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Article

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Inter-Region Relative Price Convergence in Korea[*]

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This paper examines the persistence of relative consumer price indices for 15 regions in Korea including 6 metropolitan cities and 9 provinces over the period of 1990-2016. In particular, we ask if relative regional price indices contain a common stochastic trend and find that they are not. We then investigate how quickly these relative prices converge to their long run value and find that a half-life of a deviation from the long run value is in the range of 13 to 22 months for the aggregate consumer price indices and in the range of 7 to 13 months for the tradable goods price indices, which is much quicker than the estimates of previous studies. These estimates suggest that existing monetary models with the realistic duration of price rigidities can generate the persistence in relative price indices.

Keywords: PPP, Half-Life, Panel Unit Root Tests, Real Exchange Rates, Regional Relative Price

JEL classification: F31, F40, F41

I. INTRODUCTION

Purchasing power parity (PPP), which is one of major building blocks in international macroeconomic models, states that both home and foreign aggregate price levels should equal at the equilibrium once converted to a common currency. The underlying mechanism behind PPP is that international good market arbitrage enforces broad parity in prices of individual goods and services. Of course, the effectiveness of international arbitrage depends on the degree of integration between national markets. Therefore, PPP implies that both home and foreign national

markets are completely integrated. However, it is natural to observe deviations from PPP in real world considering various barriers to complete relative price-level adjustment. Instead, previous studies ask if deviations from PPP reflected in real exchange rates converge to the long run equilibrium value. If so, how quickly do they move back to it, in response to a shock to the prices?

Numerous studies have conducted the tests for PPP using various econometric methods and data sets. In general, the consensus of those previous studies is that real exchange rates converge to PPP in the long run.[1] However, the speed of convergence of the real exchange rates is very slow: half-lives of deviations from PPP are in the range of 3 to 5 years. See, for example, Rogoff (1996), Frankel and Rose (1996), Murray and Papell (2005), and Choi et al. (2006). This slow speed is not compatible with the predictions of monetary models such as Mundell-Fleming-Dornbusch models and sticky price dynamic stochastic general equilibrium models. Those models can generate the volatility of real exchange rates consistent with data [see, for example, Chari, et al. (2002)]. However, those models should assume that prices are fixed about more than 3 years, if they intend to generate the strong persistence of the real exchange rates consistent with the speed of mean reversion in data. However, this assumption is unrealistic. Previous studies call these two apparently incompatible empirical findings the PPP puzzle [see, for example, Rogoff (1996)].

Based on such empirical evidence, studies have looked for sources that affect persistence in a deviation from PPP. Those sources include: (i) incomplete price level adjustment due to price stickiness (ii) the presence of non-tradable goods in the aggregate consumer price index; (iii) transportation costs; (iv) the influence of flexible exchange rates; (v) international trade barriers such as tariffs and non-tariff barriers. Each of these components affects the transitional dynamics of real exchange rates. In particular, the last two explanations are closely related to the so-called border effect, although one cannot precisely distinguish the effect of each component from others. For example, Engel and Rogers (1996) present evidence that both distance (which proxies the effect of transportation costs) and borders

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[1] Many studies that employed univariate unit root tests cannot reject the unit root hypothesis that real exchange rates contain a stochastic trend. See Froot and Rogoff (1995) for a survey of those studies. However, it is now well-known that these tests have very low power, in particular when sample size is small.

(which proxy the effects of exchange rates as well as of international trade barriers) explain significant proportions of deviations from PPP. During the floating exchange rate era, studies notice that nominal exchange rates combined with sticky prices affect deviations from PPP. Note that if prices of goods and services are sticky in both countries, the behavior of nominal exchange rates is very similar to that of real exchange rates. For example, Mussa (1986) and Engel (1993) present evidence that the volatility of real exchange rate changes is quite similar to that of nominal exchange rate changes during the floating exchange rate era, and attribute it to sluggish price adjustment. Betts and Devereux (1996) and Engel and Rogers (2001) also emphasize the effect of variable nominal exchange rates under local currency pricing on deviations from PPP, while controlling for the effects of international trade barriers.

This paper uses relative consumer price indices for 15 regions in Korea including 6 metropolitan cities and 9 provinces over the period of 1990-2016 and ask the same questions as previous studies. In particular, we first examine if relative regional price indices contain a common stochastic trend. Using panel unit root tests developed by Pesaran (2007), we find that those price indices converge in the long run. We then investigate how quickly these relative prices move back to their long run value. We find that a bias corrected half-life of a deviation from the long run value is in the range of 13 to 22 months, which is much quicker than the estimates of previous studies. To understand sources for deviations from PPP, we construct two relative price indices for each region, using detailed price indices and their weights in the consumer price indices: One is the tradable good price index and the other is the service (non-tradable goods) price index. We find that the tradable good price indices converge in the long run, while the service price indices have mixed evidence. Further, a bias corrected half-life of a deviation from PPP for the tradable goods price indices is in the range of 7 to 13 months. These estimates suggest that existing monetary models with the realistic duration of price rigidities can generate the persistence in relative tradable price indices.

Our study on the persistence of Korean relative regional prices attenuates the border effects since the regions in Korea have the same currency as well as there are no explicit trade barriers such as tariff and quotas across the regions. Therefore, our study provides readers with a natural experiment in which the effects of some of the above components, in particular, the border effects, are likely to be controlled. This is the main contribution of the present paper. In addition, we argue that our

dataset may have a higher quality than the datasets with national price indices in the following aspect: Governments do not construct price indices for an internationally standardized basket of goods, while Statistics Korea constructs regional price indices for the standardized basket of consumption goods.

Our study closely follows Cecchetti et al. (2002) who investigate the persistence of 19 US city consumer price indices from 1918 to 1995, while minimizing the border effects. They found that US city price indices do not have a unit root but the speed of the convergence to the long run value is extremely slow: a half-life of a deviation is about nine years, which are even slower than the estimates of previous studies that used national consumer price indices and nominal exchange rates. The main difference between our study and theirs is to use different datasets and econometric methods. We study persistent properties of the Korean price data, while they study those of the US data. We show that both the presence of non-tradable goods in the aggregate price index and sticky prices can explain a deviation from PPP but distance has no significant effect in the Korean price data. On the other hand, they show that both distance and presence of non-tradable goods in the price index play an important role in explaining a deviation from PPP in the US price data. More importantly, we use a new panel econometric method developed by Pesaran (2007), while they use both the LLC test developed by Levin et al. (2002) and the IPS test by Im et al. (2003). Pesaran (2007)'s method controls for cross section dependence in panel datasets, while the well-known LLC and IPS tests assume cross section independence. O'Connell (1998) shows that the typical panel unit root tests developed under the cross-sectional independence assumption reject too often the unit root hypothesis in the presence of significant cross-section dependence. Therefore, we view that the use of Pesaran (2007)'s method may mitigate the influence of cross section dependence which is likely to be present in panels with relative consumer good prices.

Parsley and Wei (1996) and Engel and Rogers (2001) are also closely related to our study in that they also minimize the border effects, while studying violations of law of one price (and thus deviations from PPP) using detailed price data of US cities. The main difference between the former (two studies of ours and Cecchetti et al. (2002)) and the latter (two studies of Parsley and Wei (1996) and Engel and Rogers (1996, 2001)) is that the former examines the behavior of aggregate consumer price indices, while the latter investigates the behavior of disaggregated prices. Each group of studies has different objectives. The latter can investigate

more rigorously a cause for a deviation from PPP. For example, using disaggregated prices, they can examine how the degree of tradability of goods affects a violation of law of one price and thus a deviation from PPP.[2] On the other hand, studying the behavior of aggregate price indices is useful for certain cases. For example, monetary policy makers generally pay attention to measures of aggregate inflation and thus are more concerned with the behavior of aggregate price indices, rather than that of individual goods prices. Note also that the PPP puzzle is about the behavior of aggregate price indices.

Our study is also related to studies who examine the role of non-tradable goods in explaining deviations from PPP. Those studies include Engel (1999), Betts and Kehoe (2006), and Crucini and Shintani (2008). Engel (1999) construct tradable and non-tradable goods price indices by decomposing aggregate price indices, and show that relative prices of non-tradable goods do not explain at all the variation of US real exchange rates. On the other hand, Betts and Kehoe (2006) and Crucini and Shintani (2008) reach a different conclusion. In particular, Crucini and Shintani (2008) construct tradable and non-tradable price indices using micro-price data obtained from the Economist Intelligence Unit (EIU) which surveys international retail prices annually, and find that a half-life for non-tradable goods are in general about 6 months greater than that for tradable goods for the OECD cities as well as the US cities. This result is comparable with our study: we find that half-lives for services are about 9 to 16 months greater than those for tradable goods for the Korean cities and provinces. Further, Crucini and Shintani (2008) aggregate their micro-price data using a variety of weighting methods and show that half-lives for the constructed aggregate price index are in the range of 1-2 years, consistent with our estimates.[3]

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[2] Our study also uses disaggregated price indices to examine this issue.

[3] Regarding studies that use Korean price data, our study is first to examine the persistence of Korean regional relative prices. Previous studies investigated the dynamic behavior of Korean real exchange rates constructed national price indices and exchange rates. For example, Kim (2007) examines the persistence of Korea-US and Korea-Japan real exchange rates using univariate nonlinear unit root tests. Oh and Hong (2010) also used the two real exchange rates and studied the implications of the Balassa-Samuelson hypothesis. Recently, Moon (2016) studies the persistence of sectoral relative consumer prices between Korea and Japan. See also references in Moon (2016).

We admit that our empirical study has some limitations in terms of data and empirical method. One limitation is that our empirical study on the long run PPP faces the usual kinds of index number problems, like as almost all the studies mentioned above. For example, our test of long run PPP asks whether the regional relative price indices are stationary about not zero but a fixed mean, because measured relative price indices need not be zero due to the base year normalization of the price indices even if PPP holds in the long run. The other limitation is that our empirical method for testing long run PPP assumes a linear specification of price adjustment and thus mainly focuses on the estimation of a single parameter: half-life of a shock. However, if the regional relative prices converge to the long run equilibrium nonlinearly due to some reasons such as transaction costs of arbitrage, our half-life estimates might be affected accordingly [see, for example, Taylor et al. (2001)].

The remainder of the paper is organized as follows. Section II presents our empirical framework: we present the procedure of implementing the panel unit root tests developed by Pesaran (2007). Section III displays the time series pattern of Korean regional relative price indices. Section IV presents our empirical results on the test for the presence of a common stochastic trend in the regional relative prices and our estimates for half-lives of a deviation from PPP. It also presents some explanations for short run deviations from PPP. Conclusions follow.

II. EMPIRICAL FRAMEWORK

This section presents our empirical method for studying persistent properties of regional consumer price indices data. As a first step, we investigate if regional relative price indices to the base region follow a unit root process. A basic theory that underlies the empirical examination of these prices is the PPP doctrine motivated by the commodity-arbitrage view. The view states that the law of one price holds for all tradable goods internationally and domestically. If the law of one price holds for the goods individually, it will also holds for the appropriate price index as well. However, it is natural to see that PPP does not hold continuously, considering various trade barriers and frictions in real world. Instead, we examine the dynamic behavior of deviations from PPP: the behavior of real exchange rates. In particular, we investigate whether or not deviations from PPP tend to converge to the long run value. For this, we test the hypothesis that regional relative prices

contain a stochastic trend. As a second step, we investigate how fast deviations from PPP converge to the long run value if PPP holds in the long run. Finally, the estimates of the speed of adjustments of relative prices will provide a clue for searching out reasons for short run deviations from PPP.

This section focuses on presenting our empirical method for the first step. Univariate unit root tests such as Augmented Dickey Fuller (ADF) tests were traditionally used to test the PPP hypothesis. However, it has been well understood that those tests have a low power, in particular when sample size is small: the tests are quite often incapable of distinguishing between stationary and nonstationary components if the stationary time series are highly persistent. One way to mitigate this shortcoming is to increase sample size by exploiting the panel dimension of data.[4] In this paper, we use the panel dataset with 15 regional relative price indices. We then apply Pesaran (2007)'s method to our dataset.

Consider the following specification of the dynamic linear heterogeneous panel data:

$$\Delta q_{it} = \beta_i q_{i,t-1} + \alpha_i + \gamma_i f_t + \varepsilon_{it}, \quad \text{for} \quad i = 1, 2, \cdots, N \text{ and } \quad t = 1, 2, \cdots, T \qquad (1)$$

where q_{it} is the log of the relative price of region i to the base region at time t, $\Delta q_{it} = q_{it} - q_{i,t-1}$, α_i is a region specific constant to control for the time invariant fixed effect, f_t is the unobserved time varying common factor, and ε_{it} is the region-specific (idiosyncratic) innovation. We assume that f_t is serially uncorrelated with mean zero and a constant variance. We also assume that ε_{it} is independently distributed both across region i and time t. It is worth notice two things in the error term in this panel data specification. The region specific constant α_i will control for the influence of time invariant heterogeneity across regions arising from various sources such as implicit and explicit trade barriers and different income levels. The unobserved common factor f_t will capture cross-sectional dependence in the relative prices induced by the influence of macroeconomic shocks and γ_i measures the degree of its influence on region i.

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[4] The other way to mitigate this problem is to use the dataset with long time series.

The unit root hypothesis of our interest is expressed as

$$H_0 : \beta_i = 0, \text{ for all } i, \tag{2}$$

against the heterogeneous alternatives,

$$H_a : \beta_i < 0, \text{ for at least one } i.$$

β_i governs the speed of convergence of q_{it} to the long run value. Zero value of β_i means that regional prices in response to a shock diverge from the benchmark price even in the long run.[5] Alternatively, negative value of β_i means that regional relative prices converge in the long run. We compute the half-life of a shock to q_{it} as $-\ln(2)/\ln(\rho_i)$, where $\rho_i \equiv 1 + \beta_i$. This half-life measures the speed of long run convergence. As β_i is farther away to the left from zero, the speed of convergence of the relative price to the long value (or the half-life of a shock) is getting faster (smaller).

For the test of the unit root hypothesis in (2), we use the panel unit root test developed by Pesaran (2007). The test has an advantage against well-known previous tests such as the LLC test and the IPS test in that it controls for the influence of cross-section dependence, while the latter two tests do not. Persan (2007) shows that the effect of serially uncorrelated time varying common factor f_t which governs cross-sectional dependence can be captured by adding the linear combination of cross-section mean to the typical augmented Dickey Fuller (ADF) regression. Then, the dynamic linear heterogeneous panel data model in (1) can be estimated using the following cross-sectionally augmented DF (CADF) regression:

$$\Delta q_{it} = a_i + b_i q_{i,t-1} + c_i \bar{q}_{t-1} + d_i \Delta \bar{q}_t + e_{it}, \tag{3}$$

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[5] One possible economic reason why PPP does not hold in the long run may be related to the influence of real shocks such as the productivity. For example, the Balassa-Samuelson hypothesis states that rich regions tend to have higher price levels than poor regions because the rich regions are more productive in the tradable goods sector than in the service sector.

where $\bar{q}_t = \dfrac{1}{N}\sum_{i=1}^{N} q_{it}$ is the cross section mean of regional relative prices and e_{it} is a residual.

Pesaran's test for the unit root hypothesis in (2) is based on the t-value of the OLS estimate b_i in the CADF regression that controls for the influences of time varying common component and time invariant region specific component. The t-value of b_i is defined by

$$t_i(N,T) = \frac{\Delta q_i^{'} \bar{M}_w q_{i,-1}}{\hat{\sigma}_i (q_{i,-1}^{'} \bar{M}_w q_{i,-1})^{1/2}} \qquad (4)$$

where

$$\Delta q_i = (\Delta q_{i1}, \Delta q_{i2}, \cdots, \Delta q_{iT})', q_{i,-1} = (q_{i0}, q_{i1}, \cdots, q_{i,T-1})'$$

$$\bar{M}_w = I_T - \bar{W}(\bar{W}^{'}\bar{W})^{-1}\bar{W}^{'}, \bar{W} = (\tau, \Delta\bar{q}, \bar{q}_{-1})$$

$$\tau = (1,1,\cdots,1)', \Delta\bar{q} = (\Delta\bar{q}_1, \Delta\bar{q}_2, \cdots, \Delta\bar{q}_T)', \bar{q}_{-1} = (\bar{q}_0, \bar{q}_1, \cdots, \bar{q}_{T-1})'$$

$$\hat{\sigma}_i^2 = \frac{\Delta q_i^{'} M_{i,w} \Delta q_i}{T-4} \quad \text{and} \quad M_{i,w} = I_T - G_i(G_i^{'}G_i)^{-1}G_i^{'}, G_i = (\bar{W}, q_{i,-1}).$$

The main difference between the t-value in the typical ADF regression and the t-value in (4) is that the latter controls for the influence of a serially uncorrelated time varying common component. Pesaran (2007) allows the speed of long run convergence to be different across regions. Finally, Pesaran (2007) applies the method of Im et al. (2003) to aggregate the individual CADF statistics $t_i(N,T)$ in (4). That is, a cross-sectionally augmented version of the IPS test is based on

$$CIPS(N,T) = \frac{1}{N}\sum_{i=1}^{N} t_i(N,T). \qquad (5)$$

Finally, Pesaran (2007) extends the procedure for testing the CIPS to the case where both the time varying common component and the individual specific error term are serially correlated. For the sake of simplicity, we do not present the extended version in this paper [see equation (54) in Pesaran (2007, p 283.) for the detail]. We use the $CIPS(N,T)$ for our empirical study of testing the panel unit root hypothesis in (2).[6]

III. DATA

We obtain monthly regional consumer prices data from Statistics Korea for the period of 1990M1-2016M6. Statistics Korea publishes national as well as 16 regional consumer price indices every month. Regions include 7 metropolitan cities and 9 provinces: Seoul, Busan, Daegu, Inchon, Gwangju, Daejeon, Ulsan, Gyeonggi-do, Gangwon-do, Chungcheongbuk-do, Chungcheongnam-do, Jeollabuk-do, Jeollanam-do, Gyeongsangbuk-do, Gyeongsangnam-do, Jeju-do. We consider Seoul as the base region and construct a panel dataset of 15 relative regional consumer price indices to the base (Seoul) consumer price index.

Figure 1 draws the logarithms of yearly regional consumer price indices relative to Seoul over the entire sample period: we multiply the log prices by 100.[7] Although we use monthly data for our main analysis, yearly data are used here to make visualization clear. One noticeable pattern is that there is a tendency that most relative regional prices move together over time, illustrating that there may be a significant degree of cross-section dependence in the panel. This fact motivates us to use the econometric method that controls for the influence of cross-section dependence. We also measure cross section dependence of these regional relative prices formally by calculating pair-wise correlations using residuals in an individual ADF regression that is equivalent to regression (3) without the cross section mean components. The average of those correlations is about 0.5, suggesting

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[6] Pesaran (2007) provides critical values for both individual cross-sectionally augmented DF statistics $t_i(N,T)$ and the average of individual cross-sectionally augmented DF statistics $CIPS(N,T)$ by simulations. We use these critical values for our inference.

[7] We use January price indices to construct yearly regional consumer price indices.

that panel unit root tests applied to our dataset should take into account of cross section dependence.

Figure 1. Logarithms of Regional Consumer Price Indices Relative to Seoul
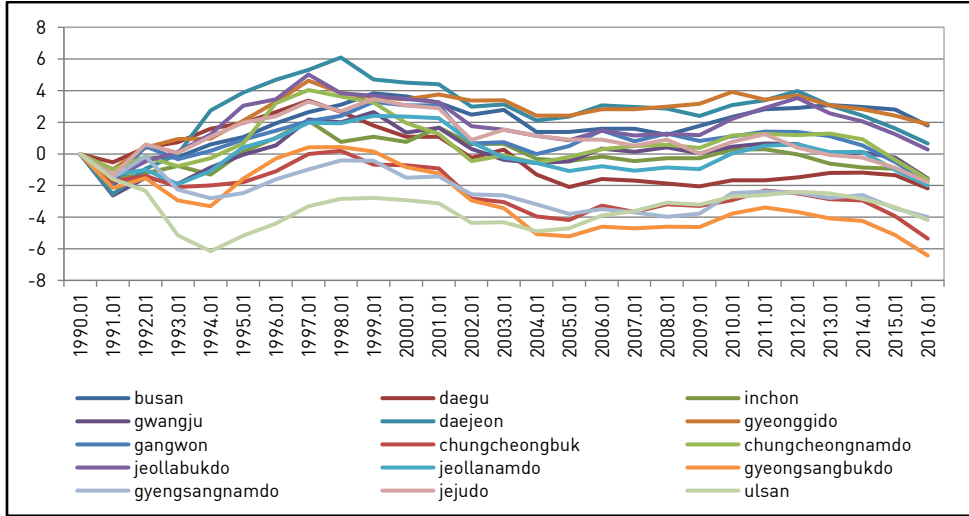
We also use the data of detailed prices to search for reasons for short-run deviations from PPP. Consumer price index includes both tradable and non-tradable goods: for example, the share of tradable goods in the overall price index in Korea is on average about 40% and the share of service is about 60%. According to Statistics Korea, the market basket of goods and services underlying the regional consumer price index (CPI) is divided into 12 major groups, 40 subgroups, and 72 sub-subgroups. Using prices and weights of 72 sub-subgroups, we construct two price indices relative to Seoul for each region. One is the tradable good price index and the other is the service (non-tradable goods) price index.

Figure 2 draws the logarithms of yearly regional tradable goods and service price indices relative to Seoul over the entire sample period: we again multiply the log prices by 100. One noticeable pattern that distinguishes the behavior of the tradable goods prices from the service prices is that the tradable goods price indices appear to move more closely than the service prices. This may suggest that a common factor may affect the tradable goods prices more strongly than the service price indices.

Figure 2. Logarithms of Regional Tradable and Service Price Indices Relative to Seoul
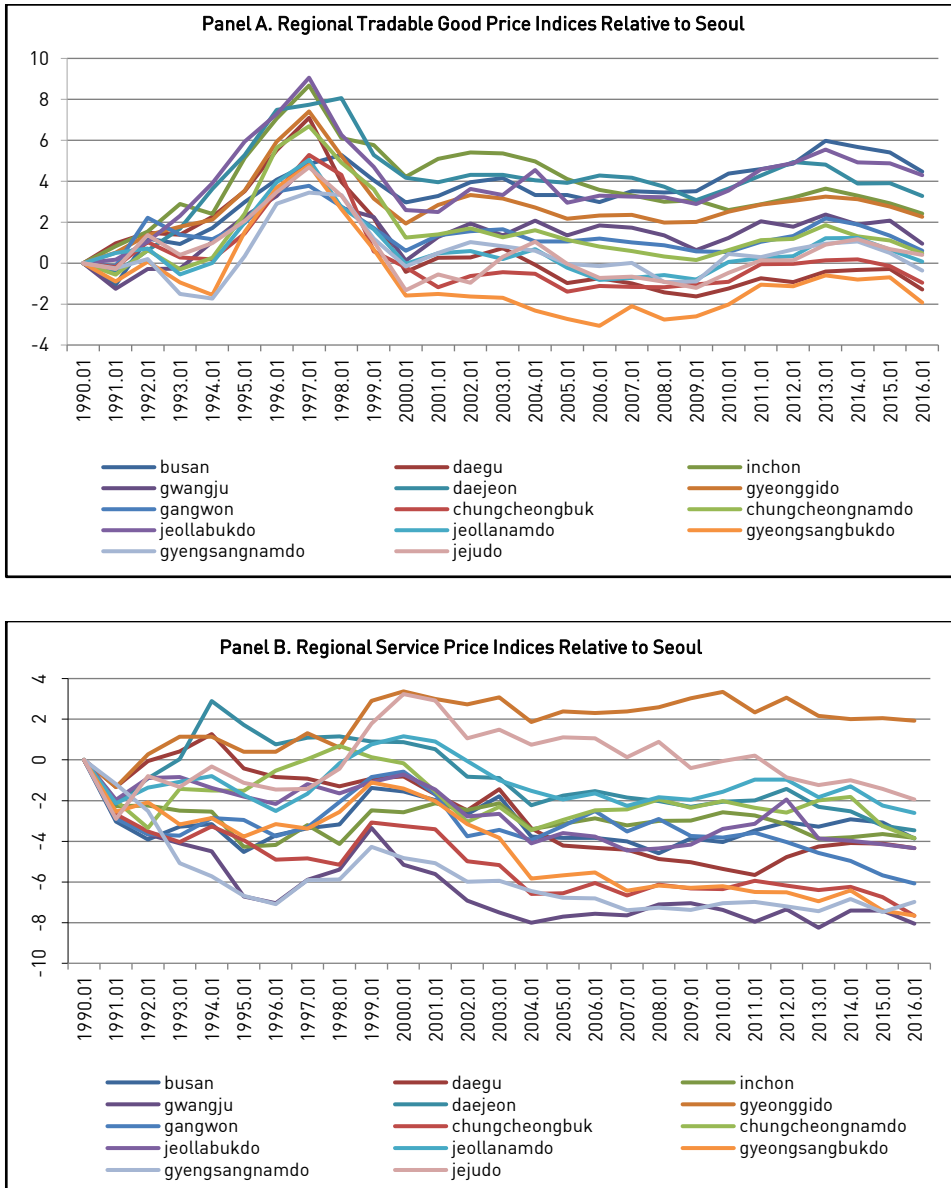
Data source: KOSIS (accessed July 17, 2016).

IV. EMPIRICAL RESULTS

1. Panel Unit Root Test Results

Table 1 displays the result of Pesaran (2007)'s panel unit root test for the sample period of 1990M1-2016M6. It reports $CIPS(N,T)$ in (5) which is the average of individual cross-sectionally augmented DF statistics. We consider various lag lengths from 0 to 24 months to see whether or not our results are driven by a particular lag length and find that the results are robust to those lag lengths.[8] In the table, we present the results for lag lengths of 0, 3, 6, 12 and 24. We find that the test rejects the unit root hypothesis at conventional levels for all the lag lengths considered. These results imply that there is little evidence of a stochastic trend in the Korean regional consumer price indices relative to Seoul.

We then examine how quickly short run deviations of the regional relative prices converge to the long run value. For this, we calculate the half-life of a deviation from PPP based on the estimate of the persistence parameter, $\hat{\rho} \equiv 1 + \hat{\beta}$. Since Pesaran's method allows the persistence parameter ρ_i to differ across regions, we report the average of those estimates, $\hat{\rho} = \sum_{i=1}^{N} \hat{\rho}_i / N$. It is also well known that the estimated persistent parameter is biased downward in small samples. Hence, we correct the bias of the panel estimate using the formula developed by Nickell (1981) and report "bias corrected $\hat{\rho}$" as well as "bias corrected half-life" in Table 1.[9]

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[8] The estimates of lag length are different across the estimation methods. As well known, AIC tends to calculate higher lag lengths, while BIC tends to calculate lower lag lengths. Therefore, we consider various lag lengths and investigate if our results are sensitive to the particular selection of lag length.

[9] Nickell (1981) showed that $\hat{\rho} - \rho \xrightarrow{p} \dfrac{A_T B_T}{C_T}$ as both $T \to \infty$ and $N \to \infty$, where

$$A_T = \frac{-(1+\rho)}{T-1}, B_T = 1 - \frac{1}{T}\frac{(1-\rho^T)}{1-\rho}, \quad \text{and} \quad C_T = 1 - \frac{2\rho(1-B_T)}{(1-\rho)(T-1)}.$$

The bias corrected half-life of a deviation is about 18.8 months when we set at 12 for the lag length. Although the estimates of the half-life vary across lag lengths, in general, they are in the range of 13.7 to 21.9 months. We obtain the lowest estimated half-life when we set at 24 months for lag length and the highest half-life when we set at 3 months for lag length in regression (3). These numbers are much smaller than the estimates reported by previous studies using national price indices and exchange rates. Recall that those previous studies reported the speed of convergence within a range of 3 to 5 years. In this sense, our results may help to understand the so-called border effects.[10]

Our estimate can also be compared to Cecchetti et al. (2002) and Crucini and Shintani (2008). Like us, they also use price data for cities within a common currency and trade area to attenuate the border effect. Crucini and Shintani (2008) report a half-life of 18 months for the US cities, which is similar to our estimate. On the other hand, Cecchetti et al. (2002) report a very slow speed of convergence with a half-life of around 9 years for the US cities. The difference between these two studies seems to come from the use of different sample periods and datasets. Crucini and Shintani (2008) obtains retail prices from Economist Intelligence Unit from 1990 to 2005 and aggregate those prices by city, while Cecchetti et al. (2002) use consumer price indices for 19 US cities from 1918 to 2005.

Table 1. Panel Unit Root Test Results (1990M1-2016M6)

Lag length	CIPS	$\hat{\rho}$	Bias corrected $\hat{\rho}$	Bias corrected Half-life (months)	N
0	-2.68**	0.958	0.963	18.5	15
3	-2.37*	0.963	0.969	21.9	15
6	-2.43**	0.961	0.967	20.7	15
12	-2.63**	0.958	0.964	18.8	15
24	-2.82**	0.945	0.951	13.7	15

Source: KOSIS (accessed July 17, 2016). * and ** represent significance at 5 and 1% level, respectively.

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[10] Oh and Hong (2010) and Moon (2016) find that real exchange rates constructed using consumer price indices for Korea, US, and Japan and bilateral nominal exchange rates between these countries do not even converge in the long run.

2. Robustness

In this subsection, we check robustness of our results in two ways: one is to investigate if the choice of the base region affects the persistence in the relative price and the other is to examine if the choice of data frequency influences the persistence in the relative price. Papell and Theodiridis (1998, 2001) motivate the first question [see also Jorion and Sweeney (1996), Papell (1997), Wei and Parsley (1995), and Canzoneri et al. (1999)]. They showed that the choice of the German mark as the base currency for constructing real exchange rates provides more favorable results on PPP than the choice of the US dollar. Hence, we investigate if our results are sensitive to the choice of the base city. The second question is motivated by Glen (1992) and Papell (1997) as well as studies in the empirical stock return literature. In particular, Glen (1992) finds that the results using monthly observations are not consistent with the mean reverting behavior of real exchange rates, while the results using yearly observations are consistent with it. On the other hand, Papell (1997) obtains results in favor of mean reversion to PPP using monthly data but not using quarterly data. Considering this mixed evidence, we examine if our results are robust with the choice of data frequency.

Table 2. Test Results When Busan is Considered as the Base Region

Lag length	CIPS	$\hat{\rho}$	Bias corrected $\hat{\rho}$	Bias corrected Half-life (months)	N
0	−2.92**	0.952	0.958	16.0	15
3	−2.61**	0.956	0.962	17.9	15
6	−2.61**	0.955	0.961	17.2	15
12	−2.58**	0.954	0.960	16.9	15
24	−2.72**	0.943	0.950	13.4	15

Data Source: KOSIS (accessed July 17, 2016). * and ** represent significance at 5 and 1% level, respectively.

1) Changing a Base Region

We begin with changing our base region: we replace the Seoul consumer price index with the Busan consumer price index for a base price index. Table 2 presents the results from the CIPS test for these new relative prices. We find that the results remain unchanged: the unit root hypothesis is rejected for all cases considered at

the conventional significant levels. In addition, we find that the speed of convergence to the long run value is quite similar to the case in which Seoul is considered as the base region, although it is slightly faster in the case with Busan than with Seoul as the base region. For example, the bias corrected half-life of a deviation is about 16.9 months when we set at 12 for the lag length as reported in Table 2. The estimates of half-life are in the range of 13.4 to 17.9 months for lag lengths of 0 to 24 months.

In addition to the Busan price index, we consider consumer price indices in other regions as the base price index and find very similar results.[11] All these results suggest that our results in favor of PPP in the long run are not sensitive to the choice of the base regional price index. Further, these results contradict with previous studies that obtain stronger evidence for PPP using real exchange rates with the German mark as the base currency than with the US dollar.

Table 3. Panel Unit Root Test Results (Quarterly Data)

Panel A: **Last Month of Each Quarter**					
Lag length	*CIPS*	$\hat{\rho}$	Bias corrected $\hat{\rho}$	Bias corrected Half-life (quarters)	N
0	−2.54**	0.897	0.914	7.7	15
1	−2.49**	0.898	0.915	7.8	15
2	−2.33*	0.905	0.922	8.5	15
4	−2.64**	0.890	0.908	7.2	15
8	−2.88**	0.852	0.870	5.0	15
Panel B: **Average of Monthly Indexes for Each Quarter**					
0	−2.25*	0.925	0.941	11.4	15
1	−2.42**	0.918	0.935	10.3	15
2	−2.37*	0.919	0.936	10.5	15
4	−2.70**	0.907	0.924	8.8	15
8	−2.96**	0.874	0.892	6.1	15

Data Source: KOSIS (accessed July 17, 2016). * and ** represent significance at 5 and 1% level, respectively.

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[11] To save the space, we do not present those results in the paper and they are available upon request.

We view that there are two issues regarding the choice of the base region: one is technical and the other is economical. Technically, Engel, Hendrickson and Rogers (1997) show that when panels are constructed using the same set of regions (countries) with different numeraires, they are linear combinations of each other. This suggests that the choice of the base region does not matter for the test of PPP in the long run. Economically, the choice of the base region may matter. For example, when using country-level data, the effect of monetary policy shocks of a base country on the deviations from PPP can be different across which country is used as the base country. In this case, the choice of the base currency is important. This is what previous studies found. When using region-level data within a country, however, monetary policy shocks are common in all regions. In this case, the choice of the base region may not affect the results. This is what we find.

2) Data Frequency

We now investigate if the choice of different data frequency affects our conclusion: we use quarterly consumer price indices to construct regional relative prices. Two types of quarterly data are constructed from monthly data. One is constructed by picking up price indices in the last month of each quarter and the other by calculating the average of monthly price indices for each quarter. Table 3 presents the panel unit root tests for both cases. Consistent with monthly data, we find strong evidence in favor of PPP in the long run for quarterly data: we reject the unit root hypothesis for all cases considered.

However, we find that the speed of convergence is different how quarterly data is constructed. That is, the speed of convergence to the long run value is slower for the quarterly data constructed using the average of monthly data than for the quarterly data obtained picking up the last month of each quarter. For example, half-lives of a PPP deviation for the former data are 11.4, 10.5, 8.8, and 6.1 quarters for lag lengths of 0,2,4, and 8 quarters, while they are 7.7, 8.5, 7.2 and 5.0 quarters, respectively, for the latter data. We also construct quarterly data by picking up either the first month or the second month of each quarter to understand this difference. We find that half-lives are quite similar for quarterly data constructed by picking up one of the three months of each quarter. This suggests that the average of monthly data apparently overestimates the parameter that governs the speed of convergence.

In general, we find that the speed of convergence is quite similar for both monthly and quarterly data constructed by picking up one of the three months of each quarter, although it is slightly slower for the quarterly data. Overall, we conclude that our results are robust to the choice of data frequency.

3. Explanations for Short-Run Deviations from PPP

We now look for reasons for short run deviations from PPP. Since our dataset attenuates the border effects, we mainly concern with the other explanations discussed in Introduction: the presence of non-tradable goods in the aggregate price index and transportation costs.

1) Services in the Price Index

The consumption basket for the consumer price index includes not only tradable goods but also non-tradable goods such as services. One of compelling arguments is, therefore, that a significant proportion of non-tradable goods in the price index may make the speed of convergence slower because the forces of arbitrage are weak and indirect among non-tradable goods. To see this more explicitly, we assume that the aggregate price index in region i is defined by $P_{it} = (P_{it}^T)^{1-\alpha}(P_{it}^N)^{\alpha}$, where P_{it} is the aggregate price index in region i at time t, P_{it}^T is the price index for tradable goods, P_{it}^N is the price index for non-tradable goods, and α is the share of non-tradable goods in the price index. Then, the logarithm of regional consumer price index relative to the base region can be expressed as

$$q_{it} = \ln(P_{it} / P_{bt}) = (1-\alpha)\ln(P_{it}^T / P_{bt}^T) + \alpha \ln(P_{it}^N / P_{bt}^N) \tag{6}$$

where P_{bt}^N (P_{bt}^T) is the price index for non-tradable (tradable) goods in the base region. As can be seen in equation (6), the persistence of regional relative prices can be significantly affected by the dynamics of relative non-tradable goods prices when α is large enough. Indeed, the value of α is in general greater than 50% in our sample.

As mentioned in Section III, we construct tradable and service price indices using price indices of 72 sub-subgroups in the consumption basket and their

corresponding weights, obtained from Statistics Korea.[12] We consider services as non-tradable goods for empirical analysis. Since these 72 price indices are the ones actually used to construct the official consumer price index, looking into the dynamic behavior of tradable and service prices separately will help us to understand the behavior of the official consumer price index.

Table 4. Panel Unit Root Test Results for Tradable Goods Prices and Service Prices

	Lag length	*CIPS*	$\hat{\rho}$	Bias corrected $\hat{\rho}$	Bias corrected Half-life
		Tradable Goods Prices			
$\ln(P_{it}^T / P_{bt}^T)$	0	−3.23**	0.936	0.942	11.6
$\ln(P_{it}^T / P_{bt}^T)$9	3	−2.88**	0.939	0.945	12.3
$\ln(P_{it}^T / P_{bt}^T)$	6	−2.88**	0.936	0.942	11.7
$\ln(P_{it}^T / P_{bt}^T)$	12	−2.79**	0.931	0.937	10.7
$\ln(P_{it}^T / P_{bt}^T)$	24	−3.01**	0.906	0.913	7.6
		Service Prices			
$\ln(P_{it}^N / P_{bt}^N)$	0	−2.63**	0.963	0.969	21.9
$\ln(P_{it}^N / P_{bt}^N)$	3	−2.52**	0.963	0.969	21.8
$\ln(P_{it}^N / P_{bt}^N)$	6	−2.20	0.967	0.973	25.4
$\ln(P_{it}^N / P_{bt}^N)$	12	−2.22	0.967	0.973	25.5
$\ln(P_{it}^N / P_{bt}^N)$	24	−1.95	0.965	0.971	23.9

Source: KOSIS (accessed July 17, 2016). The number of cross-section units is 14. * and ** represent significance at 5 and 1% level, respectively.

Table 4 displays the results of the CIPS test for both tradable goods and service price indices. We find that the test rejects the unit root hypothesis at all conventional levels for the tradable goods price indices, consistent with the results for the aggregate price indices. However, we find mixed evidence for the service

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[12] We drop 8 price indices of Tobacco, Electricity, Repair of household appliance, Other medical services, Passenger transport by railway, Passenger transport by air & sea, Package holidays, and Postal services for the construction of tradable and non-tradable price indices because those prices are either regulated or not available.

price indices. The test rejects the unit root hypothesis for lag lengths less than 4 months but does not reject it for lag lengths greater than 3 months.

Further, we find that the speed of price adjustment to the long run value is much slower for the serivce price indices than for the tradable goods price indices. For lag lengths of 0 to 24 months, the bias corrected half-lives of a deviation from PPP are in the range of 7.6 to 12.3 months for the tradable goods price indices, while they are in the range of 21.4 to 27.4 months for the service price indices. Recall that the corresponding estimates for the aggregate price indices are in the range of 13.7 to 21.9 months. Therefore, these results suggest that the presence of services in the aggregate price index may significantly contribute to slowing down the speed of convergence to PPP. Interestingly, the estimates for the speed of convergence for the tradable goods price indices suggest that existing monetary models with the realistic duration of price rigidities can generate the persistence in relative tradable price indices.

2) Distance

One example of natural trade barriers is transportation costs between regions. Regions are likely to be more actively involved in trade with their neighbors, other things being equal, because transportation costs are lower. Our econometric method for panel data controls for the influence of time invariant regional specific effects such as non-tariff trade barriers, consumer preferences, and transportation costs. Therefore, our main concern in this subsection is to investigate if the volatility of relative prices for similar goods is positively related to the transportation costs between locations. The result from this exercise may provide indirectly the influence of transportation costs on the deviations from PPP. Since transportations costs are not observable, we use distance as a proxy, following Engel and Rogers (1996), Parsley and Wei (1996), and Cecchetti et al. (2002).

We use the price indices of 72 sub subgroups in the consumption goods basket and calculate the standard deviation of the logarithm of each price index relative to Seoul over the sample period. Unfortunately, our sample includes not only metropolitan cities but also provinces. Unlike the cities, there is no clear method to measure the distance between provinces. Hence, it is necessary to make some subjective judgement. Considering this difficulty, we only consider 5 metropolitan cities and Jeju-do. Then, we run an OLS regression on the logarithm of distance and the logarithm of the logarithm of distance, following the specification of

Cecchetti et al. (2002). The inclusion of the latter variable in the regression intends to capture a non-linear effect of distance.

Table 5. Effects of Distance on the Volatility of Relative Regional Prices

	(i)	(ii)
Dependent Variable	$std(q)$	$std(\Delta q)$
ln (Distance)	0.030	0.007
	(0.041)	(0.007)
Ln(ln (Distance))	-0.114	-0.026
	(0.183)	(0.032)
R^2	0.52	0.68
Obs	384	384

Source: KOSIS (accessed July 17, 2016).

Table 5 reports the results for the effect of distance on the variation of both the relative price level and change. We find that there is little evidence on the effect of distance on the relative price variation. The estimated parameters are closely zero and not statistically significant, although their sign is positive. One possible interpretation for the result may be that the difference in transportation costs across cities may not be large enough to influence the variation of the relative prices because Korea is a small country.

V. CONCLUSIONS

Complete price-level adjustment is necessary for a market economy to achieve an efficient resource allocation. A deviation from PPP is a sign that markets are not completely integrated. Of course, PPP does not hold continuously due to various components such as sticky prices, non-tradable goods, transportation costs, and explicit and implicit trade barriers. Rather, we ask two questions in this paper: (i) do Korean regional relative consumer price indices converge in the long run?; (ii) if so, how quickly do they revert to the long run value. We find that Korean relative consumer price indices converge in the long run with a relatively fast speed, compared to other economies: half-lives of a deviation are in the range of 13.7 to 21.9 months for the aggregate price indices and 7.6 to 12.3 months for the tradable goods price indices. Of possible explanations for short run deviations, we find that the presence of non-tradable goods in the price index plays a significant role.

We deliberately attenuate the border effects by using consumer price data within a common currency and trade area. Considering the fact that the Korean economy is significantly open to the world economy, changes in import prices may also affect the dynamics of consumer prices. Therefore, it may be interesting to investigate the dynamic behavior of Korean real exchange rates constructed national price indices and nominal exchange rates. Further, Korea has had free trade agreements with several important trading partners since 2000 for the purpose of eliminating trade barriers as much as possible. Therefore, it may be interesting to investigate if these free trade agreements increased integration of consumer markets as reflected by consumer prices. We leave these issues for a future study.

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