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Article

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Price convergence, reversal speed and purchasing power parity: Stylized facts for Brazilian cities

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Abstract

This paper analyzes the price dynamics of Brazilian cities between 1995 and 2012 to identify stylized facts about price convergence, the reversal speed of deviations between relative prices and purchasing power parity (PPP). There is evidence of a strong reduction in the absolute dispersion of prices of Brazilian cities and in the variability of relative prices. The estimated half-life of deviations from PPP reversal proved to be lower than those found for cross country data and American cities. The results also indicate that the stationarity of the real exchange rate among the cities is rejected for all the series that presented a reversal speed to deviations from the PPP smaller than the average for each numerarie considered. It is argued that the evidence of price convergence associated with a process of slow reversal speed of deviations from the PPP have influence on the non-rejection of a unit root in the real exchange rate series for some cities, however, this fact does not constitute in itself evidence against the validity of the PPP.

JEL classifications: F31; R10; E31

Keywords: Purchasing power parity; Reversal speed; Real exchange rate; Price convergence

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1. Introduction

In recent years, several researchers have observed flaws in the relationship called purchasing power parity, heretofore PPP, for international data. Such observations motivated several studies¹ to investigate the behavior of the real exchange rate using within country data.

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¹ See for example Engel and Rogers (1996), Culver and Papell (1999), Cecchetti et al. (2002) and Chen and Devereux (2003).

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These flaws, represented by an incomplete adjustment of the level of international relative prices, can be explained by factors such as: (i) commercial barriers, as tariffs and quotas; (ii) barriers of bureaucratic origin in the establishment or creation of a distribution system of goods; (iii) failure in the adjustment of the real exchange rate to shocks in the relative prices; (iv) market failures, such as the presence of firms with monopoly power, with differentiated prices in segmented markets; (v) transport costs, associated with transferring goods from one region to another, and (vi) possible differences in the composition of the price indexes between countries.²

The empirical papers which analyze the validity of the PPP test if the series of deviations of the PPP, called relative prices, or the real exchange rate between countries are stationary. Authors such as [Breuer \(1994\)](#) and [Froot and Rogoff \(1995\)](#) present a survey of the literature which corroborates that the series in question have unit roots. Such evidence implies that the inflation differentials between countries, measured in the same currency, can persist indefinitely, or deviations from the PPP converge to a common average at a very low speed. Furthermore, the literature points to a consensus about the speed of convergence, or the reversal of PPP deviations, with a half-life³ between three to five years ([Abuaf and Jorion, 1990](#); [Frankel and Rose, 1996](#); [Wu, 1996](#); [Papell, 1997](#); [Lothian, 1997](#)).

The need to comprehend the persistence in PPP deviations for international data and the existence of great economic regions with a single currency, such as the European Union, encouraged specialists to analyze if countries with continental dimensions, with great diversity and regional disparities, satisfy the PPP regularity conditions and if the reversal speed is shown to be lower using intranational data. Furthermore, this approach is relevant because it shows that excessive variations in relative prices and, hence, on inflation differentials lead to the inefficient allocation of resources among economic sectors, and determine the differences in real wages and real interest rates that, in turn, influence the flows of labor and capital. Therefore, the shifting of relative prices involves substantial losses of welfare to society, besides being useful in the investigation of the degree of integration and regional growth ([Nath and Vargas-Silva, 2012](#); [Hegwood and Nath, 2013](#)). Also, with the use of intra data, it is possible to come to a better understanding of sources of persistent deviations from the PPPs found in papers using cross-country information ([Cecchetti et al., 2002](#)).

The first effort in that direction was made by [Engel and Rogers \(1996\)](#), which compared the variability in relative prices with disaggregated data of price indexes for the United States, Canada and between the two countries. The authors showed that the distance between cities located in the same country substantially explains the variation in prices of similar goods. Also, oscillations in prices at cities located in different countries were shown to be greater than those in equidistant cities within the same country.

Yet [Culver and Papell \(1999\)](#), investigated PPP regularity in the post-Bretton Woods period, using international and within country data for the United States, Canada and European countries. The authors found poor evidence of the validity of PPP with international data, when compared to what was found for European countries. Only Canada presented a clear evidence when compared to that of European countries. The price convergence speed was shown to be slower in the United States than those found for Canada and the European countries. In other words, even without problems arising from trade barriers, exchange rate volatility, monetary policy differences and other factors⁴ which restrict arbitrage in the goods market, the authors found a slow price convergence process in the United States.

Using information for the 19 more populated American cities⁵ between 1918 and 1995, [Cecchetti et al. \(2002\)](#) analyzed if the price indexes of those cities followed a common trend, and estimated the reversal speed of possible shocks to local prices. The authors found evidence of a temporary divergence in the price indexes of American cities, with a slow reversal process representing an estimated half-life of approximately nine years. The authors argue that the main reason for those findings are the presence of transportation costs and market failures.

In another important paper, [Chen and Devereux \(2003\)](#) analyzed the dispersion of absolute prices in American cities between 1918 and 2000, measured by the coefficient of variation of the price level, and found strong evidence

² For a review of these aspects, see [Rogoff \(1996\)](#) and [Taylor and Taylor \(2004\)](#).

³ Half-life is a measure of the velocity of adjustment in some variable. It indicates how fast the variable reverts its trajectory to the mean.

⁴ These factors refer to problems to construct the consumer price indexes, as consumer's preferences, weights of each item, the existence of non-tradable goods, etc.

⁵ Atlanta, Baltimore, Boston, Chicago, Cincinnati, Cleveland, Detroit, Houston, Kansas City, Los Angeles, Minneapolis, New York City, Philadelphia, Pittsburgh, Portland, San Francisco, Seattle, St. Louis and Washington D. C.

that it is smaller between American cities than between OECD⁶ countries. The authors also found indication of price convergence, and argue that the existence of convergence or divergence in the indicator between cities yields a non-stationary bilateral real exchange rate⁷; thus, for those cases, the non-stationary status of the variable is not evidence against PPP. The estimated average half-life of PPP deviations was of five years.

Authors such as [Culver and Papell \(1999\)](#), [Cecchetti et al. \(2002\)](#) and [Chen and Devereux \(2003\)](#) attribute the difficulty to reject the presence of a unit root in the real exchange rate between cities to factors such as reduced speed of reversion/adjustment and the existence of convergence or divergence in prices. In fact, stationarity requires that relative prices/real exchange rate between two cities occur at a constant level. In addition, [Simões and Marçal \(2012\)](#) point out that, high frequency data favor the appearance of anomalies in the time series, such as more intense changes in the variance of the shocks and, according to [Cavaliere \(2005\)](#), in this situation, tests would tend to indicate more frequently the presence of unit roots.

In recent papers, authors as [Hegwood and Nath \(2013\)](#) and [Basher and Carrion-i-Silvestre \(2011\)](#) point out the relation between structural breaks and slow mean reversion of relative price across cities. Others as [Nakamura and Steinsson \(2013\)](#) and [Gorodnichenko and Weber \(2016\)](#) argue that price stickiness⁸ can be one possible source of nominal price rigidity in the micro level and contribute to slow mean reversion of relative prices. Thus, the presence of structural breaks and price rigidity may also affect the results of the unit root tests.

Therefore, although stationarity of relative prices to analyze the validity of PPP is the standard technique in the literature, a slow reversal speed associated with a price convergence process can contribute to the rejection of stationarity of real exchange series between cities, which does not represent evidence against the validity of PPP.

Although the analysis of the validity of the PPP hypothesis is quite common in international literature, with various papers considering American, Canadian and European cities practically there are no papers dealing with the regional evolution of relative prices, with evidence of regional price convergence or the validity of PPP for Brazilian cities.

Motivated by that, this paper intends to fill the aforementioned gap by investigating price convergence and reversal speed in deviations to the PPP using data for Brazilian cities. Therefore, the intention of the paper is to analyze three aspects of this theme; that is, (i) is there evidence of dispersion reduction, whether absolute or relative, in prices for the considered cities? (ii) what is the adjustment, or reversal, speed for deviations from the PPP among Brazilian cities?, and (iii) does the evidence of convergence and of a slow reversal to the PPP process contribute to the non-rejection of a unit root in the real exchange series between cities?

Apart from this introduction, this paper is composed of five more sections. The following section presents the PPP Theory. The section third presents a review of literature on PPP using data for Brazil. The following section promotes a unified discussion over unit root, co-integration and structural break approaches. The section fifth section presents the stylized facts observed in this study and, lastly, in the sixth section, the concluding remarks are made.

2. PPP theory

The purchasing power parity (PPP) theory states that the difference among prices in two countries is not permanent if these prices are measured in the same exchange rate. This implies that prices converge towards a price of equilibrium.

The PPP theory is derived from the Law of One Price (LOP), that asserts the existence of a price of equilibrium between two countries if there are no trade barriers, legal barriers and transaction costs. In the presence of these trade barriers the LOP, and consequently the PPP, are not valid.

⁶ Organization for Economic Co-operation and Development (OECD). Member countries: Germany, Australia, Austria, Belgium, Canada, South Korea, Denmark, Spain, United States of America, Finland, France, Greece, Holland, Hungary, Ireland, Iceland, Italy, Japan, Luxembourg, Mexico, Norway, New Zealand, Poland, Portugal, United Kingdom, Czech Republic, Slovakia, Sweden, Switzerland, Turkey.

⁷ The following expression is used for the real exchange rate between cities, $\theta = \frac{E P^*}{P}$ (where P* is the level of external prices, P is the domestic price level and E is the nominal exchange rate, as it concerns economies with the same currency, since the nominal exchange rate, in this case, equals 1).

⁸ Sticky prices refer to problems associated to physical adjustment costs, as menu costs, and informational frictions.

There are two versions of the PPP theory, the absolute and the relative version. Let $P_{i,t}$ and $P_{i,t}^f$ be the price of the good i at time t in the local and in the foreign country, respectively. In the absolute version, the PPP theory suggests that nominal exchange rate between two countries is the ratio between the local and foreign prices; that is,

$$E_{i,t} = \frac{P_{i,t}}{P_{i,t}^f} \quad (1)$$

Usually the PPP is tested using price indexes that represent a basket of goods. The logarithm version of (1) is also frequently used to test the PPP:

$$e_t - p_t + p_t^f = 0 \quad (2)$$

where $e_t = \ln(E_{i,t})$, $p_t = \ln(P_{i,t})$ and $p_t^f = \ln(P_{i,t}^f)$.

According to this version, the PPP is valid if e_t is stationary or do not present permanent changes. Many factors can impair the validity of the absolute version of PPP such as governmental trade restrictions, nontradable goods, differences between consumption baskets etc.

In the analysis of intranational prices, as proposed in this paper, the PPP is not affected by these barriers, because there are not governmental trade restrictions within the same country and the existence of nontradable goods are minimized. Then, the investigation about the validity of PPP is rather easier to test in the intranational context.

On the other hand, the relative version of PPP states that the differences between inflations in both countries are the same as the rate of currency devaluation. To test this version the Eq. (2) can be used in a difference version.

$$\Delta e_t - \Delta p_t + \Delta p_t^f = 0 \quad (3)$$

3. Evidence for Brazil

Concerning national data for the Brazilian economy, the discussion on the validity of PPP is extensive, and various authors tested the validity of such an approach for various periods in absolute or relative form. In one of those papers, [Zini and Cati \(1993\)](#) applied unit root and cointegration tests to verify if the hypothesis that the PPP explains the real exchange rate in Brazil is valid, and if changes in the terms of trade of the economy can explain the changes in the real exchange rate for the 1855–1990 period. The tests rejected the absolute PPP hypothesis, indicating the need to search for other factors, such as changes in the terms of trade, to explain oscillations in the long run real exchange rate.

Using quarterly data between January 1980 and June 1994, and the Johansen cointegration test, [Marçal et al. \(2003\)](#) tested the PPP condition in its absolute form, and the uncovered interest rate parity (UIP). The results point out to the insufficiency of the PPP hypothesis in its absolute version. The results are more favorable when joining PPP and UIP.

In an attempt to make price comparisons between various regions simultaneously, without the need to establish anyone of them as the basis, [Azzoni et al. \(2003\)](#) presented two procedures for the construction of within region PPP indexes. Firstly, the authors built a multilateral index from a neoclassical aggregation function. The second method is developed from an econometric perspective, and has the property of estimating prices when information is not available. The results found suggest the existence of great disparity in relative prices between Brazilian cities, something which was expected due to the size of the Brazilian territory and to its cultural and income diversity.

According to [Kannebley \(2003\)](#) and [Palaia and Holand \(2010\)](#), very few authors take into account the relationship between structural breaks, such as change in the exchange rate regimen, monetary policy shocks and supply shocks, that could interfere in the path of the real exchange rate measure, which can hamper the applicability of econometric techniques for estimating the validity of PPP.

Thus, [Kannebley \(2003\)](#) discusses the relationship between test results for the validity of PPP in Brazil and the relevant economic factors in the 1968–1994 period, which was characterized by many economic policy changes, as well as changes in the macroeconomic cenaries of the country. This factors can generates structural breaks in exchange rate series. Therefore, unit root tests are performed for the existence of a structural break according to the [Perron and Vogelsang \(1992\)](#) and [Perron \(1989\)](#) formulation, and with two breaks, according to the formulation presented in [Lee and Strazicich \(2003\)](#). In all the performed tests for the relative PPP, the validity of that relationship was not rejected for the 1968–1998 period. As for the absolute PPP hypothesis, it was valid only for the real exchange rate based on

the Wholesale Price Index — Internal Availability (*Índices de Preços por Atacado – Disponibilidade Interna – IPAs*), R^{IPA} , for the 1968–1978 period.

In order to test the absolute and relative version of the PPP for Brazil, [Alves et al. \(2001\)](#), used data that goes from 1855 to 1990, and fractional cointegration technique, which allows a smooth reversion to the mean. The authors found empirical evidence that favors the relative version only.

Later on, [Gamboa and Fava \(2008\)](#), extended the previous paper using data until 2005 and introduced structural breaks into the analysis. The authors confirmed the validity of PPP in its relative version, even in the presence of structural breaks, and rejected the validity of PPP in its absolute version.

[Palaia and Holand \(2010\)](#) tested the PPP in its absolute form for Brazil through econometric procedures which contemplate the possibility of the existence of structural breaks in the time series considering the 1980–2006 period. The unit root tests with structural breaks did not favor the absolute PPP hypothesis, regardless of the price index used. A cointegration test with structural break was also performed using the [Gregory and Hansen \(1996\)](#) methodology. The test results were not sufficiently low to reject the null hypothesis of non-cointegration. The conclusion is that it is not possible to accept the validity of absolute purchasing power parity between 1980 and 2006.

Considering a period characterized by low inflation rates and commercial openness, [Feijó and Morales \(2008\)](#) analyzed the validity of PPP in Brazil, using monthly data for the 1994–2006. The authors adopted methodologies to test for unit root and cointegration, using price index and exchange rate series for Brazil and the United States of America. For the period as a whole, the PPP was not observed due to a structural break which occurred due to a change in the exchange rate regime in Brazil in January 1999. In period before the system change, there was cointegration; already for the period afterwards, no long run equilibrium relationship was found. According to the authors, these results can be, respectively, a reflection of the minidevaluations (band realignments) practised by the Brazilian authorities in the period which preceded the “break”, and of the short period analyzed.

[Simões and Marçal \(2012\)](#) analyzed the real exchange rate for Brazil using consumer’s price indexes and 21 trade partners from 1957 to 2010. The aim of their paper was to evaluate the validity of PPP by using standard unit root tests (ADF and PP) and some modern unit root tests, as [Bierens \(1997\)](#) and KPSS. The PPP was rejected by the standard tests, as ADF and PP. However, when the Bierens’ and KPSS tests were applied to price indexes without temporal aggregation the PPP was not rejected. Moreover, the authors evaluated Taylor’s hypothesis, according to which the half-life of reversal is overestimated in the presence of temporal aggregation. Using different time frequency data, they found that quarterly aggregation of monthly data was 18.92% above the monthly half-life and the annual aggregation of the same time series yielded a half-life 31.15% above the monthly half-life. Thus, in general terms, the average of 21 countries yielded a half-life 35%–56% greater than price indexes without temporal aggregation.

[Vasconcelos et al. \(2014\)](#) examined the PPP hypothesis using linear and non-linear unit root tests for the effective exchange rate of Argentina, Brazil, Chile, Colombia, Mexico, Peru and Venezuela. They firstly applied the linearity test of [Harvey et al. \(2008\)](#) and, secondly, after identifying the presence of linearity, they applied the [Ng and Perron \(2001\)](#) and [Lee and Strazicich \(2003, 2013\)](#) unit root tests. These tests consider the presence of structural breaks in the time series. In the non-linear time series, they used the [Kruse \(2011\)](#) test. The effective exchange rate was obtained from BIS (Bank of International Settlements) and data run from 1994 to 2014. The results indicated the presence of linearity in the series for Brazil, Argentina, Chile, Colombia and Peru, and non-linearity for Mexico and Venezuela. PPP was not reject for Chile, Peru and Mexico, however was rejected for the other countries.

At last, [Wanzeller and Gadelha \(2014\)](#) tested the PPP for Brazil using data from 1994 to 2013 and unit root tests that allow exogenous and endogenous forms of structural breaks. They found evidence to reject the PPP hypothesis.

Therefore, one can observe the great number of papers with national data for Brazil, and the almost complete lack of papers using within country data, although, as discussed in the previous section, the analysis of the validity of PPP using city data, or within country data, is wide spread in the international literature for American, Canadian and European cities ([Engel and Rogers, 1996](#); [Culver and Papell, 1999](#); [Cecchetti et al., 2002](#); [Chen and Devereux, 2003](#); [Faber and Stokman, 2009](#)).

4. Unit root, cointegration, structural breaks and PPP

Empirically, the PPP is a relationship among exchange rates, domestic (or local) and foreign prices, where the exchange rate differences stem from domestic and foreign inflation changes ([Enders, 2015](#)). Let p_t and p_t^f represents

the local and foreign prices at date t , respectively, and e_t denote the exchange rate at time t , all in logarithm terms, then a PPP implies that

$$e_t = p_t - p_t^f + u_t \quad (4)$$

where u_t is the deviation from PPP at date t . For example, if the domestic and foreign inflation are, respectively, 15% and 20%, the price, at domestic currency, should reduce in approximately 5%. This implies that the term u_t allows transitory deviations from PPP. Thus, the validity of PPP consists of examining the existence of an exchange rate of equilibrium. If there is no reversion of price towards an equilibrium, one can conclude that does not exist a relationship among nominal exchange rates.

In the standard approach, the PPP is tested using stationarity tests in the real exchange rates or through a cointegration test between the local and the foreign prices levels. As this paper analyzes the intranational price data from Brazil, then $e_t = 0$. This paper will choose the approach of stationarity of the relative prices, or real exchange rate between cities.

In this paper we test the stationarity of Brazilian city prices using the Augmented Dickey-Fuller (ADF) (1979) and Kwiatkowski, Phillips, Schmidt, and Shin (KPSS) (1992).

Following Davidson and MacKinnon (1993), let us consider an autoregressive process of order 1:

$$y_t = \rho y_{t-1} + z_t' \delta + \epsilon_t \quad (5)$$

where y_t is the time series and z_t are the regressors that can contain or not an intercept, or the intercept and trend, ρ and δ are parameters and ϵ_t is a white noise process. If $|\rho| > 1$, y_t is a nonstationary series and its variance increases with time and approaches infinity. If $|\rho| < 1$, it is a stationary series. Thus, the hypothesis of stationarity can be evaluated by testing whether the absolute value of ρ is strictly less than one. The standard Dickey-Fuller (DF) test is carried out by estimating Eq. (5) after subtracting y_{t-1} from both sides of the equation; that is,

$$\Delta y_t = \alpha y_{t-1} + z_t' \delta + \epsilon_t \quad (6)$$

where $\alpha = \rho - 1$. The null and alternative hypotheses may be written as:

$$H_0 : \alpha = 0 \text{ and } H_1 : \alpha < 0 \quad (7)$$

The simple Dickey-Fuller unit root test described above is valid only if the series is an AR(1) process. If the series is correlated at higher order lags, the assumption of white noise disturbances ϵ_t is violated. The Augmented Dickey-Fuller (ADF) test constructs a parametric correction for higher-order correlation by assuming that the y series follows an AR(P) process and adding p lagged difference terms of the dependent variable y to the right-hand side of the test regression:

$$\Delta y_t = \alpha y_{t-1} + z_t' \delta + \theta_1 \Delta y_{t-1} + \theta_2 \Delta y_{t-2} + \dots + \theta_p \Delta y_{t-p} + \epsilon_t \quad (8)$$

This augmented specification is then used to test (7) using the t-ratio.

The KPSS (1992) test differs from the other unit root tests in that the series is assumed to be stationary under the null. The KPSS statistic is based on the residuals from the OLS regression of y_t on the exogenous variables z_t .

Note that in the presence of structural breaks the conclusions about those tests should be taken carefully, because the majority of the stationarity tests loses power in the presence of instabilities. Thus, the structural breaks may affect the validity of PPP, as found in Hegwood and Nath (2013), Basher and Carrion-i-Silvestre (2011). Bierens (1997) states that if a time series is stationary around a nonlinear trend, the null hypothesis of stationarity cannot be rejected by the same reason; that is, the stationary tests lose power. Finally, Simões and Marçal (2012) point out that in the presence of time aggregation in low frequency data (as annual, for instance) the distorting effects of the nonlinearities on the stationarity tests are reduced.

It is not the aim of this paper, however, to investigate at a deeper level the stationarity of relative prices in Brazil. The sole purpose of this paper is otherwise to understand the stylized facts about convergence and mean reversion to PPP. A broader and more profound approach of this problem is left to future research.

5. Stylized facts

To extract the stylized facts investigated in this paper, monthly data will be used, between January 1995 and August 2012, through the Broad Consumer Price Index — *IPCA*⁹ (*Índice de Preços ao Consumidor Amplo*) for the major 11 Brazilian cities¹⁰ and the Brazilian *IPCA* obtained through the National System of Consumer Prices — *SNIPC* (*Sistema Nacional de Índice de Preços ao Consumidor*), of the Brazilian Institute of Geography and Statistics IBGE (*Instituto Brasileiro de Geografia e Estatística*).

In order to identify possible differences in the speed of reversal between tradable and non-tradable goods and verify that the evidence gathered for the general indexes exhibit regularity in a disaggregated context, the disaggregated price indexes for the food and drink, housing and clothing categories will be used. Therefore, food and drink and clothing will be used to incorporate such evidence on tradable goods, while housing is used for the non-tradable goods. It is expected that tradable goods present a lower price dispersion and, consequently, a higher convergence rate (or shorter half-life) in relative prices, since these are markets which are considered to be more integrated.

Tradable goods, which have a higher convergence rate, tend to present a lower volatility and goods with more rigid prices display a slower reversion to the average and a more persistent volatility (Nakamura and Steinsson, 2012). Crucini and Yilmazkuday (2014) point out that the price dispersion of specific goods should be considered in the evaluation of the PPP hypothesis; once sectoral traits, as market oscillation and sectoral mark up, can interfere with price volatility.

The methodology used in this paper will be performed in three stages: (i) analyze if there is evidence for a price convergence process; (ii) estimate the speed of adjustment in deviations from the PPP, or its half-life, and (iii) verify if, in fact, processes (i) and (ii) influence the unit root tests, as warned in the literature (Cecchetti et al., 2002; Chen and Devereux, 2003).

5.1. Price convergence

Initially, an analysis of price indexes dispersion was done, in its absolute and relative forms, to comprehend the dynamic behavior of prices in the Brazilian cities, as well as the exam of the existence of convergence or divergence between them.

The dispersion measurement for absolute prices was defined as the coefficient of price index variation for the cities, which is represented by:

$$cv(p_t) = cv(p_{jt}/t) = \left(\frac{\sqrt{\frac{1}{n} \sum_{j=1}^n (p_{jt} - \bar{p})^2}}{\bar{p}} \right) \times 100 \quad (9)$$

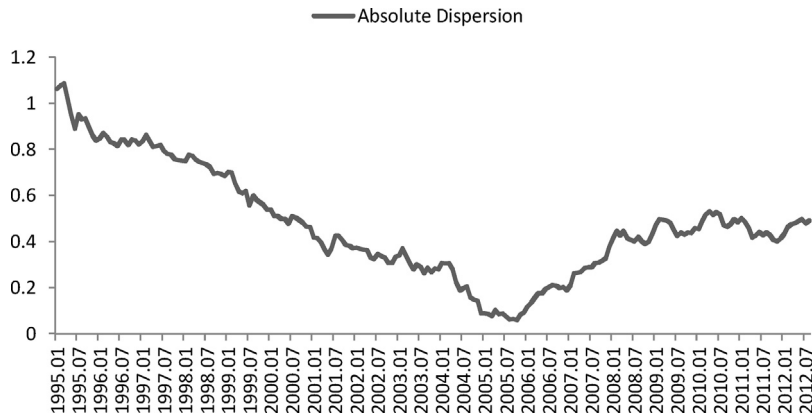
where $cv(p_t) = cv(p_{jt}/t)$ is the variation in absolute prices coefficient in period t ; p_{jt} is the price level of city j in time t and \bar{p} is the average price level, all in logarithms. The Graph 1 presents the evolution of this indicator.

As one analyzes the figure above, it can be observed that there is a strong reduction in price absolute dispersion among Brazilian cities. The greater part of such a decrease occurs between January 1995 and January 2006, where a 91.5% reduction can be noticed. In general terms, it can be said that the *IPCA* absolute dispersion presented a 53.78% decrease in the analyzed period.

Graph 2 presents the same analysis for the food and drink, clothing and housing categories. The sectoral analysis also points to a decrease in the absolute price dispersion for Brazilian cities. The major part of the decrease occurred between January 1995 and August 2005, in the housing and clothing sectors, with reductions of 89.68% and 96.22%, respectively, while for the food and drink sector, the reduction was, until December 2005, of 90.37%. At the end of the period, the reductions were respectively 41.34%, 60.30% and 62.27% for the food and drink, housing and clothing sectors. Therefore, as expected, what is considered tradable goods showed less dispersion in their prices in the period

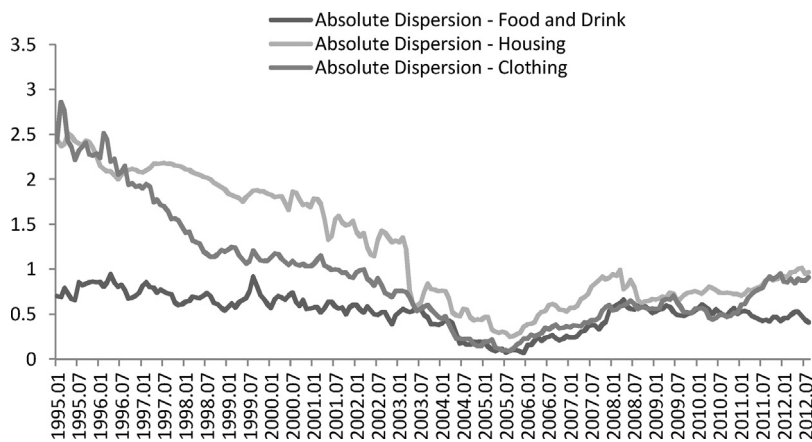
⁹ In all the indexes analyzed, an average for the year 2005 is used as the base value.

¹⁰ SNIPC — IBGE provides information for Rio de Janeiro, São Paulo, Belo Horizonte, Porto Alegre, Recife, Brasília, Belém, Fortaleza Salvador, Curitiba and Goiânia.



Graph 1. Evolution of price absolute dispersion among Brazilian cities.

Source: Elaborated by the authors.



Graph 2. Evolution of price absolute dispersion among Brazilian cities by sector.

Source: Elaborated by the authors.

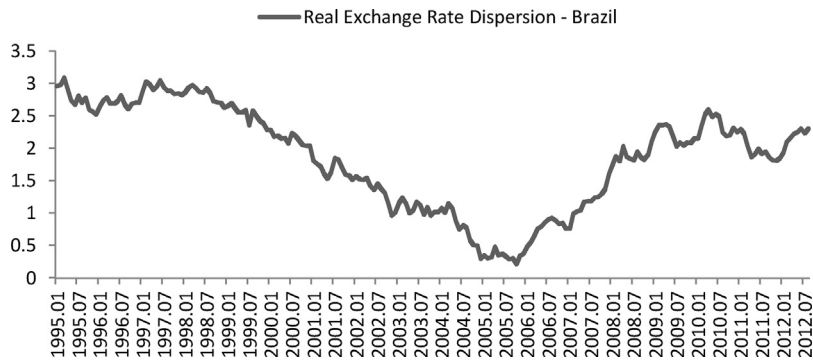
analyzed, *i.e.* after September 1996, the prices of food and drink and clothing were less dispersed than those related to housing.

This result, therefore, is an initial indication of the existence of a convergence process among price levels in Brazilian cities, even considering geographically dispersed cities and places which present significant regional differences. Such a fact can be justified by the absence of commercial barriers, exchange rate volatility and asymmetries in monetary policy.

Afterwards, the evolution of the dynamic behavior of relative prices and its dispersion over time was analyzed. The relative price, or real exchange rate, of city j in time t , was defined as,

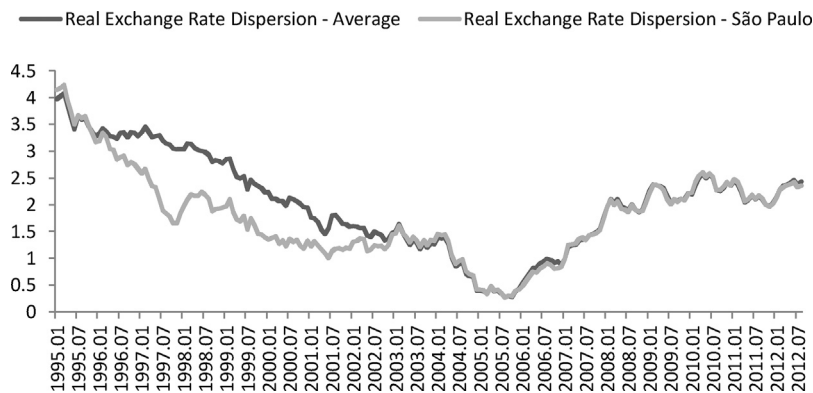
$$r_{jt} = (p_{jt} - \bar{p}) \times 100 \quad (10)$$

where p_{jt} is the price level in city j in time t , and \bar{p} is the numeraire, both in logarithm terms. It is worth noting that, as this measure refers to the same country, as shown by [Chen and Devereux \(2003\)](#), this indicator can be interpreted as the real exchange rate in relation to the numeraire. In order to identify whether the results are sensitive to the choice of numeraire with regard to dispersion and speed reversal of deviations from the PPP, this study will use as numeraire the Brazilian IPCA (real rates — Brazil), the average IPCA for the cities considered (real exchange rate — Average) and the IPCA for the city of São Paulo (real rates — São Paulo), all in logarithmic terms. It is worth noting that in the disaggregated analysis, it was used the average as a reference. The city of São Paulo is used as numeraire, because it is the most important market at state level in Brazil and because price movements in this market spill over economic activity of the rest of the country ([Arruda and Tatiwa, 2014](#)).



Graph 3. Evolution of the dispersion of relative prices of cities in relationship to Brazil as a whole.

Source: Elaborated by the authors.



Graph 4. Evolution of the dispersion of relative prices in cities in relationship to the average and city of São Paulo.

Source: Elaborated by the authors.

As in [Faber and Stokman \(2009\)](#), the measure of dispersion used for relative prices was the standard deviation, $\sigma(r_t)$, expressed as¹¹:

$$\sigma(r_t) = \sigma(r_{jt}/t) = \sqrt{\frac{1}{n} \sum_{j=1}^n (r_{jt} - \bar{r}_t)^2} \quad (11)$$

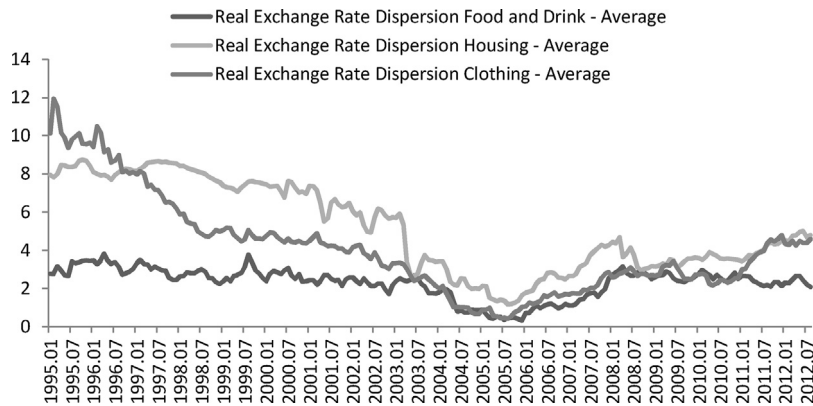
where r_{jt} is the relative price of city j in time t in relation to the considered numeraire, \bar{r}_t . The [Graph 3](#) shows the evolution of the dispersion of the real exchange rate — Brazil; *i.e.*, the one which considers the Brazilian IPCA as a reference.

One can observe that the dispersion of the real exchange rate — Brazil presents a descendent path trajectory until October 2005, with a 0.21 value; *i.e.*, a 93% decrease in price volatility in relationship to the Brazilian IPCA. At the end of the period, the decrease was of 22.3%. Next, the same analysis is performed for the average real exchange rate and the exchange rate — São Paulo. The evolution of these indicators is presented in [Graph 4](#).

The [Graph 4](#) shows that the two measurements present a descendent path, with a decreasing rate of dispersion, observed by the inclination of the graph, more accentuated for the real exchange rate — São Paulo until the beginning of 2003; and, afterwards, the volatility measurement values proceed in similar fashion. The decrease in dispersion at the end of the period was of 38.8% and 43.1% for the average and São Paulo, respectively.

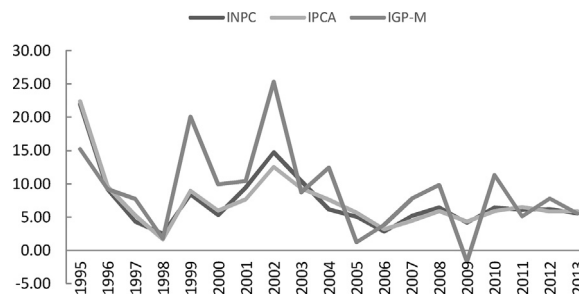
Furthermore, the same analysis was performed for the real exchange rate — average for the food and drink, housing and clothing categories. These graphs use disaggregated price indexes. The reason for that is that some authors have

¹¹ We chose to use the standard deviation as a measure of relative price dispersion for the fact that these are already calculated in relation to a numeraire, *i.e.*, deviations from a reference, and, also, as states have a common currency, they do not influence the magnitude of the measure of dispersion used ([Faber and Stokman, 2009](#)).



Graph 5. Evolution of dispersion in relative prices for cities in relationship to the average by sector.

Source: Elaborated by the authors.



Graph 6. Evolution of Brazilian inflation by INPC, IPCA and IGP-M.

Source: Elaborated by the authors.

found evidence of aggregation bias for aggregated data. [Crucini and Yilmazkuday \(2014\)](#), for example, point out that price dispersion is significantly reduced at good-specific level. They argue that trade costs and good-specific markups are averaged out in aggregated price indexes. On the other hand, [Nakamura and Steinsson \(2012\)](#) present evidence of product replacement bias. This bias refers to the frequency of product replacement without a price change. The authors found out that product replacement bias causes price indexes to appear smoother than they actually are. One way to cope with this bias is to consider disaggregated price indexes. The [Graph 5](#) presents the evolution of those indicators.

The three indicators also present a decrease in the dispersion of relative prices. At the end of the period, the reduction was of 24.97%, 39.64% and 54.58%, respectively, for the food and drink, housing and clothing categories. Once again, the evidence points to a lower dispersion in relative prices for those goods considered to be tradable.

The analysis of dispersion of relative prices also points out to convergence among relative prices. As such, following [Culver and Papell \(1999\)](#), [Cecchetti et al. \(2002\)](#) and [Chen and Devereux \(2003\)](#), these stylized facts can contribute to the non-rejection of a unit root in the relative prices series considered. However, this is not an indicative against the validity of the PPP using data for the Brazilian cities.

It is worth noting, as can be observed in all the graphs, that the reduction in the dispersion of relative prices, or price convergence, occurs with greater intensity between 2005 and 2006, showing some recovery afterwards. This fact can be explained by the reduction in inflation in Brazil in 2005, *i.e.*, the dispersion of relative prices is reduced more strongly with the decrease in the general level of inflation. [Graph 6](#) illustrates the evolution of Brazilian inflation measured by the Broad Consumer Price Index — IPCA; National Consumer Price Index — INPC and General Market Price Index —IGP-M.

The [Graph 6](#) also shows the increase of the Brazilian inflation in 2006, which may explain to an increase in the dispersion of relative prices in that period, as shown in all previous [Graphs 1–5](#). This inflationary process had a downturn from 2009 onwards, thus attenuating the increase in the dispersion of relative prices among Brazilian cities.

Furthermore, one of the causes usually attributed to deviations from the PPPs, in the short run, is the presence of price rigidity ([Rogoff, 1996](#)); *i.e.*, the fluctuations in the volatility of relative prices and the rate of reversal of deviations

Table 1
ADF unit root tests and half-life-real exchange.

Real exchange rate – reference – Brazil					Real exchange rate – reference – average				Real exchange rate – reference – São Paulo			
City	ADF-t	P-value	ρ	Half-life	ADF-t	P-value	ρ	Half-life	ADF-t	P-value	ρ	Half-life
Belo Horizonte	−1.52	0.81	0.99	69	−1.54	0.53	0.98	34	−2.78	0.20	0.99	69
Belém	−4.10	0.00 ^a	0.95	13	−3.61	0.04 ^a	0.95	13	−3.96	0.01 ^a	0.96	17
Brasília	−2.76	0.21	0.94	11	−1.71	0.08 ^a	0.97	23	−2.89	0.16	0.97	23
Curitiba	−2.04	0.57	0.96	17	−1.29	0.63	0.96	17	−2.52	0.31	0.99	69
Fortaleza	−4.55	0.00 ^a	0.93	10	−3.35	0.01 ^a	0.95	13	−4.84	0.00 ^a	0.95	13
Goiânia	−1.69	0.75	0.98	34	−1.75	0.41	0.96	17	−2.50	0.32	0.99	69
Porto Alegre	−1.90	0.64	0.98	34	−2.91	0.04 ^a	0.96	17	−1.88	0.66	0.99	69
Recife	−2.72	0.22	0.94	11	−2.73	0.07 ^a	0.93	10	−3.47	0.04 ^a	0.94	11
Rio de Janeiro	−2.14	0.03 ^a	0.97	23	−2.74	0.07 ^a	0.97	23	−1.81	0.22	0.99	69
Salvador	−3.72	0.02 ^a	0.94	11	−3.50	0.00 ^a	0.93	10	−3.48	0.04 ^a	0.96	17
São Paulo	−2.85	0.17	0.99	69	−3.16	0.09 ^a	0.98	34	–	–	–	–
Mean half-life				27	Mean half-life			19	Mean half-life			42

Source: Elaborated by the authors.

^a Statistically significant at the usual.

from the PPP would be negatively impacted by price rigidity, making the adjustment process slow. Also, [Crucini et al. \(2010\)](#) argue that, in the intranational context, the influence of price rigidity in the slow adjustment process is even greater. Therefore, the reduction of inflation in Brazil in the period considered, associated with the reduction in relative prices, is indicative of the lack of price rigidity.

5.2. Reversal speed and PPP

Next, a stationarity analysis was performed for the relative prices series, or the real exchange rate, considering as references Brazil as a whole, the average price level in the considered cities and the state of São Paulo. Additionally, the relative prices were analyzed, having the average as numeraire, of the food and drink, housing and clothing sectors. The main objective of this analysis was to gather information on the reversal speed of deviations of the PPP and verify, via a unit root test, the validity of PPP using data for Brazilian cities.

For this purpose, the augmented [Dickey-Fuller \(ADF\) test \(1979\)](#) is used¹² and the criterion for the selection of the number of lags is the one featured in [Campbell and Perron \(1991\)](#), beginning with 8 lags. The [Kwiatkowski et al. \(1992\)](#), hereinafter KPSS,¹³ will also be used. The results are featured in [Tables 1–4](#).

It is worth noting that the objective here is not only to verify the presence of a unit root in the investigated series, but to identify the pattern of behavior for the real exchange rate in Brazilian cities and estimate the half-life for the reversal of distortions from the PPP. As in [Cecchetti et al. \(2002\)](#) and [Chen and Devereux \(2003\)](#), the half-life ($mv(\rho)$) will be calculated as:

$$mv(\rho) = -\ln(2) / \ln(\rho) \quad (12)$$

where ρ is the estimated coefficient of a AR (1) process. The half-life, in this context, measures the time in which a variable reverts to the mean after a deviation. If a variable presents a large half-life, for example, this means that the variable suffers of persistent deviation. In other words, price deviations take more time to revert to the mean.

The theory of price convergence argues that, in the absence of trade barriers or composition bias, the half-life of tradable goods should be low. These results are expected in this paper because the use of intranational price data reduces the source of persistent price deviations. The results are shown in [Tables 1–3](#). Moreover, [Simões and Marçal \(2012\)](#)

¹² According to the behavior of the series, tests were done using the intercept and intercept and trend.

¹³ One of the problems of the ADF test is its low power, especially in the presence of a moving averages component near the unit circle; in other words, this test cannot reject the presence of a unit root for many economic series. Thus, [Kwiatkowski et al. \(1992\)](#) recommend using the KPSS as a complementary way to distinguish the ADF unit root series whose data are not conclusive enough.

¹⁵ The critical values 0.74, 0.46 and 0.35 and 0.21, 0.14 and 0.12 are associated with the tests with intercept and intercept and trend, respectively.

Table 2
Unit root tests – KPSS – real exchange rate.

City	Real exchange rate – reference – Brazil				Real exchange rate – reference – average				Real exchange rate – reference – São Paulo			
	Test statistic	Critical value ¹⁵			Test statistic	Critical value			Test statistic	Critical value		
		1%	5%	10%		1%	5%	10%		1%	5%	10%
Belo Horizonte	0.30	0.21	0.14	0.12	0.23	0.21	0.14	0.12	0.26	0.21	0.14	0.12
Belém	0.26	0.21	0.14	0.12	0.68 ^a	0.74	0.46	0.35	0.20 ^a	0.21	0.14	0.12
Brasília	0.20 ^a	0.21	0.14	0.12	0.28	0.21	0.14	0.12	0.19 ^a	0.21	0.14	0.12
Curitiba	0.25 ^a	0.74	0.46	0.35	0.90	0.74	0.46	0.35	0.21 ^a	0.21	0.14	0.12
Fortaleza	0.56 ^a	0.74	0.46	0.35	1.50	0.74	0.46	0.35	0.17 ^a	0.21	0.14	0.12
Goiânia	0.24	0.21	0.14	0.12	0.73 ^a	0.74	0.46	0.35	0.23	0.21	0.14	0.12
Porto Alegre	0.30	0.21	0.14	0.12	0.49 ^a	0.74	0.46	0.35	0.24	0.21	0.14	0.12
Recife	0.27	0.21	0.14	0.12	0.31 ^a	0.74	0.46	0.35	0.19 ^a	0.21	0.14	0.12
Rio de Janeiro	0.42	0.21	0.14	0.12	0.38	0.21	0.14	0.12	0.33	0.21	0.14	0.12
Salvador	0.53 ^a	0.74	0.46	0.35	0.21 ^a	0.74	0.46	0.35	0.16 ^a	0.21	0.14	0.12
São Paulo	0.18 ^a	0.21	0.14	0.12	0.17 ^a	0.21	0.14	0.12	–	–	–	–

Source: Elaborated by the authors.

^a Statistically significant at the usual.

argue that the use of price indexes with time aggregation overestimates the half-life. To avoid this kind of bias this paper adopts price data without time aggregation.

The results of the ADF test for the real exchange rate, having Brazil as a whole and São Paulo as references, rejected the stationarity at the usual significance levels in seven of the eleven cities considered; while, considering the average price level as the numeraire, the non-rejection of the presence of a unit root can be observed in only three cities. In similar conditions [Cecchetti et al. \(2002\)](#) and [Chen and Devereux \(2003\)](#) rejected stationarity in eleven of the nineteen American cities.

In virtue of the low power of the ADF test, the KPSS test was also used to verify the stationarity of the series. The results rejected stationarity, at the usual levels of significance, in six, five and four, of the eleven Brazilian cities considered, when using, respectively, Brazil as a whole, the average price level, and the state of São Paulo as a reference.

The results for the ADF and KPSS tests for the real exchange rate — average for the food and drink, housing and clothing sectors are featured, respectively, in [Tables 3 and 4](#). The ADF test for the food and drink category did not reject the presence of a unit root in six of the eleven cities analyzed, while for the KPSS test, only the relative prices of Belém, Brasília and São Paulo were not found to be stationary. In the same conditions, for the housing and clothing categories, the ADF test did not reject the unit root in nine and six cities, respectively; as for the KPSS test, a unit root was observed for, respectively, four and six cities.

Considering aspects related to the half-life, or reversal speed, of deviations from the PPP, it can be observed, as shown by [Culver and Papell \(1999\)](#), [Cecchetti et al. \(2002\)](#) and [Chen and Devereux \(2003\)](#), that the presence of a unit root in the real exchange rate series for the cities analyzed is strongly influenced by the convergence previously discussed, and by the slow adjustment of deviations from the PPP. In fact, the results presented in the tables below show that the stationarity of the real exchange rate is rejected, it a 5% significance level, for all the series that presented a reversal speed to deviations from the PPP smaller than the average each numeraries considered, or a greater half-life. Other possible explanation for this is the potential presence of shocks in the variance at high frequency data. The residuals, when monthly data is used, could present more variability than annual data and the power of rejection of stationarity tests can shrink, as pointed by [Simões and Marçal \(2012\)](#) and [Cavaliere \(2005\)](#).

The average half-life estimated for the general index, considering as a reference Brazil as a whole, the average and the state of São Paulo, was approximately of 27 months, 19 months and 42 months, respectively. Therefore, on the average, a strong economic integration among Brazilian cities can be observed, as the standard for international data is a half-life of three to five years. Moreover, even with the higher speed convergence found when comparing to countries, one can perceive a certain sensitivity of the results in relation to the choice of numeraire, although most papers make use of the average as the numeraire. Also, Brazilian cities were more integrated than those in the U.S. [Chen](#)

Table 3
ADF unit root tests and half-life – real exchange rate – average.

Food and drink					Housing				Clothing			
City	ADF-t	P-value	P	Half-life	ADF-t	P-value	ρ	Half-life	ADF-t	P-value	ρ	Half-life
Belo Horizonte	−2.29	0.17	0.95	13	−1.75	0.40	0.98	34	−2.04	0.26	0.96	17
Belém	−1.43	0.56	0.98	34	−2.87	0.05 ^a	0.93	09	−2.68	0.07 ^a	0.98	34
Brasília	−3.14	0.09 ^a	0.96	17	−0.57	0.87	0.99	69	−2.71	0.07 ^a	0.93	09
Curitiba	−2.19	0.21	0.95	13	−1.50	0.53	0.98	34	−2.82	0.05 ^a	0.95	13
Fortaleza	−6.59	0.00 ^a	0.95	13	−1.33	0.61	0.98	34	−0.85	0.80	0.99	69
Goiânia	−3.76	0.02 ^a	0.96	17	−2.01	0.28	0.97	23	−1.47	0.54	0.99	69
Porto Alegre	−3.95	0.00 ^a	0.92	08	−1.37	0.59	0.98	34	−2.53	0.11	0.97	23
Recife	−4.80	0.00 ^a	0.96	17	−2.11	0.24	0.96	17	−2.04	0.26	0.96	17
Rio de Janeiro	−2.32	0.16	0.95	13	−1.92	0.32	0.98	34	−1.17	0.68	0.98	34
Salvador	−1.46	0.55	0.98	34	−2.74	0.06 ^a	0.94	11	−3.30	0.01 ^a	0.91	07
São Paulo	−2.22	0.19	0.96	17	−0.02	0.95	0.99	69	−3.35	0.01 ^a	0.90	06
Mean half-life				18	Mean half-life			33	Mean half-life			27

Source: Elaborated by the authors.

^a Statistically significant at the usual.

and Devereux (2003), considering the aggregate U.S. prices as numeraire, found a mean half-life of approximately five years for American cities, which, under the same conditions for Brazil, it was two years and three months.

When considering the real exchange rate using the average for the food and drink, housing and clothing sectors, the estimated half-life was of 18 months, 33 months and 27 months, respectively. In other words, because they are considered to be¹⁴ more integrated markets, the rate of reversal of deviations from the PPP is shown to be greater (lower half-life), on average, for those goods considered to be tradable. What confirms the fact that markets which display less rigid prices tend to present a higher convergence rate, or a lower half-life (Nakamura and Steinsson, 2013; Gorodnichenko and Weber, 2016).

Although the literature that investigates the validity of the PPP for countries considers the stationarity of the real exchange rate as important evidence, it can be observed that the referred literature ignores cases in which the non-stationarity of the real exchange rate is related to a convergence process in prices provoked by a strong integration of markets (Cecchetti et al., 2002; Chen and Devereux, 2003). Also, the evidence shows that, in general, the presence of a unit root is not rejected in the real exchange rate series with a slow reversal speed for deviations from the PPP, *i.e.*, a greater half-life.

6. Concluding remarks

This paper tried to sort out the stylized facts about price convergence and reversal speed to PPP using data for the main Brazilian cities. Therefore, its potential contribution resides in the fact of using city data in contrast with the majority of studies in the area, which uses cross-country data. Besides that, it peruses if prices convergence, associated to a slow reversal speed, interfere in the results of unit root tests and that, consequently, the presence of unit roots would not be a strong evidence against the PPP hypothesis.

In order to do that, monthly data between January 1995 and August 2012, taken from the Broad Consumer Price Index — IPCA for the 11 major Brazilian cities and the IPCA for Brazil as a whole was used. Also, relative price indexes were built considering Brazil as a whole, the average price level for the Brazilian cities and the state of São Paulo as references. To analyze the dynamics for goods considered to be tradable and non-tradable, indexes for food and beverages, clothing and housing categories were used.

The results suggest that there is a strong reduction in absolute dispersion of prices in Brazilian cities, as well as a decrease in the variability of relative prices in all cases considered. And, as expected, this volatility was lower for tradable goods in all cases. These findings confirm the evidences found by Nakamura and Steinsson (2012) and

¹⁴ Crucini and Yilmazkuday (2014), for instance, find that price dispersion is significantly reduced at good-specific level. They argue that trade costs and good-specific markups are averaged out in aggregated price indexes.

Table 4
Unit root tests – KPSS – real exchange rate – average.

Food and drink					Housing				Clothing			
City	Test statistic	Critical value ¹⁵			Test statistic	Critical value			Test statistic	Critical value		
		1%	5%	10%		1%	5%	10%		1%	5%	10%
Belo Horizonte	0.12 ^a	0.21	0.14	0.12	0.16 ^a	0.21	0.14	0.12	0.85	0.74	0.46	0.35
Belém	0.31	0.21	0.14	0.12	0.34 ^a	0.74	0.46	0.35	1.50	0.74	0.46	0.35
Brasília	0.22	0.21	0.14	0.12	0.80	0.74	0.46	0.35	0.58 ^a	0.74	0.46	0.35
Curitiba	0.12 ^a	0.21	0.14	0.12	0.20 ^a	0.21	0.14	0.12	0.39 ^a	0.74	0.46	0.35
Fortaleza	0.09 ^a	0.21	0.14	0.12	0.20 ^a	0.21	0.14	0.12	0.49 ^a	0.74	0.46	0.35
Goiânia	0.16 ^a	0.21	0.14	0.12	0.79	0.74	0.46	0.35	1.64	0.74	0.46	0.35
Porto Alegre	0.35 ^a	0.74	0.46	0.35	0.27	0.21	0.14	0.12	1.30	0.74	0.46	0.35
Recife	0.20 ^a	0.21	0.14	0.12	0.11 ^a	0.21	0.14	0.12	1.27	0.74	0.46	0.35
Rio de Janeiro	0.65 ^a	0.74	0.46	0.35	0.85	0.74	0.46	0.35	1.43	0.74	0.46	0.35
Salvador	0.19 ^a	0.21	0.14	0.12	0.55 ^a	0.74	0.46	0.35	0.17 ^a	0.21	0.14	0.12
São Paulo	0.90	0.74	0.46	0.35	0.19 ^a	0.21	0.14	0.12	0.11 ^a	0.21	0.14	0.12

Source: Elaborated by the authors.

^a Statistically significant at the usual.

[Crucini and Yilmazkuday \(2014\)](#). Additionally, one can surmise that this decrease in price dispersion in Brazilian cities followed the process of reduced inflation in Brazil in the period analyzed. Such a result indicates a convergence process among the price levels of Brazilian cities, even considering places which are geographically dispersed and regionally different ([Cecchetti et al., 2002](#); [Chen and Devereux, 2003](#)). Such behavior can be explained by the absence of factors such as barriers to commerce, exchange rate volatility and asymmetries in monetary policy. It is also worth noting that such evidence was anticipated theoretically by authors such as [Rogoff \(1996\)](#) and [Crucini et al. \(2010\)](#).

In general terms, the average half-life estimated for Brazilian cities was found to be lower than those estimated using data for countries and American cities, being of approximately 27 months, 19 months and 42 months, having as reference, respectively, Brazil as a whole, the average and the state of São Paulo. Therefore, some sensitivity to the choice of the half-life of the numeraire can be observed. Under the same conditions, considering the real exchange rate – average food and drink, housing and clothing categories – it was found an average half-life of 18 months, 33 months and 27 months, respectively, confirming the fact that markets considered to be more integrated and with less rigid prices have a higher rate of price convergence or a lower half-life ([Nakamura and Steinsson, 2013](#); [Gorodnichenko and Weber, 2016](#)). In short, there is indication of a faster reversal of deviations from the PPP for Brazilian cities than those presented using data for countries and American cities ([Cecchetti et al., 2002](#); [Chen and Devereux, 2003](#)).

Thus, it can also be said that there is evidence of a greater integration of markets in Brazilian cities than the integration found in papers considering American cities. Furthermore, our results indicate that all series of real exchange rates that had a half-life greater than the average, for each numerarie, are no stationary at the 5% significance level. Therefore, the evidence for price convergence associated with an even slower reversal process from deviations of the PPP has influence on the non-rejection of the presence of a unit root in the real exchange rate series. However, this fact does not contradict necessarily the validity of the PPP, as shown by [Culver and Papell \(1999\)](#), [Cecchetti et al. \(2002\)](#) and [Chen and Devereux \(2003\)](#); or still, by [Simões and Marçal \(2012\)](#) and [Cavaliere \(2005\)](#), which point out that high frequency data tend to favor the presence of unit roots.

Finally, it worth noting that as a first attempt to understand the mechanics of PPP using Brazilian cities data, this paper can still be extended in two directions. One of them is to use more sophisticated unit root tests, which can embody structural breaks. The other one, is to recourse to techniques which can take into account the role of structural breaks in the measurement of half-life.

Appendix A.

See [Table A1](#).

Table A1
Descriptive statistics of the price indices.

City	Index	Mean	Median	Std. Dev.	Max	Min
Belo Horizonte	General	89.59	87.87	30.52	147.11	40.68
	Food and drink	93.83	93.44	32.18	161.28	52.54
	Housing	84.36	83.33	34.34	147.33	22.74
	Clothing	95.12	87.01	27.74	154.36	65.84
Belém	General	90.51	90.16	31.07	149.26	44.46
	Food and drink	94.65	93.03	35.08	169.23	54.91
	Housing	85.26	94.35	30.11	135.20	30.11
	Clothing	97.11	91.68	25.72	151.80	67.19
Brasília	General	88.52	89.47	29.99	143.56	40.88
	Food and drink	91.87	94.79	31.85	158.50	52.18
	Housing	87.38	86.36	34.39	154.84	27.79
	Clothing	93.12	87.10	28.15	153.66	61.27
Curitiba	General	88.21	88.84	28.20	140.92	41.74
	Food and drink	92.81	94.75	30.34	162.02	53.29
	Housing	86.52	87.69	29.40	144.47	28.37
	Clothing	91.58	87.23	26.85	144.88	58.43
Fortaleza	General	88.85	89.47	28.17	141.96	44.74
	Food and drink	92.88	95.26	30.24	159.00	53.64
	Housing	85.25	87.38	33.32	139.08	25.67
	Clothing	96.85	90.51	30.01	172.40	67.26
Goiânia	General	87.19	88.36	28.91	138.25	41.17
	Food and drink	91.83	94.49	32.40	159.66	51.23
	Housing	83.04	85.63	29.09	135.34	27.22
	Clothing	90.98	84.14	32.96	152.63	51.41
Porto Alegre	General	87.19	87.88	28.63	139.09	40.24
	Food and drink	92.91	93.49	31.37	159.86	50.05
	Housing	83.83	88.83	30.03	135.83	25.79
	Clothing	91.38	85.89	28.96	151.13	55.71
Recife	General	89.59	89.83	29.60	144.71	42.18
	Food and drink	93.49	96.17	29.97	157.56	52.49
	Housing	86.27	86.85	33.17	144.00	24.33
	Clothing	94.95	88.22	27.33	152.11	65.05
Rio de Janeiro	General	88.33	89.74	29.69	143.88	39.50
	Food and drink	91.66	95.09	30.07	157.33	52.24
	Housing	84.99	90.03	32.42	144.34	23.01
	Clothing	94.51	86.75	30.44	160.12	62.48
Salvador	General	89.52	91.68	29.29	143.75	43.06
	Food and drink	93.34	98.61	29.68	157.58	52.95
	Housing	86.67	88.34	32.44	148.34	27.54
	Clothing	93.56	87.15	27.50	149.79	63.87
São Paulo	General	89.32	89.72	26.80	138.76	42.59
	Food and drink	93.58	93.46	31.05	162.04	54.94
	Housing	88.61	92.45	25.26	134.17	28.45
	Clothing	93.30	86.19	27.46	152.22	61.96
Brazil	General	88.89	89.37	28.50	141.76	41.72

Source: Elaborated by the authors.

References

- Abuaf, N., Jorion, P., 1990. Purchasing power parity in the long run. *J. Finance* 45, 157–174.
- Alves, D.C.O., Cati, R.C., Fava, V.L., 2001. Purchasing power parity in Brazil: a test for fractional cointegration. *Appl. Econ.* 33 (9).
- Arruda, E., Tatiwa, R., 2014. Dinâmica intrarregional do Brasil: quem dirige o crescimento industrial das regiões brasileiras? *Econ. Apl.* 18 (2).
- Azzoni, C.R., do Carmo, H.E., Menezes, T., 2003. Comparações da Paridade do Poder de Compra entre Cidades: Aspectos Metodológicos e Aplicação ao Caso Brasileiro. *Pesquisa e Planejamento Econômico* 33 (Abril (1)).
- Basher, S.A., Carrion-i-Silvestre, J.L., 2011. Measuring persistence of U.S. city prices: new evidence from robust tests. *Empir. Econ.* 41, 739–745.
- Bierens, H., 1997. Testing the unit root with drift hypothesis against nonlinear trend stationarity, with an application to the U.S. price level and interest rate. *J. Econom.* 81, 29–64.
- Breuer, J.B., 1994. An assessment of the evidence on purchasing power parity. In: Williamsom, J. (Ed.), *Estimating Equilibrium Exchange Rates. Institute for International Economics*, Washington, DC, pp. 245–277.
- Campbell, J., Perron, P., 1991. Pitfalls and opportunities: what every macroeconomist should know about unit roots. *National Bureau of Economic Research — NBER Macroeconomics Annual*, vol. 6. MIT Press, Cambridge, MA.
- Cavaliere, G., 2005. Limited time series with a unit root. *Econom. Theory* 21 (5), 907–945.
- Cecchetti, S.G., Mark, N.C., Sonora, R., 2002. Price index convergence among United States cities. *Int. Econ. Rev.* 43 (4), 1081–1099.
- Chen, L.L., Devereux, J., 2003. What can US city price data tell us about purchasing power parity? *J. Int. Money Finance* 22, 213–222.
- Crucini, M., Yilmazkuday, H., 2014. Understanding long-run price dispersion. *J. Monetary Econ.* 66, 226–240.
- Crucini, Mario J., Mototsugu, S., Takayuki, T., 2010. The law-of-one-price without the border: the role of distance versus sticky prices. *Econ. J.* 120 (544), 462–480.
- Culver, S.E., Papell, D.H., 1999. Panel Evidence of Purchasing Power Parity Using Intranational and International Data. Mimeo, Department of Economics University of Houston.
- Davidson, R., MacKinnon, J.G., 1993. *Estimation and Inference in Econometrics*. Oxford University Press, Oxford.
- Dickey, D.A., Fuller, W.A., 1979. Estimators for autoregressive time series with a unit root. *J. Am. Stat. Assoc.* 74, 427–431.
- Enders, W., 2015. *Applied Econometric Time Series*, 4th ed. University of Alabama, Wiley.
- Engel, C., Rogers, J., 1996. How wide is the border. *Am. Econ. Rev.* 86 (5), 1112–1125.
- Faber, R.P., Stokman, C.J., 2009. A short history of price level convergence in Europe. *J. Money Credit Bank.* 41 (March–April (2–3)).
- Feijó, Flavio Tosi, Morales, Rodrigo Rabassa, 2008. A Validade da Paridade do Poder de Compra no Brasil Pós-Plano Real. *Sinergia (Rio Grande do Sul)* 12 (1), 39–49.
- Frankel, J.A., Rose, A.K., 1996. A panel project on purchasing power parity: mean reversion within and between countries. *J. Int. Econ.* 40, 209–224.
- Froot, K.A., Rogoff, K., 1995. Perspectives on PPP and long-run real exchange rates. In: Grossman, Gene, Rogoff, Kenneth (Eds.), *Handbook of International Economics*, vol. 3. Amsterdam, Elsevier, pp. 1645–1729.
- Gamboa, U.M.R., Fava, V.L.A., 2008. A century and a half of purchasing power parity in Brazil: a cointegration analysis with structural breaks. In: *Latin American Meeting of the Econometric Society*, Rio de Janeiro, Latin American Meeting of the Econometric Society.
- Gorodnichenko, Y., Weber, M., 2016. Are sticky prices costly? Evidence from the stock market. *Am. Econ. Rev.* 106 (01).
- Gregory, A., Hansen, B., 1996. Residual-based tests for cointegration in models with regime shifts. *J. Econom.* 70, 99–126.
- Harvey, D.I., Leybourne, S.J., Xiao, B., 2008. A powerful test for linearity when the order of integration is unknown. *Stud. Nonlinear Dyn. Econom.* 12.
- Hegwood, N.D., Nath, H.K., 2013. Structural breaks and relative price convergence among US cities. *J. Macroecon.* 36, 150–160.
- Kannebley, S., 2003. Paridade do Poder de Compra no Brasil — 1968 a 1994. *Estudos Econômicos* 33, 735–769.
- Kruse, R., 2011. A new unit root test against ESTAR based on a class of modified statistics. *Stat. Pap.* 52 (1), 71–85.
- Kwiatkowski, D., Phillips, P.C.B., Schmidt, P., Shin, Y., 1992. Testing the null hypothesis of stationarity against the alternative of a unit root. *J. Econom.* 54, 159–178.
- Lee, J., Strazicich, M.C., 2003. Minimum LM unit root test with two structural breaks. *Rev. Econ. Stat.* 85 (4), 1082–1089.
- Lee, J., Strazicich, M.C., 2013. Minimum lm unit root test with one structural break. *Econ. Bull.* 33 (4), 2483–2492.
- Lothian, J., 1997. Multi-coutry evidence on the behavior of purchasing power parity under the current float. *J. Int. Money Finance* 16, 19–35.
- Marçal, E.F., Pereira, P.L.V., Santos Filho, O.C., 2003. Paridade do poder de compra: testando dados brasileiros. *Rev. Bras. Econ.* 57 (1), 159–190.
- Nakamura, E., Steinsson, J., 2012. Lost in transit: product replacement bias and pricing to market. *Am. Econ. Rev.* 102 (7), 3277–3316.
- Nakamura, E., Steinsson, J., 2013. Price Rigidity: Microeconomic Evidence and Macroeconomic Implications, NBER Working Paper, no. 18705.
- Nath, H., Vargas-Silva, C., 2012. Remittances and relative prices. *Rev. Dev. Econ.* 16 (1), 45–61.
- Ng, S., Perron, P., 2001. Lag length selection and the construction of unit root tests with good size and power. *Econometrica* 69 (6), 1519–1554.
- Palaia, D., Holand, M., 2010. Taxa de Câmbio e Paridade de Poder de Compra no Brasil: Análise Econométrica com Quebra Estrutural. *Econ. Apl.* 14 (1).
- Papell, D.H., 1997. Searching for stationarity: purchasing power parity under current float. *J. Int. Econ.* 43, 313–332.
- Perron, P., 1989. The great crash, the oil price shock and the unit root hypothesis. *Econometrica* 57, 1361–1401.
- Perron, P., Vogelsang, T.J., 1992. Testing for a unit root in a time series with a changing mean: corrections and extensions. *J. Bus. Econ. Stat.* 10 (October (4)), 467–470.
- Rogoff, Kenneth, 1996. The purchasing power parity puzzle. *J. Econ. Lit.* 34 (2), 647–668.
- Simões, O.R., Marçal, E.F., 2012. Agregação Temporal e Não-Linearidade Afetam os Testes da Paridade do Poder de Compra: Evidência a Partir de Dados Brasileiros. *Rev. Bras. Econ.* 66 (3), 375–399.
- Taylor, Alan, Taylor, Mark, 2004. The purchasing power parity debate. *J. Econ. Perspect.* 18 (4), 135–158.

- Vasconcelos, C.R.F., Lima Júnior, L.A., Dias, T.F., 2014. Validade da paridade de poder de compra para países selecionados da América Latina: teste de raiz unitária linear e não linear. In: 42º Encontro Nacional de Economia, 2014. Anais do 42º Encontro Nacional de Economia, Natal/Rio Grande do Norte.
- Wanzeller, D.M., Gadelha, S.R.B., 2014. Paridade do poder de compra no Brasil: Uma investigação empírica. *Rev. Bras. Econ. Empresas* 14 (2), 77–95.
- Wu, Y., 1996. Are real exchange rate non-stationary? Evidence from a panel data test. *J. Money Credit Bank.* 28 (1), 54–63.
- Zini, A., Cati, R.C., 1993. Cointegração e taxa de câmbio: Testes sobre a PPP e os termos de troca do Brasil de 1855 a 1990. *Pesquisa e Planejamento Econômico* 23 (2), 349–374.