Testing for spatial market integration: Evidence for Colombia using a pair-wise approach*

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Abstract

We examine the extent of spatial market integration in Colombia using consumer price index data for 153 consumer goods in 13 cities. We find that market integration occurs more frequently in food products (both unprocessed and processed) as compared to traded and non-traded ones. There is also evidence that for the relative prices of unprocessed food, processed food and traded goods, the half-life of shocks is positively related to (two alternative measures of) the distance between cities, supporting the view that the speed of adjustment is slower for cities that are farther apart.

JEL Classification: C33; F32; F41.

Keywords: Law of one price; consumer price index data; Colombia.

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1 Introduction

Ever since the writings of Cournot and Marshall, the question of whether the price of a good in spatially separated locations is the same, after allowance is made for the transportation costs and other barriers to trade, has received a great deal of attention. This is because spatial integration helps define the extent of the market, that is, the area within which the interaction of producers and consumers determines the price of a product; see e.g. Stigler (1949) for an early reference, or Stigler and Sherwin (1985) for a treatment with several empirical illustrations. In a well-functioning market, competition guarantees that the effect of a shock to the price of a product in one location propagates to other locations within that market as well, so that producers and consumers are able to exploit arbitrage opportunities. Thus, for example, spatial integration permits distant places to absorb excess local supply, preventing excessive price falls that would otherwise hurt the profitability of local producers (Barrett (2008)). As indicated by Fackler and Goodwin (2001), spatial market integration has often been assessed through tests of the validity of the law of one price (LOOP), either by examining whether the prices of identical products traded in different locations are the same once they are converted to a common currency, as in the case of the absolute version of the law, or by testing whether price discrepancies are stationary, as in the case of the relative version of the law; see e.g. Froot and Rogoff (1995) and Sarno and Taylor (2002).

The main objective of this paper is to investigate the extent of spatial market integration in Colombia. The empirical analysis starts off with a time series approach, but in a way that subsequently also employs information from a cross-sectional dimension. The empirical modelling strategy followed in the paper involves three main stages. First, we use disaggregated consumer price index (CPI) data for different cities to assess the validity of the LOOP in its relative version. This involves testing whether discrepancies in city prices are stationary or, more formally, integrated of order zero. Second, we adapt the Pesaran (2007) pair-wise approach to test for output and growth convergence to the analysis of spatial market integration. Here the idea is that given a sample of N prices, unit root tests are conducted on all possible $(N(N-1)/2)$ price differentials, and then the total fraction of rejections is calculated. This differs from the traditional approach which requires selecting the price of a product in a base city, and then measuring the remaining $(N-1)$ price series against that base price. Under the traditional framework, outcomes may turn out to be highly sensitive to the choice of the base price. In contrast, the pair-wise approach offers the advantage that, by incorporating all possible bivariate relationships, it does not involve what can be a problematic choice of a single reference city in the computation of price differentials. Third, we examine the determinants of the speed of adjustment towards long-run equilibrium. This considers the role played by the distance between cities insofar as one would expect that the speed of adjustment towards long-run equilibrium is fastest between contiguous as opposed to more distant or non-contiguous cities. In doing this, the role played by the relative size between city pairs is also explored.

In a recent paper, Yazgan and Yilmazkuday (2011) apply the Pesaran pair-wise approach to the analysis of price convergence in the United States. Thus, further research on this important topic for a developing economy such as Colombia appears fruitful, as it would enable us to establish similarities and differences between the two countries. In addition to this, and as indicated earlier, a distinguishing feature of our paper is that we also extend the Pesaran pair-wise analysis in an important direction, by formally testing whether the speed at which inter-city price differentials adjusts to shocks (and other innovations) is positively related to the distance between cities. This aspect is not considered by Yazgan and Yilmazkuday (2011) in their analysis of US prices. Lastly, a salient feature of the paper is that we employ two measures of distance between cities, namely the number of kilometers that separates one city from another as one moves along the road network, and the amount of time that is required to cover the journey. The use of these measures is advantageous because, unlike more traditional measures (e.g. greater circle distance), the former takes into consideration the complexities of the existing road network of the country, while the latter accounts for the diverse topographical conditions of the terrain.

The paper proceeds as follows: Section 2 presents a brief review of the literature. Section 3 summarises the econometric modelling strategy. Section 4 presents and discusses the results of the empirical analysis. Section 5 offers some concluding remarks.

2 A brief review of the literature

Although a large number of authors have empirically tested whether markets are spatially integrated, Fackler and Goodwin (2001), for instance, survey more than sixty studies with a focus on agricultural products, not very many of them have explicitly considered the role of distance as a factor that helps to explain the speed of convergence of price discrepancies. Engel and Rogers (1996), using CPI data from 23 North American cities (14 in the United States and 9 in Canada) for 14 good categories sampled from June 1978 to December 1994, find that the distance between cities and the existence of a border between the United States and Canada are important factors determining the variability of relative prices. A more disaggregated analysis is performed by Parsley and Wei (1996) using a database of prices assembled from publications of the American Chamber of Commerce Researchers Association (ACCRA). The database comprises 51 traded and non-traded goods and services in 48 cities of the United States, over the period January 1975 to April 1992. Their findings indicate that the rates at which prices converge are slower for cities farther apart. In subsequent work, Parsley and Wei (2001) find, using a three-dimensional panel data set with the prices of

27 traded goods, over the period 1976Q1 through 1997Q4, across 96 cities in the United States and Japan, that the distributions of relative prices within these countries are markedly less volatile (and on average close to zero) than the corresponding distribution between them; see also Baba (2007) for an analysis using Japanese and Korean city prices. More recently, Yazgan and Yilmazkuday (2011) apply the Pesaran pair-wise approach to ACCRA price data over the period 1990Q1 through 2007Q4, and find not only ample evidence for price-level convergence, but also that the estimated convergence rates have been quicker than previously found in the literature.

In the case of Colombia, Ramírez (1999) provides an initial examination of the idea that the development of the transportation infrastructure lowers the cost of freight and reduces the variability of prices across regions. Using annual price data series for 8 agricultural commodities in 12 cities over the period 1928-1990, this author finds that price dispersion across cities declined sharply following the development of transport infrastructure in the 1930s, but that no major further declines occurred after this decade. Barón (2004) applies unit root tests to aggregate consumer price indices of food and housing in 7 Colombian cities, and finds evidence of stationarity for the relative prices of food but not for housing; this can be viewed as suggesting that market integration holds for traded goods but not for non-traded ones. Iregui and Otero (2011) apply the Hadri (2000) panel stationarity test to CPI data (January 1999 – December 2007) for 54 food products in 13 cities, and find that market integration is favoured when cities have similar population and economic characteristics. In addition to this, the speed of adjustment of prices, measured by the half lives that result from fitting vector autoregressive (VAR) models, and calculating the associated generalised impulse responses, appears faster when food products are perishable.

The role of distance is explicitly considered by Iregui and Otero (2013), who use weekly wholesale price data (01/04/2002 to 03/18/2011) for 18 agricultural products traded in markets scattered around the country, as obtained from the Sistema de Información Agropecuaria assembled by the Corporación Colombia Internacional (CCI). A highly-dimensional VAR model analysis of the half lives associated with shocks to the price series in pairs of markets suggests that for most products the distance between markets exerts a positive influence.

An important distinguishing feature of this paper is that the range of products that we study is much wider than those considered in the previous research.

3 Econometric modelling strategy

The econometric modelling strategy followed in this paper is based on the Pesaran (2007) pair-wise approach to testing for output and growth convergence. Let us denote $p_{i,k,t}$ as the price of good k in city i at time t, and define for a given city pair (i,j) and a given good k at time t, the good-level city price differential (or gap) as $g_{ij,k,t} = p_{i,k,t} - p_{j,k,t}$, where $i = 1, ..., N-1$, $j = i+1, ..., N$, and N is the total number of cities. The idea underlying the pair-wise approach is the examination of the time series properties (that is, the order of integration) of all $(N(N-1)/2)$ possible price differentials. The important point to notice here is that such an approach does not suffer from the potential pitfalls that may be involved when selecting the city price benchmark with respect to which all other prices are going to be measured. In other words, it may well be the case that the price of a good in city i is found as stationary when measured against the price observed in city j, but not when measured against the price in another city.

To examine the time series properties of $g_{ij,k,t}$ we employ the ADF and the $\text{ADF}_{\max}$ unit root tests developed by Dickey and Fuller (1979) and Leybourne (1995), respectively. The first test is the well-known regression-based procedure which, in its basic form, performs a t-test that the first order autoregressive coefficient in a first order autoregressive equation is equal to one (where this simple setup can be suitably extended to deal with the possibility of deterministic components in the data and/or with the presence of residual serial correlation). The second test, in turn, simply takes the maximum of two ADF test statistics, calculated using both forward and reversed data.

Within this framework, consider the ADF ($\text{ADF}_{\max}$) test applied to $g_{ij,k,t}$, and define the indicator function $Z_{ij,k}$ as equal to one if the unit-root null is rejected, at a significance level α. Next, Pesaran (2007) studies the fraction of the $(N(N-1)/2)$ gaps for which the unit root hypothesis is rejected, that is:

$$\bar{Z}_k = \frac{2}{N(N-1)} \sum_{i=1}^{N-1} \sum_{j=i+1}^{N} Z_{ij,k}, \tag{1}$$

and shows that under the null hypothesis of divergence (i.e. non-stationarity), the expected value of $\bar{Z}_k$ must be equal to the nominal size of the underlying unit root test statistic, α. By contrast, under the null of convergence, the proportion of rejections $\bar{Z}_k$ is expected to be high and approach 100% as $T \to \infty$.

While computation of the fraction of rejections $\bar{Z}_k$ may in itself constitute a parameter of interest, see e.g. in Pesaran (2007) and Yazgan and Yilmazkuday (2011), we develop the pair-wise approach further by considering the factors that might help to explain the speed at which relative prices adjust to shocks. To do so, we focus on the inter-city price differentials $g_{ij,k,t}$ for which the unit root null is rejected using the ADF test at the 10% significance level. For these stationary cases, we compute the approximated half-life of a shock (in months) using the well-known formula $-\ln(2/(1+\hat{\delta}))$, where $\hat{\delta}$ indicates the autoregressive coefficient in the corresponding ADF test regression; see e.g. Goldberg and Verboven (2005). The resulting half life is denoted $hl_{ij,k}$ and, in a subsequent stage of the analysis, a regression model is postulated to investigate the factors that may help to explain its variability.

4 Empirical analysis

4.1 Data

The database, obtained from the Departamento Administrativo Nacional de Estadística (DANE), consists of seasonally unadjusted monthly observations on consumer price indices for 153 products in the 13 main metropolitan areas of the country, that is Bogotá, Medellín, Cali, Barranquilla, Cartagena, Cúcuta, Bucaramanga, Pereira, Villavicencio, Pasto, Montería, Manizales and Neiva (where the cities have been listed in terms of their population, from largest to smallest). For this study, and in order to facilitate the presentation of our results, we adopt the classification of products used by the Banco de la República (the country's central bank) in its quarterly inflation report; see e.g. Banco de la República (2013). Thus, we consider three broadly defined categories, namely food (54), traded (71) and non-traded (28) products. Within the food category, we make a further distinction between unprocessed (17) and processed (37) products, where the distinguishing factor between the two groups is the degree of perishability of the good. The Data Appendix provides the detailed list of all products included in this study.[1] The sample period spans from January 1999 to February 2013, for a total of 170 time observations, and all price indices are considered after applying the logarithmic transformation.

4.2 Pair-wise tests of market integration

Table 1 reports the fraction of rejections of both the ADF and ADF_{max} unit root tests for the four product categories under consideration, based on all possible $(13 \times 12)/2 = 78$ price differentials. The tests are performed at the 5 and 10% significance levels (although only the latter are reported to

[1]The products under consideration account for more than 90% of the overall consumer price index. The remaining share corresponds to products whose prices are regulated (such as utilities, petrol and bus fares, among others) and therefore exhibit little variation over time and/or across metropolitan areas.

save space), a linear trend is included in the test regression if it is significant at the 5% level (using standard normal tables), and the optimal lag length is determined using the Akaike information criterion (AIC), with $p_{max} = 3$ lags. Considering first the results of the ADF test, it is interesting to see that the fraction of rejections varies depending on the type of product, being largest for unprocessed foods (86%), and followed by that of processed foods (54%). Smaller fractions of stationary price differentials are obtained for non-tradeable and tradeable goods with 40% and 36%, respectively. Qualitatively similar results are observed when one considers the percentages obtained when applying the ADF$_{max}$ test, although in this case the percentages of rejection are smaller for processed foods as well as for non-tradeable and tradeable goods. These findings support the view that the nature of the good appears to be a factor underlying the extent of market integration.

At this stage of the analysis, it is worth comparing our results with those obtained by Yazgan and Yilmazkuday (2011) for the United States (assuming that the product categories in the two studies consist of similar goods). In particular, these authors find that the percentages of rejection for non-perishable and non-traded good categories are equal to 60% and 44%, respectively, which are somewhat similar to our estimates for processed and non-traded goods reported above (where the comparison is based on the results obtained for the ADF test at the 10% level of significance, using the AIC to select the optimal numbers of lags). By contrast, the percentage of rejection obtained by Yazgan and Yilmazkuday for perishable goods (i.e. 58%) is lower than our estimate for unprocessed food goods.

Next, we examine whether the speed at which relative prices adjust to exogenous shocks is also related to the type of good. To do this, for each product, k, we consider only the inter-city price differentials that are stationary, based on the ADF test at the 10% significance level, and for these cases we compute the approximate half-life of a shock, which we denote as $hl_{ij,k}$. Then, the resulting half-lives are averaged by product and then by product category; see Table 2 for the results of each product category, or Table C1 in Appendix C for the results at the product level. Assuming that the half-life of a shock is inversely related to the speed of adjustment of the corresponding relative price, our findings suggest that the speed of adjustment is quickest for unprocessed and processed food products, where the average half lives are approximately 3.4 and 5.5 months, respectively. It is interesting to note that, despite difference in methodology and study period, our findings for food products corroborate those obtained by Iregui and Otero (2011). Regarding traded and non-traded products, the resulting average half lives reported in Table 2 are very similar (about 8 months). We argue that the low speed of price adjustment for traded goods in Colombia may be due to the fact that the products in this category are mainly manufactures, whose prices tend to have more of a fixed-price characteristic because of market concentration in the industrial sector. By contrast, and as pointed out by Ardeni and Freebairn (2002), agricultural product prices tend to be more of the flex-price type because of the presence of (almost) perfect competition, the influence of seasonal and climatic fluctuations, the fact that most agricultural activities are greatly dispersed on the territory, and the restrictions imposed by limited technological progress in the sector. This result is in sharp contrast to Yazgan and Yilmazkuday (2011), where the convergence rate for non-traded goods is estimated at about twice the rates obtained for perishable and non-perishable goods.

In addition to the results over the whole sample period, we also assess the time-varying nature of the speed of adjustment as successively larger sub-samples are employed for estimation. Thus, Figure 1 summarises the results when the half lives of the shocks are estimated recursively, starting with the sample sub-period 1999m1 to 2010m1, then 1999m1 to 2010m2, and so on until 1999m1 to 2013m2 (for each product category the resulting half lives are scaled by dividing them by the corresponding value in 1999m1). As can be seen from the plot, the half lives exhibit an upward movement supporting the view of slower speed of adjustment as time passes. This upward trend is particularly noticeable for processed food, traded and non-traded products, and to a lesser extent for unprocessed food products. Results at the product level (not reported here for brevity) allow us to detect a similar upward trend in the overwhelming majority of the cases, with the exceptions occurring in the unprocessed food category in items such as blackberries, cassava, plantain and potato (all varieties).

4.3 Determinants of the speed of adjustment

The analysis that follows is based on the underlying idea that price adjustments ought to take longer for cities that are farther apart. Often, the variable that has been employed in the literature to measure this effect is the (greater circle) distance between city pairs i and j; see e.g. Engel and Rogers (1996) and Parsley and Wei (1996). An important issue here is in recognising that this measure does not take into account the complexities of the road network of a country, nor the fact that covering a given distance may take different times depending on the topographical conditions of the terrain. In Colombia, for instance, the (greater circle) distance between the cities of Bogotá and Cartagena is shorter than the existing one between Bogotá and Barranquilla. However, this result is no longer valid when distance is measured by moving along the road network, as, in order to go from Bogotá to Cartagena, one has to go to Barranquilla first. Because of these considerations, we opt for two alternative measures: the first one is the distance travelled through the road network between city pairs i and j (in kilometers); and the second one is the average time it takes to go from city i to city j (in minutes). Both measures are considered in logarithms and denoted $\ln dist_{ij}$ and $\ln durt_{ij}$, respectively.[2]

[2] These variables are calculated using a personalised Java script that employs the Google Maps API v3 search engine. We are most grateful to Armando Galvis who kindly provided these data.

Examining the validity of the law of one price, Esaka (2003) argues in favour of selecting similar cities, as deviations from equilibrium may occur because of variations in consumption preferences across cities and/or in population size. Thus, it appears conceivable to ask whether the degree of similarity of a city pair is also a factor that affects the speed at which relative prices adjust. To formally test for this, we consider relative population density as an additional regressor, measured by the absolute value of the difference of the logarithms of the population densities of cities i and j, that is $\ln popd_{ij} = |\ln pop_i - \ln pop_j|$; the source of these data is DANE.

The resulting regression model to examine the determinants of the (logarithm of the) half-lives of shocks affecting relative prices is therefore:

$$\begin{aligned} \ln(hl_{ij,k}) = \beta_1 + \beta_2 \ln(popd_{ij}) + \beta_3 \ln(X_{ij}) \\ + \text{Product Dummies} + \varepsilon_{ij,k}, \end{aligned} \tag{2}$$

where X_{ij} is either $dist_{ij}$ or $durt_{ij}$, depending on the way the geographic separation of cities is measured, and $\varepsilon_{ij,k}$ is the error term in the regression. Notice that the model specified in equation (2) allows for product effects by means of the inclusion of product dummy variables. As customary, the estimate of the intercept term must be interpreted as the product against which comparisons are made, namely potatoes, beef, medicines and estimated rents for unprocessed foods, processed foods, traded and non-traded products, respectively.

Ordinary least squares estimation of the two variants of equation (2) yields the results summarised in Table 3. The estimated coefficient on $\ln dist_{ij}$ (or $\ln durt_{ij}$) is positive and statistically significant for all group categories, except for non-traded goods. This provides support for the view that the greater the geographical separation between cities, the longer it takes for their relative prices to adjust. Interestingly, this finding does not apply for the category of non-traded goods, where the estimated coefficient is not statistically different from zero; in other words, for goods that (for whatever reason) can only be consumed in the economy where they are produced, the distance to other markets is not a relevant factor affecting the speed at which their prices change, as would be expected. From a policy perspective, the results in equation (2) highlight the role that policy measures aimed at improving marketing infrastructure can play in securing (more) competitive markets all over the country.

As to relative population density, this variable turns out to be statistically significant only for the category of unprocessed foods. In this case, the estimated negative coefficient suggests that the speed of adjustment of prices increases when cities are of different sizes. Bearing in mind that unprocessed foods are mostly perishable products, this finding may be thought of as supporting the idea of corrective movements by buyers and/or sellers so that arbitrage opportunities are exploited regardless of the size of the locations where products are traded. Lastly, in all estimated regression models the product-specific dummy variables are jointly statistically significant, suggesting the need to account for product heterogeneity when modelling the speed of adjustment of relative prices.

5 Concluding remarks

In this paper we use disaggregated CPI data for 153 goods to investigate the extent of market integration in Colombia. The empirical modelling exercise draws on a pair-wise time series approach, but in a way that also utilises information from a cross-section dimension. The pair-wise approach is based on the idea of examining the time series properties of all possible city-pair price differentials for a given good. This is in contrast with the usual approach where attention is confined to the analysis of prices relative to a benchmark city, and so the selection of this benchmark might affect the outcome. Our findings reveal strong support in favour of adjustment to the relative version of the LOOP for unprocessed foods, followed by processed foods. By contrast, less support for the LOOP is found for traded and non-traded goods, which is surprising for the former category of goods, but not for the latter. We argue that the reason why a smaller number of price differentials are found to be stationary for traded goods may have to do with the market concentration that appears to characterise the manufacturing sector in Colombia.

A subsequent cross section analysis of the speed of adjustment of city price differentials reveals an interesting spatial dimension in the way prices adjust to shocks in Colombia. Indeed, we uncover evidence that for unprocessed, processed and traded goods, it takes more time for price shocks to disappear when cities are farther apart. This is regardless of whether one measures distance in kilometers through the road network, or as the time it takes to go from city to another. Distance does not appear to matter for non-traded goods. In a sense, one might think that the inclusion of the latter category serves the purposes of a control group. Lastly, the speed of adjustment of the prices of unprocessed food increases when cities are of different sizes (as measured by their population densities).

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Table 1: Proportion of stationary price differentials

Category	ADF	ADF_{max}
Unprocessed food	0.860	0.883
Processed food	0.536	0.481
Tradeable	0.359	0.250
Non-tradeable	0.396	0.240

Note: The underlying unit-root test regressions include linear trend if it is statistically significant at the 5% level, and the number of lags is selected using the Akaike information criterion with $p_{max} = 3$ lags. Both the ADF and ADF_{max} tests are performed at the 10% significance level. For each category, the proportion of stationary price differentials corresponds to the simple average of the proportion of stationary price differentials of the corresponding products.

Table 2: Half-life of a shock: Summary results by product category

Product category	Duration in months				
	hl	0 to 3	3 to 6	6 to 12	12 to +
Unprocessed food	3.4		⋆		
Processed food	5.5		⋆		
Traded	8.0			⋆	
Non-traded	8.1			⋆	

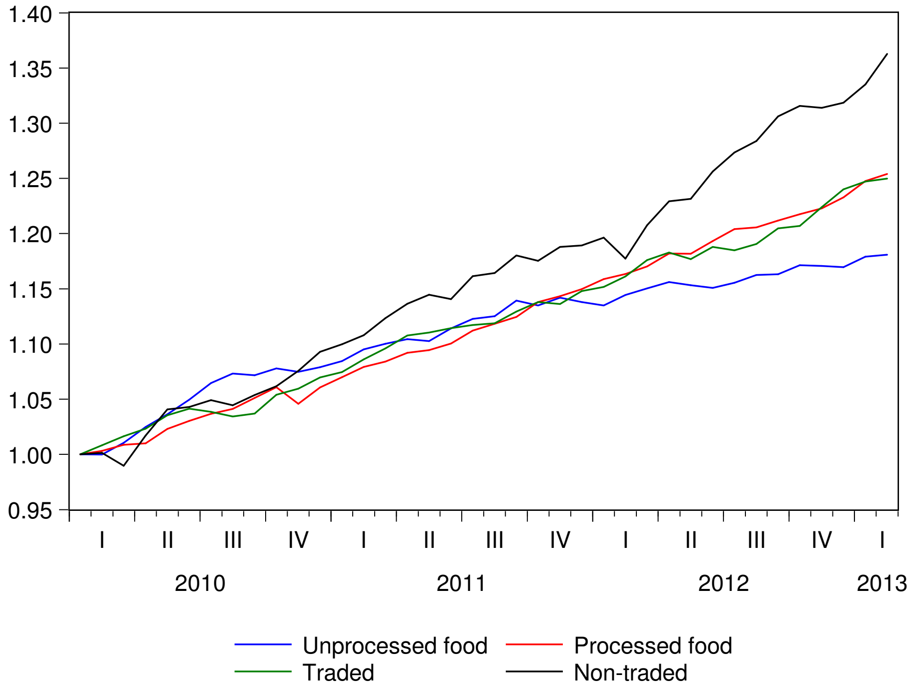
The half-life of each category is measured in months, and corresponds to the simple average of the half-lives of the individual products.

Table 3: Determinants of the half-life of inter-city price differentials

	Food							
	Unprocessed		Processed		Traded		Non-traded	
Intercept	0.361	0.392	1.090	1.148	2.020	2.054	2.256	2.251
	(0.169)	(0.157)	(0.145)	(0.135)	(0.197)	(0.192)	(0.327)	(0.311)
$\ln durt_{ij}$	0.086		0.100		0.051		-0.027	
	(0.025)		(0.021)		(0.020)		(0.040)	
$\ln dist_{ij}$		0.082		0.092		0.046		-0.027
		(0.023)		(0.020)		(0.018)		(0.037)
$\ln popd_{ij}$	-0.029	-0.030	0.008	0.007	0.011	0.011	0.007	0.007
	(0.012)	(0.012)	(0.012)	(0.012)	(0.011)	(0.011)	(0.019)	(0.019)
Obs.	1141	1141	1546	1546	1990	1990	864	864
R^2	0.554	0.554	0.225	0.225	0.228	0.228	0.273	0.273
F-stat.	94.030	93.918	11.550	11.509	11.459	11.466	21.328	21.299

Note: The numbers in parentheses are White's heteroskedastic consistent standard errors. All regression include product-specific dummy variables.

Figure 1: Recursive estimates of the half life of a shock



Note: The half lives of the shocks have been normalised so that they are equal to 1 in 2010m01.

A Data appendix

The following are the products included within each category:

Unprocessed food (17 products): Bananas; blackberries; carrots; cassava; eggs (all sizes); fresh vegetables; kidney beans (fresh, dried); onion (all varieties); oranges; other dried vegetables (lentils, chickpea); other fresh fruits; other roots; peas (fresh, dried); plantain; potato (all varieties); tomato; and tree tomato.

Processed food (37 products): Beef (all cuts); bread (all varieties); burger in bun - eat in; canned vegetables (kidney beans; peas); canteen meals; cereals (all varieties); cheese (all types); chicken (all cuts); chocolate; coffee; cold fast food; fats; fish (all types); flour (all varieties); hot fast food; juices; milk (all types); oils (soya, maize, sunflower); other bakery products; other cereals; other condiments; other dairy products; other fish products; other groceries (crisps, jam); other meats; other non-alcoholic beverages; panela (sugar cane by-product); pasta (all varieties); pork (all cuts); restaurant meals; rice (all varieties); salt; soft drinks; soups and creams; sugar; various jams; and various sauces.

Non-traded goods (28 products): Bedroom furniture; car park charges; dining room furniture; dry-cleaning; enrollment fees; enrollment fees (higher education); estimated rents; gaming (e.g. lottery tickets); hairdressing fees; hospital and ambulance charges; lab exams; living room furniture; other education expenses; other household furniture; other personal grooming services; postal charges; prepaid medicine and health insurance; private general medical and dental examinations; private specialised medical examination; recreational services; rents; school fees; tailoring and hiring of clothing; television services; tourism; various bank charges; vehicle maintenance and repairs; and X-rays, ultrasound scans and electrocardiograms.

Traded goods (71 products): Aguardiente (spirit); air fares; audio systems and recorders; babies clothing (underwear); bed linen; beer; blankets and bedspreads; books; boy's trousers; car batteries; car service (motor oil); car tyres; compact disks; children's clothing (trousers); children's clothing (various shirts); children's footwear; cigarettes; cleaning products and disinfectants; clocks and watches; cooker (all types); corporal hygiene products; crockery set; curtains; cutlery set; dishwasher; equipment for house; facial care (various cosmetics); fridge/freezer; hair care products; insecticides; jewellery (gold and silver); kitchen equipment; mattresses and pillows; medicines; men's clothing (trousers and jeans); men's clothing (underpants, t-shirts, socks); men's clothing (various shirts); men's footwear; nappies and others; newspapers; non-durable kitchen goods; notebooks; oral hygiene products; orthopaedic equipment and others; other alcoholic drinks; other audio-visual equipment; other children's clothing; other household electric appliances; other medicines and contraceptives; other men's clothing; other motoring expenditure; other personal effects; other personal grooming products; other recreational items; other school expenses; other school materials; other telephone services; other women's clothing; periodicals; soaps; sport shoes; sports equipment (e.g. bicycles); televisions; textbooks; towels, tablecloths and furniture covers; washing powder, bleach and fabric conditioners; waxes (solid and liquid); women's clothing (blouses); women's clothing (trousers and jeans); women's clothing (underwear); and women's footwear.

B Proportion of stationary price differentials

Table B.1: Detailed results for categories and products

Group	ADF	ADF_{max}
Bananas	0.795	0.872
Blackberries	0.859	0.872
Carrots	0.987	0.949
Cassava	0.885	0.885
Eggs (all sizes)	0.756	0.769
Fresh vegetables	0.910	0.949
Kidney beans (fresh, dried)	0.731	0.821
Onion (all varieties)	0.936	0.949
Oranges	0.962	1.000
Other dried vegetables (lentils, chickpea)	0.269	0.385
Other fresh fruits	0.821	0.782
Other roots	0.872	0.962
Peas (fresh, dried)	0.974	0.974
Plantain	0.897	0.923
Potato (all varieties)	0.987	0.974
Tomato	1.000	1.000
Tree tomato	0.987	0.949
Unprocessed food	0.860	0.883
Beef (all cuts)	0.538	0.667
Bread (all varieties)	0.423	0.385
Burger in bun - eat in	0.321	0.231
Canned vegetables (kidney beans, peas)	0.667	0.179
Canteen meals	0.449	0.269
Cereals (all varieties)	0.564	0.410
Cheese (all types)	0.679	0.564
Chicken (all cuts)	0.603	0.410
Chocolate	0.333	0.321
Coffee	0.731	0.756
Cold fast food	0.346	0.141
Fats	0.423	0.449
Fish (all types)	0.615	0.603
Flour (all varieties)	0.423	0.410
Hot fast food	0.462	0.282
Juices	0.487	0.487
Milk (all types)	0.513	0.526
Oils (soya, maize, sunflower)	0.718	0.615
Other bakery products	0.577	0.590
Other cereals	0.500	0.397
Other condiments	0.526	0.192
Other dairy products	0.526	0.577
Other fish products	0.679	0.449

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Table B.1 – *Continued from previous page*

Group	ADF	ADF$_{max}$
Other groceries (crisps, jam)	0.282	0.333
Other meats	0.462	0.449
Other non-alcoholic beverages	0.372	0.436
Panela (sugar cane by-product)	0.500	0.372
Pasta (all varieties)	0.641	0.756
Pork (all cuts)	0.500	0.551
Restaurant meals	0.551	0.256
Rice (all varieties)	0.833	0.859
Salt	0.538	0.667
Soft drinks	0.564	0.628
Soups and creams	0.641	0.654
Sugar	0.615	0.705
Various jams	0.654	0.641
Various sauces	0.564	0.590
Processed food	0.536	0.481
Aguardiente (spirit)	0.385	0.269
Air fares	0.872	0.038
Audio systems and recorders	0.269	0.321
Babies clothing (underwear)	0.064	0.128
Bed linen	0.282	0.231
Beer	0.385	0.333
Blankets and bedspreads	0.256	0.141
Books	0.385	0.231
Boy's trousers	0.321	0.231
Car batteries	0.321	0.295
Car service (motor oil)	0.321	0.231
Car tyres	0.231	0.192
Compact disks	0.397	0.423
Children's clothing (trousers)	0.218	0.115
Children's clothing (various shirts)	0.346	0.167
Children's footwear	0.103	0.026
Cigarettes	0.397	0.308
Cleaning products and disinfectants	0.577	0.500
Clocks and watches	0.333	0.218
Cooker (all types)	0.308	0.179
Corporal hygiene products	0.564	0.410
Crockery set	0.167	0.218
Curtains	0.244	0.064
Cutlery set	0.397	0.244
Dishwasher	0.269	0.282
Equipment for house	0.244	0.167
Facial care (various cosmetics)	0.526	0.397
Fridge/freezer	0.462	0.256
Hair care products	0.551	0.372

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Table B.1 – *Continued from previous page*

Group	ADF	ADF_{max}
Insecticides	0.372	0.269
Jewellery (gold and silver)	0.385	0.231
Kitchen equipment	0.321	0.359
Mattresses and pillows	0.449	0.321
Medicines	0.321	0.115
Men's clothing (trousers and jeans)	0.269	0.205
Men's clothing (underpants, t-shirts, socks)	0.385	0.256
Men's clothing (various shirts)	0.179	0.115
Men's footwear	0.282	0.090
Nappies and others	0.410	0.436
Newspapers	0.410	0.179
Non-durable kitchen goods	0.615	0.705
Notebooks	0.615	0.397
Oral hygiene products	0.333	0.308
Orthopaedic equipment and others	0.295	0.167
Other alcoholic drinks	0.423	0.308
Other audio-visual equipment	0.295	0.218
Other children's clothing	0.487	0.192
Other household electric appliances	0.321	0.231
Other medicines and contraceptives	0.615	0.538
Other men's clothing	0.256	0.103
Other motoring expenditure	0.346	0.333
Other personal effects	0.090	0.103
Other personal grooming products	0.372	0.179
Other recreational items	0.103	0.000
Other school expenses	0.449	0.308
Other school materials	0.269	0.103
Other telephone services	0.333	0.154
Other women's clothing	0.346	0.090
Periodicals	0.449	0.500
Soaps	0.385	0.449
Sport shoes	0.205	0.179
Sports equipment (e.g. bicycles)	0.372	0.167
Televisions	0.372	0.308
Textbooks	0.423	0.333
Towels, tablecloths and furniture covers	0.436	0.295
Washing powder, bleach and fabric conditioners	0.667	0.705
Waxes (solid and liquid)	0.500	0.321
Women's clothing (blouses)	0.231	0.128
Women's clothing (trousers and jeans)	0.218	0.115
Women's clothing (underwear)	0.385	0.154
Women's footwear	0.333	0.103
Traded	0.359	0.250
Bedroom furniture	0.474	0.269

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Table B.1 – *Continued from previous page*

Group	ADF	ADF$_{max}$
Car park charges	0.244	0.026
Dining room furniture	0.321	0.192
Dry-cleaning	0.423	0.256
Enrollment fees	0.218	0.282
Enrollment fees (higher education)	0.590	0.295
Estimated rents	0.090	0.026
Gaming (e.g. Lottery tickets)	0.359	0.179
Hairdressing fees	0.359	0.128
Hospital and ambulance charges	0.410	0.205
Lab exams	0.256	0.192
Living room furniture	0.410	0.218
Other education expenses	0.538	0.256
Other household furniture	0.346	0.205
Other personal grooming services	0.385	0.192
Postal charges	0.205	0.256
Prepaid medicine and health insurance	0.654	0.538
Private general medical and dental examinations	0.141	0.090
Private specialised medical examination	0.410	0.154
Recreational services	0.628	0.628
Rents	0.192	0.064
School fees	0.551	0.410
Tailoring and hiring of clothing	0.244	0.051
Television services	0.641	0.154
Tourism	0.462	0.462
Various bank charges	0.628	0.667
Vehicle maintenance and repairs	0.513	0.218
X-rays, ultrasound scans and electrocardiograms	0.385	0.103
Non-traded	0.396	0.240

Note: The underlying unit-root test regressions include linear trend if it is statistically significant at the 5% level, and the number of lags is selected using the Akaike information criterion with $p_{max} = 3$ lags. Both the ADF and ADF$_{max}$ tests are performed at the 10% significance level. For each category, the proportion of stationary price differentials corresponds to the simple average of the proportion of stationary price differentials of the corresponding products.

C Estimated half-life of a shock

Table C.1: Detailed results for categories and products

Product	Duration in months				
	hl	0 to 3	3 to 6	6 to 12	12 to +
Bananas	4.0		⋆		
Blackberries	2.2	⋆			
Carrots	2.2	⋆			
Cassava	5.7		⋆		
Eggs (all sizes)	3.4		⋆		
Fresh vegetables	2.9	⋆			
Kidney beans (fresh, dried)	5.9		⋆		
Onion (all varieties)	3.0	⋆			
Oranges	2.6	⋆			
Other dried vegetables (lentils, chickpea)	5.4		⋆		
Other fresh fruits	3.5		⋆		
Other roots	6.5			⋆	
Peas (fresh, dried)	1.9	⋆			
Plantain	2.9	⋆			
Potato (all varieties)	2.6	⋆			
Tomato	0.9	⋆			
Tree tomato	2.7	⋆			
Unprocessed food	3.4		⋆		
Beef (all cuts)	6.0			⋆	
Bread (all varieties)	5.9		⋆		
Burger in bun - eat in	5.3		⋆		
Canned vegetables (kidney beans, peas)	6.7			⋆	
Canteen meals	5.6		⋆		
Cereals (all varieties)	4.5		⋆		
Cheese (all types)	3.3		⋆		
Chicken (all cuts)	4.5		⋆		
Chocolate	4.2		⋆		
Coffee	3.7		⋆		
Cold fast food	6.9			⋆	
Fats	5.3		⋆		
Fish (all types)	4.6		⋆		
Flour (all varieties)	8.0			⋆	
Hot fast food	5.9		⋆		
Juices	8.3			⋆	
Milk (all types)	5.4		⋆		
Oils (soya, maize, sunflower)	5.2		⋆		
Other bakery products	4.6		⋆		
Other cereals	6.2			⋆	
Other condiments	10.6			⋆	

Continued on next page

Table C.1 – *Continued from previous page*

Product	Duration in months				
	hl	0 to 3	3 to 6	6 to 12	12 to +
Other dairy products	4.9		⋆		
Other fish products	5.4		⋆		
Other groceries (crisps, jam)	5.6		⋆		
Other meats	4.3		⋆		
Other non-alcoholic beverages	6.3			⋆	
Panela (sugar cane by-product)	7.0			⋆	
Pasta (all varieties)	4.9		⋆		
Pork (all cuts)	5.7		⋆		
Restaurant meals	7.0			⋆	
Rice (all varieties)	3.2		⋆		
Salt	5.1		⋆		
Soft drinks	4.7		⋆		
Soups and creams	4.7		⋆		
Sugar	4.6		⋆		
Various jams	4.0		⋆		
Various sauces	4.8		⋆		
Processed food	5.5		⋆		
Aguardiente (spirit)	6.4			⋆	
Air fares	9.0			⋆	
Audio systems and recorders	7.1			⋆	
Babies clothing (underwear)	6.3			⋆	
Bed linen	7.2			⋆	
Beer	5.5		⋆		
Blankets and bedspreads	12.9				⋆
Books	6.6			⋆	
Boy's trousers	7.8			⋆	
Car batteries	6.2			⋆	
Car service (motor oil)	7.6			⋆	
Car tyres	7.7			⋆	
Compact disks	4.4		⋆		
Children's clothing (trousers)	7.7			⋆	
Children's clothing (various shirts)	10.3			⋆	
Children's footwear	11.9			⋆	
Cigarettes	6.2			⋆	
Cleaning products and disinfectants	6.3			⋆	
Clocks and watches	7.9			⋆	
Cooker (all types)	8.1			⋆	
Corporal hygiene products	6.0			⋆	
Crockery set	7.1			⋆	
Curtains	15.8				⋆
Cutlery set	6.7			⋆	
Dishwasher	6.7			⋆	

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Table C.1 – *Continued from previous page*

Product	Duration in months				
	hl	0 to 3	3 to 6	6 to 12	12 to +
Equipment for house	9.0			⋆	
Facial care (various cosmetics)	6.0			⋆	
Fridge/freezer	6.1			⋆	
Hair care products	5.8		⋆		
Insecticides	5.9		⋆		
Jewellery (gold and silver)	6.8			⋆	
Kitchen equipment	5.1		⋆		
Mattresses and pillows	6.9			⋆	
Medicines	14.8				⋆
Men's clothing (trousers and jeans)	8.4			⋆	
Men's clothing (underpants, t-shirts, socks)	10.3			⋆	
Men's clothing (various shirts)	11.6			⋆	
Men's footwear	10.0			⋆	
Nappies and others	5.2		⋆		
Newspapers	9.2			⋆	
Non-durable kitchen goods	4.8		⋆		
Notebooks	6.3			⋆	
Oral hygiene products	8.1			⋆	
Orthopaedic equipment and others	7.8			⋆	
Other alcoholic drinks	6.4			⋆	
Other audio-visual equipment	5.7		⋆		
Other children's clothing	9.7			⋆	
Other household electric appliances	5.3		⋆		
Other medicines and contraceptives	6.6			⋆	
Other men's clothing	11.3			⋆	
Other motoring expenditure	5.5		⋆		
Other personal effects	11.7			⋆	
Other personal grooming products	8.7			⋆	
Other recreational items	3.8		⋆		
Other school expenses	8.5			⋆	
Other school materials	10.3			⋆	
Other telephone services	5.4		⋆		
Other women's clothing	9.5			⋆	
Periodicals	6.7			⋆	
Soaps	5.1		⋆		
Sport shoes	8.3			⋆	
Sports equipment (e.g. bicycles)	9.5			⋆	
Televisions	6.7			⋆	
Textbooks	6.1			⋆	
Towels, tablecloths and furniture covers	7.7			⋆	
Washing powder, bleach and fabric conditioners	4.2		⋆		
Waxes (solid and liquid)	6.2			⋆	
Women's clothing (blouses)	9.3			⋆	

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Table C.1 – *Continued from previous page*

Product	Duration in months				
	hl	0 to 3	3 to 6	6 to 12	12 to +
Women's clothing (trousers and jeans)	15.8				⋆
Women's clothing (underwear)	15.2				⋆
Women's footwear	16.9				⋆
Traded	8.0			⋆	
Bedroom furniture	6.2			⋆	
Car park charges	15.1				⋆
Dining room furniture	8.4			⋆	
Dry-cleaning	8.9			⋆	
Enrollment fees	3.8		⋆		
Enrollment fees (higher education)	6.9			⋆	
Estimated rents	9.4			⋆	
Gaming (e.g. Lottery tickets)	4.5		⋆		
Hairdressing fees	10.6			⋆	
Hospital and ambulance charges	8.9			⋆	
Lab exams	8.0			⋆	
Living room furniture	6.5			⋆	
Other education expenses	9.0			⋆	
Other household furniture	8.2			⋆	
Other personal grooming services	10.0			⋆	
Postal charges	4.1		⋆		
Prepaid medicine and health insurance	5.0		⋆		
Private general medical and dental examinations	18.8				⋆
Private specialised medical examination	12.7				⋆
Recreational services	5.5		⋆		
Rents	10.2			⋆	
School fees	4.2		⋆		
Tailoring and hiring of clothing	8.8			⋆	
Television services	8.1			⋆	
Tourism	5.5		⋆		
Various bank charges	3.5		⋆		
Vehicle maintenance and repairs	8.1			⋆	
X-rays, ultrasound scans and electrocardiograms	9.0			⋆	
Non-traded	8.1			⋆	