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# Mexico's Integration into NAFTA Markets: A View from Sectoral Real Exchange Rates and Transaction Costs

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**Mexico's Integration into NAFTA Markets: A View from Sectoral Real Exchange Rates and Transaction Costs**

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**Abstract**



A self-exciting threshold autoregressive model is used to measure transaction costs that may explain relative price differentials and nonlinearities in the behavior of sectoral real exchange rates across Mexico, Canada, and the U.S. Interpreting price threshold bands as transactions costs, we find evidence that Mexico still face higher transaction costs than their developed counterparts, even though trade liberalization lowers relative price differentials between countries. The distance between countries and nominal exchange rate volatility are found to be determinants of transaction costs that limit price convergence. Other factors—including weak domestic competition and transportation—are also likely to be important.

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# I. INTRODUCTION

**Is Mexico reaping the full benefits of its integration within NAFTA markets?** The analysis of relative price differentials across countries and sectors offers a way to evaluate the degree of market integration. The study of NAFTA members is of particular interest, allowing an assessment of whether regional trade liberalization has resulted in faster price convergence and smaller price differentials across countries, and, greater market integration.

**The Law of One Price, or "LOOP," states that identical goods should sell for the same price across countries when prices are expressed in a common currency**. Evidence has shown, however, that prices of goods fail to fully equalize between countries, indicating that markets are not perfectly integrated—due to some kind of transaction costs that limit price arbitrage. Obstacles to integration include transport costs and (explicit or implicit) trade barriers. Our analysis sheds light on the following questions:

- **Is the degree of Mexico–U.S. integration similar to that of Canada–U.S. integration?** We find that transaction costs are larger for the Mexico–U.S. country pair than for the Canada–U.S. pair.

- **Have markets become more integrated, with reduced transaction costs, after the introduction of NAFTA?** Our results show that NAFTA significantly reduced price differentials between the U.S. and Mexico, as trade liberalization evidently reduced transaction costs, though this was not uniform across sectors.

- **What are some of the determinants of transaction costs?** In addition to trade liberalization, sharing a common border and having lower exchange rate volatility are found to reduce transaction costs. However, it appears that industry or good-specific characteristics must account for a large part of transaction costs.

**The empirical methodology analyzes dynamics in relative price adjustment and innovates by taking the perspective of an emerging market—Mexico**.[2] Due to transaction costs, it may not be profitable to arbitrage away relative price differences across countries (see Dumas, 1992; Sercu and others, 1995 and O'Connell, 1998). When the marginal costs of arbitrage exceed the marginal benefit, there is a zone of no-trade and consequently prices in two locations fail to equalize. Outside this zone, arbitrage is profitable and the sectoral real exchange rate (SRER) can become mean-reverting. The existence of such "threshold band" requires the use of a nonlinear model—more specifically, a threshold autoregressive model (Tong, 1990; and Hansen, 1996, 1997). The estimated price thresholds are a measure of

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[2] There is now an established literature on nonlinear behavior of sectoral real exchange rates for developed markets (see Obstfeld and Taylor, 1997; Sarno, Taylor and Chowdhury, 2004; Imbs and others, 2003; and Juvenal and Taylor, 2008).

transaction costs, and the absence of relative price convergence is interpreted as a sign of weak market integration. Our paper intends to use recently developed testing techniques to confirm whether the autoregressive process outside the threshold band is different from the random walk observed inside the band. We also attempt to identify determinants of transaction costs across country pairs, sectors, and over time.

**The remainder of the paper is organized as follows.** Section II reviews theoretical considerations on nonlinear dynamics in sectoral real exchange rates and presents the corresponding econometric methodology. The results are discussed in Section III. The determinants of transaction costs are studied in Section IV. The last section summarizes and concludes.

## II. Nonlinear Dynamics in Real Exchange Rates

### A. Theoretical Underpinnings

**According to the law of one price (LOOP), there should be no price differentials across countries for similar goods when prices are expressed in a common currency**. At the aggregate level, the LOOP translates into purchasing power parity (PPP). The LOOP is based on the assumption that there are no transaction costs or impediments to trade that would prevent perfect arbitrage and allow sectoral price differentials—it relies on a frictionless goods arbitrage.

Deviations $x^i_{jt}$ from the LOOP for a sector *j* in country *i* at time *t* are defined as:

$$x^i_{jt} = s^i_t + p^i_{jt} - p_{jt} \tag{1}$$

where $s^i_t$ is the logarithm of the nominal exchange rate between country *i*'s currency and the reference country, $p^i_{jt}$ is the logarithm of the price of good *j* in country *i* at time *t* and $p_{jt}$ is the logarithm of the price of good *j* in the reference country at time *t*.

**Ample empirical evidence (Isard, 1977; Richardson, 1978 and Giovannini, 1988) suggests that relative prices do not converge, or only in a very long-term horizon, and that price differentials are persistent**. These studies also found that relative price differentials are significant and highly correlated with exchange rate movements.

**The existence of transaction costs, in the form of transport costs or (explicit or implicit) trade barriers, is an explanation for lack of price convergence**.[3] Several theoretical

[3] Heckscher (1916) first pointed out at the possibility of nonlinearities in relative prices in the presence of trade frictions. In the case of Mexico, González and Rivadeneyra (2004) investigate the LOOP between Mexican cities and provide empirical evidence that transactions costs (including tariff and nontariff barriers) explain departures from the LOOP.

studies account for the importance of transaction costs in modeling deviations from the LOOP (for example, Dumas, 1992; Sercu and others, 1995; O'Connell, 1998). These studies suggest that frictions to trade imply the presence of significant nonlinearities in sectoral real exchange rate dynamics. That is, transaction costs generate a band in which the marginal costs of arbitrage exceed the marginal benefit. Within this band, there is a zone of no-trade and consequently prices in two locations fail to equalize. Outside this band, arbitrage is profitable and the sectoral real exchange rate can become mean-reverting.[4]

**Empirical studies have investigated the presence of nonlinearities in deviations from the LOOP using a TAR model and focusing on developed markets**. Obstfeld and Taylor (1997) find evidence of significant transaction costs in a sample of 32 international locations, using disaggregated data on clothing, food and fuel. Sarno and others (2004) provide support for nonlinear mean reversion, with considerable cross-country and sectoral variations. They use annual price data interpolated into quarterly for nine sectors and quarterly data on five exchange rates vis-à-vis the U.S. dollar. Juvenal and Taylor (2008) study the presence of nonlinearities in deviations from the LOOP for 19 sectors in 10 European countries and find significant evidence of threshold adjustment with transaction costs varying considerable across sectors and countries.

### B. Estimation Methodology and SETAR Model

**To analyze patterns in relative price convergence, we model deviations from the LOOP using a self-exciting threshold autoregressive (SETAR) model for each sectoral exchange rate**. More precisely, we investigate the presence of nonlinearities in deviations from the LOOP using a threshold-type model with two regimes. To analyze the characteristics of the threshold dynamics, we proceed in three steps:

- First, we explore the validity of the nonlinear threshold model with respect to a null hypothesis of a random walk (unit root process). In other words, we first test for the existence of *some* degree of price convergence as opposed to no price convergence at all.[5] Our paper innovates using new testing techniques.[6]

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[4] The analysis was extended to consider a wide range of frictions to trade. For example, O'Connell and Wei (2002) allow for fixed and proportional market frictions. Under their assumptions, arbitrage becomes profitable only when deviations in relative prices outweigh initial sunk costs. However, they argue that, with proportional market frictions, the required adjustments may be small, thereby preventing the emergence of large price deviations, but leading to persistent, though small deviations from the LOOP.

[5] A failure to reject the unit root hypothesis implies that deviations from the LOOP are a uniform unit root process and thus, prices in two locations are disconnected. This test allows to identify if there is any difference in the autoregressive parameters between the inner band and the outer band regimes. This test is an important improvement to the methodology used in the earlier literature. Earlier studies directly test for nonlinearity with respect to a linear model but do not test if the outer regime is nonstationary. Peel and Taylor (2002) present a novel procedure that is close to ours in the context of covered interest parity. More precisely, we use the

(continued…)

- Second, for all cases in which some degree of price convergence is found, we assess whether price convergence is characterized by an asymmetric adjustment consistent with arbitrage arguments. That is, we test whether a nonlinear model fits the data better than a linear one.

- Finally, when we find evidence of nonlinear price convergence both in the pre-NAFTA and post-NAFTA periods, we test if the size of the threshold band is equal in both periods. As noted in Hansen (1997), conventional tests have asymptotic nonstandard distributions, so the distributions should be approximated using a bootstrap procedure.

**The model tests for the existence of a threshold band, within which deviations from the LOOP are smaller than transaction costs and consequently are not arbitraged**. In this case, the SRER would follow a unit root process—the LOOP would not hold. In the outer regime, deviations from the LOOP would be higher than transaction costs, making arbitrage profitable. In this case the process would become mean reverting. We test whether the autoregressive process followed by the real exchange rate switches across regimes.

A simple three-regime TAR model may be written as:

$$q^i_{jt} = \alpha q^i_{jt-1} + \varepsilon^i_{jt} \text{ if } \left| q^i_{jt-d} \right| \le \kappa^i_j \tag{2}$$

$$q^i_{jt} = \kappa^i_j (1-\rho) + \rho q^i_{jt-1} + \varepsilon^i_{jt} \text{ if } q^i_{jt-d} > \kappa^i_j \tag{3}$$

$$q^i_{jt} = -\kappa^i_j (1-\rho) + \rho q^i_{jt-1} + \varepsilon^i_{jt} \text{ if } q^i_{jt-d} < -\kappa^i_j \tag{4}$$

$$\varepsilon^i_{jt} \sim N(0, \sigma^2)$$

Under the assumption that adjustments from deviations from the LOOP are symmetric outside the threshold band, the model is simplified to Equation (5):

$$\Delta q^i_{jt} = \left[ (\rho - 1)\left( q^i_{jt-1} - \kappa^i_j \right) \right] 1\left( q^i_{jt-d} > \kappa^i_j \right) + \left[ (\rho - 1)\left( q^i_{jt-1} + \kappa^i_j \right) \right] 1\left( q^i_{jt-d} < -\kappa^i_j \right) + \varepsilon^i_{jt} \tag{5}$$

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procedure developed by Enders and Granger (1998) to test for the null hypothesis of nonstationarity against and alternative of stationarity with threshold adjustment.

[6] Some studies outside the analysis of exchange rates take into account the relevance of testing a SETAR model against a nonstationary process. For example, Enders and Granger (1998) analyze the uncovered interest parity in a nonlinear fashion and test for threshold adjustment against a unit root. Similarly, Peel and Taylor (2002) model the covered interest parity using a SETAR model and test the nonlinear model against a nonstationary and a linear process. Interestingly, these methods have generally not been applied in exchange rates studies. An important exception is Kapetanios and Shin (2006) but the application is on aggregate real exchange rates and not on sectoral real exchange rates.

where $q_{jt}^{i}$ to be the demeaned component of the relative price difference $x_{jt}^{i}$, given by $x_{jt}^{i} = c_{j}^{i} + q_{jt}^{i}$ ($q_{jt}^{i}$ is estimated as an OLS residual), $\kappa_{j}^{i}$ is the threshold parameter for sector *j* in country *i*, $q_{jt-d}^{i}$ is the threshold variable for sector *j* and country *i*. The parameter *d* accounts for the delay with which economic agents react to real exchange rate deviations.

The model described is a TAR (1, 2, *d*), where 1 is the autoregressive parameter, 2 represents the number of thresholds and *d* is the delay parameter. Further, because the threshold variable is assumed to be the lagged dependent variable, the model is called Self-Exciting TAR, or SETAR (1, 2, *d*) with the given parameters. In what follows, we restrict the value of $\alpha$ to unity[7] under the assumption that deviations from the LOOP are persistent within the threshold band—that is, when $\left|q_{jt-d}^{i}\right| \leq \kappa_{j}^{i}$, the process follows a random walk. When $\left|q_{jt-d}^{i}\right| > \kappa_{j}^{i}$ the process becomes mean reverting as long as $\rho < 1$.

Hence,

$$\Delta q_{jt}^{i} = B_{jt}^{i}\left(\kappa_{j}^{i}, d\right)' \Gamma + \varepsilon_{jt}^{i} \tag{6}$$

where $B_{jt}^{i}\left(\kappa_{j}^{i}, d\right)'$ is a (1 x 2) row vector that describes the behavior of $\Delta q_{jt}^{i}$ in the outer regime and $\Gamma$ is a (2 x 1) vector containing the autoregressive parameters to be estimated.

More precisely,

$$B_{jt}^{i}\left(\kappa_{j}^{i}, d\right)' = \left[X'1\left(q_{jt-d}^{i} > \kappa_{j}^{i}\right) \quad Y'1\left(q_{jt-d}^{i} < -\kappa_{j}^{i}\right)\right] \tag{7}$$

where $X' = \left[q_{jt-1}^{i} - \kappa_{j}^{i}\right]$, $Y' = \left[q_{jt-1}^{i} + \kappa_{j}^{i}\right]$ and $\Gamma' = \left[\rho - 1 \quad \rho - 1\right]$.

## C. Testing Procedures

**The key variables of the model (i.e., the threshold and autoregressive parameters), are estimated simultaneously using least squares via a grid search over** $\kappa_{j}^{i}$. We follow the methodology presented in Hansen (1997). The range of the grid search is selected to include all the observations between the 15th and 85th percentile of the threshold variable, to ensure that results are not driven by outliers. Further, the model is estimated for values of *d* from 1 to 4 months. The value of $\kappa_{j}^{i}$ and $d$ that minimize the sum of squared residuals is chosen.

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[7] This restriction is widely used in the literature. See Obstfeld and A.M. Taylor (1997), Imbs and others (2003), Sarno and others (2004) and Juvenal and Taylor (2008).

**As outlined in Section II.B, we test whether TAR-type nonlinearity is superior to a unit root process and a linear process**. These tests require pre-estimation of both the linear model under the null hypothesis as well as the TAR model under the alternative.

**When we find evidence of nonlinearities both in the pre-NAFTA and post-NAFTA periods, we test if the size of the threshold band is equal in both periods**. The conventional tests have asymptotic nonstandard distributions. In order to overcome the inference problems, the empirical marginal significance levels of the test must be calculated using Monte Carlo simulation procedures. Following Hansen (1997) and Peel and Taylor (2002) we use the likelihood ratio statistic $F_T = T\left(\frac{\tilde{\sigma}^2 - \hat{\sigma}^2}{\hat{\sigma}^2}\right)$ where T is the sample size, and $\tilde{\sigma}^2$ and $\hat{\sigma}^2$ are the restricted and unrestricted estimates of the residual variance. Hence, $\tilde{\sigma}^2$ is equal to 1/T times the sum of squared residuals resulting from the estimation of (5) with the restriction to be tested imposed and $\hat{\sigma}^2$ is 1/T times the sum of squared residuals from the estimation of the unconstrained nonlinear model in (5).

The asymptotic distribution of $F_T(\kappa, d)$ may be approximated using a bootstrap procedure:

1. Estimate the model under the null hypothesis.

2. Generate T+100 observations from a data generating process calibrated using the restricted estimates.

3. Discard the first 100 artificial data points and use the remaining T to estimate the restricted and unrestricted models.

4. Based on the estimation in 3, construct the value of the likelihood ratio statistic.

$$F_T^* = T\left(\frac{\tilde{\sigma}^{*2} - \hat{\sigma}^{*2}}{\hat{\sigma}^{*2}}\right)$$

5. Repeat steps 2–5 1,000 times.

6. The asymptotic approximation to the bootstrap p-value of the test is calculated by the number of times in which $F_T^*$ exceeds $F_T$.

## III. ESTIMATION RESULTS

**We use disaggregated monthly data on consumer price indices (CPI) for 18 sectors** from January 1980 to December 2006, for Mexico, the United States, and Canada.[8]

### A. Testing for Nonlinear Price Convergence

Table 1 reports the results of the estimation of the SETAR model.

**The first step consists of testing the null hypothesis of a unit root (Figure 1).** Essentially, this allows us to determine whether the autoregressive process is the same outside and inside the threshold band—assuming it follows a unit root process inside the band. A failure to reject the null hypothesis implies that the SRER is nonstationary and consequently prices in two locations are disconnected and the LOOP does not hold. Our interpretation of such a case is that transaction costs are so large that arbitrage is not profitable and the threshold band is wide enough to contain the whole time series of the SRER. A number of observations follow from this first set of results:

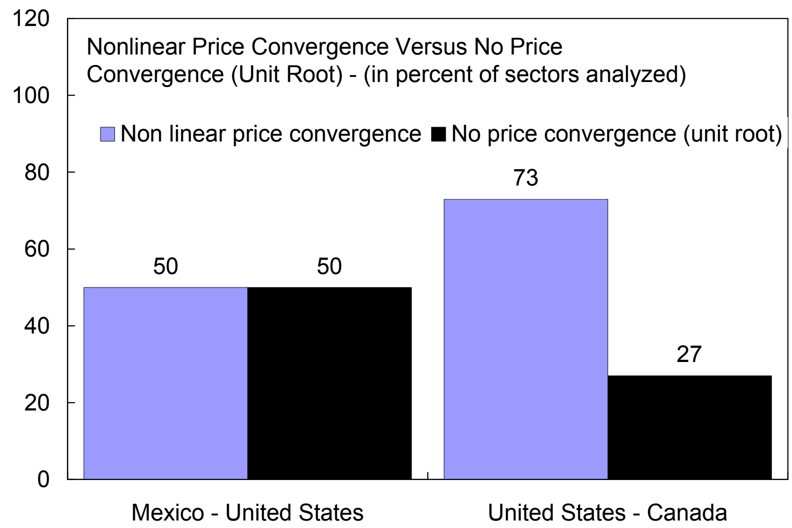
- Results provide a first indication that **NAFTA led to greater integration between the United States and Mexico**, with price equalization between locations taken as a sign of higher degree of market integration. Half of the SRERs in the pre-NAFTA period followed a unit root process and only four of them in the post-NAFTA period.

- By contrast, results suggest that **the Canadian and U.S. markets have been more closely integrated**, with a further improvement with NAFTA.

[8] The data sources for the CPI indices are the Bank of Mexico, the U.S. Bureau of Labor Statistics and Statistics Canada. Monthly nominal exchange rates are period averages taken from the International Financial Statistics (IFS) of the International Monetary Fund (IMF).

**Figure 1. Extent of Price Convergence between Mexico–U.S. and Canada–U.S.**

**Pre-NAFTA**




**Post-NAFTA**

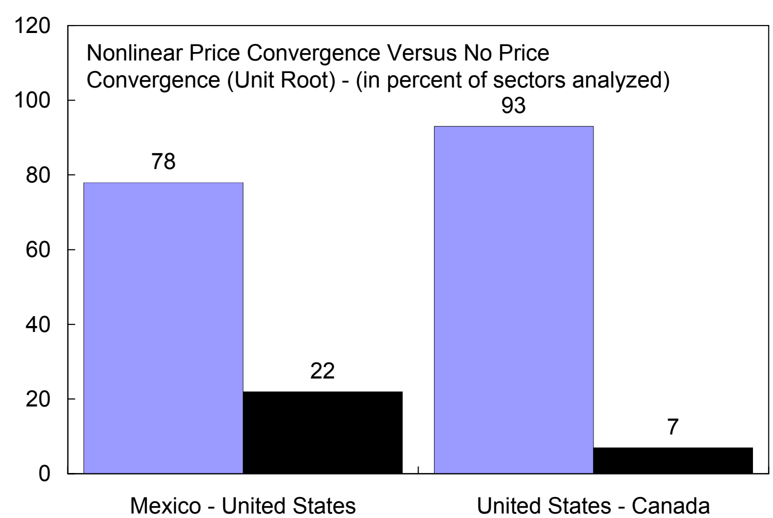


**Table 1. SETAR Estimation Results**

| | Mexico - United States | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Pre-NAFTA | | | | Post-NAFTA | | | | |
| | Threshold | Mean-reversion | Unit root test | Hansen Test | Threshold | Mean-reversion | Unit root test | Hansen Test | |
| Sector | k | ρ | *p-value Ha* | *p-value Hb* | k | ρ | *p-value Ha* | *p-value Hb* | *p-value Hc* |
| Bread | -- | -- | 0.52 | | -- | -- | 0.24 | | |
| Meat | 0.27 | 0.92 | | 0.00 | 0.09 | 0.96 | | 0.00 | 0.00 |
| Fish | -- | -- | 0.15 | | 0.02 | 0.96 | | 0.00 | |
| Dairy | 0.28 | 0.85 | | 0.00 | 0.10 | 0.75 | | 0.00 | 0.00 |
| Fruits | -- | -- | 0.25 | | 0.05 | 0.84 | | 0.00 | |
| Vegetables | 0.09 | 0.78 | | 0.00 | 0.15 | 0.70 | | 0.00 | 0.05 |
| Nonalcoholic beverages | -- | -- | 0.35 | | 0.15 | 0.81 | | 0.00 | |
| Alcoholic beverages | 0.10 | 0.92 | | 0.00 | -- | -- | 0.11 | | |
| Tobacco | 0.32 | 0.73 | | 0.00 | 0.14 | 0.86 | | 0.00 | 0.00 |
| Clothing (women) | 0.18 | 0.86 | | 0.00 | 0.09 | 0.83 | | 0.00 | 0.01 |
| Clothing (men) | -- | -- | 0.13 | | 0.16 | 0.87 | | 0.00 | |
| Footwear | 0.07 | 0.95 | | 0.02 | 0.08 | 0.87 | | 0.00 | 0.64 |
| Fuel | -- | -- | 0.34 | | -- | -- | 0.59 | | |
| Furniture | -- | -- | 0.28 | | 0.18 | 0.86 | | 0.00 | |
| Medication | -- | -- | 0.14 | | 0.20 | 0.85 | | 0.00 | |
| Vehicles | 0.14 | 0.75 | | 0.00 | 0.12 | 0.64 | | 0.00 | 0.39 |
| Gasoline | -- | -- | 0.23 | | -- | -- | 0.11 | | |
| Photo | 0.19 | 0.97 | | 0.03 | 0.19 | 0.85 | | 0.00 | 0.00 |

| | Canada - United States | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Pre-NAFTA | | | | Post-NAFTA | | | | |
| | Threshold | Mean-reversion | Unit root test | Hansen Test | Threshold | Mean-reversion | Unit root test | Hansen Test | |
| Sector | k | ρ | *p-value Ha* | *p-value Hb* | k | ρ | *p-value Ha* | *p-value Hb* | *p-value Hc* |
| Bread | -- | -- | 0.36 | | 0.09 | 0.93 | | 0.00 | |
| Meat | 0.06 | 0.91 | | 0.00 | 0.04 | 0.94 | | 0.00 | 0.39 |
| Fish | 0.08 | 0.85 | | 0.00 | 0.04 | 0.90 | | 0.00 | 0.08 |
| Dairy | 0.07 | 0.91 | | 0.00 | 0.07 | 0.95 | | 0.00 | |
| Fruits | 0.16 | 0.95 | | 0.02 | 0.09 | 0.79 | | 0.00 | |
| Vegetables | 0.14 | 0.80 | | 0.00 | 0.05 | 0.79 | | 0.00 | 0.01 |
| Alcoholic beverages | 0.15 | 0.89 | | 0.00 | 0.14 | 0.93 | | 0.00 | 0.47 |
| Tobacco | -- | -- | 0.14 | | -- | -- | 0.41 | | |
| Clothing (women) | 0.05 | 0.94 | | 0.00 | 0.13 | 0.81 | | 0.00 | 0.07 |
| Clothing (men) | -- | -- | 0.23 | | 0.14 | 0.93 | | 0.00 | |
| Footwear | -- | -- | 0.18 | | 0.08 | 0.96 | | 0.00 | |
| Fuel | 0.08 | 0.95 | | 0.00 | 0.04 | 0.94 | | 0.00 | 0.07 |
| Furniture | 0.16 | 0.91 | | 0.00 | 0.10 | 0.95 | | 0.00 | 0.02 |
| Vehicles | 0.08 | 0.92 | | 0.00 | 0.07 | 0.94 | | 0.00 | 0.54 |
| Gasoline | 0.27 | 0.79 | | 0.00 | 0.26 | 0.72 | | 0.00 | 0.46 |

Notes: This table shows the results from the estimation of the SETAR (1, 2, d) model in equation (5). k is the value of the threshold and ρ is the outer root of the TAR process. The estimation of k, ρ and d is done simultaneously via a grid search over k and d as described in section II. p-value Ha, p-value Hb and p-value Hc represent, respectively, the marginal significance levels of the null hypothesis of unit root in the outer regime, null hypothesis of linearity and null hypothesis of equality of thresholds pre- and post- NAFTA.

**The second step**—conducted only for cases in which SRER does not follow a unit root process and using the Hansen test—**tests whether the nonlinear threshold model is superior when tested against a linear process in which no threshold exists**. Table 1 reports the p-values indicating the significance level at which the linearity hypothesis can be rejected. In all cases the SETAR model clearly outperforms the linear one, confirming the existence of thresholds and therefore providing an estimate of transaction costs.

## B. Estimated Transaction Costs

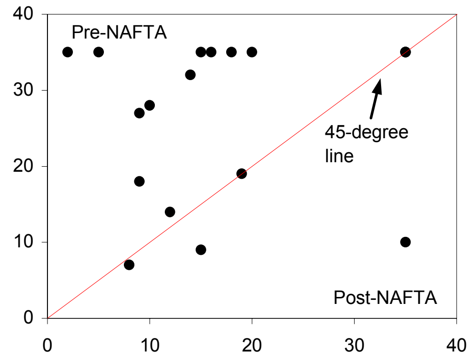
**Table 1 also reports the estimated thresholds for each SRER—that we interpret as a measure of overall transaction costs and reflecting the degree of market integration:**

- Across sectors, the results generally confirm that **highly homogenous sectors**—for example, fish products and fruits—**show low threshold bands**. This is a standard result in the literature for other country pairs (see Juvenal and Taylor, 2008).

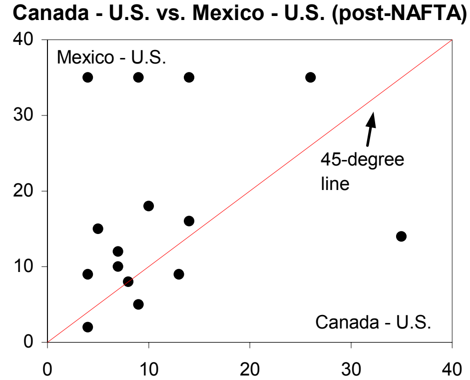
- **For the United States—Mexico SRERs, evidence of a strong NAFTA effect is found**. The range of transaction costs across sectors is smaller, from 7–32 percent in the pre-NAFTA period to 2–20 percent in the post-NAFTA period, also with a number of cases in which transaction costs go from "infinite" (unit root process) to measurable. Transaction costs bands are reduced in a number of sectors, suggesting greater market integration.

- Overall, **average transaction costs among NAFTA members are 34 percent higher between the U.S. and Mexico than between the U.S. and Canada.** This result confirms previous evidence that the United States and Canada are the most integrated among NAFTA members.[9]

**Estimated transaction costs (in percent /1):**
**Mexico - U.S.: Pre-NAFTA vs. Post-NAFTA**




**Canada - U.S. vs. Mexico - U.S. (post-NAFTA)**




Source: IMF staff calculations.
1/ In cases of absence of price convergence, transaction costs are too large to be estimated, and reported here as 35 percent.

[9] One possible alternative explanation for finding that thresholds are lower between the U.S. and Canada than between Mexico and the U.S. may be that goods are more homogenous between the first two countries. More generally, the comparability of the sectors may vary across country pairs. First, wealth effects may be at play. The relatively large income differences between Mexico and the U.S. and Canada affects the specific goods

(continued…)

- **In comparison to the work of Juvenal and Taylor (2007), threshold bands among NAFTA members are on average slightly lower than between the United States and European countries**. Interestingly, when considering the United Kingdom as a reference country, their estimated country average transaction costs range from 7 percent to 17 percent. The latter benchmark is probably most relevant to our study for comparison purposes given the process of liberalization among European countries and the distance factor.[10]

### C. Robustness of Results

**To gauge the sensitivity of empirical results to underlying assumptions and variable definitions, we conduct three robustness checks**.

**First, we consider the possibility of long-run trends in the measured price differentials** arising from aggregation issues in price indices or from the presence of nontradable components (Harrod- Balassa-Samuelson effect). This follows from the assumption that price data for different countries refer to identical pure tradable goods. We allow for the presence of a long-run trend in our relative prices. We define $q^i_{jt}$ to be the detrended and demeaned component of the price difference $x^i_{jt}$, given by $x^i_{jt} = c^i_j + \theta t + q^i_{jt}$. As we described above, $q^i_{jt}$ is estimated as an OLS residual.

**Overall, our baseline findings prove to be robust to using detrended sectoral real exchange rates instead of the demeaned series.** Table 2 shows the results of the estimation of the SETAR model with detrended sectoral real exchange rates. The conceptual problem with including a trend in the real exchange rate is that it implies that the real exchange rate converges to a different mean across time. This is in a way contradictory to the LOOP. Hence, our preferred measure is the demeaned series. The stability of our results with the different measures indicates that the trend component may not be of the utmost importance.

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sampled in each CPI category. This may complicate the analysis, with the composition between luxury, middle, and ordinary products varying across countries. Second, statistical differences exist in the compilation of price level data, notably in adjustments for quality changes. A solution to this problem is to look at more disaggregated price indices and SRERs. Preliminary work on this is reported in Box 1.

[10] Other studies of the behavior of relative prices between the United States and Canada provide results that are broadly consistent with our findings. Engle and Rogers (1996) study deviations from the LOOP for 14 goods sectors for different US and Canadian cities. They show that the Canadian and U.S. markets are not perfectly integrated. Engle, Rogers and Yi Wang (2005) investigate the LOOP between U.S. and Canadian cities using actual prices (instead of price indices). They find that absolute price differences between US and Canadian prices are higher than 7 percent. Both studies show that distance and border play a significant role in explaining price differentials between cities.

**Second, we test the sensitivity of the results to a structural break in the Mexican series over the study period, 1980–2006, during the Tequila crisis**. The results reported in the paper assume a constant mean over the period, consistent with the LOOP hypothesis. However, as a robustness check, we also test the sensitivity of the results to (i) allowing for a different mean over the Tequila Crisis from 1994:12 to 1995:12, and (ii) restricting the estimation period to 1996–2006. This was intended to assess whether the Tequila crisis would significantly affect our findings. The results of the latter robustness test are not reported here to preserve space but available from the author's upon request. Overall, they are broadly consistent with the ones we discuss here, which reflects that Tequila crisis does not significantly affect our findings.

**Our baseline findings are again robust to these checks**. Table 3 reports the estimated thresholds for each SRER, allowing for a different mean for the real exchange rate during the Tequila crisis. Across sectors, we find that homogenous goods have lower transaction costs than other goods in the sample. Across country pairs, average transaction costs among NAFTA members are 27 percent higher between the U.S. and Mexico than between the U.S. and Canada, slightly less than in the results without taking into account the Tequila crisis.

**Table 2. SETAR Estimation Results (Detrended Data)**

| | Mexico - United States | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Pre-NAFTA | | | | Post-NAFTA | | | | |
| | Threshold | Mean-reversion | Unit root test | Hansen Test | Threshold | Mean-reversion | Unit root test | Hansen Test | |
| Sector | k | ρ | *p-value Ha* | *p-value Hb* | k | ρ | *p-value Ha* | *p-value Hb* | *p-value Hc* |
| Bread | -- | -- | 0.31 | | -- | -- | 0.14 | | |
| Meat | 0.26 | 0.92 | | 0.00 | 0.03 | 0.94 | | 0.00 | 0.01 |
| Fish | -- | -- | 0.18 | | 0.03 | 0.95 | | 0.00 | |
| Dairy | 0.29 | 0.84 | | 0.00 | 0.09 | 0.83 | | 0.00 | 0.01 |
| Fruits | -- | -- | 0.13 | | 0.02 | 0.82 | | 0.00 | |
| Vegetables | 0.06 | 0.77 | | 0.00 | 0.15 | 0.78 | | 0.00 | 0.05 |
| Nonalcoholic beverages | -- | -- | 0.16 | | 0.10 | 0.76 | | 0.00 | |
| Alcoholic beverages | 0.22 | 0.79 | | 0.00 | -- | -- | 0.17 | | |
| Tobacco | -- | -- | 0.15 | | 0.16 | 0.90 | | 0.00 | 0.01 |
| Clothing (women) | 0.17 | 0.88 | | 0.00 | 0.18 | 0.80 | | 0.00 | 0.02 |
| Clothing (men) | -- | -- | 0.33 | | 0.15 | 0.77 | | 0.00 | |
| Footwear | 0.11 | 0.93 | | 0.02 | 0.09 | 0.88 | | 0.00 | 0.52 |
| Fuel | -- | -- | 0.22 | | -- | -- | 0.70 | | |
| Furniture | -- | -- | 0.46 | | 0.16 | 0.81 | | 0.00 | |
| Medication | -- | -- | 0.27 | | 0.15 | 0.88 | | 0.00 | |
| Vehicles | 0.16 | 0.79 | | 0.00 | 0.09 | 0.70 | | 0.00 | 0.42 |
| Gasoline | -- | -- | 0.19 | | -- | -- | 0.17 | | |
| Photo | 0.16 | 0.96 | | 0.02 | 0.17 | 0.90 | | 0.00 | 0.02 |

| | Canada - United States | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Pre-NAFTA | | | | Post-NAFTA | | | | |
| | Threshold | Mean-reversion | Unit root test | Hansen Test | Threshold | Mean-reversion | Unit root test | Hansen Test | |
| Sector | k | ρ | *p-value Ha* | *p-value Hb* | k | ρ | *p-value Ha* | *p-value Hb* | *p-value Hc* |
| Bread | -- | -- | 0.40 | | 0.15 | 0.83 | | 0.00 | |
| Meat | -- | -- | 0.23 | | 0.03 | 0.95 | | 0.00 | 0.39 |
| Fish | 0.11 | 0.85 | | 0.00 | 0.02 | 0.94 | | 0.00 | 0.08 |
| Dairy | 0.05 | 0.94 | | 0.00 | 0.07 | 0.92 | | 0.00 | |
| Fruits | 0.11 | 0.88 | | 0.02 | 0.09 | 0.83 | | 0.00 | |
| Vegetables | 0.04 | 0.72 | | 0.00 | 0.03 | 0.85 | | 0.00 | 0.01 |
| Alcoholic beverages | 0.08 | 0.91 | | 0.00 | 0.10 | 0.82 | | 0.00 | 0.47 |
| Tobacco | -- | -- | 0.22 | | -- | -- | 0.22 | | |
| Clothing (women) | 0.04 | 0.90 | | 0.00 | 0.09 | 0.80 | | 0.00 | 0.07 |
| Clothing (men) | 0.06 | 0.88 | | 0.00 | 0.11 | 0.94 | | 0.00 | |
| Footwear | -- | -- | 0.12 | | 0.05 | 0.90 | | 0.00 | |
| Fuel | 0.05 | 0.90 | | 0.00 | 0.09 | 0.86 | | 0.00 | 0.07 |
| Furniture | 0.08 | 0.87 | | 0.00 | 0.06 | 0.91 | | 0.00 | 0.02 |
| Vehicles | 0.09 | 0.80 | | 0.00 | 0.10 | 0.95 | | 0.00 | 0.54 |
| Gasoline | 0.16 | 0.97 | | 0.00 | 0.05 | 0.80 | | 0.00 | 0.46 |

Notes: See Table 1.

**Table 3. SETAR Estimation Results (Controlling for Different Mean during Tequila Crisis)**

| | Mexico - United States | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Pre-NAFTA | | | | Post-NAFTA | | | | |
| | Threshold | Mean-reversion | Unit root test | Hansen Test | Threshold | Mean-reversion | Unit root test | Hansen Test | |
| Sector | k | ρ | *p-value Ha* | *p-value Hb* | k | ρ | *p-value Ha* | *p-value Hb* | *p-value Hc* |
| Bread | -- | -- | 0.52 | | -- | -- | 0.54 | | |
| Meat | 0.27 | 0.92 | | 0.00 | 0.14 | 0.82 | | 0.00 | 0.01 |
| Fish | -- | -- | 0.15 | | 0.13 | 0.91 | | 0.00 | |
| Dairy | 0.28 | 0.85 | | 0.00 | 0.07 | 0.71 | | 0.00 | 0.02 |
| Fruits | -- | -- | 0.25 | | 0.05 | 0.77 | | 0.00 | |
| Vegetables | 0.09 | 0.78 | | 0.00 | 0.04 | 0.83 | | 0.00 | 0.07 |
| Nonalcoholic beverages | -- | -- | 0.35 | | 0.14 | 0.78 | | 0.00 | |
| Alcoholic beverages | 0.10 | 0.92 | | 0.00 | 0.11 | 0.93 | | 0.00 | 0.58 |
| Tobacco | 0.32 | 0.73 | | 0.00 | 0.08 | 0.89 | | 0.00 | 0.01 |
| Clothing (women) | 0.18 | 0.86 | | 0.00 | 0.09 | 0.83 | | 0.00 | 0.02 |
| Clothing (men) | -- | -- | 0.13 | | 0.10 | 0.79 | | 0.00 | |
| Footwear | 0.07 | 0.95 | | 0.02 | 0.08 | 0.94 | | 0.00 | 0.47 |
| Fuel | -- | -- | 0.34 | | 0.14 | 0.75 | | 0.00 | |
| Furniture | -- | -- | 0.28 | | 0.11 | 0.90 | | 0.00 | |
| Medication | -- | -- | 0.14 | | 0.17 | 0.77 | | 0.00 | |
| Vehicles | 0.14 | 0.75 | | 0.00 | 0.12 | 0.83 | | 0.00 | 0.28 |
| Gasoline | -- | -- | 0.23 | | -- | -- | 0.25 | | |
| Photo | 0.19 | 0.97 | | 0.03 | 0.12 | 0.91 | | 0.00 | 0.06 |

| | Canada - United States | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Pre-NAFTA | | | | Post-NAFTA | | | | |
| | Threshold | Mean-reversion | Unit root test | Hansen Test | Threshold | Mean-reversion | Unit root test | Hansen Test | |
| Sector | k | ρ | *p-value Ha* | *p-value Hb* | k | ρ | *p-value Ha* | *p-value Hb* | *p-value Hc* |
| Bread | -- | -- | 0.36 | | 0.09 | 0.93 | | 0.00 | |
| Meat | 0.06 | 0.91 | | 0.00 | 0.04 | 0.94 | | 0.00 | 0.39 |
| Fish | 0.08 | 0.85 | | 0.00 | 0.04 | 0.90 | | 0.00 | 0.08 |
| Dairy | 0.07 | 0.91 | | 0.00 | 0.07 | 0.95 | | 0.00 | |
| Fruits | 0.16 | 0.95 | | 0.02 | 0.09 | 0.79 | | 0.00 | |
| Vegetables | 0.14 | 0.80 | | 0.00 | 0.05 | 0.79 | | 0.00 | 0.01 |
| Alcoholic beverages | 0.15 | 0.89 | | 0.00 | 0.14 | 0.93 | | 0.00 | 0.47 |
| Tobacco | 0.23 | 0.95 | | 0.01 | 0.05 | 0.95 | | 0.03 | 0.02 |
| Clothing (women) | 0.05 | 0.94 | | 0.00 | 0.13 | 0.81 | | 0.00 | 0.07 |
| Clothing (men) | -- | -- | 0.23 | | 0.14 | 0.93 | | 0.00 | |
| Footwear | -- | -- | 0.18 | | 0.08 | 0.96 | | 0.00 | |
| Fuel | 0.08 | 0.95 | | 0.00 | 0.04 | 0.94 | | 0.00 | 0.07 |
| Furniture | 0.16 | 0.91 | | 0.00 | 0.10 | 0.95 | | 0.00 | 0.02 |
| Vehicles | 0.08 | 0.92 | | 0.00 | 0.07 | 0.94 | | 0.00 | 0.54 |
| Gasoline | 0.27 | 0.79 | | 0.00 | 0.26 | 0.72 | | 0.00 | 0.46 |

Notes: See Table 1.

## D. Half-Lives of Relative Price Adjustments

**A usual measure of the speed of mean reversion is the half-life, the time it takes for the effect of 50 percent of a shock to die out.** Table 2 reports the estimated half-lives (in terms of months) of price deviations from the LOOP, for the Mexico–U.S. and the Canadian–U.S. SRERs.

**We compute the half-life taking into account the regime-switching nature of the SETAR model**.[11] This is important in the context of our model because the half-life takes different values depending on whether the SRER is within or outside the threshold band. The half-life is infinite with the threshold band and depend on ρ (more exactly, equal to ln(0.5)/ln(ρ)) outside the band. We compute the half-lives for a 10 percent, 20 percent, 30 percent, 40 percent, and 50 percent shocks by stochastic simulation using the generalized impulse response functions procedure developed by Koop and others (1996).

**For the Mexico–U.S. pair, the average relative price adjustment is significantly faster in the post-NAFTA period.** For example, for a 10 percent shock, the average half-life pre-NAFTA was 20 months, while the average was reduced to 11 months in the post-NAFTA period. Our results also bring additional observations:

- **In the post-NAFTA period, there is less variation across different shock sizes than in the pre-NAFTA period**—suggesting that relative prices adjust more quickly, independently of the size of the price shock. In the post-NAFTA period, almost 60 percent of the SRERs adjust (by half) to a 10 percent shock within 6 to 9 months. In contrast, most (70 percent) SRERs take more than a year to adjust in the pre-NAFTA period, and 55 percent more than 18 months.

- **Half-lives vary substantially across sectors**. Relative prices adjust relatively fast for homogenous goods, such as food products. The relative price of the more high-end products takes longer to adjust, for example furniture, and photographic equipment.

**The speed of relative price adjustment in the post-NAFTA period is comparable for the Mexico–U.S. and the Canada–U.S. pair**—for a 10 percent shock, the average half-lives are 11 months and 12 months, respectively, in the post-NAFTA period. This contrasts with significant differences in the pre-NAFTA period, when Mexico–U.S. relative prices were much slower to adjust than Canada–U.S. prices.

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[11] Previous studies computed the half-life of the SETAR model in the outer regime, which depends on the parameter ρ, as in a linear model (ln (0.5)/ln(ρ)). This has the limitation that it does not consider the regime switching that takes place within and outside the band and provides misleading results.

**Table 4. Estimation of Half-Lives for Sectoral Real Exchange Rates (in months)**

| | Mexico - United States | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Pre-NAFTA | | | | | Post-NAFTA | | | | |
| | Shock (%) | | | | | Shock (%) | | | | |
| Sector | 10 | 20 | 30 | 40 | 50 | 10 | 20 | 30 | 40 | 50 |
| Bread | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Meat | 36 | 26 | 20 | 17 | 15 | 29 | 25 | 23 | 22 | 21 |
| Fish | -- | -- | -- | -- | -- | 19 | 18 | 18 | 18 | 18 |
| Dairy | 20 | 15 | 11 | 9 | 8 | 7 | 5 | 5 | 5 | 5 |
| Fruits | -- | -- | -- | -- | -- | 6 | 5 | 5 | 5 | 5 |
| Vegetables | 4 | 4 | 4 | 4 | 4 | 5 | 5 | 5 | 5 | 5 |
| Non alcoholic beverages | -- | -- | -- | -- | -- | 7 | 7 | 6 | 6 | 6 |
| Alcoholic beverages | 13 | 12 | 12 | 11 | 11 | -- | -- | -- | -- | -- |
| Tobacco | 18 | 12 | 8 | 7 | 6 | 8 | 7 | 7 | 7 | 7 |
| Women's clothing | 10 | 10 | 10 | 9 | 9 | 5 | 5 | 5 | 5 | 5 |
| Men's clothing | -- | -- | -- | -- | -- | 10 | 8 | 8 | 7 | 7 |
| Footwear | 18 | 17 | 16 | 16 | 16 | 6 | 6 | 6 | 6 | 6 |
| Fuel | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Furniture | -- | -- | -- | -- | -- | 14 | 10 | 8 | 8 | 8 |
| Medications | -- | -- | -- | -- | -- | 10 | 8 | 8 | 8 | 7 |
| Vehicles | 6 | 5 | 5 | 4 | 3 | 6 | 4 | 4 | 4 | 4 |
| Gasoline | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Photo | 55 | 49 | 44 | 40 | 37 | 24 | 14 | 10 | 9 | 8 |
| Average | 20 | 17 | 14 | 13 | 12 | 11 | 9 | 8 | 8 | 8 |

| | Canada - United States | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Pre-NAFTA | | | | | Post-NAFTA | | | | |
| | Shock (%) | | | | | Shock (%) | | | | |
| Sector | 10 | 20 | 30 | 40 | 50 | 10 | 20 | 30 | 40 | 50 |
| Bread | -- | -- | -- | -- | -- | 14 | 12 | 12 | 11 | 11 |
| Meat | 11 | 10 | 10 | 10 | 9 | 13 | 12 | 12 | 12 | 12 |
| Fish | 6 | 5 | 4 | 4 | 4 | 9 | 8 | 8 | 8 | 8 |
| Dairy | 12 | 10 | 10 | 10 | 10 | 16 | 15 | 15 | 14 | 14 |
| Fruits | 27 | 24 | 21 | 20 | 19 | 5 | 5 | 5 | 5 | 5 |
| Vegetables | 7 | 6 | 6 | 6 | 6 | 5 | 5 | 5 | 5 | 5 |
| Alcoholic beverages | 13 | 10 | 9 | 9 | 9 | 17 | 16 | 15 | 14 | 13 |
| Tobacco | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Women's clothing | 14 | 13 | 12 | 12 | 11 | 7 | 7 | 6 | 6 | 6 |
| Men's clothing | -- | -- | -- | -- | -- | 18 | 15 | 14 | 13 | 13 |
| Footwear | -- | -- | -- | -- | -- | 25 | 22 | 20 | 20 | 19 |
| Fuel | 17 | 15 | 15 | 15 | 15 | 12 | 12 | 12 | 12 | 11 |
| Furniture | 21 | 15 | 13 | 12 | 12 | 29 | 24 | 21 | 19 | 18 |
| Vehicles | 13 | 12 | 11 | 11 | 11 | 14 | 13 | 13 | 13 | 12 |
| Gasoline | 8 | 7 | 6 | 6 | 6 | 7 | 5 | 5 | 5 | 5 |
| Average | 14 | 12 | 11 | 10 | 10 | 12 | 11 | 11 | 10 | 10 |

**Notes:** The columns show the half-life of the TAR model as a whole for a given shock estimated conditional on average initial history. The half-lives for a 10%, 20%, 30%, 40% and 50% shocks are computed by stochastic simulation using the generalized impulse response functions procedure developed by Koop and others (1996).

## Box 1. Real Exchange Rate Thresholds at the Aggregate CPI Level

Estimation of convergence thresholds can also be conducted at the level of the national CPI index, although the interpretation of the estimated thresholds is much less clear. Still, the results based on aggregate indices may be of some interest, and it turns out that they are broadly similar to the pattern of the sectoral findings. The results are reported in Table 5.

For all three country pairs, we find evidence of nonlinear convergence of aggregate price levels for both the pre- and post-NAFTA periods. The size of the thresholds is significantly smaller in the post-NAFTA period, and is smaller for the U.S.–Canada country pair than for the U.S.–Mexico pair. After NAFTA, the estimated thresholds for the U.S.–Canada and the U.S.–Mexico pairs are reduced, respectively, from 13 percent to 10 percent and from 18 percent to 14 percent, respectively.

This finding of thresholds at the aggregate level suggests that limitations to price convergence at the sectoral level can also be an issue of macroeconomic significance. This point may be worthy of analysis in empirical studies of (national-level) real exchange rates.

**Table 5. SETAR Estimation Results for Aggregate Price Indices**

| | Real Exchange Rate based on aggregate CPI | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Pre-NAFTA | | | | Post-NAFTA | | | | |
| | Threshold | Mean-reversion | Unit root test | Hansen Test | Threshold | Mean-reversion | Unit root test | Hansen Test | |
| | k | ρ | *p-value Ha* | *p-value Hb* | k | ρ | *p-value Ha* | *p-value Hb* | *p-value Hc* |
| Mexico - U.S. | 0.18 | 0.95 | | 0.00 | 0.14 | 0.83 | | 0.00 | 0.01 |
| Canada - U.S. | 0.13 | 0.87 | | 0.00 | 0.10 | 0.93 | | 0.00 | 0.09 |
| | Real Exchange Rate based on aggregate CPI (with dummy for the Tequila crisis period) | | | | | | | | |
| | Pre-NAFTA | | | | Post-NAFTA | | | | |
| | Threshold | Mean-reversion | Unit root test | Hansen Test | Threshold | Mean-reversion | Unit root test | Hansen Test | |
| | k | ρ | *p-value Ha* | *p-value Hb* | k | ρ | *p-value Ha* | *p-value Hb* | *p-value Hc* |
| Mexico - U.S. | 0.18 | 0.95 | | 0.00 | 0.10 | 0.91 | | 0.00 | 0.00 |
| Canada - U.S. | 0.13 | 0.87 | | 0.00 | 0.10 | 0.93 | | 0.00 | 0.04 |

Notes: This table shows the results from the estimation of the SETAR (1, 2, d) model in equation (5). k is the value of the threshold and ρ is the outer root of the TAR process. The estimation of k, ρ and d is done simultaneously via a grid search over k and d as described in section II. p-value Ha, p-value Hb and p-value Hc represent, respectively, the marginal significance levels of the null hypothesis of unit root in the outer regime, null hypothesis of linearity and null hypothesis of equality of thresholds pre- and post- NAFTA.

## IV. Determinants of Thresholds in Real Exchange Rates

**In the spirit of the gravity models used to explain trade patterns, we investigate in this section the main determinants of the estimated transaction costs in sectoral real exchange rates**. In their simplest form, gravity equations relate trade to distance between trading partners, as a proxy for transaction costs (see for example the initial work of Linneman (1969)). The models were enriched to account for other determinants of trade. Imbs and others (2003) studied the determinants of relative price dynamics for European countries, using a gravity-type model. They find that distance and exchange rate volatility are strongly correlated with thresholds and the half-life of exchange rate deviations.
The model is defined as:

$$\kappa_j^i = \lambda_j^i + \sum_{k=1}^{K} \Phi_j^i(k) z_j^i(k) + \varepsilon_j^i \qquad (9)$$

where $z_j^i$ is a vector of explanatory variables. We assess in equation (9) whether transaction costs, measured by the threshold $\kappa_j^i$, are explained by selected explanatory variables.

**The explanatory variables are intended to capture determinants of transaction costs.** Given the small number of country pairs and their relative closeness, distance appears to be a poor proxy for transaction costs.[12] Instead, we include a dummy variable that takes value 1 when countries share a common border. The second variable is the volatility of the nominal exchange rate. Measured as the standard deviation of monthly exchange rate observations, the volatility variable is a proxy for uncertainty of the macroeconomic environment. Third, we include a measure of "tradability," defined as the sum of imports and exports to the total output in a sector for a given country. Fourth, we use the number of establishments in each sector as a proxy for competition, or concentration, in each sector. Lastly, a dummy for the post-NAFTA period is used.

**We examine the determinants of thresholds for the entire sample**, including all three country pairs (we include here the Mexico–Canada pair), including the pre- and post-NAFTA periods. The 94 thresholds computed in the previous section constitute the observations.

[12] Note that the three NAFTA countries studied here are all relatively large in terms of land area, so that for example the distance between two cities within a given country could well exceed the distance between two cities in different countries. This situation contrasts with the literature on price convergence within Europe.

**Table 6. Threshold Regressions**

| Determinants of Thresholds | | |
|---|---|---|
| | (1) | (2) |
| Distance | -0.041 * | -0.040 * |
| Dummy post NAFTA | -0.109 ** | -0.116 ** |
| Exchange Rate Volatility | 4.020 *** | 3.991 *** |
| Firms | -0.001 | - |
| Tradability | -0.042 | - |
| $R^2$ | 0.33 | 0.33 |
| N | 94 | 94 |

Notes: *** indicates a 1 percent degree of confidence, ** indicates a 5 percent degree of confidence, * indicates a 10 percent degree of confidence.

**Three variables appear significant: the post-NAFTA dummy, the border effect, and exchange rate volatility.** For the latter two variables, the results are in line with findings in the rest of the literature. For example, Imbs and others (2003) find that distance, exchange rate volatility, tradability, and industry competition explain the level of thresholds. The dummy post-NAFTA is also strongly significant and negative, confirming our previous results that the introduction of NAFTA reduced transaction costs. However, our attempt to use sectoral variables to explain transaction costs is not successful: neither the number of firms in a sector nor the degree of "tradability" in a sector are found to be statistically significant (column (1) of Table 6). The poor quality of the data and the approximation in proxying intra-industry trade and sectoral competition are a probable explanation for the lack of significance. In column (2), the two variables are excluded, with little change in the results.

**Using other types of models, the determinants of relative price differences between the United States and Canada have been extensively studied in the literature**. The results are broadly consistent with our findings. Engel and Rogers (1996) the Canadian and U.S. markets are not perfectly integrated and that distance and border are major determinants of price differentials between cities. Engel, Rogers, and Yi Wang (2005) investigate the LOOP between U.S. and Canadian cities using actual prices (instead of price indices). They find that absolute price differences between U.S. and Canadian prices are higher than 7 percent. In addition, their results show that distance and border play a significant role in explaining price differentials between cities.

## V. Summary of Results and Conclusion

**Using a SETAR model, we find significant differences in transaction costs in different sectors and countries.** Looking at the Mexico–U.S. and Canada–U.S. country pairs, the estimated price thresholds range from 2 percent to 32 percent.

- Across sectors, the results generally confirm that highly homogenous sectors—fish and fruits—show low threshold bands.

- Across country pairs, interpreting the size of the price threshold as a measure of market integration, we find significant differences between the three NAFTA members, with Mexico being relatively less integrated. Overall, average transaction costs among NAFTA members are 34 percent higher between the U.S. and Mexico than between the U.S. and Canada.

We also document the impact of NAFTA on the integration of the three countries and find that NAFTA substantially reduced transaction costs between Mexico and the U.S. while its impact was less marked between Canada and the U.S.

To analyze the adjustment of relative prices to shocks, we also compute the half-lives of the Mexico-U.S. sectoral real exchange rates, a measure of the time it takes for the effect of 50 percent of a price shock to die out. On average, the average half-life was substantially reduced after the introduction of NAFTA, going down from 20 months in the pre-NAFTA period to 11 months post-NAFTA.

**The border effect and exchange rate volatility are found to be significant determinants of transaction costs**. The dummy post-NAFTA is also strongly significant and negative, confirming that the introduction of NAFTA reduced transaction costs.

**The analysis therefore supports the arguments that (i) emerging markets—in this case, Mexico—still face higher transaction costs than their developed counterparts; and (ii) trade liberalization may help in lowering relative price differentials between countries**. We suspect that lack of competition may be a major determinant of high price thresholds. With limited data, we provide only tentative evidence on this issue.

**From the point of view of Mexico, the findings imply that domestic goods' prices today respond more fully, and more quickly, than in the past to either (i) a change in the domestic price in the U.S., or (ii) a change in the nominal exchange rate**. While greater transmission of sectoral relative price shocks may have consequences for the conduct of monetary policy, it should be distinguished from the question of "exchange rate pass-through" to the overall consumer price index. Such overall pass-through is determined also by other factors, including monetary policy and the business cycle. However, in the last several years, the fluctuation of Mexico's peso against the U.S. dollar has been fairly modest—with maximum and minimum monthly averages differing by only about 10 percent. Exchange rate movements within such a range are smaller than the transaction cost bands that we find for many sectors, implying that pass-through of such exchange rate changes to domestic prices will often be limited or even nonexistent. For Mexico, therefore, it may now be that movements in U.S. prices—rather than nominal exchange rate fluctuations—are the more relevant source of variation in domestic prices of certain traded goods.

**The main conclusion of the paper is that Mexico has made progress, but still has considerable room for improvement, in reducing barriers to goods market integration and achieving full benefits of globalization.** It would be important to further analyze the reasons why transactions costs between Mexico–U.S. continue to exceed those for Canada–

U.S. for many types of goods, and to determine whether these costs can be reduced through policy actions—for example, by developing logistics, transportation, and internal distribution mechanisms, or by enhancing the state of competition among domestic firms and reducing remaining barriers to external trade.

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