Non-linear adjustment in law of one price deviations and physical characteristics of goods

Berka, Martin
Massey University, Department of Commerce

November 2006

Non-linear adjustment in law of one price deviations and physical characteristics of goods

Martin Berka
Department of Commerce, Massey University*

Abstract

At the level of individual goods, heterogeneity in marginal transaction costs, proxied by price-to-weight and price-to-volume ratios, together with measures of pricing power within industries, explains a large part of the variation in thresholds of no-adjustment as well as in conditional half-life of law of one price deviations. Prices of goods that are more heavy or voluminous deviate further before becoming mean-reverting. Moreover, after becoming mean-reverting, prices of heavier (more voluminous) goods converge more slowly. Size of the market is also important in explaining threshold heterogeneity. These factors explain up to 60% of the variation in no-adjustment threshold estimates across 49 goods in US-Canada post Bretton Woods monthly CPI data.

These results open two avenues for the importance of marginal transaction costs in accounting for real exchange rate persistence: first through generating persistence in individual real exchange rate components, and second by accentuating persistence in the process aggregation of heterogeneous components (the "aggregation bias" of Imbs, et. al. 2005). They also highlight the relevance of theoretical modeling of transaction frictions for understanding real exchange rate persistence.

Keywords: Law of One Price Deviations, Real Exchange Rate Persistence, Non-Linearities, transaction costs, Physical Weight, Physical Volume, Threshold Autregressive Models

JEL Classification: F36, F31

*Private Bag 102 904, Auckland, New Zealand, ph: +649-414-0800 ext 9474, fax: +649-441-8177, email: m.berka@massey.ac.nz

1 Introduction

This paper shows that the non-linear behaviour of differences in prices of traded products between Canada and US is significantly related to the marginal shipping costs proxied by the physical characteristics of the products. Estimates of thresholds in law of one price deviations for goods are significantly negatively related to price-to-weight ratios and price-to-volume ratios of the same products. Size of the market is also important in explaining threshold heterogeneity: goods with smaller market shares tend to have wider thresholds. These factors explain up to 60% of the variation in threshold estimates. Furthermore, estimates of half-lives of convergence outside of said thresholds are also significantly negatively related to price-to-weight ratios and stowage factors. Not only do price differences of goods goods that are relatively heavier deviate further before becoming mean-reverting, price differences also persist longer outside of said thresholds.

These results suggest existence of two channels through which marginal shipping costs generate persistence in price deviations of traded goods: directly through "iceberg costs" and indirectly by affecting optimal decisions for the mode of transport. Due to the heterogeneity in the marginal shipping costs of traded goods, the two effects can be respectively detected in the heterogeneous thresholds of price deviations as well as in the heterogeneous conditional half-lifes. Consequently, detailed modeling of marginal shipping costs as an empirically important avenue for explaining persistence and volatility of price deviations[1].

The empirical framework in this paper is based on the role that transaction costs play in impeding arbitrage. Many theories of international price deviations rely on the existence of sticky prices in an environment with real rigidities. Such theories explicitly assume limits to arbitrage, implying very large transaction costs. In the extreme case, markets in such models are segmented in the presence of local currency pricing by firms and households cannot arbitrage away price differences (e.g., Betts and Devereux (2000)). Trade and open macro models often link differences in prices to transportation frictions by assuming that a form of shipping costs is added to the price of the product at the point of origin (or,

[1]To the extent that this heterogeneity is important for our understanding of the persistence in the deviations of real exchange rates (see the "aggregation bias" discussion: Imbs et. al. (2004), (2005), Chen and Engel (2004)), this result contributes to our understanding of PPP puzzle as well.

equivalently, that a fraction of the product's value disappears in the course of transport). Even with market segmentation and pricing to market these theories frequently include a condition $p_{it} = p^*_{it}/(1-\tau)$ where p_{it} is a c.i.f. price of good i at time t in home country (measured at factory gates), p^* is price of the same good abroad and τ is an iceberg shipping cost (Obstfeld & Rogoff (2000), Novy (2006)). The above condition is observationally equivalent to arbitrage condition at the level of factory gate prices.

Hecksher (1916) showed the importance of arbitrage for sustainability of price deviations in his calculation of the "commodity points". In a modern application of that idea, Obstfeld and Taylor (1997) found that such commodity points were visible in the non-linearity of deviations in sectoral law of one price deviations when estimated by threshold-autoregressive (TAR) models. Their estimates of non-linear threshold are positively related to distance and exchange rate volatility, both measures of transaction costs. Zussmann (2002) finds that tariffs also determine the width of the no-arbitrage band. Imbs et. al. (2003) confirm these results and show existence of a similar relationship between transaction costs and conditional half-lives of deviations in prices outside the thresholds. All studies find heterogeneity across sectors in threshold estimates or estimates of conditional half-lives.

This paper argues that, at the level of individual goods, marginal shipping costs vary in proportion to the "relative value" of goods, i.e., their price-to-weight or price-to-volume ratios. The key insight is that physical characteristics of goods matter in shipment (the dependance of freight rates on weight and volume relative to their price has been documented by Hummels 1999, 2001). Ceteris paribus, trade friction create a smaller ad-valorem wedge for goods that are lighter or less voluminous relative to their price (high-valued products). Conversely, goods with large volume or weight relative to their price sustain larger deviations before the price difference justifies shipment[2]. To the extent that the heterogeneity in price deviations across goods and services contributes to the dynamics of aggregate real exchange rates (e.g., through the "aggregation effect" in Imbs et. al. (2005)), marginal shipping costs are also important for explaining the persistence and volatility components of the PPP puzzle.

[2]For example, a 10% difference in price of a PC between downtown and a suburb may offset the transport costs to a more distant location. But a 10% price difference of a less valuable good - e.g., an equally-sized bag of potatoes - may be insufficient to justify the transport from an equally far-away location.

The remainder of the paper is structured as follows: section 2 outlines the idea, section 3 discusses the data, section 4 presents the results and section 5 concludes.

2 Arbitrage

Many open macro (Novy 2006) and trade (Hummels and Skiba 2004) models imply that shipping costs and trade barriers lead to differences in prices of goods, at least at the dock level. Such condition is commonly expressed as $SP_{j,g} = P_{i,g} + A_{i,j,g}$ where $P_{i,g}$ is the local currency price of good g in country i, S the nominal exchange rate between i and j and $A_{i,j,g}$ the marginal transaction cost. $A_{i,j,g}$ is usually modeled as a constant consisting of marginal transport cost[3] and marginal trade barrier (tariffs, etc.): $A_{i,j,g} = t + B$. It can be interpreted as the minimum price difference that makes arbitrage trade profitable between i and j. In an environment with perfectly competitive transport sector using constant returns to scale technology and where sellers of goods have no pricing power, price differences in excess of marginal transaction costs would be arbitraged away:

$$-A_{i,j,g} \leq SP_{j,g} - P_{i,g} \leq A_{i,j,g} \tag{1}$$

There are environments in which price differences can exceed marginal transaction costs, e.g., pricing power on the side of sellers, market segmentation, or non-constant returns to scale in transportation sector. Nevertheless, marginal transaction costs in any environment split the price-difference space into two regions: a region of no-arbitrage outlined by (1) and a region with some level of arbitrage where (1) does not hold. This implies a non-linearity in the behaviour of the observed price differences: a random walk process in the first region and mean reversion in the second region[4].

It is well known that neither the marginal transport costs nor the tariff barriers are constant across goods and locations. Consequently, the random-walk and mean-reverting regions vary systematically – an implication explored before using threshold-autoregressive

[3]Transport costs also matter through their importance in distribution. Burstein et. al. (2003) find distribution margins can account for up to 60% of price differences between US and some latin-American countries.

[4]Such non-linearity also exists in the presence of other reasons for trade.

models. Obstfeld and Taylor (1997), Zussman (2002), Imbs et. al. (2003) use distance, exchange rate volatility[5], tariffs and non-tariff trade barriers as measures of transaction costs to identify variation in threshold estimates for bilateral real exchange rates.

At the level of an individual good g, transport costs also depend on good-specific physical characteristics. Hummels (2001, 2003) estimates the dependance of freight costs on physical weight of the goods across four modes of transport (air, ocean, truck and rail) using US Census data and Transborder Surface Trade Database. Weight-to-price ratios are highly positively significant in explaining the freight rates[6], more so than the distance of the shipment. To illustrate the implication for non-linearity of price-differences, let the total transport costs follow a flexible Cobb-Douglas form. Specifically, let the transport cost depend positively on the weight of a shipment $w_g q_g$, distance between locations d_{ij}, value of the shipment $P_{ig} q_g$ (insurance costs) and negatively on the total trade volume M_{ij} between two locations[7]: $T_{ijg} = (w_g q_g)^{\alpha_1} d_{ij}^{\alpha_2} (P_{ig} q_g)^{\alpha_3} M_{ij}^{\alpha_4}$. $\alpha_k \in (0,1)$ $k = 1, ..., 3$; $\alpha_4 \in (-1, 0)$ because doubling of distance, shipment size, etc., does not require doubling of resources used in transportation (decreasing returns to factor accumulation due to efficiency gains – see Hummels (2001)). Condition (1) can then be expressed as a condition for good-specific real exchange rate with predictions about the determinants of the no-arbitrage bounds

$$1 - \left(\frac{t_{ijg}}{P_{ig}} + \frac{B_{ijg}}{P_{ig}} \right) \leq \frac{SP_{jg}}{P_{ig}} \leq 1 + \left(\frac{t_{ijg}}{P_{ig}} + \frac{B_{ijg}}{P_{ig}} \right) \tag{2}$$

where $t_{ijg} = \alpha_1 q_g^{\alpha_1 + \alpha_3 - 1} w_g^{\alpha_1} d_{ij}^{\alpha_2} P_{ig}^{\alpha_3} M_{ij}^{\alpha_4}$ is the marginal transport cost. The assumptions on αs imply that bounds of inequality (2) are increasing in the physical characteristic of the good w_g and decreasing in its price P_{ig} as well as the aggregate trade volume M_{ij}. Through (2), heterogeneity of marginal transaction costs implies that the non-linearity in price differences is good-specific; wider threshold estimates for heavier, more distant products, or for goods between locations that see little mutual trade. Heterogeneity in thresholds of sectoral real exchange rate found by Obstfeld & Taylor (1997) and Imbs, et. al. (2003) is a result of aggregation in good-specific non-linearities driven by heterogeneous

[5]Through the effects of uncertainty in a fixed-cost environment.
[6]Regressions in Hummels (2001) contain up to half million datapoints
[7]Bigger trade routes justify use of larger vessels, longer trains, etc.

marginal transaction costs at the level of individual goods.

3 Data

I use disaggregated consumer price index data to measure price differences. This limits the type of questions the study can address as the data does not contain information about the absolute size of of price differences[8]. However, information about dynamic properties of price levels is fully preserved in the dynamics of price index data. Consequently, de-meaning of the price index dataset is harmless while de-trending it removes information about price dynamics. The CPI data in this study is de-meaned but not detrended. Properties of aggregate US-Canada exchange rates are summarized in tables 4, 5 and 6. We see that both nominal and real exchange rates are more stationary before Bretton Woods period. This is true for raw, linearly-detrended as well as HP-detrended series.

3.1 Price index dataset

The price index dataset contains disaggregated price series of 63 groups of goods and services in the United States and Canada between 1970:1 and 2000:8 (some series start after 1970), as well as the aggregate consumer price index and the nominal exchange rate. Choice of the country combination is guided by the availability of data at a level of disaggregation at which physical characteristics of products can be estimated as well as by the sufficient time-span of the monthly series. Data for matching categories was obtained from Bureau of Labor Statistics and Statistics Canada, respectively, and is all demeaned. 49 of the series represent goods and 14 services[9], covering 73.5% of the CPI overall (goods cover 24.1% and services 46.7% of the CPI, respectively[10]). Using the taxonomy of Lebow and Rudd (2001), 77% of durable goods, 70% of nondurable goods and 39% of services are included in the data (see table 1 in Appendix A.2).

[8]See Crucini, Telmer and Zachariadis (2005) for a price level analysis that documents widespread law of one price violations (hence mean does not equal parity) across the EU.

[9]The services are included only to allow an indirect check of data consistency. Lack of tradability of services in this dataset lead one to expect wider threshold estimates than for goods.

[10]Source: CPI all urban consumers, Bureau of Labor Statistics, December 2001. Some of the groups are a subset of other groups - all such double accounts are accounted for in this reported measure.

3.2 Physical weights dataset

The dataset of physical weights and individual prices for each good (or group) necessary in estimations using price-to-weight data is constructed using a following data-collection procedure[11]. When available, weights are obtained from statistical agencies or government bodies. Otherwise, manufacturers' associations are searched for average weights of particular goods or product groups. In a minority of cases when neither of the approaches works, weights are estimated as an average of the market's large manufacturer's product range (e.g., for watches, an average weight is set equal to a current average weight of a Timex watch). Average prices are obtained in a similar manner, with a search of US data sources preceding a search of Canadian data sources. Price level necessary to construct a price-to-weight ratios across goods corresponds to an average USD price in year 2000. When a price is unavailable in 2000, the last available price is inflated by the CPI inflation rate of the relevant country. Weight (and price) data of groups of products (e.g., women's apparel) are computed as weighted averages of weights (and prices) of components using the expenditure shares from US urban average CPI in December 2001 as weights. The composition of all groups, data sources, as well as price and weight estimates are documented in table 2 in Appendix B.

3.3 Volume dataset

The dataset of physical volumes of is calculated indirectly using data on stowage factors from the German Transportation Information Service database[12]. A stowage factor of a cargo is the ratio of weight to stowage space (the unit is ton/m^3) required under normal conditions, including all packaging. Consequently, the volume of a unit of the good can be calculated using the stowage factor and weight of a good. Because stowage factors for goods can vary depending on packaging, water contents, and compression, I use the average of all quoted stowage factors in calculating the volume of a good. I find stowage ratios for products that are not included in the German database from other sources. Table 3 in Appendix B documents the data sources.

[11] This data can not be obtained from a single source.

[12] A website run by the German Insurance Association `http://www.tis-gdv.de/tis e/ware/inhalt.html`

4 Empirical framework and results

The first part of this section estimates threshold-autoregressive (TAR) models on good-specific real exchange rate data. The second part assesses the extent to which heterogeneity in marginal transaction costs explains heterogeneity of threshold estimates and conditional half-lifes. The discrete break in good-specific real exchange rates implied by equation (2) guides the choice of a discrete self-exciting TAR models[13]. The nature of the break driven by heterogeneity of t_{ijg} across goods can be captured well by a highly disaggregated data on hand[14]. Logarithm of good-specific real exchange rate z_t^g is used as the object of first-stage estimation: $z_t^g = p_t^g - p_t^{g*} + s_t$, where t is a time index and g is a good (service) index, p and p^* denote logarithm price indexes in US and Canada, respectively, and s_t is the logarithm of the nominal exchange rate.

Specification of a TAR model requires selection of a number of thresholds, number of autoregressive lags p and of an optimal delay parameter d_p. I assume two thresholds[15] for each good. As there is no a-priori reason for t_{ijg} to have different effects in appreciation and depreciation, I assume symmetry: $\gamma_1^g = -\gamma_2^g \equiv \gamma^g \ \forall g$. The main model is a Band-TAR(2,p,d) specified as:

$$\Delta z_t^g = \begin{cases} \bar{\beta}^{g,out}(\bar{z}_t^g - \gamma^g) + e_t^{out} & \text{if } z_{t-d_p}^g > \gamma^g \\ \bar{\beta}^{g,in}\bar{z}_t^g + e_t^{in} & \text{if } \gamma^g \geq z_{t-d_p}^g \geq -\gamma^g \\ \bar{\beta}^{g,out}(\bar{z}_t^g + \gamma^g) + e_t^{out} & \text{if } -\gamma^g > z_{t-d_p}^g \end{cases} \quad (3)$$

where $\bar{z}_t$ is the vector of the appropriate lagged values of z_t, $e_t^{out} \sim N(0, {\sigma_B^{out}}^2)$ and $e_t^{in} \sim N(0, {\sigma_B^{in}}^2)$.

[13] Self-exciting threshold autoregressive (SETAR) models can be thought of as a combination of several (typically two) regimes which differ in the degree of stationarity they impose on the series. The decision on which regime shall the variable observe depends on a position of a control variable - in "self-exciting" models this is just a lagged value of the examined series.

[14] Aggregation would make smooth threshold autoregressive models more appropriate. Smooth threshold autoregressive models are a fluid combination of a non-stationary and a stationary regime akin to a string. A larger deviation of the RER rises with the weight placed on the stationary regime relative to the non-stationary one. Therefore, reversion occurs for *any* deviation and its strength rises in the size of the deviation (see Tong (1990), Granger and Teräsvirta (1993) for reference on non-linear time series analysis).

[15] One threshold following sufficient appreciation, another one after depreciation.

For robustness, Equilibrium-TAR (Eq-TAR) model is also estimated:

$$\Delta z_t^g = \begin{cases} \bar{\beta}^{g,out} \bar{z}_t^g + e_t^{out} & \text{if } z_{t-d_p}^g > \gamma^g \\ \bar{\beta}^{g,in} \bar{z}_t^g + e_t^{in} & \text{if } \gamma^g \geq z_{t-d_p}^g \geq -\gamma^g \\ \bar{\beta}^{g,out} \bar{z}_t^g + e_t^{out} & \text{if } -\gamma^g > z_{t-d_p}^g \end{cases} \quad (4)$$

where $e_t^{out} \sim N(0, \sigma_E^{out2})$ and $e_t^{in} \sim N(0, \sigma_E^{in2})$. Because the identification of the thresholds relies on (2), both specifications assume no mean reversion of price difference between the thresholds (a restriction of $\bar{\beta}^{g,in} = 0$). The two specifications differ in their assumptions on mean-reversion of z_g outside thresholds. Band-TAR assumes that price differences converge back to the no-arbitrage threshold, in line with equation (2). Eq-TAR assumes convergence back to the middle of the no-arbitrage band (mean). Hence, Band specification produces faster conditional convergence speeds. The results from both specifications are very similar. See Appendix A for details on estimation and testing of a TAR(2,p,d) model.

4.1 Non-linearities

Columns 4 and 5 of table 7 show that a vast majority of the series can not reject the H_0 of unit root by either ADF or Philips-Perron tests[16]. Unit roots appear to be rejected for the more valuable series with the notable exception of foods. At the other extreme, data for many services and non-traded goods is not stationary even in their OLS point estimates. Tsay's test for threshold non-linearity[17] rejects linearity for 49 out of 63 series in favour of a TAR specification (column 3 of table 7). Therefore, threshold autoregressive models provide a better characteristic of price differences than linear models for the bulk of the series[18]. The non-linearities are distributed fairly evenly across all goods and services.

[16] Both tests take into account the appropriate lag structure chosen by analyzing the partial autocorrelation function.

[17] With two symmetric thresholds, Tsay's test (Tsay 1986) is more appropriate than Hansen's (1997) single-threshold non-linearity test (Tsay's the test is described in Appendix A.2).

[18] The precision with which we can conclude non-linearity or non-stationarity depends on the length and breadth of the sample as well as on whether the test statistic controls for the serial correlation of the error terms. O'Connel (1998) shows how failure to account for serial correlation leads to serious size distortions. Papell (1997) shows that various panel datasets provide stronger rejection of the unit root hypothesis than a similar time-series analyses. While panels improve the power of unit root tests, they suffer from series of other problems (see, e.g., Lyhagen (2000), Bornhorst (2003), Banerjee et. al. (2001)). In addition, power of unit root tests drops further when the underlying DGP is not linear.

Space limitations require reporting of only general results. As is well known, model misspecification causes incorrectly long half-life estimates (Obstfeld & Taylor 1997). This is highlighted in the reduction of an average half-life for all series with AR point estimates inside the unit circle from 126 months under AR(1) specification to 63 months under TAR(2,p,d). Slightly larger reductions are observed for goods (drop from 112 to 52 months on average) than services (drop from 202 to 123 months). Services and medical products have the longest AR half lifes, followed surprisingly by high-tech goods (PCs and audio-visual equipment – see tables 8 and 9). Price differences for cars, car parts, clothing and footwear are quickest in converging to mean. The conditional half lifes under TAR are calculated using impluse response functions, allowing them to exceed linear half-lifes. Vice goods, medical and chemical products, and marginally for cars, car parts, clothing and footwear all see a marginal increases in half-life while high-tech goods drop significantly. General findings also confirm – at a greater level of disaggregation than in Imbs et. al, (2003) and in a two-country setting – a positive correlation between AR half-life and threshold width, as well as between AR half-life and the reduction of half-life from AR to TAR specification (see figure 2). Slowly-reverting goods tend to have larger thresholds and larger drops in conditional persistence.

4.2 Determinants of thresholds

Arbitrage condition (2) predicts a relationship between the estimates of thresholds $\hat{\gamma^g}$ in equations (3) and (4) and good-specific determinants of marginal transaction costs. This guides a conjecture

$$\hat{\gamma^g} = \beta_0 + \sum_{i=1}^{k} \beta_i y_i^g + \epsilon^g \tag{5}$$

where y_g^i is a vector of good-specific determinants of marginal transaction costs including measures of physical characteristics of goods (price-to-weight, price-to-volume ratios or stowage factors) and measures of trade barriers (tariffs). It also includes measures of price-setting power and market structure (market size proxy and industry concentration measures). The importance of physical characteristics for the marginal transport costs is explained in section 2 above. Tariffs are measured as an average tariff rate for the product category in 1989, date approximately half way through the gradual tariff-reduction process under NAFTA[19]. With increasing returns to scale in production (e.g., in the presence of fixed costs), market size matters in profits. Larger markets are more attractive, lowering sellers' price-setting power. I include CPI expenditure shares across goods as a measure of the price-setting power. Market structure is obviously also directly relevant for price-setting power of the firms. Herfindahl-Herschmann index from 1997 US Economic Census is included as a measure of pricing power due to individual market structure[20]. Finally, a dummy for tobacco is added to the right-hand side variables due to a complicated one-sided change in federal as well as provincial taxes in Canada in the spring of 1994 (see figures 3 and 4)[21].

Price-to-weight ratios are highly significant in explaining thresholds (column 2 of table 12). Heavier goods (relative to their value) with larger marginal transport costs have wider thresholds of no-arbitrage. A ten-fold increase in the price-to-weight ratio increases the threshold by 0.73 percentage points (i.e., widens the no-arbitrage band by 1.46 percentage points). Column 6 of table 12 examines a logarithmic specification, allowing the interpretation of the coefficient as an elasticity of threshold with respect to price-to-weight ratios[22]. Coefficient of $\log(P/W)$ is -1.46 and highly significant. Estimations with price-to-volume ratios have negative sign but are not significant. Specifications explain up to 46% of the variation in thresholds. These important new results show that at the individual goods, real exchange rate non-linearity is caused by good-specific characteristics that drive marginal transaction costs. Aggregation of these effects leads to heterogeneity in RER at sectoral level.

Measures of price-setting power are also important in explaining thresholds. Expenditure share is negatively related to threshold width (at 10% significance). A hypothesis

[19] For groups of goods, a weighted average tariff computed using CPI weights of constituent products is computed.

[20] Value-added based index is used. Data is available from `http://www.census.gov/epcd/www/concentration.html`.

[21] Due to an increase in smuggling of cigarettes, Canadian federal and provincial governments lowered cigarette taxes, leading to a structural break in tobacco price differences. The tax drop occurred at different times, and in different amounts, in different Canadian provinces (figure 3, see Gruber et. al. (2002)) for details), making it impossible to remove this outlier point from aggregate Canadian tobacco price index. The enormous jump in the tobacco real exchange rate (figure 4) is interpreted as a non-linearity by the TAR estimation and causes a mis-specified threshold estimate for tobacco.

[22] Equation (2) is in levels while TAR estimates relate to $\log(RER)$.

consistent with this finding is that of market size determining price-setting power, possibly because of a lower degree of monopoly power in larger markets. Tariffs and Herfindahl-Herschmann index are not significant[23].

4.2.1 Robustness of threshold regressions

Robustness of these results is confirmed with three methods: exclusion of goods with limited tradability, Tobit estimations allowing for linearity control and finally by a complete re-estimation of TAR models in which thresholds are imposed to drop at the rate equal to the drop in US-Canada transport costs found in recent empirical literature.

First, threshold regressions are re-estimated while excluding goods that are known to have limited tradability. The second section of table 13 excludes natural gas and gasoline for which trade normally requires sophisticated and expensive distribution networks (pipelines), making physical characteristics poor measures of marginal transport costs. The third section of the same table also excludes alcoholic beverages whose licensing requirements make trade complicated within countries and much more so between countries. As expected, price-to-weight and price-to-volume ratios are more significant than in the original specification.

Second, to control for linearity of the series equation (5) is re-estimated with Tobit estimator setting $\gamma^g = 0$ for those goods for which I either can not reject linearity (second section of table 14), or can not reject linearity and reject stationarity (first section of table 14). In addition, in the third section of table 14 I re-estimate OLS using only the series for which linearity is rejected (these robustness checks follow Imbs. et. al. (2003)). The original results carry through in all cases, with an increase in significance of the expenditure weights.

Finally, EQ-TAR(2,p,d) and BAND-TAR(2,p,d) models are re-estimated under the constraint that marginal transport costs have declined throughout the sample period. I use a direct estimate of Novy (2006) that Canada-US transport costs dropped by 39% between 1960 and 2002[24]. Table 15 shows the second-stage regression results based on the threshold estimates which incorporate such decline in transport costs between US and Canada. The

[23] Obstfeld and Taylor (1997) and Imbs et. al. (2003) also report insignificance of tariffs.

[24] This overall decline rate is pro-rated to the sample length, and the thresholds are forced to decline at this rate for all series over their sample period.

results are highly significant, explaining up to 60% of variation in thresholds. An increase in the size of the price-to-weight and expenditure share coefficients is seen in all specifications. This is not unexpected as thresholds now take into account the empirically documented decline in transport costs.

4.3 Determinants of conditional persistence

This section investigates the possibility that persistence of prices also depends on marginal transaction costs. The estimation is based on

$$\hat{hl^g} = \delta_0 + \sum_{i=1}^{k} \delta_i x_i^g + \nu^g \tag{6}$$

where $\hat{hl^g}$ is the conditional half-life estimated by impulse response functions using TAR estimates from (3) and x_i is a vector of explanatory variables. In addition to the determinants of transaction costs and measures of pricing-power included in y_i a dummy variable for chilling is included in x_i[25]. Although many open macro models can generate persistence in relative prices, very few make predictions about the relationship between conditional convergence speeds and marginal transaction costs. Imbs et. al. (2003) establish that relationship empirically in a cross-country sectoral real exchange rate setting.

Persistence of price differences outside of the thresholds co-varies negatively with price-to-weight ratios as well as with the refrigeration requirements (table 16 summarizes initial results). Price differences for goods with larger marginal transaction costs (heavier goods) take longer to converge to the no-adjustment bound (the elasticity is approximately -0.2). This is likely caused by the importance of marginal transaction costs in the decision on the *mode* of transport. Hummels (2001b) estimates that, in bilateral US trade data, each day saved shipping is worth 0.8 percentage ad-valorem points for manufactured products. Larger average price differences for goods with bigger marginal transport costs then justify use of slower mode of transport[26]. On the other hand, more valuable goods are transported

[25]The variables equals 1 for goods requiring refrigeration in transport. The hypothesis is that the cost of refrigeration would require quicker transport, lowering conditional half-life.

[26]This may also be a consequence of partial substitution into cheaper but slower transport modes for goods that have larger marginal transport costs (here identified by their physical characteristics).

more quickly, thus lowering their conditional half-life.

4.3.1 Robustness of persistence regressions

The above results are robust to various specifications. Exclusion of goods with poor tradability such as energies and alcoholic beverages increases the significance of the relationship (columns 3 to 6 of table 16). For the remaining products, conditional persistence of price differences is also highly significantly explained by their respective stowage factors (weight to packed volume ratios). Heavier goods (relative to their volume) again exhibit longer persistence.

The results also carry through to unconditional linear half-lifes, with similar level of significance (column 1 of table 17). Tobit estimations, performed in the same way as for threshold estimates, also confirm the results (columns 2-4). Tariffs are significant in explaining persistence, implying that the influence of the trade barriers is not limited to a constant price wedge. A possible reason for slower disappearance of higher-tariff goods may lie in lower trade volumes fir such goods. An additional marginal significance of Herfindahl-Herschmann index in some Tobit regressions is particularly intriguing due to its negative sign which implies that price convergence is quicker in more concentrated industries. This somewhat counter-intuitive result may be caused by a larger degree of producer pricing in more concentrated industries. Expenditure shares enter with a negative sign (implying quicker conditional convergence for goods with larger markets) but are not significant. Results carry through in OLS specification that excludes linear series (columns 6 and 7), and OLS with linearity control (columns 8 and 9).

5 Conclusion

Physical characteristics of goods, through their importance in marginal transaction costs, explain a large part of the threshold non-linearity and conditional persistence of law-of-one-price deviations. Visible at a sufficiently detailed level of disaggregation, this mechanism drives the heterogeneity at higher levels of aggregation such as the sectoral real exchange rates. In post-Bretton Woods US-Canada monthly data for 49 products and product groups, heavier goods (relative to their price) see their price differences diverge further before becoming mean reverting (transport costs are higher for those goods because they are more difficult to move). Furthermore, after becoming mean reverting, price differences for heavier goods converge more slowly, possibly due to choice of slower mode of transport for goods with larger average price differences. Both mechanisms increase the unconditional persistence of the price differences of products with higher marginal transaction costs. While the relationship between physical characteristics of products and freight costs is not unknown, its implications for the behaviour of price differentials have not yet been explored.

This account of the heterogeneity in the behaviour of price differences also sheds light on the potential sources of the most formidable components of the purchasing power parity puzzle - the persistence of real exchange rates. Imbs, et. al. (2005b) show how the peculiar nature of aggregating heterogeneous real exchange rate components accentuates the persistence at the level of the aggregate real exchange rate. There is a discussion about whether such "aggregation bias" explains PPP puzzle (see also Chen and Engel (2004)). To the extent that a large part of the heterogeneity in real exchange rate components is accounted for by the heterogeneity in marginal transaction costs across goods, my study shows that persistence in real exchange rates – and hence the PPP puzzle – is driven by the composition of a trade basket at micro level. Consequently, economic models that take heterogeneity of marginal transaction costs into account may stand a better chance in explaining the puzzling persistence in aggregate real exchange rates. It would be interesting to further verify these results in a geographically larger dataset with heterogeneity of countries as well as locations (both within and between countries).

6 Acknowledgements

I would like to thank Michael B. Devereux, John F. Helliwell and James M. Nason for their support. I am also grateful for the discussions with Brian R. Copeland, Werner Antweiler as well as the participants of the INE/TARGET international workshop.

Appendix

A Specification and estimation of a TAR

Specification and estimation of TAR(2,p,d) proceeds in three steps[27] that are repeated for all 63 series: selection of an appropriate lag-structure p for the linear model, selection of the delay parameter d, and finally estimation and testing of the non-linear model. Specifically:

1. With monthly data, up to 12 lags are considered. Examination of the partial autocorrelogram (Granger and Teräsvirta (1993)) narrows the potential candidates, of which I choose a combination with the lowest Akaike information criterion (or Schwarz Bayesian information criterion) as long as the residuals are not serially correlated and are normally distributed[28]. Appropriate model specification is important at this stage because omitted autocorrelation may lead to rejection of the the linear model and in general complicate interpretation of test results (Kilian and Taylor (2003)).

2. Given the lag structure p and the set of feasible values of the delay parameter $d \in \{1, 2, ..., 12\}$), optimal d_p is selected by a procedure suggested in Tsay (1989):

$$\hat{F}(p, d_p) = \max_{\nu \in S} \hat{F}(p, \nu)$$

   where $\hat{F}$ is the F-statistic described in the Appendix A.2. This procedure selects the value of the delay parameter which gives the most significant result in testing for a non-linearity. P-values of the optimal d_p can then also be used as a general nonparametric test of non-linearity.

3. Given optimal p and d_p, parametric maximum likelihood estimation procedure according to Obstfeld and Taylor (1997) (who follow Fanizza (1990), Balke and Fomby (1997) and Prakash (1996)) obtains $\hat{\gamma}$ and $\hat{\beta}$. Practically, the procedure is a best-

[27] See Granger and Teräsvirta (1993), Teräsvirta(1994), Tsay (1986), Tsay(1989).

[28] Selected combination is tested for residual serial correlation using Breusch-Goodfrey LM test and by examining the Q-statistic, and for the residual normality using Lomnicki-Jarque-Berra statistic. Residual normality is frequently rejected which can be result of the sample size. Most of the time, these criteria select the same model.

fit grid search for a threshold parameter γ that maximizes the log-likelihood ratio $LLR = 2(L_a - L_0)$ where

$$
\begin{aligned}
L_a(\beta_{in}, \beta_{out}, \sigma_{in}, \sigma_{out}, \gamma) &= -\frac{1}{2} n_{in} \Big[\log(2\pi) + \log\Big[\frac{\sum_{I_{in}} e^2_{t,in}}{n_{in}-2}\Big] + \frac{n_{in}-2}{n_{in}} \Big] \\
&\quad -\frac{1}{2} n_{out} \Big[\log(2\pi) + \log\Big[\frac{\sum_{I_{out}} e^2_{t,out}}{n_{out}-2}\Big] + \frac{n_{out}-2}{n_{out}} \Big], \\
L_0(\beta, \sigma) &= -\frac{1}{2} n \Big[\log(2\pi) + \log\Big[\frac{\sum e^2_t}{n-2}\Big] + \frac{n-2}{n} \Big] \\
\text{where } e_{t,in} &= \Delta z_{t,in} - \beta_{in} \bar{z}_{t,in} \\
e_{t,out} &= \Delta z_{t,out} - \beta_{out} \bar{z}_{t,out} \\
\text{and } e_t &= \Delta z_t - \beta \bar{z}_t
\end{aligned}
$$

Choices of γ with less than 10 observation above the threshold are not considered due to excessive sample bias. Estimates of $\hat{\beta}$ are used in computing conditional half-life of convergence (using impulse response functions)[29].

4. Two tests are used to assess the non-linear TAR against the linear alternative: likelihood ratio test and Tsay's general nonparametric F-test. Likelihood ratio test uses a statistic obtained during the grid-search. However, this statistic does not follow the asymptotic χ^2 distribution in a non-linear model because the threshold parameter γ is not identified under H_0 of linearity. Hence, a Monte Carlo simulation of 5000 draws is used to obtain p-values of the LLR statistic. Tsay's general nonparametric F-test uses the minimal p-value of two F-statistics: one from an arranged regression using ascending ordering of the case data, another with descending orderings of the case data.

A.1 Log-likelihood ratio test

Log likelihood ratio (LLR) tests the likelihood that the non-linear model describes the data better than the linear autoregressive model. The statistic is computed during the TAR(2,p,d) estimation, and measures the difference between log-likelihoods of an optimal

[29] For $p = 1$, half-life $= -\frac{\log(2)}{\log(1+\hat{\beta}^{*g})}$ where $\hat{\beta}^{*g}$ is Kendall's bias-adjusted slope coefficient: $\hat{\beta}^{*g} = \frac{n\beta+1}{n-3}$.

TAR(2,p,d) and a corresponding AR(p) model. LLR statistic of a non-linear model does not follow the usual χ^2 distribution because the parameters of the nonlinear alternative are not identified under H_0 of linearity (Granger and Teräsvirta (1993)). There exists more than one set of restrictions which makes a TAR(2,p,d) model linear. Monte Carlo simulation is used to obtain an empirical distribution of LLR for all goods and from it compute the empirical p-values of LLR statistics Tables 10 and 11 provide empirical p-values of the hypothesis that a TAR(2,p,d) is better than AR(p) for EQ-TAR and BAND-TAR models, respectively. At 10% significance level, LLR test results imply that TAR(2,p,d) is a better model than the linear AR(p) for 40% of series (30% in Equilibrium TAR).

A.2 Tsay's F-test for non-linearity

The F-test for non-linearity consists of several steps. First, data is arranged into *cases* of $(\Delta z_t, 1, z_{t-1}, ..., z_{t-k})$ such that $k \in M$ where M is a set of all relevant lags as determined in stage 1 of the model-specification (see previous section). Second, these cases are arranged in ascending order according to z_{t-d} where d is the threshold delay parameter[30] (see Tsay (1986), Obstfeld and Taylor (1997)). Third, an arranged autoregression is run on the ordered case data using recursive least squares:

$$\Delta z_t = \sum_{k \in M}^{k^{max}} \alpha_k z_{t-k} + u_t \tag{7}$$

Recursive least square technique provides predictive residuals which are then used in Tsay's nonlinearity test. The recursive estimates are updated as follows (see Tsay (1986), Tong (1990), Ertel and Fowlkes (1976)):

$$\begin{aligned}
\hat{\beta}_{m+1} &= \hat{\beta}_m + K_{m+1}[\Delta z_{m+1} - \beta_m \bar{z}_m] \\
K_{m+1} &= P_m \bar{z}_{m+1} / D_{m+1} \\
D_{m+1} &= 1 + \bar{z}'_{m+1} P_{m+1} \bar{z}_{m+1} \\
P_{m+1} &= (I - P_m \frac{\bar{z}_{m+1} \bar{z}'_{m+1}}{D_{m+1}}) P_m
\end{aligned}$$

[30] Cases are analyzed in an ordered fashion because of the lack of knowledge of the position of a threshold ex-ante.

where m denotes a case, $\bar{z}_m$ is a vector of all RHS variables in equation (7) (hence $\beta = (\alpha_1 \ ... \ \alpha_{k^{max}})'$) and I is an identity matrix. The recursion is initiated by a regular OLS on the first b cases where $b = n/10 + p$, n is the total number of observations and p is the number of elements in M[31]. The first b cases are then scrapped. The predictive ($\hat{a}_m$) and standardized predictive ($\hat{e}_m$) residuals are obtained as: $\hat{a}_{m+1} = \Delta z_{m+1} - \beta_m \bar{z}_m$ and $\hat{e}_{m+1} = \hat{a}_{m+1}/\sqrt{D_{m+1}}$.

Fourth, standardized predictive residuals are regressed on the RHS variables.

$$\begin{aligned} \hat{e}_m &= \sum_{k \in M}^{k^{max}} \gamma_k z_{m-k} + \epsilon_m \\ F &= \frac{(\sum \hat{e}_t^2 - \sum \epsilon_t^2)/(p+1)}{\sum \epsilon_t^2/(n-d-b-p-h)} \end{aligned} \tag{8}$$

The F-statistic follows an F distribution with $p+1$ and $n-d-b-p-h$ degrees of freedom where $h \equiv \max\{1, p+1-d\}$.

Intuitively, a threshold implies a parameter change in the arranged autoregression (7) at the threshold level. Therefore, while predictive residuals will be orthogonal to the regressors for the cases that fall below the threshold, they will become biased above the threshold, destroying the orthogonality with the regressors. Such regime change then leads to a rejection of orthogonality and can be tested by the F-statistic (8). Rejection of orthogonality implies a rejection of a linear AR model for a non-linear TAR alternative.

[31]Therefore $P_b = (\bar{z}_b{}'\bar{z}_b{}^{-1})$.

Table 1: Coverage of CPI by the data.

Relative importance of components in the Consumer Price Indexes (1999-2000 weights): U.S. city average, December 2001. **Bold** series are **not included** in the dataset.

Item	CPI-U	CPI-W
All items	100.000	100.000
Food and beverages	15.719	17.229
Food	14.688	16.228
Food at home	8.468	9.798
Cereals and bakery products	1.298	1.468
Cereals and cereal products	.444	.525
Flour and prepared flour mixes	.058	.070
Breakfast cereal	**.249**	**.278**
Rice, pasta, cornmeal	**.137**	**.177**
Bakery products	**.854**	**.944**
Meats, poultry, fish, and eggs	2.271	2.831
Meats, poultry, and fish	2.178	2.712
Meats	1.450	1.832
Beef and veal	.693	.868
Uncooked ground beef	.255	.334
Uncooked beef roasts	.115	.132
Uncooked beef steaks	.278	.351
Uncooked other beef and veal	.045	.051
Pork	.468	.610
Bacon, breakfast sausage, & rel. products	.148	.190
Ham	**.104**	**.132**
Pork chops	.112	.156
Other pork including roasts and picnics	.105	.132
Other meats	**.289**	**.355**
Poultry	.414	.518
Chicken	.329	.423
Other poultry including turkey	.085	.095
Fish and seafood	.314	.362
Fresh fish and seafood	.187	.219
Processed fish and seafood	.126	.143
Eggs	.093	.119
Dairy and related products	**.916**	**1.021**
Fruits and vegetables	1.204	1.307
Fresh fruits and vegetables	.928	.995
Fresh fruits	.466	.490
Apples	.084	.095
Bananas	.088	.100
Citrus fruits	.079	.085
Other fresh fruits	.215	.210
Fresh vegetables	.462	.505
Potatoes	.080	.092
Lettuce	**.059**	**.066**
Tomatoes	.094	.109
Other fresh vegetables	.230	.238
Processed fruits and vegetables	**.276**	**.312**
Nonalc. beverages and bev. materials	**.967**	**1.132**
Juices and nonalcoholic drinks	.710	.853
Carbonated drinks	.364	.468
Frozen noncarbonated juices and drinks	.036	.039
Nonfrozen noncarbonated juices and drinks	.310	.346
Beverage materials including coffee and tea	.257	.280
Coffee	.100	.105
Other beverage materials including tea	**.157**	**.174**
Other food at home	1.811	2.038
Sugar and sweets	.315	.339
Sugar and artificial sweeteners	.056	.069
Candy and chewing gum	**.200**	**.207**
Other sweets	**.059**	**.063**
Fats and oils	.265	.316
Butter and margarine	.090	.103
Salad dressing	.076	.089
Other fats and oils including peanut butter	.098	.125
Other foods	1.232	1.383
Food away from home	6.220	6.430
Full service meals and snacks	2.649	2.198
Limited service meals and snacks	**2.741**	**3.354**
Food at employee sites and schools	**.296**	**.375**
Food - vending mach. & mobile vendors	**.151**	**.229**
Other food away from home	**.383**	**.275**
Alcoholic beverages	1.031	1.001
Alcoholic beverages at home	.682	.709
Beer, ale, and other malt beverages at home	.352	.469
Distilled spirits at home	.109	.102
Wine at home	.221	.139
Alcoholic beverages away from home	.348	.292
Housing	40.873	38.141
Shelter	31.522	29.212
Rent of primary residence	6.421	8.395
Lodging away from home	2.702	1.523
Housing at school, excluding board	.241	.176
Other lodg. away from home incl. hotels	2.461	1.347
Owners' equivalent rent of primary residence	22.046	18.980
Tenants' and household insurance	.353	.314
Fuels and utilities	4.511	4.829
Fuels	3.654	3.955
Fuel oil and other fuels	.188	.177
Fuel oil	.121	.105
Other household fuels	.068	.072
Gas (piped) and electricity	3.466	3.778
Electricity	2.521	2.762
Utility natural gas service	.945	1.017
Water and sewer and trash collection services	.857	.873
Water and sewerage maintenance	.633	.660
Garbage and trash collection	**.224**	**.213**
Household furnishings and operations	4.840	4.101
Window & floor coverings & other linens	**.289**	**.254**
Furniture and bedding	1.051	.955
Bedroom furniture	.306	.284
Living room, kitchen, & dining room furniture	.555	.495
Other furniture	.181	.154
Unsampled furniture	.010	.021
Appliances	.364	.416
Major appliances	.199	.226
Other appliances	**.151**	**.176**
Unsampled appliances	**.013**	**.015**
Other household equip. & furnishings	**.806**	**.565**
Tools, hardware, outdoor eq. & supplies	**.649**	**.595**
Housekeeping supplies	.862	.959
Household cleaning products	.392	.459
Household paper products	**.200**	**.221**
Miscellaneous household products	**.270**	**.279**
Household operations	**.820**	**.357**
Apparel	4.399	4.831
Men's and boys' apparel	1.122	1.243
Men's apparel	.880	.927
Men's suits, sport coats, and outerwear	.201	.189
Men's furnishings	.191	.196
Men's shirts and sweaters	.263	.279
Men's pants and shorts	.203	.241
Unsampled men's apparel	.021	.023
Boys' apparel	**.242**	**.316**
Women's and girls' apparel	1.807	1.864
Women's apparel	1.515	1.504
Women's outerwear	.108	.111
Women's dresses	.214	.247
Women's suits and separates	.762	.712
Women's underwear, nightwear, sportswear	.400	.399
Unsampled women's apparel	.032	.036
Girls' apparel	**.292**	**.360**
Footwear	.874	1.165
Men's footwear	.290	.416
Boys' and girls' footwear	**.177**	**.269**
Women's footwear	.407	.480
Infants' and toddlers' apparel	**.203**	**.256**
Jewelry and watches	.394	.303
Watches	.058	.057
Jewelry	.336	.245
Transportation	17.055	19.393
Private transportation	15.845	18.452
New and used motor vehicles	8.614	10.145
New vehicles	5.083	4.897
Used cars and trucks	**2.195**	**4.099**
Leased cars and trucks	**1.061**	**.925**
Car and truck rental	**.120**	**.085**
Unsampled new & used motor veh.	**.155**	**.140**
Motor fuel	2.564	3.153
Gasoline (all types)	2.536	3.120
Other motor fuels	.028	.033
Motor vehicle parts and equipment	.421	.530
Tires	.234	.262
Vehicle accessories other than tires	**.187**	**.268**
Motor vehicle maintenance and repair	1.400	1.438
Motor vehicle body work	.082	.077
Motor vehicle maintenance and servicing	.478	.475
Motor vehicle repair	.821	.868
Unsampled service policies	.020	.019
Motor vehicle insurance	2.288	2.679
Motor vehicle fees	**.558**	**.506**
Public transportation	1.211	.941
Airline fare	.761	.508
Other intercity transportation	**.187**	**.124**
Intracity transportation	.256	.300
Unsampled public transportation	**.006**	**.008**
Medical care	5.810	4.620
Medical care commodities	1.377	1.006
Prescription drugs and medical supplies	.959	.680
Nonprescription drugs and medical supplies	.418	.326
Internal & respiratory over-the-counter drugs	.304	.250
Nonprescription medical equip. & supplies	.114	.076
Medical care services	4.434	3.614
Professional services	2.784	2.245
Physicians' services	1.503	1.280
Dental services	.747	.584
Eyeglasses and eye care	.288	.240
Services by other medical professionals	.247	.142
Hospital and related services	1.353	1.092

Item	CPI-U	CPI-W	Item	CPI-U	CPI-W
Hospital services	1.271	1.075	Cigarettes	.864	1.360
Nursing homes and adult daycare	.082	.017	Tobacco products other than cigarettes	.057	.073
Health Insurance	.297	.276	Unsampled tobacco and smoking prods	.007	.008
Recreation	6.019	5.649	Personal care	3.384	3.059
Video and audio	1.645	1.803	Personal care products	.706	.815
Televisions	.150	.157	Hair, dental, shaving, & pers. care	.374	.434
Cable television	.928	1.034	Cosmetics, perfume, bath, nail preps	.327	.374
Other video equipment	.055	.064	Unsampled personal care products	.005	.006
Video casset., discs, & other media incl. rental	.148	.182	**Personal care services**	**.901**	**.900**
Audio equipment	.117	.131	**Miscellaneous personal services**	**1.562**	**1.161**
Audio discs, tapes and other media	**.147**	**.159**	Miscellaneous personal goods	.215	.183
Unsampled video and audio	**.099**	**.076**	**Special aggregate indexes**		
Pets, pet products and services	**.711**	**.703**	All items	100.000	100.000
Sporting goods	.628	.728	Commodities	41.300	45.559
Sports vehicles including bicycles	.286	.413	Commodities less food and beverages	25.582	28.330
Sports equipment	.333	.309	Nondurables less food and beverages	13.493	14.685
Unsampled sporting goods	**.009**	**.006**	Nondurables less food, bev. & apparel	9.094	9.854
Photography	.241	.215	Durables	12.089	13.645
Photographic equipment and supplies	.110	.092	Services	58.700	54.441
Photographers and film processing	**.129**	**.122**	Rent of shelter	31.169	28.898
Unsampled photography	**.001**	**.001**	Transportation services	6.638	6.573
Other recreational goods	.497	.512	Other services	10.963	10.033
Toys	.360	.399	All items less food	85.312	83.772
Sewing machines, fabric and supplies	**.058**	**.052**	All items less shelter	68.478	70.788
Music instruments and accessories	**.062**	**.049**	All items less medical care	94.190	95.380
Unsampled recreation commodities	**.016**	**.012**	Commodities less food	26.612	29.331
Recreation services	**1.861**	**1.364**	Nondurables less food	14.524	15.687
Recreational reading materials	.436	.324	Nondurables less food and apparel	10.125	10.855
Newspapers and magazines	.265	.210	Nondurables	29.212	31.915
Recreational books	.170	.114	Nondurables less food	14.524	15.687
Unsampled recreational reading materials	.001	.000	Nondurables less food and apparel	10.125	10.855
Education and communication	5.813	5.637	Nondurables	29.212	31.915
Education	2.726	2.382	Apparel less footwear	3.525	3.666
Educational books and supplies	.220	.203	Services less rent of shelter	27.531	25.543
Tuition, other school fees, and childcare	2.506	2.178	Services less medical care services	54.266	50.827
College tuition and fees	1.162	.877	Energy	6.218	7.109
Elementary & high school tuition & fees	**.338**	**.258**	All items less energy	93.782	92.891
Child care and nursery school	**.840**	**.895**	All items less food and energy	79.094	76.663
Technical & business sch. tuition & fees	**.084**	**.077**	Commodities less food & energy	23.860	26.001
Unsampled tuition, fees, & childcare	**.083**	**.071**	Energy commodities	2.752	3.330
Communication	**3.087**	**3.255**	Services less energy services	55.234	50.663
Other goods and services	4.312	4.499	Domestically produced farm food	7.099	8.204
Tobacco and smoking products	.928	1.441	Utilities and public transportation	8.785	9.217

* CPI-U are weights for BLS series "CPI, All Urban Consumers". CPI-W are weights for BLS series "CPI, Urban Wage Earners and Clerical Workers.

B Constructing the price and weight, and volume datasets

Table 2: Data sources on weights and prices

item	unit	price	curr.	weight (kg)	p/w (USD/kg)	note
Apples	kg	2.57	CND	1	1.7	05/00-05/01 average, Statcan Table 326-0012
Audio equipment	stereo unit	150	USD	6	25	www.jandr.com (the largest retailer in US), includes packaging
Beef	ground, 1kg	4.63	CND	1	3.06	05/00-05/01 average, Statcan Table 326-0012
Beer	six pack	5.40	USD	2.30	2.35	See Grossmann & Markowitz (1999)
Car purchase	car	24,923	USD	1326.13	18.79	1996 avg. extrapolated to 2000, American Automobile Manufacturers' Association 1996
Car parts	tire	100	USD	10	10	
Cheese	kg	8.69	USD	1	8.69	Avg. of American processed cheese (Series APU0000710211) and Cheddar cheese (Series APU0000710212) BLS, 2001 average monthly
Clothes						
Clothes (men)	basket[#]	USD			50.52	U.S. Department of Commerce, 2000
Clothes (women)	basket[#]	USD			52.93	U.S. Department of Commerce, 2000
Coffee	roast, 300g	3.27	CND	0.3	7.20	05/00-05/01 average, Statcan Table 326-0012
Educ. books & supplies						
Eggs	dozen	1.91	CND	0.73	1.74	05/00-05/01 average, Statcan Table 326-0012 weight: a 30-dozen egg container weighs 47lb.
Electricity	500 kWh	48.55	USD	–	–	BLS, average 2001 price (Series APU000072621)
Fats and oils	basket[*]	1.81	USD	0.598	3.68	StatCan, Avg price in Calgary in Nov 2001 for Salad dressing, avg. price in NYC, Feb 2001
Fish and seafood	basket[+]	2.85	USD	1	2.85	Fish processing industry data, wholesale prices.
Flour	2.5kg	3.37	CND	2.50	0.89	05/00-05/01 average, Statcan Table 326-0012
Footwear						
Footwear (men)	pair, avg of casual and athletic	46.50	USD	0.73	63.70	
Footwear (women)	pair, athletic	43.88	USD	0.56	81.00	
Fuel oil	liter	0.34	USD	0.86	0.39	Avg price, BLS 2001, Series APU000072511
Furniture	bed	200	CND	46.7	4.3	IKEA
Gas	1000 ft^3	7.45	USD	18.16	0.41	Avg price for year 2000, Energy Information Administration, Natural Gas Monthly, Jan 2002
Gasoline	liter	0.38	USD	0.70	0.54	Avg. price, BLS, 2001, Series APU000074714
House chemicals	75oz pack of laundry deterg.	2.30	USD	2.13	1.16	1997 NYC price extrapolated into 2001
Jewelry	–					
Laundry appliances	washer	887	USD	158.9	5.58	2002 avg. price for Maytag
Liquor	750ml whiskey	11.74	USD	0.75	15.65	BLS avg. price for 1986, adjusted by CPI inflation (series APU0000720211)
Medical care products						
Non-prescription med.						
Pants	pair, jeans, avg.	50.18	USD	1.36	36.86	Parsley & Wei (2001) and US Department of Commerce, avg. price 01/00-07/00
PC	unit	1000	USD	20	50	Dell.com average price in 2002.
Personal care products	a basket[1]	12.58	CND	8.31	2.77	05/00-05/01 average, Statcan Table 326-0012
Photo equipment	–					
Pork	kg, chops	9.29	CND	1	6.14	05/00-05/01 average, Statcan Table 326-0012
Potatoes	4.54kg	3.83	CND	4.54	0.56	05/00-05/01 average, Statcan Table 326-0012
Poultry	kg	4.45	CND	1	2.94	05/00-05/01 average, Statcan Table 326-0012
Prescription medicine	–					
Sport equipment	basket[%]	99.67	USD	2.10	65.00	http://www.usolympicteam.com/sports2/ih/az equip.html
Sport vehicles	bicycle	225	USD	15	15.00	
Sugar	1lb	0.43	USD	0.45	0.95	BLS avg. price for 2001 (Series APU0000715212)
Tobacco	200 cigs	37.78	CND	0.25	99.80	05/00-05/01 average, Statcan Table 326-0012
Toys	basket	31.33	USD	2.55	13.19	average of 5 age-group categories from Toys'R'Us 2001.
Video equipment	basket[**]	226.67	USD	8.73	25.96	from J&R website, the largest US retailer, includes packaging.
Watches	piece	50	USD	0.2	250	Timex website avg. price, weight approximated
Wine	liter	5.96	USD	1.3	4.58	BLS avg. price, 2001 (series APU0000720311)
Fresh fruits	basket	19.36	USD	8	2.42	BLS avg. price, 2001
Reading materials	book	30	USD	0.5	60	
Tomatoes	kg	2.90	USD	1	2.9	BLS avg. price, 2001 (series APU0000712311)

[#]Men's basket: coats, blazers, trousers, suits. Women's basket: coats, dresses, blazers, trousers, suits, and skirts. [*]Margarine (Canola, 1.36kg), Butter (Parchment, 454g), Shortening (454g), Oil (Canola, 1l), Lard (454g), Peanut butter (500g), and Salad dressing (8oz). Weights equal CPI weights. [+]Canned fish composition matches the composition of the fish processing industry data. **Canned**: Tuna (48%), Salmon (12%), Clams (8%), Sardines, Shrimp, **Fillets**: Cod (4.7%), Flounder (1.7%), Haddock, Rockfish, Pollock (11%) and Other (11%), **Fresh fish** approximated by 50% tuna and 50% salmon. [%]Sports basket: ski boots, skis and bindings, tennis racquet, basketball, golf set (11pc), dozen golf balls, hockey stick, hockey skates, inline skates and hockey helmet. [**]Average of a TV set, a VCR, and a camcorder.

Table 3: Data sources on volume

item	unit	price	stowage factor	volume (m^3)	p/v (USD/m^3)	note
Total RER-CPI						
Apples	kg	2.57	2.622	0.003	647.4	boxes, http://www.tis-gdv.de/tis e/ware/obst/apfel/apfel.htm
Audio equipment	stereo unit	150	5.495	0.055	2730	http://www.jr.com/JRProductPage.process?Product=3967701
Beef	ground, 1kg	4.63	1	0.001	3057.8	http://www.tis-gdv.de/tis e/ware/fleisch/gekuehlt/gekuehlt.htm
Beer	six pack	5.40	1.556	0.004	1508.9	http://www.tis-gdv.de/tis e/ware/lebensmi/bier/bier.htm
Car purchase	car	24,923	8.399	11.138	2237.7	http://www.fordvehicles.com/Cars/focus/features/specdimensions/
Car parts	tire	100	4.041	0.04	2474.6	http://amchouston.home.att.net/stowage factors.htm
Cheese	kg	8.69	1.397	0.001	6222	http://www.tis-gdv.de/tis e/ware/milchpro/kaese/kaese.htm
Clothes						
Clothes (men)	basket#		4.728		10686.4	http://www.tis-gdv.de/tis e/ware/textil/konfektion/konfektion.htm
Clothes (women)	basket#		4.728		11208.1	http://www.tis-gdv.de/tis e/ware/textil/konfektion/konfektion.htm
Coffee	roast, 300g	3.27	1.961	0.001	3671.3	Rodrigues et. al. (2003)
Educ. books & supplies						
Eggs	dozen	1.91	2.755	0.002	630.7	measure
Electricity	500 kWh	48.55		–	–	
Fats and oils	basket*	1.81	1.25	–	2944	German transportation database source for each component
Fish and seafood	basket+	2.85	1.85	–	1537.8	German transportation database source for most components
Flour	2.5kg	3.37	1.33	0.003	669.4	http://amchouston.home.att.net/stowage factors.htm
Footwear						
Footwear (men)	pair, avg of casual and athletic	46.50	21.918	0.016	2906.3	Mens shoe box 14-3/4" x 10-1/8" x 5-5/8"
Footwear (women)	pair, athletic	43.88	28.351	0.014	2857.1	
Fuel oil	liter	0.34	1.163	0.001	338	
Furniture	bed	200	4.73	0.22	909.1	http://www.ikea-usa.com/webapp/wcs/stores/servlet/... ...ProductDisplay?catalogId=10101&storeId=12&productId=32145&... ...langId=-1&parentCats=10103*10144
Gas	1000 ft^3	7.45	1559.298	28.317	0.3	
Gasoline	liter	0.38	1.434	0.001	337	
House chemicals	75oz pack of laundry deterg.	2.30	10.591	0.021	109.5	measurement
Jewelry	–					
Laundry appliances	washer	887	4.506	0.716	1238.8	http://www.maytag.com/products/images/products/dmsearcywash.pdf
Liquor	750ml whiskey	11.74	1.75	0.001	8944.8	http://www.tis-gdv.de/tis e/ware/genuss/rum/rum.htm
Medical care products						
Non-prescription med.						
Pants	pair, jeans, avg.	50.18	3.57	0005	10328	http://www.tis-gdv.de/tis e/ware/textil/konfektion/konfektion.htm
PC	unit	1000	25	0.5	2000	http://www.shipit.co.uk/Overseas Removals Companies Volumes.htm
Personal care products	a basket[1]	12.58	8.664	0.024	346.2	measurement of basket items
Photo equipment	–					
Pork	kg, chops	9.29		1	6.14	
Potatoes	4.54kg	3.83	1.7	0.002	3609.1	http://www.tis-gdv.de/tis e/ware/gemuese/kartoffe/kartoffe.htm
Poultry	kg	4.45	1	0.005	557.1	assume same volume as beef
Prescription medicine	–					
Sport equipment	basket#	99.67	23.61	0.036	2753.3	various sources for items#
Sport vehicles	bicycle	225	17.864	0.268	839.7	http://www.crateworks.com/frameset.html?page=features
Sugar	1lb	0.43	1.354	0.001	699.5	http://www.tis-gdv.de/tis e/ware/zucker/weiszuck/weiszuck.htm
Tobacco	200 cigs	37.78	0.002	6	13861	http://www.discount-cigarettes-online.biz/templates/faq.php
Toys	basket	31.33	–	0.2	156.7	guess
Video equipment	basket*	226.67	0.044	5	5191.4	http://www.tis-gdv.de/tis e/ware/maschinen/unterhaltung/unterhaltung.htm
Watches	piece	50	–	0.0012	41667	dims: 20x10x5cm, volume direct
Wine	liter	5.96	1.175	0.0015	3973.3	same stowage factor as liquor
Fresh fruits	basket	19.36	2.95	0.024	820.3	German transportation database source for each component
Reading materials	book	30	1.78	0.001	33707.9	http://www.tis-gdv.de/tis e/ware/papier/zeitung/zeitung.htm
Tomatoes	kg	2.90	2.373	0.002	1221.9	http://www.tis-gdv.de/tis e/ware/gemuese/tomaten/tomaten.htm

Basket composition identical to that of above table. Additional data sources: #Sports basket contains ski boots (http://www.snowshack.com/head-boot-bag.html), skis and bindings (http://www.snowshack.com/salomon-equipe-2pr-skibag.html), tennis racquet, basketball (http://experts.about.com/q/2551/1184149.htm), golf set (11pc, length 44in = 111cm), dozen golf balls (http://www.overstock.com/cgi-bin/d2.cgi?PAGE=PROFRAME&PROD ID=676397), hockey stick (http://www.unleash.com/picks/sportinggoods/topsportinggoodshockeysticks.asp), hockey skates (15-in x 9-in x 15-in bag), and inline skates and hockey helmet http://secure1.esportspartners.com/store-redskins/main detail.cfm?nCategoryID=4&nObjGroupID=134&nProductID=56453

References

[1] American Automobile Manufacturers' Association. *Motor Vehicles Facts and Figures.* AAMA, Washington, D.C., 1996.

[2] Anindya Banerjee, Massimiliano Marcellino, and Chiara Osbat. Some cautions on the use of panel methods for integrated series of macro-economic data. manuscript, July 2001.

[3] Caroline Betts and Michael B. Devereux. Exchange rate dynamics in a model of pricing-to-market. *Journal of International Economics*, 50(1):215–244, February 2000.

[4] Fabian Bornhorst. On the use of panel unit root tests on cross-sectionally dependent data: an application to PPP. Working Paper ECO 2003/24, European University Institute, November 2003.

[5] Ariel Burstein, Joao C. Neves, and Sergio Rebelo. Distribution costs and real exchange rate dynamics during exchange-rate-based stabilizations. *Journal of Monetary Economics*, 50:1189–1214, September 2003.

[6] Shiu-Sheng Chen and Charles Engel. Does "aggregation bias" explain the PPP puzzle? Working Paper 10304, NBER, February 2004.

[7] Mario Crucini, Chris Telmer, and Marios Zachariadis. Dispersion in real exchange rates. Mimeo, Vanderbilt University, Carnegie Mellon University, Ohio State University, February 2000.

[8] Mario Crucini, Chris Telmer, and Marios Zachariadis. Understanding European real exchange rates. *American Economic Review*, 95(3):724–738, June 2005.

[9] James E. Ertel and Edward B. Fowlkes. Some algorithms for linear splines and piecewise linear regression. *Journal of the American Statistical Association*, 71:640–648, 1976.

[10] C.W.J. Granger and Timo Teräsvirta. *Modelling Nonlinear Economic Relationships.* Oxford University Press, Oxford, 1993.

[11] Michael Grossmann and Sarah Markowiz. Alcohol regulation and violence on college campuses. Working Paper 7129, NBER, May 1999.

[12] Jonathan Gruber, Anindya Sen, and Mark Stabile. Estimating price elasticities when there is smuggling: the sensitivity of smoking to price in Canada. Working Paper 8962, NBER, May 2002.

[13] Bruce Hansen. Inference in TAR models. *Studies in Nonlinear Dynamics and Econometrics*, 2(1):1–14, April 1997.

[14] David Hummels. Have international transportation costs declined? University of Chicago, July 1999.

[15] David Hummels. Time as a trade barrier. Purdue University, July 2001.

[16] David Hummels. Towards a geography of trade costs. University of Chicago, September 2001.

[17] David Hummels and Alexandre Skiba. Shipping the good apples out? An empirical confirmation of the Alchian-Allen conjecture. *Journal of Political Economy*, 112:1384–1402, 2004.

[18] Jean Imbs, Haroon Mumtaz, Morten O. Ravn, and Helene Rey. Non linearites and real exchange rate dynamics. *Journal of the European Economic Association*, 1(2-3):639–649, April May 2003.

[19] Jean Imbs, Haroon Mumtaz, Morten O. Ravn, and Helene Rey. Aggregation bias does explain the PPP puzzle. Discussion Paper 5237, CEPR, September 2005.

[20] Jean Imbs, Haroon Mumtaz, Morten O. Ravn, and Helene Rey. PPP strikes back: Aggregation and the real exchange rate. *Quarterly Journal of Economics, forthcoming*, 2005.

[21] Lutz Kilian and Mark P. Taylor. Why is it so difficult to beat the random walk forecast of exchange rates? *Journal of International Economics*, 60:87–107, May 2003.

[22] David E. Lebow and Jeremy B. Rudd. Measurement error in the consumer price index: Where do we stand? Finance and Economic Discussion Papers 61, The Federal Reserve Board, December 2001.

[23] Johan Lyhagen. Why not use standard panel unit root tests for testing PPP. Working Papers Series in Economics and Finance 413, Stockholm School of Economics, December 2000.

[24] Dennis Novy. Is the iceberg melting less quickly? international trade costs after world war ii. University of Cambridge manuscript, July 2006.

[25] Dennis Novy. Trade costs in a model of pricing-to-market. University of Cambridge manuscript, July 2006.

[26] Maurice Obstfeld and Alan M. Taylor. Nonlinear aspects of goods-market arbitrage and adjustment: Heckschers commodity points revisited. *Journal of the Japanese and International Economics*, (11):441–479, 1997.

[27] Paul G. J. O'Connel. The overvaluation of purchasing power parity. *Journal of International Economics*, 44:1–19, 1998.

[28] David H. Papell. Searching for stationarity: Purchasing power parity under the current float. *Journal of International Economics*, (43):313–332, 1997.

[29] Melissa A. A. Rodrigues, Maria Lucia A. Borges, Adriana S. Franca, Leandro S. Oliveira, and Paulo C. Correa. Evaluation of physical characteristics of coffee during roasting. Manuscript, December 2003.

[30] Timo Teräsvirta. Specification, estimation and evaluation of smooth transition autoregressive models. *Journal of the American Statistical Association*, 89(425):208–218, March 1994.

[31] Howell Tong. *Non-linear Time Series: A Dynamic Systems Approach*. Clarendon Press, Oxford, 1990.

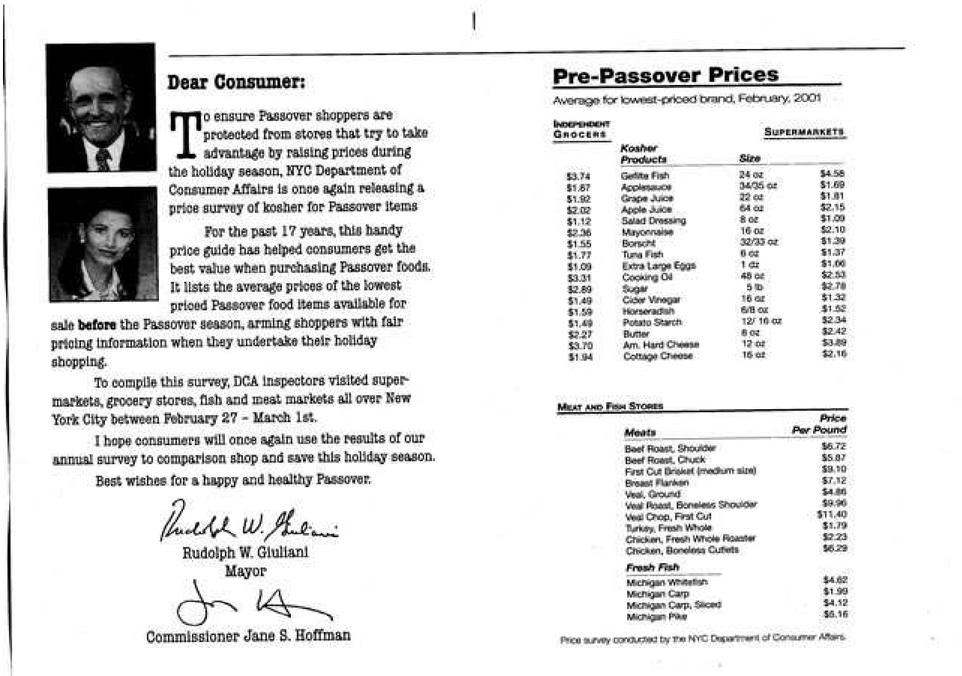
[32] Ruey S. Tsay. Nonlinearity tests for time series. *Biometrika*, 73(2):461–466, August 1986.

[33] Ruey S. Tsay. Testing and modeling threshold autoregressive processes. *Journal of the American Statisctical Association*, 84(405):231–240, March 1989.

[34] Asaf Zussman. Limits to arbitrage: Trading frictions and deviations from purchasing power parity. Manuscript, December 2002.

C Figures

Figure 1: Some prices in NYC, February 2001



Dear Consumer:

To ensure Passover shoppers are protected from stores that try to take advantage by raising prices during the holiday season, NYC Department of Consumer Affairs is once again releasing a price survey of kosher for Passover items

For the past 17 years, this handy price guide has helped consumers get the best value when purchasing Passover foods. It lists the average prices of the lowest priced Passover food items available for sale **before** the Passover season, arming shoppers with fair pricing information when they undertake their holiday shopping.

To compile this survey, DCA inspectors visited supermarkets, grocery stores, fish and meat markets all over New York City between February 27 – March 1st.

I hope consumers will once again use the results of our annual survey to comparison shop and save this holiday season.

Best wishes for a happy and healthy Passover.

Rudolph W. Giuliani
Mayor

Commissioner Jane S. Hoffman

Pre-Passover Prices

Average for lowest-priced brand, February, 2001

Independent Grocers	Kosher Products	Size	Supermarkets
$3.74	Gefilte Fish	24 oz	$4.58
$1.67	Applesauce	34/35 oz	$1.69
$1.92	Grape Juice	22 oz	$1.81
$2.02	Apple Juice	64 oz	$2.15
$1.12	Salad Dressing	8 oz	$1.09
$2.36	Mayonnaise	16 oz	$2.10
$1.55	Borscht	32/33 oz	$1.39
$1.77	Tuna Fish	6 oz	$1.37
$1.09	Extra Large Eggs	1 dz	$1.66
$3.31	Cooking Oil	48 oz	$2.53
$2.89	Sugar	5 lb	$2.78
$1.49	Cider Vinegar	16 oz	$1.32
$1.59	Horseradish	6/8 oz	$1.52
$1.49	Potato Starch	12/ 16 oz	$2.34
$2.27	Butter	8 oz	$2.42
$3.70	Am. Hard Cheese	12 oz	$3.89
$1.94	Cottage Cheese	16 oz	$2.16

Meat and Fish Stores

Meats	Price Per Pound
Beef Roast, Shoulder	$6.72
Beef Roast, Chuck	$5.87
First Cut Brisket (medium size)	$9.10
Breast Flanken	$7.12
Veal, Ground	$4.86
Veal Roast, Boneless Shoulder	$9.96
Veal Chop, First Cut	$11.40
Turkey, Fresh Whole	$1.79
Chicken, Fresh Whole Roaster	$2.23
Chicken, Boneless Cutlets	$6.29
Fresh Fish	
Michigan Whitefish	$4.62
Michigan Carp	$1.99
Michigan Carp, Sliced	$4.12
Michigan Pike	$5.16

Price survey conducted by the NYC Department of Consumer Affairs.

Figure 2: Thresholds and Half Lives

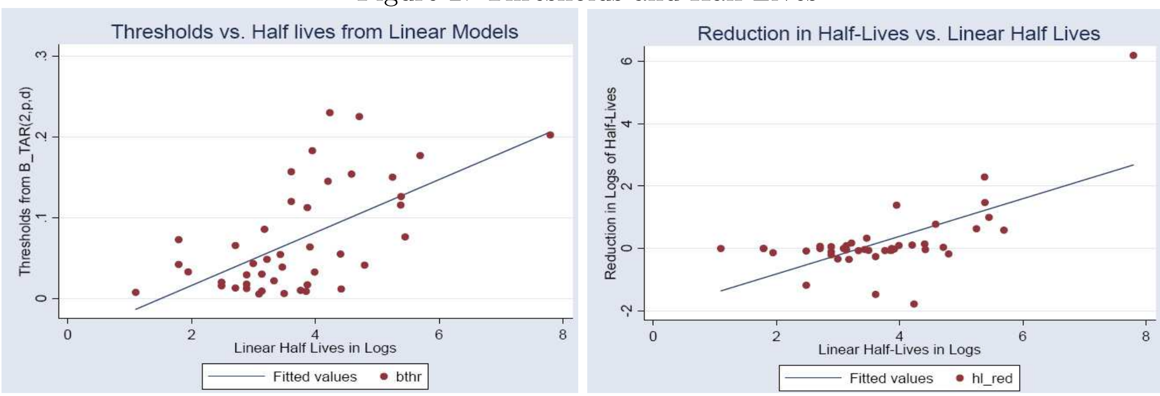


Figure 3: Drop in Canadian Tobacco taxes, 1994

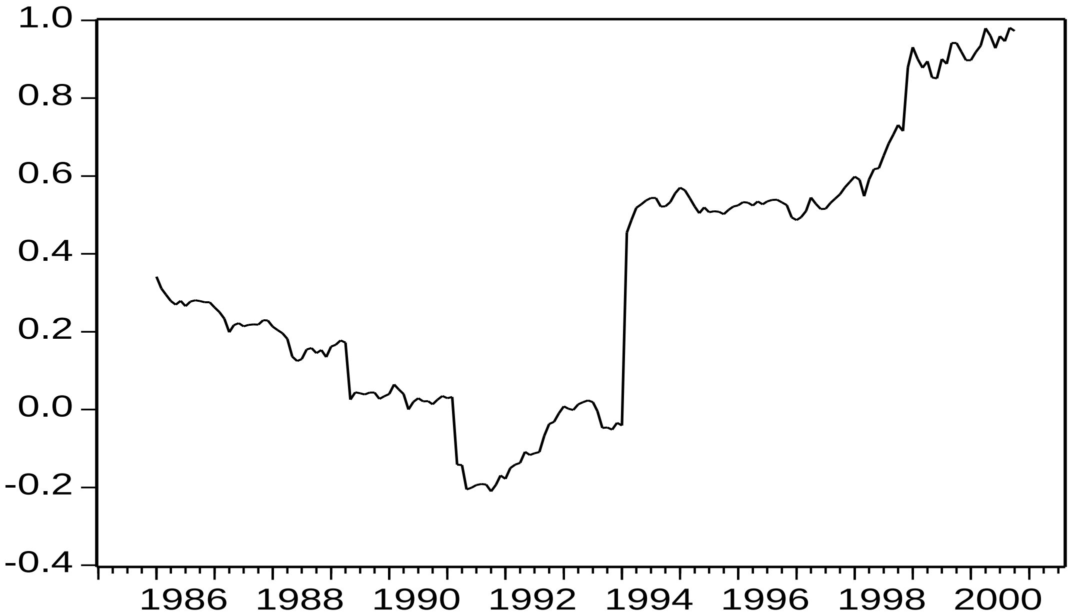
Table 1: Cigarette tax rates per carton of 200 cigarettes[1–12]

	Year; tax rate, $		
Province	1993	1994	Date of change
Provinces where provincial taxes were cut			
Quebec	29.61	8.61	February 1994*
New Brunswick	29.45	15.45	February 1994
Ontario	28.85	9.65	February 1994†
Prince Edward Island	35.45	21.20	March 1994‡
Nova Scotia	29.45	15.45	April 1994
Provinces where provincial taxes were not cut			
Newfoundland	36.41	31.41	NA§
Manitoba	31.85	26.85	NA
Saskatchewan	31.85	26.85	NA
Alberta	29.85	24.85	NA
British Columbia	37.85	32.85	NA

*The tax rate in Quebec subsequently increased, reaching $10.81 in May 1995.
†The tax rate in Ontario subsequently increased, reaching $10.85 in February 1995.
‡The tax rate in PEI was further reduced to $19.20 in June 1994.
§NA = not applicable.

188 CAN MED ASSOC J • 15 JANV. 1997; 156 (2)

Figure 4: Effects of tobacco tax change



D Tables

Table 4: Long run properties of exchange rates

	Sample: 1947:1–2000:8			Sample: 1947:1–1969:12			Sample: 1970:1–2000:8		
	NER	RER	Rel. CPI	NER	RER	Rel. CPI	NER	RER	Rel. CPI
Lags[0]	1	11	13	6	12	13	1	11	13
ADF stat.[1]	0.057	-0.923	-1.923*	-0.667	-1.195	-1.444	0.471	-0.614	-1.495
ADF stat.[2]	0.067	-0.884	-1.931	-1.545	-2.083	-3.19**	-0.225	-0.881	-1.882
ADF stat.[3]	-16.6***	-5.4***	-5.5***	-9.9***	-3.35**	-4.2***	-12.6***	-4.2***	-4.0***
Half life[4]	– (1.001)	– (1.0014)	146.4	74.2	27.3	10.5	14145	– (1.0015)	140

Table 5: Long run properties of linearly detrended exchange rates

	Sample: 1947:1–2000:8			Sample: 1947:1–1969:12			Sample: 1970:1–2000:8		
	NER	RER	Rel. CPI	NER	RER	Rel. CPI	NER	RER	Rel. CPI
Lags[0]	11	1	13	13	12	12	11	13	13
ADF stat.[1]	-2.93***	-2.09**	-2.26***	-2.57***	-3.22***	-2.11**	-1.87*	-1.74*	-1.98**
ADF stat.[2]	-2.93**	-2.09	-2.25	-2.74*	3.37**	-2.1	-1.86	-1.72	-1.99
ADF stat.[3]	-6.01***	-5.3***	-5.35***	-4.39***	-3.35**	-3.95***	-4.48***	-4.16***	-4.3***
Half life[4]	98.7	64.1	128	66	15.4	13	154.3	228.3	321.9

Table 6: Long run properties of HP-detrended exchange rates

	Sample: 1947:1–2000:8			Sample: 1947:1–1969:12			Sample: 1970:1–2000:8		
	NER	RER	Rel. CPI	NER	RER	Rel. CPI	NER	RER	Rel. CPI
Lags[0]	11	11	13	15	13	13	12	11	17
ADF stat.[1]	-8.2***	-7.4***	-7.8***	-4***	-4.6***	-5.3***	-5.4***	-5.9***	-5.6***
ADF stat.[2]	-8.2***	-7.4***	-7.9***	-4***	-4.6***	-5.3***	-5.4***	-5.9***	-5.6***
ADF stat.[3]	-9.2***	-8.6***	7.5***	-6***	-5.7***	-5.1***	-5.9***	-5.8***	-5.8***
Half life[4]	5	4.5	4.9	5	4.3	3.2	4.9	4.6	5.9

All series are demeaned and in logarithms.

[0] Lags may vary for ADF tests in differences, depending on the PACF criteria.

[1] Augmented Dickey-Fuller test in levels, no intercept, no trend.

[2] Augmented Dickey-Fuller test in levels, with intercept, no trend.

[3] Augmented Dickey-Fuller test in differences, with intercept, no trend.

[4] AR(1) half-life is calculated without a constant.

Table 7: Long run properties: ADF and half-life convergence

	obs	Tsay's non-linear test (p-value)[1]	ADF p-value[2]	Philips-Perron[2]	half-life$_A$	half-life^3_B
Apples	367	0.000	0.000	0.000	5	6
Audio equipment	189	0.018	0.919	0.935	182	–
Beef	358	0.000	0.159	0.383	20	29
Beer	367	0.026	0.606	0.595	114	–
Car purchase	367	0.118	0.093	0.114	19	27
Car maintenance	265	–	0.953	0.954	1216	–
Car parts	118	0.066	0.111	0.133	22	–
Cheese	189	–	0.968	0.952	–	–
Clothes	224	0.125	0.438	0.514	26	83
Clothes (men)	224	0.097	0.545	0.593	34	265
Clothes (women)	224	0.132	0.182	0.337	15	26
Coffee	358	0.003	0.840	0.778	130	–
Educat. books & supplies	71	0.011	0.936	0.937	119	–
Eggs	367	0.016	0.000	0.000	5	6
Electricity	367	0.191	0.670	0.643	107	–
Fats and oils	142	0.003	0.618	0.572	35	–
Fish and seafood	190	0.134	0.916	0.907	175	–
Flour	274	0.084	0.382	0.345	40	258
Footwear	367	0.007	0.076	0.124	21	31
Footwear (men)	190	0.166	0.230	0.338	15	27
Footwear (women)	274	0.010	0.157	0.375	19	32
Fuel oil	334	0.001	0.416	0.454	39	117
Furniture	370	0.020	0.619	0.625	59	804
Gas	367	0.010	0.124	0.095	16	21
Gasoline	367	0.079	0.422	0.467	43	132
House chemicals	367	–	0.978	0.962	–	–
Jewelry	118	0.008	0.340	0.335	21	–
Laundry appliances	190	0.194	0.851	0.846	94	–
Liquor	274	0.153	0.797	0.733	103	–
Medical care products	266	–	0.987	0.982	–	–
Non-prescription medicine	167	0.031	0.882	0.859	132	–
Pants	274	0.117	0.000	0.124	11	14
PC	35	0.259	0.398	0.394	6	519
Personal care products	358	0.215	0.000	0.884	338	–
Photo equipment	190	–	0.947	0.947	579	–
Pork	266	–	0.404	0.531	23	45
Potatoes	270	0.000	0.000	0.000	4	4
Poultry	367	0.058	0.016	0.049	14	17
Prescription medicine	190	0.004	0.993	0.988	–	–
Sport equipment	266	0.067	0.476	0.464	37	200
Sport vehicles	266	0.000	0.435	0.445	48	–
Sugar	142	0.041	0.704	0.697	39	–
Tobacco	178	–	0.964	0.951	–	–
Toys	190	0.093	0.000	0.569	31	622
Video equipment	58	0.118	0.614	0.569	10	–
Watches	94	0.014	0.001	0.003	2	3
Wine	331	0.086	0.439	0.422	69	–
Airfare	367	0.054	0.000	0.000	5	5
Cable TV	201	0.049	0.752	0.785	45	–
Car insurance	367	0.009	0.533	0.450	43	132
Child care	117	–	0.991	0.990	451	–
Dental services	367	–	0.985	0.994	260	–
Fresh fruits	367	–	0.859	0.911	77	–
Intra-city transport	273	0.202	0.431	0.426	32	102
Margarine	367	0.094	0.296	0.286	31	60
Medical services	189	–	0.975	0.976	438	–
Reading materials	273	0.010	0.000	0.607	48	–
Rent	367	0.030	0.976	0.962	1195	–
Restaurant meals	367	0.082	0.870	0.771	117	–
Shelter	265	0.000	0.000	0.934	509	–
Tomatoes	367	0.033	0.002	0.051	8	9
Tuition	273	0.001	0.000	0.014	44	779
Water and sewerage	330	0.089	0.816	0.803	120	–

[1] Test requires stationarity. [2] McKinnon asymptotic p-values. [3] After correcting for small-sample bias in AR(1) coefficient using Kendall's formula.

Table 8: EQ-TAR Summary

	STD	AR(1) half life	TAR(2,1,1) threshold	TAR(2,1,1) half life	AR(p) half life	TAR(2,p,d) threshold	TAR(2,p,d) half life
Foods	0.147	45	0.144	34	41	0.083	58
Vice goods	0.188	72	0.115	79	91	0.134	105
Clothing and footwear	0.075	20	0.035	21	26	0.041	19
Tech stuff	0.085	156	0.077	45	540	0.063	38
Fuels	0.149	51	0.109	45	50	0.070	48
Medical and chemical	0.146	235	0.194	100	244	0.131	90
Cars and car parts	0.074	20	0.039	19	27	0.046	23
Laundry appliances	0.099	94	0.134	26	98	0.154	25
Furniture	0.092	59	0.125	30	67	0.145	34
Services	0.133				224	0.054	241
CPI-RER	0.111		0.071		162	0.012	213

Table 9: BAND-TAR Summary

	STD	AR(1) half life	TAR(2,1,1) threshold	TAR(2,1,1) half life	AR(p) half life	TAR(2,p,d) threshold	TAR(2,p,d) half life
Foods	0.147	45	0.146	22	41	0.083	29
Vice goods	0.188	72	0.149	70	55	0.144	149
Clothing and footwear	0.075	20	0.027	23	26	0.022	31
Tech stuff	0.085	156	0.079	33	540	0.063	27
Fuels	0.149	51	0.097	43	50	0.069	50
Medical and chemical	0.146	235	0.193	332	244	0.105	527
Cars and car parts	0.074	20	0.039	22	27	0.035	26
Laundry appliances	0.099	94	0.074	111	98	0.154	45
Furniture	0.092	59	0.127	43	67	0.145	60
Services	0.133				224	0.065	160
CPI-RER	0.111		0.071	1733	162	0.012	193

Table 10: EQ-TAR(2,p,d) results

	LLR	TAR(2,p,d) threshold	TAR(2,p,d) halflife	p-value (old, 600)
Total RER-CPI	-9.1	0.012	213	0.056
Apples	20.9	0.073	6	0.126
Audio equipment	12.6	0.078	115	0.103
Beef	13.4	0.039	23	0.235
Beer	1.8	0.041	113	0.260
Car purchase	2.9	0.022	25	0.278
Car maintenance	-1.9	0.086	470	0.114
Car parts	1	0.070	20	0.425
Cheese	-2.7	0.081	563	0.113
Clothes	1	0.084	21	0.201
Clothes (men)	-11.8	0.132	8	0.189
Clothes (women)	-7.1	0.009	23	0.270
Coffee	1.3	0.223		0.070
Educational books and supplies	1.4	0.116	9	0.131
Eggs	-1.9	0.034	7	0.414
Electricity	1.4	0.059	79	0.218
Fats and oils	2.7	0.033	53	0.211
Fish and seafood	-2.1	0.152	27	0.107
Flour	20.5	0.157	27	0.124
Footwear	-6.3	0.006	34	0.192
Footwear (men)	-2.4	0.019	22	0.367
Footwear (women)	-13.4	0.020	13	0.214
Fuel oil	4.1	0.112	45	0.204
Furniture	10.4	0.145	34	0.194
Gas	44.5	0.043	18	0.029
Gasoline	28.3	0.064	48	0.190
House chemicals	-1.3	0.166		0.152
Jewelry	-2.1	0.080	18	0.386
Laundry appliances	-2.2	0.154	25	0.185
Liquor	-4.1	0.012	86	0.075
Medical care products	-4.9	0.027		0.091
Non-prescription medicine	2	0.150	42	0.143
Pants	-5.1	0.016	11	0.327
PC	-1.4	0.018	18	0.000
Personal care products	-3.2	0.263	138	0.211
Photo equipment	-1.1	0.202	37	0.114
Pork	-3.6	0.013	15	0.288
Potatoes	1.3	0.065	14	0.356
Poultry	20.5	0.086	15	0.103
Prescription medicine	-3.7	0.047		0.077
Sport equipment	-4.3	0.055	49	0.183
Sport vehicles	43.1	0.183	11	0.066
Sugar	1.6	0.030	23	0.410
Tobacco	106.8	0.301	172	0
Toys	10.8	0.145	18	0.201
Video equipment	5.9	0.012	18	0.177
Watches	-5.2	0.007	3	0.332
Wine	30.1	0.230	47	0.029
Airfare	-2.3	0.015	11	
Cable TV	22.1	0.042	51	
Car insurance	23.2	0.025	48	
Child care	10.1	0.018		
Dental services	9.4	0.046		
Fresh fruits	-12.5	0.051	11	
Intra-city transport	4.9	0.036	51	
Margarine	0.9	0.117	15	
Medical services	0.3	0.161		
Reading materials	-2.2	0.017	48	
Rent	-3.3	0.016	1066	
Restaurant meals	5	0.040	63	
Shelter	-2.2	0.033	146	
Tomatoes	-28.5	0.042	6	
Tuition	-0.05	0.017	17	
Water and sewerage	-2.7	0.114	75	

LLR test p-values obtained by Monte Carlo simulation, 5000 iterations.

Table 11: BAND-TAR(2,p,d) results

	LLR	TAR(2,p,d) threshold	TAR(2,p,d) halflife	p-value
Total RER-CPI	-9	0.012	193	0.057
Apples	23	0.073	6	0.094
Audio equipment	13	0.076	86	0.087
Beef	15.1	0.039	23	0.243
Beer	1.3	0.041	144	0.179
Car purchase	1.2	0.022	30	0.249
Car maintenance	-1.9	0.167	58	0.110
Car parts	6.5	0.048	21	0.446
Cheese	-1	0.163	24	0.106
Clothes	-2.2	0.087	36	0.208
Clothes (men)	-11.8	0.010	46	0.182
Clothes (women)	-7.3	0.009	24	0.229
Coffee	1.4	0.225	107	0.071
Educational books and supplies	-1.7	0.116	22	0.090
Eggs	-4	0.033	8	0.413
Electricity	2.5	0.055	71	0.211
Fats and oils	3.1	0.033	49	0.185
Fish and seafood	-2.5	0.126	50	0.107
Flour	17.3	0.157	48	0.230
Footwear	-6.6	0.006	35	0.164
Footwear (men)	-3	0.006	22	0.365
Footwear (women)	-14.1	0.020	39	0.212
Fuel oil	5.9	0.112	48	0.206
Furniture	10.4	0.145	60	0.165
Gas	41.9	0.043	28	0.088
Gasoline	28.7	0.064	51	0.134
House chemicals	-1.3	0.125	188	0.192
Jewelry	-1.3	0.029	17	0.398
Laundry appliances	-2.3	0.154	45	0.194
Liquor	-4.1	0.012	86	0.1
Medical care products	-4.9	0.027	9634	0.079
Non-prescription medicine	0.9	0.150	101	0.144
Pants	-5.6	0.016	13	0.291
PC	-1.6	0.018	22	0.000
Personal care products	-2.2	0.177	165	0.236
Photo equipment	1.2	0.202	5	0.0104
Pork	-3.6	0.013	15	0.286
Potatoes	-0.6	0.065	14	0.175
Poultry	18.6	0.086	34	0.296
Prescription medicine	-4	0.047	1655	0.064
Sport equipment	-5.6	0.009	50	0.224
Sport vehicles	40.5	0.183	13	0.085
Sugar	2.7	0.030	21	0.375
Tobacco	107.5	0.303	106	0.000
Toys	8.7	0.120	161	0.211
Video equipment	5.6	0.012	20	0.169
Watches	-3.4	0.008	3	0.273
Wine	27	0.230	409	0.090
Airfare	-2.4	0.015	11	0.319
Cable TV	22.4	0.042	50	0.077
Car insurance	23.2	0.025	51	0.141
Child care	10	0.019	461	0.164
Dental services	8.4	0.046		0.161
Fresh fruits	-13	0.051	11	0.324
Intra-city transport	5.2	0.061	60	0.191
Margarine	1	0.054	32	0.247
Medical services	0.9	0.166	165	0.170
Reading materials	-2.4	0.017	51	0.102
Rent	-3.1	0.016	542	0.121
Restaurant meals	5.1	0.040	68	0.053
Shelter	-1.7	0.033	119	0.041
Tomatoes	-28.5	0.042	6	0.443
Tuition	1.3	0.028	18	0.431
Water and sewerage	-1.6	0.114	76	0.239

LLR test p-values obtained by Monte Carlo simulation, 5000 iterations.

Table 12: Threshold regressions

	1	2	3	4	5	6
dep. var.	Thr_B	Thr_B	Thr_B	Thr_B	Thr_B	Thr_B
Cnst	**8.7*****	**11*****	**8.7*****	**7.8*****	**10*****	**10*****
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
P/W	-0.036	**-0.073*****	**-0.061*****	–	**-0.17*****	–
	(0.168)	(0.006)	(0.008)		(0.002)	
P/W^2	–	–	–	–	**0.0005****	–
					(0.021)	
log(P/W)	–	–	–	–	–	**-1.46*****
						(0.01)
P/V	–	–	–	-0.0001	–	–
				(0.11)		
D_{tob}	–	**29*****	**28*****	**24*****	**32*****	**27*****
		(0.001)	(0.000)	(0.001)	(0.000)	(0.000)
tariff	–	-14.5	–	–	–	–
		(0.6)				
CPI^{weight}	–	**-2.2***	–	–	–	–
		(0.098)				
Herfindahl	–	0.001	–	–	–	–
		(0.57)				
R^2	0.05	0.46	0.37	0.29	0.46	0.35
F-stat	0.17	0.003	0.002	0.002	0.000	0.000
N	41	34	41	41	41	41

p-values in parentheses. A $^{*}\sim 10\%$, ** 5% and *** 1% significance.

Table 13: Threshold regressions - robustness

	1	2	3	4	5	6
dep. var.	$Thr_{B,NT}$	$Thr_{B,NT}$	$Thr_{B,NTE}$	$Thr_{B,NTE}$	$Thr_{B,NTAE}$	$Thr_{B,NTAE}$
Cnst	**8.68*****	**8.42*****	**8.9*****	**7.9*****	**8.7*****	**7.7*****
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
P/W	**-0.059****	–	**-0.064*****	–	**-0.062*****	–
	(0.013)		(0.008)		(0.006)	–
P/V	–	**-0.0002****	–	**-0.00012***	–	**-0.0001***
		(0.052)		(0.107)		(0.10)
R^2	0.16	0.1	0.18	0.07	0.21	0.08
F-stat	0.013	0.05	0.008	0.048	0.006	0.099
N	2.36	2.48	38	38	35	35

p-values in parentheses. A $^{*}\sim 10\%$, ** 5% and *** 1% significance. "$_{NT}$" is a regression excluding tobacco due to a large discrete jump in its relative price in 1994 following a tax change. "$_{NTE}$" excludes tobacco and energies (gasoline, natural gas). "$_{NTAE}$" excludes tobacco, alcohol (liquor, beer, wine) and energies (gasoline, natural gas)

Table 14: Threshold regressions

	Tobit						OLS, Non-linear series only		
	Non-linear only			Non-lin. & Stationary					
	1	2	3	4	5	6	7	8	9
Const.	**7.6***	**8.6*****	**10*****	**12*****	**10*****	**11*****	**11****	**9*****	**10*****
	(0.06)	(0.00)	(0.000)	(0.00)	(0.00)	(0.00)	(0.02)	(0.00)	(0.00)
P/W	**-0.062***	**-0.058****	**-0.17****	**-0.076*****	**-0.067*****	**-0.18*****	**-0.066****	**-0.05****	**-0.14****
	(0.06)	(0.036)	(0.022)	(0.003)	(0.004)	(0.001)	(0.026)	(0.042)	(0.048)
$(P/W)^2$	–	–	**0.0006***	–	–	**0.0006****	–	–	0.0004
			(0.057)			(0.013)			(0.17)
CPI^{weight}	**-6.46***	**-5.92****	**-5.8****	**-3.08****	**-2.4****	**-2.2***	-1.8	–	–
	(0.07)	(0.045)	(0.037)	(0.034)	(0.05)	(0.056)	(0.2)		
Tariff	10.6	–	–	-14.4	–	–	-3.1	–	–
	(0.78)			(0.59)			(0.93)		
Herfindahl	0.001	–	–	-0.00048	–	–	-0.002	–	–
	(0.72)			(0.80)			(0.53)		
D_{tob}	**34*****	**35*****	**35*****	**33*****	**30*****	**35*****	**29****	**26*****	**30*****
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.013)	(0.00)	(0.00)
N	34	41	41	34	41	41	23	30	30
LogL or R^2	17.3	28.3	30.1	42.6	53.7	56.8	0.5	0.39	0.43
LR χ^2 or F-prob	16.3	19.6	23.4	21.3	21.8	28.2	0.023	0.012	0.002

p-values in parentheses. A * $\sim$ sig. at 10%, ** at 5% and *** at 1%. "D_{tob}" is a dummy variable (= 1 for tobacco) due to a large discrete jump in its relative price in 1994 following a tax change.

Table 15: Threshold regressions (estimates with **drop in transport costs**)

	Tobit						OLS, Non-linear series only		
	Non-linear only			Non-linear and Stationary					
	1	2	3	4	5	6	7	8	9
Cnst	**9****	**11*****	**12*****	**13*****	**11*****	**13*****	**13.5*****	**13*****	**11*****
	(0.045)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.007)	(0.00)	(0.00)
P/W	**-0.071****	**-0.067****	**-0.19*****	**-0.085*****	**-0.076*****	**-0.2*****	**-0.077*****	**-0.06****	**-0.06****
	(0.039)	(0.025)	(0.010)	(0.003)	(0.003)	(0.001)	(0.009)	(0.018)	(0.018)
$(P/W)^2$	–	–	**0.0006***	–	–	**0.0006****	–	–	0.0004
			(0.061)			(0.013)			(0.174)
CPI^{weight}	**-9.2****	**-8.84****	**-7.8****	**-3.8****	**-3.2****	**-3****	**-10.6****	**-8.4****	–
	(0.043)	(0.02)	(0.025)	(0.018)	(0.029)	(0.029)	(0.023)	(0.032)	
tariff	11.1	–	–	-14.6	–	–	-5.1	–	–
	(0.78)			(0.62)			(0.88)		
Herfindahl	0.002	–	–	0.0001	–	–	0.0033	–	–
	(0.60)			(0.96)			(0.31)		
D_{tob}	**37*****	**40*****	**44*****	**34*****	**33*****	**38*****	**34*****	**36*****	**32*****
	(0.003)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.004)	(0.00)	(0.00)
N	34	41	41	34	41	41	23	30	30
LogL or R^2	18.5	26.2	28	39.3	49.3	52.5	0.61	0.47	0.41
LR χ^2 or F-prob	16.3	21.8	25.4	21.2	21.8	28.19	0.004	0.000	0.003

p-values in parentheses. A * $\sim$ sig. at 10%, ** at 5% and *** at 1%. "D_{tob}" is a dummy variable (= 1 for tobacco) due to a large discrete jump in its relative price in 1994 following a tax change.

Table 16: Half life regressions

	1	2	3	4	5	6
dep. var.	hl_B	$hl_{B,NT}$	$hl_{B,NTAE}$	$hl_{B,NTAE}$	$hl_{B,NTAE}$	$hl_{B,NTAE}$
Cnst	**60*****	**79*****	**62*****	**34*****	**40*****	**50*****
	(0.002)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
P/W	**-0.5***	**-0.45***	**-0.31***	–	**-0.27***	**-0.33****
	(0.06)	(0.096)	(0.074)		(0.085)	(0.036)
Stow. factor	–	–	–	**1.18****	**1.3*****	**1.14****
				(0.017)	(0.008)	(0.019)
D_{chill}	**-66****	**-54***	**-37****	–	–	-28
	(0.027)	(0.066)	(0.045)			(0.11)
tariff	**468***	–	–	–	–	–
	(0.085)					
R^2	0.18	0.12	0.16	0.16	0.24	0.30
F-stat(prob)	0.058	0.086	0.063	0.017	0.013	0.011
N	41	40	35	35	35	35

p-values in parentheses. A * $\sim$ 10%, ** 5% and *** 1% significance. "$_{NT}$" is a regression excluding tobacco due to a large discrete jump in its relative price in 1994 following a tax change. "$_{NTAE}$" is a regression excluding tobacco, alcohol and energies (the latter two due to poor tradability). Stowage factor is a ratio of weight to stowage space of a product, measured in ton/m^3. "D_{chill}" is a dummy variable =1 for beef, cheese, eggs, fish and seafood, poultry, fresh fruits, margarine and tomatoes.

Table 17: Half-life regressions, robustness

		Conditional half-lives							
		Tobit			**OLS, Non-lin series only**		**OLS, Lin. control**	
	AR(p)	Non-lin only	Non-lin & Station.					
	1	2	3	4	6	7	8	9
Cnst	**104*****	**85***	**120*****	**85*****	**117***	**57****	**96*****	**66****
	(0.001)	(0.080)	(0.001)	(0.002)	(0.057)	(0.02)	(0.005)	(0.002)
P/W	**-0.51***	**-0.61***	**-0.69****	**-0.55****	**-0.64***	**-0.5***	**-0.62****	**-0.5***
	(0.081)	(0.099)	(0.015)	(0.052)	(0.085)	(0.094)	(0.046)	(0.06)
CPI^{weight}	-4.32	**-72.8***	-28	–	-51	–	-6.3	–
	(0.76)	(0.089)	(0.13)		(0.36)		(0.69)	
tariff	-0.5	666	502	**639****	790	**712****	440	**456***
	(0.42)	(0.13)	(0.11)	(0.045)	(0.36)	(0.052)	(0.20)	(0.098)
Herfindahl	-0.02	-0.34	**-0.046***	**-0.035***	-0.038	–	-0.02	–
	(0.33)	(0.32)	(0.066)	(0.096)	(0.36)		(0.38)	
D_{tob}	–	171	133	–	107	–	70	–
		(0.156)	(0.12)		(0.42)		(0.43)	
D_{chill}	–	-77.2	**-85.7****	**-78.5****	**-111.5***	**-87****	**-77***	**-68****
		(0.136)	(0.025)	(0.044)	(0.056)	(0.019)	(0.065)	(0.024)
N	31	34	34	34	23	30	34	41
R^2, LogL	0.16	-143	-181	-183	0.32	0.25	0.24	0.19
F-prob, $LR\chi^2$		9.7	12.9	8.57	0.33	0.055	0.37	0.099

p-values in parentheses. A * $\sim$ sig. at 10%, ** at 5% and *** at 1%. "D_{tob}" is a dummy variable (= 1 for tobacco) due to a large discrete jump in its relative price in 1994 following a tax change. "D_{chill}" is a chilling dummy =1 for items requiring refrigeration. "Linearity control" includes a dummy=1 for series that can not reject linearity.