

# THE PURCHASING POWER PARITY ACROSS MEXICAN CITIES: A DATA PANEL ANALYSIS

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## ***Introduction***

Regional differences in Mexico are quite important. The gap of development between the northern states and southern states is particularly severe. This issue is the consequence of a low rate of economic convergence among states and regions. In accordance with recent studies<sup>1</sup>, in the last twenty years the rate of convergence has become stagnant or even worsened resulting in a divergence between states and regions. As the differences between rich and poor states continues growing, result interesting to know if such economical divergence is manifested through nominal divergence via prices. If the prices for the same kind of goods, show different performance for different regions and in accordance with the Balassa-Samuelson approach, those prices are determined by their rates of productivity, is possible to say than the stationarity in prices is a consequence of market integration degree. Therefore, a more integrated market boost the level of real convergence, and at any time more real convergence produce more integrated markets.

In this sense for this study, the degree of market integration is obtained when is contrasted the validity of the Purchasing Power Parity (PPP) through the

stationarity of prices, and the method chosen to do it will be unit roots tests for panel data. At the same time the study of relative prices across cities in a common market provide an interesting opportunity of analysis, due to less factors<sup>2</sup> affect the price convergence than in international comparison. Where the structural factors have more influence on the PPP than the different criteria to build the prices indexes or the different fiscal and duty schedules across countries.

### **Theoretical framework**

Due to the theory of Purchasing Power Parity (PPP) has been always controversial since it is proposed by Cassell in 1916, during all this time has been a great quantity of works to test the PPP from different approaches: long time series, cointegration – see Canzonery; (1999) and panel methods - see Taylor; (1996). Although the number of studies which grant validity to the PPP is quiet important, there is mixed results with some supporting the idea and others against the evidence of PPP. In that sense have risen many arguments to explain the PPP fault, by example from the different criteria employed to build the indexes across countries to the kind of econometrics tools used in the analysis and is precisely this aspect which one has captured more attention by the researchers.

Earlier researches on relative PPP relied on standard two stage least square regression emphasizing the level of the variables, but later investigations showed

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<sup>1</sup> Cermeño 2001

<sup>2</sup> Trade barriers, failures in the nominal exchange rate to adjust the relative price-level shocks, differences across the weighted price index, firms with international markets segmented, differences in language, tastes etc.

that the level of real exchange rates were not stationeries. Later were used unit root tests or two-step cointegration on a bilateral real exchange rate, however as well failed. Then, their critics stressed than one of the weaknesses of these kind of tests is that they rest on two countries models and is ignored the influence that other countries may have on bilateral exchange rates. Like an answer a multicountry, multiregion or multicity analysis of the PPP which one implies that the shocks to any one of the currencies within the union will also affect the other currencies within the currency area, arise the first multilateral studies – see Kugler & Lenz (1993) through multivariable Johansen method. Whence the panel data approach is a properly tool to study the problem and is not difficult to transfer the focus toward the intra-country approach.

Thus since middle of the 90's several studies have conducted numerous applications of time series methods applied to panels, especially panel unit root tests for a lot of topics, like stationarity on real salaries, balance account or exchange rate. Is in this sense, than a set of tests for panels has been developed like answers to the low power of the simple univariate tests, due to generally those tests do not have sufficient capacity to reject the null hypothesis of a unit root unless the sample size is large.

Albeit there are several tests<sup>3</sup> for unit roots based on panel data, especially there are two tests which have showed to be enough successful, the first test belong to Levin & Lin (LL) and the second test was developed in 1997 by Im, Pesaran and

Shin (IPS). Both tests share the same analysis structure through the Dickey-Fuller test (ADF), so far as both look for series which one follow a unit root process, however the LL test belong to the first generation<sup>4</sup> of this kind of tests.

### ***The basic model***

The PPP theory says that the exchange rate between currencies of two countries is equal to the relationship between the price levels of those countries. Hence a reduction in the purchasing power of the local currency (through an increase of the local level price) imply an equivalent depreciation of local currency, but when are analyzed several regions inside one economy, there is not such adjust mechanism because just exist one currency. Then, to transfer the analysis to one country and several cities has to be calculated the "real exchange rate" or relative prices through the consumer price index per cities (CPI). To do this, is tested a *strong form of the PPP*, which suppose than the real exchange rate must be equal to one, even may exist small variations in the short term, such instability tends to disappear almost entirely for the long term. Hence is possible and sufficient to apply a stationary test to check the *PPP* validity.

Thus, in order with the traditional frame of the relative PPP, and once has been applied logarithms to the standard equation<sup>5</sup> is obtained:

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<sup>3</sup> Others test like Quah & Breitung and Mayer and Mayer, have showed poor performance.

<sup>4</sup> Expression coined by Boucher, Mc Nown y Wallace.

$$y_t = y_0 + P_{i0} - P_{j0}$$

After apply first differences and adding white noise like an error term we get the “ex-ante” expression of the PPP or of “efficient markets” in accordance with Frenkel:

$$(y_t - y_{t-1}) = (P_{it} - P_{i,t-1})(P_{jt} - P_{j,t-1}) + v_t = \Pi_{it} - \Pi_{jt} + v_t$$

Notice than in the last equation has been omitted the first term, wich one display the nominal exchange rate, because in an intra-country analysis its vaule always is equal to one, by other side  $p_{it}$  and  $p_{jt}$  are the inflation rates of the cities  $i$  and  $j$ . If  $v_t$  is white noise, the real exchange rate follows a “random walk”, this meaning that when exist a deviation of the relative PPP will be eliminated along time, in this sense the ex-ante PPP also may be expressed in short way like:

$$\Delta y_{it} = \sum_{n=1}^p \beta_n \Delta y_{i,t-n} + v_t$$

Where  $y_{it}$  is the real exchange rate or ratio of relative prices, while the lags are adding to get residuals which can be independent and identically distributed  $N(0,1)$ . At the same time,  $y_{it}$  follows a stochastic process which is generated by an auto regressive process of first order. Recording, than the principal objective is to test

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<sup>5</sup>  $y_0 = TP_{i0}/P_{j0}$

the null hypothesis of unit root for the lag variable coefficient, the equation is expressed as:

$$\Delta y_{it} = \mathbf{a}_i + \mathbf{b}_i y_{i,t-1} + \mathbf{e}_{it}$$

It is worth saying than this equation<sup>6</sup> is the base for both tests, then to correct the problem of heteroscedasticity and autocorrelation, the original equation must be normalized<sup>7</sup> using the standard errors of the regression through dividing the equation by the errors. Thus, once has been corrected the equation with the ADF context has a simplified form like:

$$\Delta \bar{y}_{i,t} = \mathbf{a}_i + \mathbf{b}_i y_{i,t-1} + \sum_{j=1}^{p_i} \mathbf{r}_{ij} \Delta y_{i,t-j} + \mathbf{e}_{i,t}$$

Since the elemental Dickey-Fuller (ADF) test is the base for both analysis, the objective is to know whether or not the prices across cities are unit roots process, likewise if the prices for different type of goods converge or not across cities in accordance with the Balassa-Samuelson theory.

Finally, from a panel data perspective, is possible to see how the test power is a direct function of the panel size. Because the analysis goes from a simple time series with just  $T$  time observations, to a  $T \times N$  panel with cross –section observations, where to keep the asymptotic normality in the estimators,  $N$  has to be large enough but not as big as  $T$ .

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<sup>6</sup> The model could has other variants, like time effect, unit-specific time etc.

<sup>7</sup> Proposed by Levi & Lin

### ***The Levin & Lin and IPS Tests***

As has been mentioned already, nowadays exist a great quantity of tests of unit roots for panel data, however the tests chosen here have shown a proper behaviour. From a comparative analysis, many studies have concluded that the IPS test is more powerful than the LL test, but the comparisons are not totally valid because even although both tests share the same null hypothesis, their alternative hypothesis is different. At the same time while LL test is based on pooled regressions, while the IPS test amounts to a combination of different tests. In accordance with Monte Carlo studies, is possible to say that IPS test is superior to LL test but just especially for small samples. However, the IPS test loose power when is not properly selected the order (lags) of the underlying ADF regressions, especially when the order is underestimated. Then, taking account all this controversy, seems appropriate to use both tests and compare their results.

The framework used for the LL test was the unit-specific fixed effects; this approach try to offset the restriction imposed by a common lagged parameter across all the units ( $N$ ) in the panel. The conditional convergence occurs when the intercept differs between cities and the real relative prices are  $I(0)$ . This fact may occur if price shocks are transmitted one-by-one, through domestic factors such as differentials of productivity across cities or likewise when the preferences for tradable and non-tradable goods affect underlying price growth, causing a difference between real relative prices for the cities.

Thus the null hypothesis, which means that all have to be non stationary, therefore exist unit roots:

$$H_0 : \mathbf{b}_1 = \mathbf{b}_2 = \dots = \mathbf{b}_N = \mathbf{b} = 0$$

Against the alternative hypothesis:

$$H_1 : \mathbf{b}_1 = \mathbf{b}_2 = \dots = \mathbf{b}_N = \mathbf{b} < 0$$

Nevertheless, precisely the major limitation of the LL test is the fact than the coefficient " $\beta$ " is the same for all observations, implying homogeneity which is difficult to find in real cases. Therefore, if the null hypothesis is rejected it,<sup>8</sup> can be said that all the relative prices within the panel are stationary; in this sense the PPP is maintained.

Respect to the IPS test, its principal contribution is that relaxes the assumption about the alternative hypothesis, which supposed that all coefficients had to be equals among them. Likewise, the important fact to note is that the IPS test is a way of combines the evidence of the unit root hypothesis from  $N$  unit root tests performed on  $N$  cross section units.

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<sup>8</sup> The criteria, to test the unit root is the next: if the *t-ratio* for the estimated coefficient of  $z$  is larger than the critic value, then reject the null of a unit root. In a mathematical form: If  $\tau(\beta_{\text{calc}}) > \beta_{\text{table}} \Rightarrow$  reject  $H_0$ , if  $\tau(\beta_{\text{calc}}) < \beta_{\text{table}} \Rightarrow$  accept  $H_0$

Therefore, is changed the former assumption of homogeneity across the units, then is defined the null hypothesis for each unit in the panel data as:

$$H_0 : \mathbf{b}_1 = \mathbf{b}_2 = \dots = \mathbf{b}_N = \mathbf{b} = 0$$

Against the alternative, where at least one serie follow a stationary process:

$$H_1 : \dots \mathbf{b}_i < 0 \dots i = 1, 2, \dots, N_1 ; \dots \mathbf{b}_i = 0, \dots i = N_1 + 1, N_2 + 2, \dots, N$$

Since the disturbances for the underlying Dickey-Fuller regressions are serially correlated, due to different cities belong to the same country and suffering the effects of the same monetary policy, is used the equation<sup>9</sup> named  $\bar{t}$ , which is based on the average of the individual unit root  $t$ -statistics:

$$y_{\bar{t}} = \frac{\sqrt{N} \left\{ \bar{t}_{NT}(p, \mathbf{r}) - \frac{1}{N} \sum_{i=1}^N E[t_{iT}(p_i, 0) / \mathbf{b}_i = 0] \right\}}{\sqrt{\frac{1}{N} \sum_{i=1}^N \text{Var}[t_{iT}(p_i, 0) / \mathbf{b}_i = 0]}}$$

As can be seen, this equation allows to the coefficient to differ across groups and is more general and flexible than the homogeneous and alternative hypothesis of the LL test. It is worth saying that; the expected mean values and the variance

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<sup>9</sup> However here it was found practical problem because while the mean and variance vary as the lag included in the ADF vary, for practical terms and use of their tables (Im, Shin& Pesaran) it is necessary to take the same variance and mean for all the cities.

were evaluated via stochastic simulation by the authors and reported in their paper<sup>10-11</sup>.

To carry out the test, a numeraire city<sup>12</sup> is chosen in this case was Mexico City, due to is the principal economic centre and the country capital. So once obtained the logarithm of the quotient between each city index and Mexico City index, was applied the simple ADF test to each series. To determine the lags used in the test, was used the Campbell and Perron's criteria as former test, (see Annex).

### ***Empirical evidence***

The most analysis in the PPP scheme have been international comparisons, in contrast systematic intra-national analysis just has been present in a few number of examples, basically for the United States and Canada; Cacchetti & Sonora (2000) and Japan; Esaka (2002). In such cases, the PPP has been valid, although the distance and transport cost appeared like principals elements against the PPP.

Recently an study for 50 Spanish cities with a time period of 43 years (conducted by Carrión, Del Barrio and Lopez, 2004) confirmed the existence of PPP through panel data and unit roots tests, although also was founded a large persistence of short-run deviations from the PPP.

<sup>10</sup> Et. Al. Im, Shin & Pesaran, Appendix tables 2003.

<sup>11</sup> For practical applications when there is an unbalanced data, it is necessary to do more simulations to get the critical values. In the same context, when there is serial correlation and the ADF t-test for individual series is applied, the length included in the regression affects directly the value of the mean and variance, and therefore the value of the t-statistic IPS test. Then the practice, to make use of the tables it is imperative to use the same lag length for all the ADF regressions for individual series.

Quoting to Officer (1976) and Maeso (1997), whose say than the structural factors, such technologic differences, development differences and bias induced by the productivity, affect strongly the validity of the PPP for the long term, is opportune to suppose than the nominal convergence via prices is supported by a most real convergence and is registred by the half-life, which show the convergence speed for the prices toward the PPP. That is mean, the time necessary to reach the half of the average value after have suffered one shock. Frankel & Rose found an average half-life of 4 years for a panel formed with 150 countries; however the values swing between 3 and 7 years. In that sense Papell and Murray; (2002), have criticized this conclusions because they argue that were not used appropriate techniques to measure the persistence in PPP deviations.

In accordance with the proposed study, were formed 8 panels for different kind of goods (tradables and non tradables), each panel has 276 observations ( $T$ ) and 16 cities ( $N$ ). However, before to contrast the LL and IPS tests, is convenient to analyze the stationarity for each city with the simple ADF test of unit roots for time series.

Thus, the prices indexes per city were obtained of INEGI (Instituto Nacional de Estadística Geografía e Informática), the National Bureau of Statistic and the Central Bank (Banco de México). The indexes are monthly and were gathered for

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<sup>12</sup> The critics of test, say that the results may to change in function of the numeraire city chosen.

sixteen cities that represent every one of the seven geographical regions<sup>13</sup>. The period of study was from January 1980 to April 2001. Those cities belong to the group<sup>14</sup> of cities monitored to build the NCPI (National Consumer Price Index).

In accordance with the empirical evidence, which has showed that the non tradable goods affect the validity of PPP and in order to know better the degree of market integration for each kind of good, were used consumer price indexes in the disaggregated form which represent tradable and no-tradable goods. Then, one group has been conformed by Food & Drinks, Furniture, Clothes & Shoes, in the category of tradable goods, while by side of non tradable goods side we took Health, Education, Electricity, Housing and Transport.

Thus, to get the results for the univariate analysis, it was applied the Augmented Dickey-Fuller (ADF) test for each one of the individual series to check its stationarity. The series was derived from the logarithm of the ratio between each city and the average index:  $[\ln (y/x) = \alpha + \epsilon]$  for 16 cities:

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<sup>13</sup> Cities by region, which one are important economic places: Northwest, Mexicali & Culiacan; North, Juarez City & Turreon; Northeast, Monterrey; Western, Guadalajara & Morelia; North-Centre, Leon & San Luis Potosi; Eastern, Merida & Veracruz; South, Acapulco & Tapachula and Center, Mexico City, Puebla & Toluca.

<sup>14</sup> Nowadays there are 45 cities, which at least there are one city per each one of the 31 federal states and Federal District.

**Table 1**  
**ADF TEST FOR DIFFERENT PRICE INDEXES 1980-2001**

<b>CITY</b>	Food & Drinks	Cloth & Shoes	Furniture	Electric. & Comb.	Transp.	Education	Health	Housing
<b>Acapulco</b>	N	N	N	Y*	N	Y**	N	N
<b>Mexico City</b>	N	N	Y*	Y	N	N	N	N
<b>Culiacan</b>	Y*	N	N	Y	N	N	Y	Y**
<b>Guadalajara</b>	Y	N	N	Y	Y	N	N	N
<b>Juarez City</b>	N	N	N	N	N	N	N	N
<b>Leon</b>	Y**	N	N	Y	N	N	N	N
<b>Merida</b>	N	N	Y*	Y	N	N	N	N
<b>Morelia</b>	N	N	N	Y	Y	N	Y	N
<b>Monterrey</b>	N	Y**	N	Y	N	N	Y	N
<b>Mexicali</b>	N	N	N	Y	N	Y*	N	Y
<b>Puebla</b>	N	N	N	Y	N	N	N	N
<b>San Luis P.</b>	N	N	Y**	N	Y	N	N	N
<b>Tapachula</b>	Y**	N	N	Y	N	N	N	N
<b>Toluca</b>	Y	N	Y**	Y	N	N	Y**	N
<b>Torreon</b>	Y	N	N	Y	N	Y	N	Y
<b>Veracruz</b>	N	N	N	Y	N	N	N	Y
<b>Number of stationaries cities</b>	6	1	4	14	3	3	4	4

Note: \* = 10% of significance, \*\* = 5% de significance, if there is not asterisk mean that exist complete significance at the three levels of confidence.

In accordance with the table 1 are deduced interesting results, while for Electricity & Combustibles there are fourteen series stationeries series (87.5%), for Cloth & Shoes only one city (6.2%) is stationary. Likewise, the rest of kinds of goods have a small number of stationaries cities, due to go from 18 to 37% of the all cities. Then like conclusion, the null hypothesis of unit root cannot be rejected and just is possible to conclude convergence via price for the Electricity & Comsutible market.

Respect to the Levin & Lin test, all the series for goods are stationary at 1% significance level, except Cloth & Shoes, which is not stationary with any significance level. Is worthy to say that to keep the independence across cities has been subtracted the cross section mean, see Annex. The IPS test as well has showed that all the goods are strongly stationeries with 1% of significance, with the exception of Cloth & Shoes. Due to both tests arrive to the same results, is possible to say that the PPP holds across Mexican cities and at the same time has been evident the low power of the conventional unit root tests. Have to be highlighted than Electricity & Combustible registered highest statistic both LL test as IPS test in harmony with simple ADF tests, which found 14 stationaries series, therefore the results just are strengthened.

**Table2**  
**PANEL UNIT ROOT TESTS ACROSS MEXICAN CITIES 1980-2001**

Sort of Good	Half-life	Levin & Lin	IPS
	Months	$t_{\tau}$	$?_t$
<b>Food &amp; Drinks</b>	16	-9.551	-5.8757
<b>Furniture</b>	29	-7.227	-2.4170
<b>Cloth &amp; Shoes</b>	53	-4.836*	-0.5928*
<b>Transport</b>	16	-8.657	-2.5344
<b>Health</b>	24	-7.602	-3.5855
<b>Household</b>	36	-7.410	-2.9598
<b>Electricity &amp; Combustible</b>	6	-16.288	-15.1921
<b>Education</b>	19	-7.880	-2.1864

	Critical Values		
Significance Level	1%	5%	10%
<b>Levin &amp; Lin ( <math>t_{\tau}</math> )</b>	-6.88	-6.29	-5.98
<b>IPS ( <math>?_t</math> )</b>	-2.04	-1.89	-1.81

Note: All the statistics are significatives at 1%, 5% and 10% in accordance with the originals tables built it by the authors.

\* No significative, even at 10%

Finally the half-live, which measure the price convergence speed when is produced any shock, was for Electricity and Combustible quite short (just 6 months), while for

Cloth and Shoes the half life for price divergences is almost 4 years and half. Likewise Housing, Furniture and Health had a long half life<sup>15</sup> cycle, with 3, 2.5 and 2 years respectively; therefore, these results tell us that although the series are stationeries, the convergence rate is slow. It is important to mention that the technique employed here, nowadays is controversial due to do not take account explicitly several correlations, sampling uncertainty and the small sample bias.

### ***Results and final comments***

Is possible, to conclude that the purchasing power parity is held by the 16 biggest Mexican cities. When the simple ADF test was applied, all the goods except Electricity and Combustible registered weakness in the stationarity.

In accordance with the theory, here was showed that the LL test and the IPS test grant a more degree of freedom to assess stationarity. Thus for the Mexican case both tests to find validity the purchasing power parity, except for Cloth and Shoes and at the same time have showed the low power of the conventional tests. The possible explanation for this result could be found in the fact that prices for Cloth and Shoes were less regulated by policy makers due to until last years of 80s the government kept an important control on the most prices, likewise until recent times, the market for this products was quite segmented, where the transport cost and the consumer discrimination have had an important role. At the same time, those goods show a quite spread industry, formed in many cases by semi-

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<sup>15</sup> The formula to obtain it is  $-\ln(2)/\ln(\mathbf{r}_i)$

manufacture entities, where there are many non-tradable factors which are incorporate in its productive process, and therefore affect the integration degree.

With respect to the results obtained from the rest of indexes, their stationarity respond to a national market, which tend to be integrated even if the distance between regions become huge Mc Callum (1995), because imply as well a more integrated labour market and therefore similar wage structure and because finally is just that, a national market without all the factors presents in international comparisons.

Likewise the control prices policy, one time managed in Mexico, permitted certain degree of homogenisation in prices, despite the inequalities in regional development across the country. It is worth saying, that until nowadays the Petrol price is regulated (through the only oil monopolystic national company) which is the same for all the country except the northern borderline, as well is the same case for the gas and electricity fares, that issue explain why the index for this set of goods was heavily stationarie.

Thus, after twenty years of structural change suffered by the Mexican economy, where among many policies, has adopted an intense desregulations and economic liberation through more private sector in the economy, whose results have had important relative prices adjusts and more role for the markets. Is possible to say that Mexican market is integrated due to the price dispersions is stationarie, at the same time has been showed like the panel unit root tests are more powerful than the conventional tests. However at least in this case the nominal convergence

degree do not obey to the real convergence degree, due to economic disparities across Mexican regions.

By other hand, the objective for further studies is to compare the tests employed in this paper with others news focus, especially the models which are based on the system of equations seemingly un-related (SURADF), due to in recent times this test has had a good behaviour and even showed to be superiors. As well is contemplated re-estimate the half-lives based on the impulse response function, which recalculate appropriate confidence intervals.

## ***Annex***

### ***Application of the Levin & Lin test***

Thus following the proper methodology, we must take the prices index by city and apply logarithms. Then we must subtract the cross-section averages from the data to eliminate the influence of common time effects, and therefore the autocorrelation

$$\bar{y}_{i,t} = y_{i,t} - (1/N) \sum_{i=1}^n y_{i,t}$$

Now we applied the augmented Dickey-Fuller (ADF) test to each individual series and normalize the disturbances:

$$\Delta \bar{y}_{i,t} = \mathbf{a}_i + \mathbf{b}_i y_{i,t-1} + \sum_{j=1}^{p_i} \mathbf{g}_{ij} \Delta y_{i,t-j} + \mathbf{e}_{i,t}$$

But the practical way to run the test is for each city and type of good performing the regression  $\Delta \bar{y}_{i,t}$  on a constant, and  $p_i$  lagged values of  $\Delta \bar{y}_{i,t}$ , where the lag lengths are obtained through Campbell and Perron's criteria. This to consist of start with  $p_i = 6$ , to run the regression, and if the absolute value of the t-ratio for  $\hat{g}_{i6}$  is less than 1.96 (or the significance level is smaller than 5%) we have to continue and try with  $p_i = 5$  and reestimate the equation. The process must be repeated until the t-ratio of the estimated coefficient with the longest lag exceeds 1.96. In the case when there is not such a ratio, the first lag was chosen. Likewise the model adopted was without a time trend because it would not be consistent with the long term of PPP.

Once we established the proper lag, the model must be run and we must obtain the residuals of the regression  $\hat{e}_{i,t}$ . After run  $\bar{q}_{i,t-1}$  on the same variables of the base equation and we get the residuals of this regression denoted as  $\hat{v}_{i,t-1}$ .

The next step was to run  $\hat{e}_{i,t}$  on  $\hat{v}_{i,t-1}$  without constant to obtain the residuals of this regression  $\hat{e}_{i,t}$ , through the next equation:

$$\hat{e}_{i,t} = \mathbf{r}_i \hat{v}_{i,t-1} + \mathbf{e}_{i,t}$$

To get  $\hat{\mathbf{r}}_i$  is equivalent to run by OLS the base equation, and obtain  $\hat{\mathbf{b}}_i$  directly.

Since the residuals of the series have heteroscedasticity, the authors suggested the following normalization to reduce it:

$$\hat{\mathbf{s}}_{ei}^2 = \frac{1}{T - p_i - 1} \sum_{t=p_i+2}^T (\hat{e}_{i,t} - \hat{\mathbf{r}}_i v_{i,t-1})^2$$

$$\tilde{e}_{i,t} = \frac{\hat{e}_{i,t}}{\hat{\mathbf{s}}_{ei}}$$

$$\tilde{v}_{i,t-1} = \frac{\hat{v}_{i,t-1}}{\hat{\mathbf{s}}_{ei}}$$

Once done all the last manipulations per each city, it is applied to a panel of fixed effects which allows us to account for possible heterogeneity, such as differing income levels and sales taxes, which can lead to permanent differences in relative prices across cities, therefore the model:

$$\tilde{e}_{i,t} = \mathbf{a}_i + \mathbf{r}_i \tilde{v}_{i,t-1} + \tilde{e}_{i,t}$$

Now we can obtain t statistic:

$$t_r = \frac{\hat{\mathbf{r}}}{RSE(\hat{\mathbf{r}})}$$

Where

$$RSE(\hat{\mathbf{r}}) = \hat{\mathbf{S}}_e \left[ \sum_{i=1}^N \sum_{t=2+pi}^T \hat{v}_{i,t-1}^2 \right]^{-1/2}$$

$$\hat{\mathbf{S}}_e^2 = \frac{1}{N\tilde{T}} \sum_{i=1}^N \sum_{t=2+pi}^T (\tilde{e}_{i,t} - \hat{\mathbf{r}}\tilde{v}_{i,t-1})^2$$

$\tilde{T} = T - p - 1$  and  $\bar{p} = \frac{1}{N} \sum_{i=1}^N p_i$  is the average lag length used in the individual ADF regression.

However this t-statistic reported is not centered at zero, and by this way Levin and Lin suggested the use of the following adjusted t-statistic<sup>16</sup>

$$t_r^* = \frac{t_r = 0 - N\tilde{T}\hat{\mathbf{S}}_{NT}^{-2}RSE(\hat{\mathbf{r}})\mathbf{m}_T^*}{\mathbf{s}_T^*}$$

Where  $\mathbf{m}_T^*$  and  $\mathbf{s}_T^*$  are the mean and the standard deviation obtained by the authors through Monte Carlo simulation and tabulated in their original paper. To calculate the *t-statistic* adjusted it is necessary to estimate the ratio of long run to short run standard deviation for each individual series, and after to calculate the average ratio for the panel through the formula:

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<sup>16</sup> Pp. 634 Madala and Wu (1999)

$$\hat{S}_{NT} = \frac{1}{N} \sum_{i=1}^N \frac{\hat{\mathbf{S}}_{yi}}{\hat{\mathbf{S}}_{ei}}$$

While the log-run variance  $\hat{\mathbf{S}}_{yi}^2$  is granted by

$$\hat{\mathbf{S}}_{yi}^2 = \frac{1}{T-1} \sum_{t=2}^T \Delta y_{i,t}^2 + 2 \sum_{L=1}^{\bar{K}} w_{\bar{K}T} \left( \frac{1}{T-1} \sum_{t=L+2}^T \Delta y_{i,t} \Delta y_{i,t-L} \right)$$

Respect to the last equation,  $\bar{K}$  is the lag truncation parameter and  $w_{\bar{K}T}$  is the lag window. Then, once the variance has been obtained is possible to use the adjusted *t-statistic* equation and contrast it with the original tables made by the authors, for this case which one include fixed effects.

## References

Alves, D., Cati,R. and Vera L., 2001. Purchasing power parity in Brazil: a test for fractional cointegration. *Applied Economics* 33, 1175-1185

Andrés, J., Hernando, I. and Kruger, M., 1996. Growth inflation and the exchange rate regime. *Economic Letters*, 53. 61-65

Baltagi, B., 2001. *Econometric Analysis of Panel Data. Second Edition*

Banamex, 2001 and 2002 (several numbers). Mexico: The report of the economic situation.

Banerjee, Anindya, 1999. Panel data unit roots and cointegration: an overview. *Oxford Bulletin of Economics and Statistics, Special Issue* 0305-9049

Bernstein, D., 2000. Generalized purchasing power parity and the case of the European Union as a successful currency area. *Applied Economics Journal*, Vol.28 No.4

Boucher-Breuer, J., Mc Nown, R. and Wallace, M., 2001. Misleading inferences from panel unit root tests with an illustration from purchasing power parity. *Review of International Economics*, 9(3), 482-493

Boucher-Breuer, J., Mc Nown, R. and Wallace, M., 2002. Series-specific Unit Root Tests with Panel Data. *Oxford Bulletin of Economics and Statistics*, 64, 5.

Canzoneri M., Cumby R. and Diba B., 1999. Relative labor productivity and the real exchange rate in the long run: evidence for a panel of OECD countries. *Journal of International Economics* 47, 245-266

Cacchetti, S., Mark, N and Sonora, R., 2000. Price level convergence among United States cities: Lessons for the European Central Bank. NBER Working Paper 7681

Cermeño, R., 2001. Decrecimiento y convergencia de los estados mexicanos: un análisis con modelos de panel. *El Trimestre Económico* No. 272.

Carrión, J. Del Barrio, T & López, E. 2004. Evidence on the purchasing power parity in a panel of cities. *Applied Economics*. No. 36

Choi, In, 2001. Unit root tests for panel data. *Journal of International Money and Finance* 20, 249-272

Click, R., 1996. Contrarian MacParity. *Economic Letters*, 59. 209-212

Coakley, J. and Fuertes, A. M., 1997. New panel unit root tests of PPP. *Economic Letters* 57 17-22

Coe, P. and Seretis, A., 2002. Bounds tests of the theory of purchasing power parity. *Journal of Banking and Finance*. 26 179-199

Cuddington, J. and Liang H., 2000. Purchasing power parity over two centuries?. *Journal of International Money and Finance* 19, 753-757

DeLoach, S., 2001. More evidence in favor of the Balassa-Samuelson Hypothesis. *Review of International Economics*, 9(2), 336-342

Engel, C. and Rogers, J., 1996. How wide is the border? *The American Economic Review*. Vol 86. No.5

Esaka, Taro,. 2002. Panel unit root tests of purchasing power parity between Japanese cities, 1960-1998: disaggregated price data. *Japan and the world economy* 440, 1-12

Esquivel, G.,1999. Convergencia regional en México, 1940-1995. *El Trimestre Económico*. No 264

Fleissig, A. and Strauss, J., 2000. Panel unit root tests of purchasing power parity for price indices. *Journal of International Money and Finance*, 19, 489-506

Guillaumont Jeanneney, S. and Hua, P., 2002. The Balassa-Samuelson effect and inflation in the Chinese provinces. *China Economic Review* 13, 134-160

Gómez-Galvarriato, A. and Musacchio, A., 2000. Un nuevo índice de precios para México, 1986-1929. *El Trimestre Económico*. No 265

Honohan, P., 1992. Price and monetary convergence in currency unions: the franc and rand zones. *Journal of International Money and Finance* 11, 397-410.

Im, K., Pesaran, H.M. and Shin, Y., 2003. Testing for unit roots in heterogeneous panels. *Journal of Econometrics*. No. 62

Laureti, L., 2002. Purchasing power parity and integration empirical evidence in the Mediterranean countries. *Journal of Policy Modeling* 23, 731-751

Levin, A. and Lin, Ch., 2002. Unit root tests in panel data: Asymptotic and finite-sample properties. *Journal of Econometrics* No. 108

Macdonald, G., Allen, D. and Cruickshank, S., 2002. Purchasing power parity-evidence from a new panel test. *Applied Economics*, 34. 1319-1324.

Maddala, S. and Wu, S., 1999. A comparative study of unit root tests with panel data and a new simple test. Oxford Bulletin of Economics and Statistics, Issue 0305-9049

Maddala, S. and Wu, S., 2000. Cross-country growth regressions: problems of heterogeneity, stability and interpretation. Applied Economics, 32. 635-642

Mc Callum, J., 1995. National border matter: Canada.-U.S. regional trade patterns. The American Economic Review. Vol. 85 No.3

Mc Coskey, S. and Kao, Ch., 1998. A residual-based test of the null of cointegration in panel data. Manuscript , Center for Policy Research, Syracuse University

Mc Nown, R. and Wallace, M., 1989. National price levels, purchasing power parity and cointegration: a test of four high inflation economies. Journal of International Money and Finance. 8, 533-545

Montuenga, V.M., 1998. Price convergence during the EC lifetime. Working Paper 411.98 IDEA Universitat Autònoma de Barcelona.

Phillips, P. C. B., 1987. Time series regression with a unit root. Econometrica, Vol. 55. No. 2, 277-301

Raymond, J. and Garcia-Greciano, B., 1999. Tipo de cambio real de la peseta y productividad. Una visión de largo plazo. *Revista de Economía Aplicada* Vol. 5 No. 15 p31-47 Invierno.

Sorensen, A., 2001. Comparing apples to orange: Productivity convergence and measurement across industries and countries: comment. *The American Economic Review*. Vol 91 No.4

Taylor, A., 2002. A century of purchasing power parity. *The Review of Economics and Statistics*. 84(1) 139-150

White, H. and Domowitz, Ian., 1984. Nonlinear regression with dependent observations. *Econometrica*, Vol. 52, No.1

Wu, J., 2000. Mean reversion of the current account: evidence from the panel data unit-root test. *Economic Letters* 66, 215-222

Wu, J., and Chen, S., 1999. Are real exchange rates stationary based on panel unit-root tests? Evidence from pacific basin countries. *International Journal of Finance and Economics* 4, 243-252