	0.72	0.72	0.72	0.71	0.74	0.72
Transition from $p^{nr}$ to $p^r$	0.28	0.28	0.28	0.29	0.26	0.28
Transition from $p^r$ to $p^{nr}$	0.11	0.10	0.11	0.11	0.09	0.11
Transition from $p^r$ to $p^r$	0.89	0.90	0.89	0.89	0.91	0.89
Transition from $c^{nr}$ to $c^{nr}$	0.85	0.85	0.85	0.85	0.84	0.86
Transition from $c^{nr}$ to $c^r$	0.15	0.15	0.15	0.15	0.16	0.14
Transition from $c^r$ to $c^{nr}$	0.02	0.01	0.02	0.02	0.01	0.01
Transition from $c^r$ to $c^r$	0.98	0.99	0.98	0.98	0.99	0.99
Mean of actual markups	0.29	0.30	0.28	0.33	0.27	0.27
Std. Dev. of actual markups	0.53	0.61	0.24	0.67	0.25	0.25
Mean of reference markups	0.32	0.32	0.30	0.36	0.29	0.29
Std. Dev. of reference markups	0.52	0.60	0.23	0.66	0.24	0.24
Implied duration of $\Delta p$	7.7	8.2	6.9	8.2	9.6	9.5
Implied duration of $\Delta c$	134.5	141.0	123.0	150.0	158.2	110.3
Implied duration of $\Delta p^r$	93.4	96.6	89.7	104.4	90.2	141.6
Implied duration of $\Delta c^r$	202.6	207.6	191.9	215.6	246.6	217.7

Note: City names are Bogotá (Bog), Medellín (Med), Barranquilla (Bar) and Cali (Cal).  $p^r$  and  $p^{nr}$  denote reference and non-reference prices, respectively;  $c^r$  and  $c^{nr}$  denote reference and non-reference costs, respectively.  $\Delta$  denotes absolute change.

Table 2: Fraction of days price (cost) spent at, below or above reference price (cost)

Product	Same		Below		Above	
	<i>p</i>	<i>c</i>	<i>p</i>	<i>c</i>	<i>p</i>	<i>c</i>
All products	0.72	0.91	0.19	0.05	0.09	0.04
(Pe) Beef (minute steak <i>own</i> )	0.67	0.91	0.28	0.04	0.05	0.05
(Pe) Beef (ribs <i>own</i> )	0.63	0.90	0.29	0.06	0.08	0.03
(Pe) Beef (rump steak <i>asa</i> )	0.65	0.88	0.26	0.07	0.09	0.05
(Pe) Beef (rump steak <i>own</i> )	0.58	0.88	0.34	0.06	0.08	0.06
(Pe) Beef (sirloin <i>own</i> )	0.63	0.90	0.31	0.04	0.07	0.06
(Pe) Beef (thick flank <i>own</i> )	0.63	0.90	0.29	0.05	0.08	0.05
(Pe) Catfish fillets (imported)	0.78	0.83	0.16	0.08	0.06	0.09
(Pe) Chicken breast	0.71	0.97	0.25	0.02	0.04	0.01
(Pe) Chicken breast with skin <i>own</i>	0.73	0.97	0.21	0.03	0.06	0.01
(Pe) Cooked prawn <i>asa</i>	0.67	0.80	0.24	0.11	0.09	0.09
(Pe) Eggs 30 units red <i>br1</i>	0.81	0.93	0.11	0.04	0.07	0.03
(Pe) Full fat milk (6X900ml) <i>own</i>	0.64	0.85	0.23	0.09	0.13	0.07
(Pe) Lactose-free milk (6X1100ml) <i>br1</i>	0.74	0.95	0.17	0.02	0.10	0.03
(Pe) Lactose-free milk UHT (4X946ml) <i>br2</i>	0.72	0.94	0.13	0.03	0.15	0.03
(Pe) Lactose-free milk (6X1300ml) <i>br3</i>	0.88	0.98	0.06	0.00	0.06	0.02
(Pe) Packet of sausages 500gr <i>br1</i>	0.73	0.97	0.16	0.01	0.11	0.01
(Pe) Papaya melona	0.62	0.74	0.24	0.15	0.14	0.11
(Pe) Red mojarra fish	0.73	0.75	0.22	0.14	0.06	0.11
(Pe) Roast chicken <i>br1</i>	0.91	0.93	0.04	0.04	0.05	0.03
(Pe) Salmon fillets	0.74	0.81	0.18	0.10	0.08	0.09
(NPe) Dog food <i>own</i>	0.68	0.94	0.23	0.02	0.09	0.04
(NPe) Rice 5kg <i>br1</i>	0.69	0.91	0.16	0.04	0.15	0.04
(NPe) Soya oil X 3000cm3 <i>own</i>	0.62	0.91	0.26	0.06	0.12	0.04
(NPe) Sugar 2.5kg <i>own</i>	0.70	0.93	0.19	0.03	0.12	0.03
(NPe) Toilet paper 12 rolls <i>own</i>	0.62	0.90	0.19	0.04	0.19	0.06
(NPe) Bedspread	0.78	0.96	0.19	0.03	0.03	0.01
(NPe) Pillow 50X70 <i>br1</i>	0.88	0.99	0.10	0.01	0.02	0.00
(NPe) Pillow 65X45 <i>br1</i>	0.89	0.99	0.09	0.00	0.02	0.01
(NPe) Pressure cooker 6lt <i>br1</i>	0.81	0.94	0.11	0.03	0.08	0.03
(NPe) Set of two towels <i>br1</i>	0.87	0.99	0.10	0.01	0.03	0.00
(NPe) Car battery <i>own</i>	0.68	0.92	0.23	0.04	0.09	0.04
(NPe) Printer paper 75gr	0.79	0.95	0.12	0.02	0.09	0.03
(NPe) Tyres R13	0.78	0.93	0.13	0.03	0.08	0.03

Note: Henceforth, (Pe) denotes perishable foods while (NPe) denotes non-perishable products. Also, *asa*, *own*, *br1*, *br2* and *br3* indicate assisted sale, own brand, and brands 1, 2 and 3, respectively. All products have between 24,744 and 50,366 observations giving a total of 1,501,233.

Table 3: Fraction of months in which daily prices (costs) are constant for the whole month

Product	$p$	$c$
All products	0.16	0.69
Perishable	0.13	0.62
Non-perishable	0.19	0.80
(Pe) Beef (minute steak <i>own</i> )	0.02	0.66
(Pe) Beef (ribs <i>own</i> )	0.01	0.65
(Pe) Beef (rump steak <i>asa own</i> )	0.12	0.57
(Pe) Beef (rump steak <i>own</i> )	0.02	0.55
(Pe) Beef (sirloin <i>own</i> )	0.01	0.62
(Pe) Beef (thick flank <i>own</i> )	0.02	0.63
(Pe) Catfish fillets (imported)	0.13	0.46
(Pe) Chicken breast	0.03	0.86
(Pe) Chicken breast with skin <i>own</i>	0.18	0.87
(Pe) Cooked prawn <i>asa</i>	0.06	0.35
(Pe) Eggs 30 units red <i>br1</i>	0.39	0.75
(Pe) Full fat milk (6X900ml) <i>own</i>	0.09	0.52
(Pe) Lactose-free milk (6X1100ml) <i>br1</i>	0.11	0.86
(Pe) Lactose-free milk UHT (4X946ml) <i>br2</i>	0.11	0.79
(Pe) Lactose-free milk (6X1300ml) <i>br3</i>	0.51	0.91
(Pe) Packet of sausages 500gr <i>br1</i>	0.06	0.89
(Pe) Papaya melona	0.02	0.13
(Pe) Red mojarra fish	0.04	0.18
(Pe) Roast chicken <i>br1</i>	0.59	0.70
(Pe) Salmon fillets	0.20	0.39
(NPe) Dog food <i>own</i>	0.03	0.74
(NPe) Rice 5kg <i>br1</i>	0.17	0.71
(NPe) Soya oil X 3000cm3 <i>own</i>	0.04	0.73
(NPe) Sugar 2.5kg <i>own</i>	0.11	0.79
(NPe) Toilet paper 12 rolls <i>own</i>	0.08	0.64
(NPe) Bedspread	0.13	0.87
(NPe) Pillow 50X70 <i>br1</i>	0.27	0.95
(NPe) Pillow 65X45 <i>br1</i>	0.29	0.95
(NPe) Pressure cooker 6lt <i>br1</i>	0.25	0.77
(NPe) Set of two towels <i>br1</i>	0.36	0.97
(NPe) Car battery <i>own</i>	0.13	0.69
(NPe) Printer paper 75gr	0.29	0.78
(NPe) Tyres R13	0.28	0.79

Table 4: Selected conditional probabilities of price and reference price changes

Product	Probability of:			
	$\Delta p   \text{no } \Delta c$	$\Delta p^r   \text{no } \Delta c^r$	$\Delta p   \Delta c$	$\Delta p^r   \Delta c^r$
All products	0.18	0.01	0.44	0.57
Perishable	0.22	0.01	0.41	0.55
Non-perishable	0.14	0.01	0.55	0.60
(Pe) Beef (minute steak <i>own</i> )	0.33	0.01	0.59	0.55
(Pe) Beef (ribs <i>own</i> )	0.32	0.01	0.34	0.56
(Pe) Beef (rump steak <i>asa own</i> )	0.31	0.01	0.52	0.59
(Pe) Beef (rump steak <i>own</i> )	0.38	0.01	0.60	0.59
(Pe) Beef (sirloin <i>own</i> )	0.36	0.01	0.54	0.58
(Pe) Beef (thick flank <i>own</i> )	0.33	0.01	0.65	0.65
(Pe) Catfish fillets (imported)	0.14	0.00	0.25	0.29
(Pe) Chicken breast	0.30	0.01	0.39	0.55
(Pe) Chicken breast with skin <i>own</i>	0.24	0.01	0.34	0.32
(Pe) Cooked prawn <i>asa</i>	0.22	0.01	0.33	0.35
(Pe) Eggs 30 units red <i>br1</i>	0.10	0.01	0.64	0.77
(Pe) Full fat milk (6X900ml) <i>own</i>	0.21	0.01	0.52	0.62
(Pe) Lactose-free milk (6X1100ml) <i>br1</i>	0.13	0.01	0.76	0.64
(Pe) Lactose-free milk UHT (4X946ml) <i>br2</i>	0.12	0.01	0.67	0.76
(Pe) Lactose-free milk (6X1300ml) <i>br3</i>	0.06	0.01	0.12	0.79
(Pe) Packet of sausages 500gr <i>br1</i>	0.15	0.01	0.78	0.70
(Pe) Papaya melona	0.28	0.01	0.33	0.70
(Pe) Red mojarra fish	0.16	0.01	0.22	0.33
(Pe) Roast chicken <i>br1</i>	0.02	0.00	0.54	0.72
(Pe) Salmon fillets	0.12	0.01	0.50	0.57
(NPe) Dog food <i>own</i>	0.24	0.01	0.42	0.93
(NPe) Rice 5kg <i>br1</i>	0.12	0.01	0.60	0.66
(NPe) Soya oil X 3000cm3 <i>own</i>	0.30	0.01	0.73	0.67
(NPe) Sugar 2.5kg <i>own</i>	0.16	0.01	0.74	0.65
(NPe) Toilet paper 12 rolls <i>own</i>	0.23	0.02	0.59	0.73
(NPe) Bedspread	0.12	0.01	0.29	0.25
(NPe) Pillow 50X70 <i>br1</i>	0.09	0.01	0.10	0.46
(NPe) Pillow 65X45 <i>br1</i>	0.08	0.00	0.33	0.53
(NPe) Pressure cooker 6lt <i>br1</i>	0.08	0.01	0.16	0.41
(NPe) Set of two towels <i>br1</i>	0.07	0.00	0.07	0.14
(NPe) Car battery <i>own</i>	0.14	0.01	0.52	0.61
(NPe) Printer paper 75gr	0.08	0.01	0.16	0.52
(NPe) Tyres R13	0.08	0.01	0.51	0.58

Note:  $\Delta p$  and  $\Delta c$  respectively denote change in price and cost, and  $r$  denotes reference.

Table 5: Transition matrices for prices and costs

Product	NR to NR		NR to R		R to NR		R to R	
	<i>p</i>	<i>c</i>	<i>p</i>	<i>c</i>	<i>p</i>	<i>c</i>	<i>p</i>	<i>c</i>
All products	0.72	0.85	0.28	0.15	0.11	0.02	0.89	0.98
Perishable	0.69	0.85	0.31	0.15	0.13	0.02	0.87	0.98
Non-perishable	0.78	0.87	0.22	0.13	0.07	0.01	0.93	0.99
(Pe) Beef (minute steak <i>own</i> )	0.55	0.89	0.45	0.11	0.22	0.01	0.78	0.99
(Pe) Beef (ribs <i>own</i> )	0.65	0.89	0.35	0.11	0.21	0.01	0.79	0.99
(Pe) Beef (rump steak <i>asa own</i> )	0.65	0.89	0.35	0.11	0.19	0.02	0.81	0.98
(Pe) Beef (rump steak <i>own</i> )	0.65	0.88	0.35	0.12	0.25	0.02	0.75	0.98
(Pe) Beef (sirloin <i>own</i> )	0.62	0.89	0.38	0.11	0.23	0.01	0.77	0.99
(Pe) Beef (thick flank <i>own</i> )	0.63	0.88	0.37	0.12	0.22	0.01	0.78	0.99
(Pe) Catfish fillets (imported)	0.70	0.87	0.30	0.13	0.09	0.03	0.91	0.97
(Pe) Chicken breast	0.54	0.83	0.46	0.17	0.19	0.01	0.81	0.99
(Pe) Chicken breast with skin <i>own</i>	0.61	0.86	0.39	0.14	0.15	0.00	0.85	1.00
(Pe) Cooked prawn <i>asa</i>	0.74	0.85	0.26	0.15	0.13	0.04	0.87	0.96
(Pe) Eggs 30 units red <i>br1</i>	0.76	0.87	0.24	0.13	0.05	0.01	0.95	0.99
(Pe) Full fat milk (6X900ml) <i>own</i>	0.77	0.82	0.23	0.18	0.13	0.03	0.87	0.97
(Pe) Lactose-free milk (6X1100ml) <i>br1</i>	0.79	0.81	0.21	0.19	0.07	0.01	0.93	0.99
(Pe) Lactose-free milk UHT (4X946ml) <i>br2</i>	0.81	0.86	0.19	0.14	0.07	0.01	0.93	0.99
(Pe) Lactose-free milk (6X1300ml) <i>br3</i>	0.80	0.92	0.20	0.08	0.03	0.00	0.97	1.00
(Pe) Packet of sausages 500gr <i>br1</i>	0.76	0.77	0.24	0.23	0.09	0.01	0.91	0.99
(Pe) Papaya melona	0.66	0.73	0.34	0.27	0.20	0.09	0.80	0.91
(Pe) Red mojarra fish	0.73	0.82	0.27	0.18	0.10	0.06	0.90	0.94
(Pe) Roast chicken <i>br1</i>	0.81	0.86	0.19	0.14	0.02	0.01	0.98	0.99
(Pe) Salmon fillets	0.80	0.89	0.20	0.11	0.07	0.03	0.93	0.97
(NPe) Dog food <i>own</i>	0.75	0.87	0.25	0.13	0.12	0.01	0.88	0.99
(NPe) Rice 5kg <i>br1</i>	0.84	0.87	0.16	0.13	0.07	0.01	0.93	0.99
(NPe) Soya oil X 3000cm3 <i>own</i>	0.69	0.88	0.31	0.12	0.19	0.01	0.81	0.99
(NPe) Sugar 2.5kg <i>own</i>	0.78	0.84	0.22	0.16	0.10	0.01	0.90	0.99
(NPe) Toilet paper 12 rolls <i>own</i>	0.79	0.86	0.21	0.15	0.13	0.02	0.87	0.98
(NPe) Bedspread	0.79	0.91	0.21	0.09	0.06	0.00	0.94	1.00
(NPe) Pillow 50X70 <i>br1</i>	0.68	0.88	0.32	0.12	0.05	0.00	0.95	1.00
(NPe) Pillow 65X45 <i>br1</i>	0.65	0.88	0.35	0.12	0.04	0.00	0.96	1.00
(NPe) Pressure cooker 6lt <i>br1</i>	0.81	0.88	0.19	0.12	0.04	0.01	0.96	0.99
(NPe) Set of two towels <i>br1</i>	0.76	0.88	0.24	0.12	0.04	0.00	0.96	1.00
(NPe) Car battery <i>own</i>	0.84	0.87	0.16	0.13	0.08	0.01	0.92	0.99
(NPe) Printer paper 75gr	0.83	0.86	0.17	0.14	0.04	0.01	0.96	0.99
(NPe) Tyres R13	0.84	0.90	0.16	0.10	0.04	0.01	0.96	0.99

Note: NR and R denote non-reference and reference, respectively.

Table 6: Markov chain transition matrix for price and cost by last 3 digits

		To									
		000-099	100-199	200-299	300-399	400-499	500-599	600-699	700-799	800-899	900-999
Prices											
From	000-099	0.56	0.06	0.03	0.03	0.03	0.03	0.02	0.04	0.05	0.16
	100-199	0.04	0.66	0.08	0.02	0.03	0.02	0.02	0.03	0.03	0.06
	200-299	0.03	0.10	0.59	0.07	0.03	0.03	0.02	0.03	0.03	0.06
	300-399	0.02	0.03	0.07	0.57	0.12	0.03	0.03	0.03	0.03	0.07
	400-499	0.02	0.03	0.03	0.09	0.65	0.06	0.02	0.02	0.02	0.05
	500-599	0.02	0.02	0.03	0.02	0.08	0.61	0.09	0.03	0.03	0.06
	600-699	0.02	0.02	0.02	0.02	0.03	0.08	0.63	0.09	0.04	0.06
	700-799	0.02	0.02	0.02	0.02	0.02	0.02	0.07	0.61	0.10	0.08
	800-899	0.03	0.02	0.02	0.02	0.02	0.02	0.03	0.09	0.60	0.16
	900-999	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.03	0.89
Costs											
From	00-099	0.97	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
	100-199	0.00	0.97	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	200-299	0.01	0.01	0.94	0.01	0.00	0.01	0.00	0.00	0.00	0.00
	300-399	0.00	0.00	0.01	0.96	0.01	0.01	0.00	0.00	0.00	0.00
	400-499	0.00	0.00	0.00	0.00	0.97	0.02	0.00	0.00	0.00	0.00
	500-599	0.00	0.00	0.00	0.00	0.01	0.96	0.00	0.00	0.00	0.00
	600-699	0.00	0.00	0.00	0.00	0.00	0.01	0.97	0.01	0.00	0.00
	700-799	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.97	0.01	0.00
	800-899	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.96	0.01
	900-999	0.02	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.94

Note: Summary results for all products.

Table 7: Mean and standard deviation of actual and reference daily markups

Product	Actual		Reference	
	Mean	s.d.	Mean	s.d.
All products	0.29	0.53	0.32	0.52
(Pe) Beef (minute steak <i>own</i> )	0.18	0.16	0.23	0.13
(Pe) Beef (ribs <i>own</i> )	0.14	0.20	0.19	0.18
(Pe) Beef (rump steak <i>asa own</i> )	0.33	0.79	0.37	0.78
(Pe) Beef (rump steak <i>own</i> )	0.16	0.17	0.22	0.15
(Pe) Beef (sirloin <i>own</i> )	0.21	0.15	0.28	0.12
(Pe) Beef (thick flank <i>own</i> )	0.14	0.33	0.19	0.32
(Pe) Catfish fillets (imported)	0.54	0.28	0.59	0.29
(Pe) Chicken breast	0.20	0.16	0.25	0.11
(Pe) Chicken breast with skin <i>own</i>	0.98	3.01	1.01	2.98
(Pe) Cooked prawn <i>asa</i>	0.54	0.19	0.59	0.17
(Pe) Eggs 30 units red <i>br1</i>	0.02	0.12	0.02	0.12
(Pe) Full fat milk (6X900ml) <i>own</i>	0.00	0.12	0.02	0.11
(Pe) Lactose-free milk (6X1100ml) <i>br1</i>	0.10	0.08	0.12	0.10
(Pe) Lactose-free milk UHT (4X946ml) <i>br2</i>	0.03	0.12	0.02	0.12
(Pe) Lactose-free milk (6X1300ml) <i>br3</i>	0.13	0.04	0.14	0.03
(Pe) Packet of sausages 500gr <i>br1</i>	0.22	0.09	0.23	0.09
(Pe) Papaya melona	0.28	0.35	0.28	0.30
(Pe) Red mojarra fish	0.22	0.14	0.25	0.13
(Pe) Roast chicken <i>br1</i>	0.30	0.15	0.30	0.14
(Pe) Salmon fillets	0.23	0.18	0.25	0.17
(NPe) Dog food <i>own</i>	0.45	0.13	0.48	0.11
(NPe) Rice 5kg <i>br1</i>	0.08	0.14	0.08	0.14
(NPe) Soya oil X 3000cm3 <i>own</i>	0.25	0.12	0.27	0.11
(NPe) Sugar 2.5kg <i>own</i>	0.16	0.18	0.18	0.19
(NPe) Toilet paper 12 rolls <i>own</i>	0.29	0.22	0.29	0.20
(NPe) Bedspread	0.43	0.20	0.48	0.15
(NPe) Pillow 50X70 <i>br1</i>	0.59	0.16	0.61	0.14
(NPe) Pillow 65X45 <i>br1</i>	0.67	0.15	0.69	0.11
(NPe) Pressure cooker 6lt <i>br1</i>	0.43	0.16	0.44	0.14
(NPe) Set of two towels <i>br1</i>	0.57	0.22	0.60	0.21
(NPe) Car battery <i>own</i>	0.41	0.17	0.44	0.17
(NPe) Printer paper 75gr	0.39	0.18	0.39	0.17
(NPe) Tyres R13	0.29	0.12	0.30	0.12

Table 8: Implied duration of actual and reference price and cost changes

Product	Actual		Reference	
	<i>p</i>	<i>c</i>	<i>p</i>	<i>c</i>
All products	7.7	134.5	93.4	202.6
(Pe) Beef (minute steak <i>own</i> )	3.0	75.4	79.3	103.7
(Pe) Beef (ribs <i>own</i> )	3.1	82.2	78.5	97.1
(Pe) Beef (rump steak <i>asa own</i> )	3.2	52.8	66.1	84.6
(Pe) Beef (rump steak <i>own</i> )	2.6	50.6	66.7	77.1
(Pe) Beef (sirloin <i>own</i> )	2.8	72.1	65.0	99.2
(Pe) Beef (thick flank <i>own</i> )	2.9	69.9	68.4	85.0
(Pe) Catfish fillets (imported)	6.9	26.7	136.7	78.8
(Pe) Chicken breast	3.4	119.0	112.3	327.6
(Pe) Chicken breast with skin <i>own</i>	4.1	166.5	108.4	336.4
(Pe) Cooked prawn <i>asa</i>	4.4	18.5	88.0	63.9
(Pe) Eggs 30 units red <i>br1</i>	9.7	79.0	78.0	128.2
(Pe) Full fat milk (6X900ml) <i>own</i>	4.5	18.8	59.9	76.8
(Pe) Lactose-free milk (6X1100ml) <i>br1</i>	7.1	48.8	71.8	200.3
(Pe) Lactose-free milk UHT (4X946ml) <i>br2</i>	7.7	67.0	52.6	151.8
(Pe) Lactose-free milk (6X1300ml) <i>br3</i>	17.9	320.7	139.5	574.3
(Pe) Packet of sausages 500gr <i>br1</i>	6.2	57.2	70.6	337.7
(Pe) Papaya melona	3.5	7.1	48.7	69.8
(Pe) Red mojarra fish	6.1	11.2	101.9	69.0
(Pe) Roast chicken <i>br1</i>	30.6	53.8	133.7	139.7
(Pe) Salmon fillets	7.7	28.4	68.3	60.1
(NPe) Dog food <i>own</i>	4.1	87.9	62.8	142.3
(NPe) Rice 5kg <i>br1</i>	7.7	45.2	57.0	110.6
(NPe) Soya oil X 3000cm3 <i>own</i>	3.2	46.7	58.3	147.8
(NPe) Sugar 2.5kg <i>own</i>	6.0	47.3	60.6	135.5
(NPe) Toilet paper 12 rolls <i>own</i>	4.1	32.4	43.9	96.9
(NPe) Bedspread	8.4	233.8	141.6	241.9
(NPe) Pillow 50X70 <i>br1</i>	11.3	620.0	159.4	635.7
(NPe) Pillow 65X45 <i>br1</i>	12.6	554.5	296.1	554.5
(NPe) Pressure cooker 6lt <i>br1</i>	13.1	114.1	94.4	136.1
(NPe) Set of two towels <i>br1</i>	14.9	866.0	204.4	934.0
(NPe) Car battery <i>own</i>	6.8	94.4	64.6	102.0
(NPe) Printer paper 75gr	12.4	136.5	74.5	140.2
(NPe) Tyres R13	12.5	133.8	70.1	148.4

Note: Implied duration (in days) is calculated as the inverse of the frequency of a change in the corresponding price or cost of a product. For all products, it is the average of the implied duration of the individual products.



Table 9: NARDL main estimation results

Product	$t_{BDM}$	$\mathcal{LR}^{(+)}$	$\mathcal{LR}^{(-)}$	Symmetry test	
				$SR$	$\mathcal{LR}$
(Pe) Beef (minute steak <i>own</i> )	-4.10‡	0.37‡	-0.73‡	[0.048]	[0.000]
(Pe) Beef (ribs <i>own</i> )	-3.63‡	0.01	-0.22	[0.158]	[0.264]
(Pe) Beef (rump steak <i>asa own</i> )	-4.12‡	1.08‡	-1.39‡	[0.122]	[0.003]
(Pe) Beef (rump steak <i>own</i> )	-5.27‡	0.53‡	-0.52‡	[0.145]	[0.670]
(Pe) Beef (sirloin <i>own</i> )	-2.63	n.a.	n.a.	n.a.	n.a.
(Pe) Beef (thick flank <i>own</i> )	-4.73‡	0.99‡	-0.98‡	[0.003]	[0.884]
(Pe) Catfish fillets (imported)	-9.42‡	0.78‡	-0.73‡	[0.000]	[0.148]
(Pe) Chicken breast	-4.70‡	0.16	0.57	[0.348]	[0.026]
(Pe) Chicken breast with skin <i>own</i>	-1.12	n.a.	n.a.	n.a.	n.a.
(Pe) Cooked prawn <i>asa</i>	-5.58‡	1.16‡	-1.18‡	[0.000]	[0.664]
(Pe) Eggs 30 units red <i>br1</i>	-7.45‡	0.22	-0.66‡	[0.000]	[0.000]
(Pe) Full fat milk (6X900ml) <i>own</i>	-6.82‡	0.76‡	-0.74‡	[0.202]	[0.274]
(Pe) Lactose-free milk (6X1100ml) <i>br1</i>	-6.62‡	0.91‡	-0.92‡	[0.218]	[0.508]
(Pe) Lactose-free milk UHT (4X946ml) <i>br2</i>	-5.80‡	0.42‡	-0.41‡	[0.319]	[0.395]
(Pe) Lactose-free milk (6X1300ml) <i>br3</i>	-5.48‡	0.80‡	0.00	[0.290]	[0.000]
(Pe) Packet of sausages 500gr <i>br1</i>	-6.79‡	0.82‡	-0.81‡	[0.266]	[0.032]
(Pe) Papaya melona	-6.44‡	0.98‡	-0.99‡	[0.842]	[0.395]
(Pe) Red mojarra fish	-7.38‡	0.75‡	-0.75‡	[0.000]	[0.923]
(Pe) Roast chicken <i>br1</i>	-5.09‡	0.71‡	-0.74‡	[0.008]	[0.392]
(Pe) Salmon fillets	-6.06‡	0.53‡	-0.50‡	[0.000]	[0.120]
(NPe) Dog food <i>own</i>	-5.60‡	2.39‡	-2.47‡	[0.668]	[0.819]
(NPe) Rice 5kg <i>br1</i>	-4.22‡	1.17‡	-1.19‡	[0.309]	[0.278]
(NPe) Soya oil X 3000cm3 <i>own</i>	-6.16‡	1.29‡	-1.31‡	[0.810]	[0.339]
(NPe) Sugar 2.5kg <i>own</i>	-6.01‡	0.87‡	-0.89‡	[0.867]	[0.151]
(NPe) Toilet paper 12 rolls <i>own</i>	-7.13‡	0.91‡	-0.92‡	[0.231]	[0.723]
(NPe) Bedspread	-3.76‡	0.13	-1.58	[0.430]	[0.525]
(NPe) Pillow 50X70 <i>br1</i>	-4.23‡	0.96‡	0.51	[0.816]	[0.063]
(NPe) Pillow 65X45 <i>br1</i>	-7.48‡	0.72‡	-2.66	[0.522]	[0.599]
(NPe) Pressure cooker 6lt <i>br1</i>	-7.32‡	0.49‡	-0.21	[0.719]	[0.013]
(NPe) Set of two towels <i>br1</i>	-0.81	n.a.	n.a.	n.a.	n.a.
(NPe) Car battery <i>own</i>	-4.99‡	1.19‡	-1.06‡	[0.003]	[0.298]
(NPe) Printer paper 75gr	-3.15	n.a.	n.a.	n.a.	n.a.
(NPe) Tyres R13	-5.06‡	0.95‡	-0.80‡	[0.468]	[0.380]

Note: The critical values of the  $t_{BDM}$  statistic for  $k = 1$  are -3.22 and -3.82 at the 5 and 1% significance levels (see Pesaran et al., 2001, Table CII(iii)).  $\mathcal{LR}^{(+)}$  and  $\mathcal{LR}^{(-)}$  denote the long-run price response when there is a permanent change in cost by 1 and -1, respectively. † and ‡ indicate statistical significance at the 5 and 1% levels, respectively. The restriction of short-run symmetry is  $\sum_{i=0}^{q-1} \pi_i^+ = \sum_{i=0}^{q-1} \pi_i^-$  for all  $i = 0, \dots, q - 1$ . The restriction for long-run symmetry is  $\beta^+ = \beta^-$ . Probability values in brackets. n.a. indicates not applicable.

Table 10: Probit model for the determinants of the likelihood of asymmetry

	Colombia stores		Bogotá stores	
	Coef.	HCSE	Coef.	HCSE
Number of suppliers	-0.045 <sup>‡</sup>	(0.019)	-0.051 <sup>‡</sup>	(0.022)
Cost volatility	-2.439 <sup>‡</sup>	(0.722)	-1.598 <sup>‡</sup>	(0.540)
Own brand	-0.223 <sup>‡</sup>	(0.112)	-0.299 <sup>‡</sup>	(0.095)
Perishable	0.189 <sup>†</sup>	(0.105)	0.136	(0.102)
Observations	29		30	
$R^2$	0.377		0.365	

Note: The table reports marginal effects. For Colombia (Bogotá) stores the dependent variable is defined as taking the value of one if the probability value of the long-run symmetry test in the last column of Table 9 (A.8) is less than 0.05, and 0 otherwise. White (1980) heteroskedastic consistent standard errors in parentheses. <sup>†</sup> and <sup>‡</sup> denote statistical significance at the 5% and 1% levels, respectively.

## A Appendix: Results for Bogotá

Table A.1: Fraction of days price (cost) spent at, below or above reference price (cost). Bogotá

Product	Same		Below		Above	
	<i>p</i>	<i>c</i>	<i>p</i>	<i>c</i>	<i>p</i>	<i>c</i>
All products	0.71	0.90	0.20	0.05	0.09	0.05
(P) Beef (minute steak <i>own</i> )	0.69	0.90	0.27	0.05	0.04	0.05
(Pe) Beef (ribs <i>own</i> )	0.64	0.89	0.29	0.07	0.07	0.03
(Pe) Beef (rump steak <i>asa own</i> )	0.58	0.87	0.31	0.08	0.11	0.06
(Pe) Beef (rump steak <i>own</i> )	0.57	0.87	0.35	0.07	0.09	0.06
(Pe) Beef (sirloin <i>own</i> )	0.63	0.89	0.32	0.05	0.05	0.06
(Pe) Beef (thick flank <i>own</i> )	0.62	0.90	0.29	0.05	0.08	0.05
(Pe) Catfish fillets (imported)	0.80	0.84	0.13	0.08	0.06	0.08
(Pe) Chicken breast	0.69	0.94	0.26	0.04	0.05	0.03
(Pe) Chicken breast with skin <i>own</i>	0.65	0.96	0.29	0.03	0.06	0.00
(Pe) Cooked prawn <i>asa</i>	0.69	0.78	0.24	0.12	0.07	0.11
(Pe) Eggs 30 units red <i>br1</i>	0.80	0.92	0.12	0.04	0.08	0.04
(Pe) Full fat milk (6X900ml) <i>own</i>	0.62	0.84	0.25	0.09	0.13	0.08
(Pe) Lactose-free milk (6X1100ml) <i>br1</i>	0.68	0.95	0.20	0.02	0.12	0.03
(Pe) Lactose-free milk UHT (4X946ml) <i>br2</i>	0.69	0.94	0.16	0.03	0.15	0.02
(Pe) Lactose-free milk (6X1300ml) <i>br3</i>	0.77	0.98	0.11	0.00	0.12	0.02
(Pe) Packet of sausages 500gr <i>br1</i>	0.70	0.97	0.17	0.01	0.13	0.02
(Pe) Papaya melona	0.62	0.72	0.23	0.17	0.15	0.11
(Pe) Red mojarra fish	0.72	0.70	0.23	0.16	0.04	0.14
(Pe) Roast chicken <i>br1</i>	0.91	0.92	0.04	0.04	0.05	0.04
(Pe) Salmon fillets	0.73	0.76	0.20	0.13	0.07	0.11
(NPe) Dog food <i>own</i>	0.66	0.93	0.24	0.03	0.09	0.04
(NPe) Rice 5kg <i>br1</i>	0.63	0.89	0.20	0.05	0.17	0.06
(NPe) Soya oil X 3000cm3 <i>own</i>	0.65	0.89	0.26	0.07	0.09	0.04
(NPe) Sugar 2.5kg <i>own</i>	0.70	0.93	0.19	0.03	0.11	0.04
(NPe) Toilet paper 12 rolls <i>own</i>	0.63	0.89	0.19	0.04	0.18	0.07
(NPe) Bedspread	0.77	0.95	0.20	0.03	0.03	0.02
(NPe) Pillow 50X70 <i>br1</i>	0.86	0.99	0.11	0.01	0.02	0.00
(NPe) Pillow 65X45 <i>br1</i>	0.89	0.99	0.08	0.00	0.03	0.01
(NPe) Pressure cooker 6lt <i>br1</i>	0.81	0.94	0.12	0.02	0.07	0.04
(NPe) Set of two towels <i>br1</i>	0.88	0.99	0.10	0.01	0.03	0.00
(NPe) Car battery <i>own</i>	0.68	0.92	0.23	0.04	0.08	0.04
(NPe) Printer paper 75gr	0.79	0.94	0.13	0.03	0.08	0.03
(NPe) Tyres R13	0.77	0.93	0.14	0.03	0.09	0.04

Note: All products have between 5,572 and 14,167 observations giving a total of 423,647.

Table A.2: Fraction of months in which daily prices (costs) are constant for the whole month.  
Bogotá

Product	$p$	$c$
All products	0.12	0.66
Perishable	0.09	0.59
Non-perishable	0.17	0.78
(Pe) Beef (minute steak <i>own</i> )	0.00	0.65
(Pe) Beef (ribs <i>own</i> )	0.00	0.63
(Pe) Beef (rump steak <i>asa own</i> )	0.00	0.59
(Pe) Beef (rump steak <i>own</i> )	0.01	0.56
(Pe) Beef (sirloin <i>own</i> )	0.01	0.60
(Pe) Beef (thick flank <i>own</i> )	0.00	0.66
(Pe) Catfish fillets (imported)	0.15	0.50
(Pe) Chicken breast	0.08	0.80
(Pe) Chicken breast with skin <i>own</i>	0.01	0.84
(Pe) Cooked prawn <i>asa</i>	0.07	0.30
(Pe) Eggs 30 units red <i>br1</i>	0.31	0.67
(Pe) Full fat milk (6X900ml) <i>own</i>	0.01	0.43
(Pe) Lactose-free milk (6X1100ml) <i>br1</i>	0.03	0.86
(Pe) Lactose-free milk UHT (4X946ml) <i>br2</i>	0.02	0.78
(Pe) Lactose-free milk (6X1300ml) <i>br3</i>	0.31	0.89
(Pe) Packet of sausages 500gr <i>br1</i>	0.04	0.89
(Pe) Papaya melona	0.02	0.05
(Pe) Red mojarra fish	0.04	0.09
(Pe) Roast chicken <i>br1</i>	0.56	0.65
(Pe) Salmon fillets	0.16	0.25
(NPe) Dog food <i>own</i>	0.01	0.75
(NPe) Rice 5kg <i>br1</i>	0.10	0.64
(NPe) Soya oil X 3000cm3 <i>own</i>	0.05	0.71
(NPe) Sugar 2.5kg <i>own</i>	0.10	0.78
(NPe) Toilet paper 12 rolls <i>own</i>	0.09	0.58
(NPe) Bedspread	0.10	0.87
(NPe) Pillow 50X70 <i>br1</i>	0.25	0.95
(NPe) Pillow 65X45 <i>br1</i>	0.27	0.95
(NPe) Pressure cooker 6lt <i>br1</i>	0.23	0.73
(NPe) Set of two towels <i>br1</i>	0.35	0.96
(NPe) Car battery <i>own</i>	0.11	0.69
(NPe) Printer paper 75gr	0.29	0.78
(NPe) Tyres R13	0.26	0.78

Table A.3: Selected conditional probabilities of price and reference price changes. Bogotá

Product	Probability of:			
	$\Delta p   \text{no } \Delta c$	$\Delta p^r   \text{no } \Delta c^r$	$\Delta p   \Delta c$	$\Delta p^r   \Delta c^r$
All products	0.19	0.01	0.43	0.56
Perishable	0.23	0.01	0.41	0.55
Non-perishable	0.14	0.01	0.55	0.58
(Pe) Beef (minute steak <i>own</i> )	0.35	0.01	0.51	0.58
(Pe) Beef (ribs <i>own</i> )	0.32	0.01	0.29	0.49
(Pe) Beef (rump steak <i>asa own</i> )	0.35	0.01	0.47	0.64
(Pe) Beef (rump steak <i>own</i> )	0.39	0.01	0.54	0.66
(Pe) Beef (sirloin <i>own</i> )	0.37	0.01	0.52	0.58
(Pe) Beef (thick flank <i>own</i> )	0.34	0.01	0.63	0.66
(Pe) Catfish fillets (imported)	0.13	0.00	0.21	0.26
(Pe) Chicken breast	0.28	0.01	0.42	0.44
(Pe) Chicken breast with skin <i>own</i>	0.32	0.01	0.32	0.18
(Pe) Cooked prawn <i>asa</i>	0.21	0.00	0.31	0.31
(Pe) Eggs 30 units red <i>br1</i>	0.10	0.01	0.71	0.78
(Pe) Full fat milk (6X900ml) <i>own</i>	0.21	0.01	0.56	0.62
(Pe) Lactose-free milk (6X1100ml) <i>br1</i>	0.16	0.01	0.80	0.64
(Pe) Lactose-free milk UHT (4X946ml) <i>br2</i>	0.15	0.01	0.74	0.83
(Pe) Lactose-free milk (6X1300ml) <i>br3</i>	0.09	0.01	0.15	0.92
(Pe) Packet of sausages 500gr <i>br1</i>	0.16	0.01	0.81	0.80
(Pe) Papaya melona	0.28	0.01	0.33	0.78
(Pe) Red mojarra fish	0.17	0.00	0.21	0.26
(Pe) Roast chicken <i>br1</i>	0.03	0.00	0.51	0.64
(Pe) Salmon fillets	0.13	0.00	0.41	0.49
(NPe) Dog food <i>own</i>	0.26	0.01	0.43	0.89
(NPe) Rice 5kg <i>br1</i>	0.16	0.01	0.58	0.66
(NPe) Soya oil X 3000cm3 <i>own</i>	0.25	0.01	0.72	0.66
(NPe) Sugar 2.5kg <i>own</i>	0.15	0.01	0.76	0.57
(NPe) Toilet paper 12 rolls <i>own</i>	0.23	0.01	0.58	0.72
(NPe) Bedspread	0.13	0.01	0.25	0.23
(NPe) Pillow 50X70 <i>br1</i>	0.09	0.01	0.13	0.52
(NPe) Pillow 65X45 <i>br1</i>	0.08	0.00	0.20	0.33
(NPe) Pressure cooker 6lt <i>br1</i>	0.09	0.01	0.15	0.37
(NPe) Set of two towels <i>br1</i>	0.07	0.00	0.06	0.13
(NPe) Car battery <i>own</i>	0.17	0.01	0.51	0.59
(NPe) Printer paper 75gr	0.08	0.01	0.21	0.53
(NPe) Tyres R13	0.08	0.01	0.52	0.63

Note:  $\Delta p$  and  $\Delta c$  respectively denote change in price and cost, and  $r$  denotes reference.

Table A.4: Transition matrices for prices and costs. Bogotá

Product	NR to NR		NR to R		R to NR		R to R	
	<i>p</i>	<i>c</i>	<i>p</i>	<i>c</i>	<i>p</i>	<i>c</i>	<i>p</i>	<i>c</i>
All products	0.72	0.85	0.28	0.15	0.11	0.02	0.89	0.98
Perishable	0.69	0.84	0.31	0.16	0.14	0.02	0.86	0.98
Non-perishable	0.78	0.87	0.22	0.13	0.08	0.01	0.92	0.99
(Pe) Beef (minute steak <i>own</i> )	0.50	0.89	0.50	0.11	0.22	0.01	0.78	0.99
(Pe) Beef (ribs <i>own</i> )	0.63	0.90	0.37	0.10	0.21	0.01	0.79	0.99
(Pe) Beef (rump steak <i>asa own</i> )	0.68	0.88	0.32	0.12	0.23	0.02	0.77	0.98
(Pe) Beef (rump steak <i>own</i> )	0.66	0.88	0.34	0.12	0.26	0.02	0.74	0.98
(Pe) Beef (sirloin <i>own</i> )	0.59	0.89	0.41	0.11	0.24	0.01	0.76	0.99
(Pe) Beef (thick flank <i>own</i> )	0.64	0.88	0.36	0.12	0.22	0.01	0.78	0.99
(Pe) Catfish fillets (imported)	0.68	0.88	0.32	0.12	0.08	0.02	0.92	0.98
(Pe) Chicken breast	0.61	0.85	0.39	0.15	0.17	0.01	0.83	0.99
(Pe) Chicken breast with skin <i>own</i>	0.62	0.86	0.38	0.14	0.21	0.01	0.79	0.99
(Pe) Cooked prawn <i>asa</i>	0.74	0.86	0.26	0.14	0.12	0.04	0.88	0.96
(Pe) Eggs 30 units red <i>br1</i>	0.76	0.87	0.24	0.13	0.06	0.01	0.94	0.99
(Pe) Full fat milk (6X900ml) <i>own</i>	0.77	0.80	0.23	0.20	0.14	0.04	0.86	0.96
(Pe) Lactose-free milk (6X1100ml) <i>br1</i>	0.80	0.81	0.20	0.19	0.09	0.01	0.91	0.99
(Pe) Lactose-free milk UHT (4X946ml) <i>br2</i>	0.79	0.82	0.21	0.18	0.09	0.01	0.91	0.99
(Pe) Lactose-free milk (6X1300ml) <i>br3</i>	0.84	0.94	0.16	0.06	0.05	0.00	0.95	1.00
(Pe) Packet of sausages 500gr <i>br1</i>	0.76	0.76	0.24	0.24	0.10	0.01	0.90	0.99
(Pe) Papaya melona	0.67	0.73	0.33	0.27	0.21	0.10	0.79	0.90
(Pe) Red mojarra fish	0.73	0.80	0.27	0.20	0.10	0.09	0.90	0.91
(Pe) Roast chicken <i>br1</i>	0.77	0.86	0.23	0.14	0.02	0.01	0.98	0.99
(Pe) Salmon fillets	0.79	0.88	0.21	0.12	0.08	0.04	0.92	0.96
(NPe) Dog food <i>own</i>	0.74	0.87	0.26	0.13	0.13	0.01	0.87	0.99
(NPe) Rice 5kg <i>br1</i>	0.84	0.87	0.16	0.13	0.10	0.02	0.90	0.98
(NPe) Soya oil X 3000cm3 <i>own</i>	0.70	0.88	0.30	0.12	0.16	0.01	0.84	0.99
(NPe) Sugar 2.5kg <i>own</i>	0.78	0.84	0.22	0.16	0.09	0.01	0.91	0.99
(NPe) Toilet paper 12 rolls <i>own</i>	0.78	0.85	0.22	0.15	0.13	0.02	0.87	0.98
(NPe) Bedspread	0.77	0.91	0.23	0.09	0.07	0.00	0.93	1.00
(NPe) Pillow 50X70 <i>br1</i>	0.70	0.87	0.30	0.13	0.05	0.00	0.95	1.00
(NPe) Pillow 65X45 <i>br1</i>	0.64	0.89	0.36	0.11	0.04	0.00	0.96	1.00
(NPe) Pressure cooker 6lt <i>br1</i>	0.79	0.87	0.21	0.13	0.05	0.01	0.95	0.99
(NPe) Set of two towels <i>br1</i>	0.73	0.90	0.27	0.10	0.04	0.00	0.96	1.00
(NPe) Car battery <i>own</i>	0.80	0.88	0.20	0.12	0.09	0.01	0.91	0.99
(NPe) Printer paper 75gr	0.82	0.87	0.18	0.13	0.05	0.01	0.95	0.99
(NPe) Tyres R13	0.85	0.90	0.15	0.10	0.05	0.01	0.96	0.99

Note: NR and R denote non-reference and reference, respectively.

Table A.5: Markov chain transition matrix for prices and costs. Bogotá

		To									
		000-099	100-199	200-299	300-399	400-499	500-599	600-699	700-799	800-8599	900-999
Prices											
From	000-099	0.53	0.06	0.03	0.03	0.03	0.03	0.02	0.04	0.06	0.17
	100-199	0.04	0.60	0.11	0.03	0.04	0.03	0.02	0.03	0.03	0.07
	200-299	0.03	0.11	0.58	0.08	0.03	0.03	0.02	0.03	0.03	0.06
	300-399	0.02	0.03	0.08	0.55	0.12	0.03	0.02	0.03	0.03	0.07
	400-499	0.02	0.03	0.03	0.09	0.64	0.07	0.02	0.02	0.03	0.05
	500-599	0.02	0.03	0.03	0.03	0.09	0.60	0.09	0.03	0.04	0.06
	600-699	0.02	0.02	0.02	0.02	0.03	0.08	0.62	0.09	0.04	0.06
	700-799	0.02	0.02	0.02	0.02	0.03	0.02	0.08	0.61	0.11	0.08
	800-899	0.03	0.02	0.02	0.02	0.02	0.02	0.03	0.10	0.57	0.17
	900-999	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.03	0.88
Costs											
From	000-099	0.96	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02
	100-199	0.00	0.97	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	200-299	0.01	0.01	0.93	0.01	0.01	0.01	0.01	0.00	0.01	0.00
	300-399	0.00	0.00	0.01	0.95	0.01	0.01	0.01	0.00	0.00	0.00
	400-499	0.00	0.00	0.00	0.01	0.96	0.01	0.00	0.00	0.00	0.00
	500-599	0.00	0.00	0.00	0.00	0.01	0.96	0.01	0.00	0.00	0.00
	600-699	0.00	0.00	0.00	0.00	0.00	0.01	0.96	0.01	0.00	0.00
	700-799	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.96	0.01	0.00
	800-899	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.95	0.01
	900-999	0.03	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.01	0.93

Note: Summary results for all products.

Table A.6: Mean and standard deviation of actual and reference daily markups. Bogotá

Product	Actual		Reference	
	Mean	s.d.	Mean	s.d.
All products	0.28	0.24	0.30	0.23
(Pe) Beef (minute steak <i>own</i> )	0.20	0.16	0.25	0.13
(Pe) Beef (ribs <i>own</i> )	0.15	0.19	0.20	0.16
(Pe) Beef (rump steak <i>asa own</i> )	0.24	0.15	0.29	0.12
(Pe) Beef (rump steak <i>own</i> )	0.17	0.14	0.22	0.10
(Pe) Beef (sirloin <i>own</i> )	0.24	0.15	0.31	0.10
(Pe) Beef (thick flank <i>own</i> )	0.14	0.12	0.19	0.09
(Pe) Catfish fillets (imported)	0.56	0.27	0.59	0.28
(Pe) Chicken breast	0.24	0.17	0.30	0.14
(Pe) Chicken breast with skin <i>own</i>	0.32	0.18	0.37	0.16
(Pe) Cooked prawn <i>asa</i>	0.54	0.19	0.60	0.17
(Pe) Eggs 30 units red <i>br1</i>	0.01	0.11	0.01	0.11
(Pe) Full fat milk (6X900ml) <i>own</i>	0.02	0.11	0.04	0.10
(Pe) Lactose-free milk (6X1100ml) <i>br1</i>	0.10	0.08	0.12	0.11
(Pe) Lactose-free milk UHT (4X946ml) <i>br2</i>	0.03	0.12	0.03	0.12
(Pe) Lactose-free milk (6X1300ml) <i>br3</i>	0.13	0.05	0.14	0.04
(Pe) Packet of sausages 500gr <i>br1</i>	0.23	0.09	0.24	0.08
(Pe) Papaya melona	0.27	0.32	0.26	0.29
(Pe) Red mojarra fish	0.27	0.15	0.31	0.13
(Pe) Roast chicken <i>br1</i>	0.29	0.12	0.29	0.12
(Pe) Salmon fillets	0.23	0.16	0.25	0.15
(NPe) Dog food <i>own</i>	0.45	0.13	0.48	0.11
(NPe) Rice 5kg <i>br1</i>	0.05	0.10	0.06	0.10
(NPe) Soya oil X 3000cm3 <i>own</i>	0.25	0.12	0.27	0.10
(NPe) Sugar 2.5kg <i>own</i>	0.16	0.18	0.20	0.20
(NPe) Toilet paper 12 rolls <i>own</i>	0.28	0.21	0.28	0.18
(NPe) Bedspread	0.43	0.19	0.48	0.14
(NPe) Pillow 50X70 <i>br1</i>	0.59	0.17	0.61	0.16
(NPe) Pillow 65X45 <i>br1</i>	0.66	0.15	0.68	0.11
(NPe) Pressure cooker 6lt <i>br1</i>	0.44	0.15	0.45	0.13
(NPe) Set of two towels <i>br1</i>	0.56	0.23	0.59	0.21
(NPe) Car battery <i>own</i>	0.41	0.16	0.44	0.17
(NPe) Printer paper 75gr	0.39	0.18	0.39	0.16
(NPe) Tyres R13	0.28	0.12	0.29	0.12



Table A.7: Implied duration of actual and reference prices and costs changes. Bogotá

Product	Actual		Reference	
	<i>p</i>	<i>c</i>	<i>p</i>	<i>c</i>
All products	6.9	123.0	89.7	191.9
(Pe) Beef (minute steak <i>own</i> )	2.8	70.0	72.2	104.8
(Pe) Beef (ribs <i>own</i> )	3.1	78.2	83.7	94.3
(Pe) Beef (rump steak <i>asa own</i> )	2.8	42.8	52.9	75.3
(Pe) Beef (rump steak <i>own</i> )	2.5	44.8	58.3	76.7
(Pe) Beef (sirloin <i>own</i> )	2.7	66.1	63.7	91.9
(Pe) Beef (thick flank <i>own</i> )	2.9	73.3	61.8	86.2
(Pe) Catfish fillets (imported)	7.5	29.0	144.5	83.1
(Pe) Chicken breast	3.6	61.8	97.5	222.4
(Pe) Chicken breast with skin <i>own</i>	3.2	127.3	106.8	300.9
(Pe) Cooked prawn <i>asa</i>	4.7	16.5	101.1	60.9
(Pe) Eggs 30 units red <i>br1</i>	8.8	56.7	67.0	102.0
(Pe) Full fat milk (6X900ml) <i>own</i>	4.2	14.6	61.3	77.3
(Pe) Lactose-free milk (6X1100ml) <i>br1</i>	5.7	42.6	62.1	202.2
(Pe) Lactose-free milk UHT (4X946ml) <i>br2</i>	6.0	44.9	47.2	131.0
(Pe) Lactose-free milk (6X1300ml) <i>br3</i>	11.3	280.8	80.2	561.5
(Pe) Packet of sausages 500gr <i>br1</i>	5.7	53.0	67.1	345.2
(Pe) Papaya melona	3.5	6.7	43.1	62.9
(Pe) Red mojarra fish	5.7	7.9	120.0	60.0
(Pe) Roast chicken <i>br1</i>	24.8	47.3	138.6	142.8
(Pe) Salmon fillets	7.0	18.8	78.6	52.8
(NPe) Dog food <i>own</i>	3.8	85.4	61.7	136.3
(NPe) Rice 5kg <i>br1</i>	5.8	33.6	51.3	99.0
(NPe) Soya oil X 3000cm3 <i>own</i>	3.8	41.2	62.2	139.9
(NPe) Sugar 2.5kg <i>own</i>	6.0	43.1	65.2	134.8
(NPe) Toilet paper 12 rolls <i>own</i>	4.1	26.9	44.8	91.9
(NPe) Bedspread	7.4	229.3	151.2	229.3
(NPe) Pillow 50X70 <i>br1</i>	10.5	615.2	150.5	615.2
(NPe) Pillow 65X45 <i>br1</i>	12.2	543.5	247.1	543.5
(NPe) Pressure cooker 6lt <i>br1</i>	11.6	98.0	104.5	126.0
(NPe) Set of two towels <i>br1</i>	13.8	799.0	212.2	905.6
(NPe) Car battery <i>own</i>	5.7	95.3	66.9	102.2
(NPe) Printer paper 75gr	11.8	131.5	73.1	131.5
(NPe) Tyres R13	12.6	133.0	63.0	144.6

Note: Implied duration (in days) is calculated as the inverse of the frequency of a change in the corresponding price or cost of a product. For all products, it is the average of the implied duration of the individual products.

Table A.8: NARDL main estimation results. Bogotá

Product	$t_{BDM}$	$\mathcal{LR}^{(+)}$	$\mathcal{LR}^{(-)}$	Symmetry test	
				$SR$	$\mathcal{LR}$
(Pe) Beef (minute steak <i>own</i> )	-4.11‡	0.41‡	-0.93‡	[0.126]	[0.000]
(Pe) Beef (ribs <i>own</i> )	-3.53‡	0.03	-0.27	[0.129]	[0.501]
(Pe) Beef (rump steak <i>asa own</i> )	-5.50‡	0.34‡	-0.38‡	[0.095]	[0.574]
(Pe) Beef (rump steak <i>own</i> )	-5.11‡	0.52‡	-0.50‡	[0.502]	[0.805]
(Pe) Beef (sirloin <i>own</i> )	-2.58	n.a.	n.a.	n.a.	n.a.
(Pe) Beef (thick flank <i>own</i> )	-4.70‡	0.99‡	-1.02‡	[0.198]	[0.797]
(Pe) Catfish fillets (imported)	-9.03‡	0.61‡	-0.60‡	[0.015]	[0.927]
(Pe) Chicken breast	-5.13‡	0.14	0.27	[0.959]	[0.001]
(Pe) Chicken breast with skin <i>own</i>	-5.35‡	0.23	-0.22	[0.645]	[0.900]
(Pe) Cooked prawn <i>asa</i>	-6.05‡	0.91‡	-0.93‡	[0.000]	[0.565]
(Pe) Eggs 30 units red <i>br1</i>	-7.15‡	0.30‡	-0.55‡	[0.019]	[0.000]
(Pe) Full fat milk (6X900ml) <i>own</i>	-7.39‡	0.71‡	-0.70‡	[0.111]	[0.209]
(Pe) Lactose-free milk (6X1100ml) <i>br1</i>	-6.25‡	0.83‡	-0.84‡	[0.243]	[0.553]
(Pe) Lactose-free milk UHT (4X946ml) <i>br2</i>	-6.22‡	0.34‡	-0.32‡	[0.135]	[0.216]
(Pe) Lactose-free milk (6X1300ml) <i>br3</i>	-5.71‡	0.76‡	0.00	[0.288]	[0.000]
(Pe) Packet of sausages 500gr <i>br1</i>	-6.17‡	0.92‡	-0.90‡	[0.188]	[0.099]
(Pe) Papaya melona	-6.06‡	0.93‡	-0.93‡	[0.978]	[0.983]
(Pe) Red mojarra fish	-7.51‡	0.55‡	-0.54‡	[0.001]	[0.190]
(Pe) Roast chicken <i>br1</i>	-6.45‡	0.57‡	-0.59‡	[0.000]	[0.485]
(Pe) Salmon fillets	-6.66‡	0.55‡	-0.54‡	[0.000]	[0.578]
(NPe) Dog food <i>own</i>	-5.48‡	1.81‡	-1.93‡	[0.434]	[0.756]
(NPe) Rice 5kg <i>br1</i>	-6.70‡	1.07‡	-1.08‡	[0.007]	[0.293]
(NPe) Soya oil X 3000cm3 <i>own</i>	-6.87‡	1.39‡	-1.41‡	[0.185]	[0.126]
(NPe) Sugar 2.5kg <i>own</i>	-6.43‡	0.83‡	-0.85‡	[0.587]	[0.132]
(NPe) Toilet paper 12 rolls <i>own</i>	-7.36‡	0.87‡	-0.87‡	[0.181]	[0.777]
(NPe) Bedspread	-3.87‡	0.23	-2.18	[0.515]	[0.313]
(NPe) Pillow 50X70 <i>br1</i>	-6.19‡	0.98‡	0.79	[0.379]	[0.010]
(NPe) Pillow 65X45 <i>br1</i>	-7.43‡	0.52‡	0.53	[0.280]	[0.629]
(NPe) Pressure cooker 6lt <i>br1</i>	-7.55‡	0.51‡	-0.27	[0.257]	[0.013]
(NPe) Set of two towels <i>br1</i>	-1.90	n.a.	n.a.	n.a.	n.a.
(NPe) Car battery <i>own</i>	-5.66‡	1.11‡	-0.93‡	[0.003]	[0.105]
(NPe) Printer paper 75gr	-3.16	n.a.	n.a.	n.a.	n.a.
(NPe) Tyres R13	-5.63‡	0.94‡	-0.78‡	[0.235]	[0.294]

Note: The critical values of the  $t_{BDM}$  statistic for  $k = 1$  are -3.22 and -3.82 at the 5 and 1% significance levels (see Pesaran et al., 2001, Table CII(iii)).  $\mathcal{LR}^{(+)}$  and  $\mathcal{LR}^{(-)}$  denote the long-run price response when there is a permanent change in cost by 1 and -1, respectively. † and ‡ indicate statistical significance at the 5 and 1% levels, respectively. The restriction of short-run symmetry is  $\sum_{i=0}^{q-1} \pi_i^+ = \sum_{i=0}^{q-1} \pi_i^-$  for all  $i = 0, \dots, q - 1$ . The restriction for long-run symmetry is  $\beta^+ = \beta^-$ . Probability values in brackets. n.a. indicates not applicable.