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Unbiased Estimation of the Half-Life to Price Index Convergence among U.S. Cities

Estimates of the half-life to convergence of prices across a panel of cities are subject to bias from three potential sources: inappropriate cross-sectional aggregation of heterogeneous coefficients, presence of lagged dependent variables in a model with individual fixed effects, and time aggregation of commodity prices. This paper finds no evidence of heterogeneity bias in annual CPI data for 17 U.S. cities from 1918 to 2006, but correcting for the "Nickell bias" and time aggregation bias produces a half-life of 7.5 years, shorter than estimates from previous studies.

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An advantage of examining real exchange rates (relative prices) between cities within a single country is that some of the plausible explanations for slow convergence or for the complete breakdown of international purchasing power parity (PPP), such as nominal exchange rate movements, trade barriers, and differences in CPI baskets, do not hold. Thus, by studying the behavior of intranational city prices we can hope to gain a better understanding of deviations from PPP. This is the primary motivation behind the relatively recent literature that examines the PPP hypothesis using aggregate price data for cities within the same country.[1] An

1. Examples of this literature include Culver and Papell (1999), Cecchetti et al. (2002), and Chen and Devereux (2003) for the United States; Carrion-i-Silvestre et al. (2004) for Spain; and Sonora (2005) for Mexico. While Chen and Devereux consider absolute price convergence, others examine relative price convergence. These aggregate studies were preceded by two very interesting and influential papers by Engel and Rogers (1996) and Parsley and Wei (1996). Both examine disaggregate prices of various commodities across the U.S. cities.

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examination of city level or regional price index convergence is also useful in its own right, as persistent deviations of relative prices across regions create the possibility of persistent regional differences in real interest rates and wage rates within a country resulting in misallocation of productive resources.[2]

Previous studies based on the U.S. city-level aggregate CPI data either provide little support for PPP (Culver and Papell 1999) or present evidence of slow convergence (Cecchetti et al. 2002). Both these studies use panel unit root tests. Use of the panel techniques to test for convergence and to estimate half-life is appealing because such methods combine cross-sections with time series to increase the number of observations, potentially increasing the power of the tests and the precision of half-life estimates.

However, Choi et al. (2006) recently emphasize that estimating half-life from panel data may introduce three potential sources of bias. First, if the dynamic behavior of price indices across cities exhibits sufficient heterogeneity (i.e., the autoregressive coefficients are significantly different across cities), then panel estimation of a common autoregressive coefficient will be biased upward and so will be the implied half-life. Second, in small samples, the estimation of a dynamic regression with a constant leads to a downward bias. Nickell (1981) discusses this small-sample bias in the panel context and, therefore, it is known as the "Nickell bias." Finally, the annual CPI data are averages of goods and services prices recorded monthly, rather than point-in-time sampled prices. This time-averaging (also referred to as *time aggregation*) process introduces a moving average structure into the regression error when city prices are modeled as autoregressive processes. Failure to account for this imparts an additional upward bias in the estimation of the autoregressive coefficient and the implied half-life. Because the magnitude of half-life is very sensitive to the value of autoregressive coefficients, failure to correct for those biases in panel estimation of these coefficients can lead to inaccurate measure of half-life.

The objective of this paper was to take cognizance of and correct for these biases in the estimation of the half-life to price index convergence among the U.S. cities. We use annual aggregate CPI data for 17 U.S. cities between 1918 and 2006 and apply a panel estimation technique that accounts for possible cross-sectional dependence. We find little evidence of any significant heterogeneity in the dynamic behavior of price indices across cities and therefore rule out any upward bias stemming from such heterogeneity. However, we do find that the half-life—after correcting for the combined Nickell and time aggregation bias—is about 7.5 years, the best estimate available with annual city-level CPI.

The rest of the paper is organized as follows. Section 1 describes the data and methodology. The results are presented in Section 2. For comparison, we also calculate

2. One might argue that absolute price convergence is more interesting because faster convergence signifies better market integration for consumption items and therefore greater efficiency. Lack of reliable data is a major problem in studying absolute price convergence. Previously, Parsley and Wei (1996) used the American Chamber of Commerce Research Association (ACCRA) survey price data for the period 1975 through 1992 but Koo et al. (2000) show that these price data contain substantial errors and biases. Chen and Devereux (2003), in their study of absolute price convergence, construct "absolute prices" by applying growth rates of CPI backward and forward to actual cost of living data for 1989.

and report the unbiased estimates of the half-life for the time period and cities covered in Cecchetti et al. (2002). Section 3 includes our concluding remarks.

1. DATA AND METHODOLOGY

We use annual CPI data for 17 U.S. cities from 1918 to 2006, obtained from the Bureau of Labor Statistics (BLS).[3,4] We construct relative price series for each city by using the following equation:

$$r_{i,t} = 100 \times \left(\ln P_{i,t} - \frac{1}{n} \sum_{j=1}^{n} \ln P_{j,t} \right), \tag{1}$$

where $r_{i,t}$ is the relative price and $P_{i,t}$ is the CPI in city i in year t, and n is the number of cities. Note that this relative price represents the percentage deviation of CPI in a city from the average across cities and is equivalent to modeling price indices in different cities having a common time effect component.[5] We conduct panel unit root tests to determine the stochastic trending properties of relative prices. In addition to Levin–Lin (1993) and Im–Pesaran–Shin (1997) test procedures, we conduct the Phillips and Sul (2004) panel unit root test. Results indicate that relative prices are stationary and thus support previous findings. Since our objective is to obtain unbiased estimates of the half-life, we do not report the unit root test results.

We closely follow the methodology described in Choi et al. (2006). In order to determine if there is any possibility of an upward bias in the panel estimate of the half-life due to heterogeneous dynamic behavior of prices across cities, we first conduct a test of heterogeneity of estimated autoregressive coefficients of relative prices in different cities. This test procedure—discussed in detail by Choi et al. (2004)—involves obtaining recursive mean adjusted seemingly unrelated regression (SUR) estimates of the autoregressive coefficients of relative prices and subsequently constructing a Wald test statistic with homogeneity restrictions under the null hypothesis. Note that this procedure has the desirable property of mitigating size distortion due to the small-sample bias. Once we determine that there is little evidence of cross-sectional heterogeneity (which is the case in our study, as we will see in the next section), it is appropriate to apply panel estimation techniques to pooled data. This leaves us with two potential biases in the panel estimates of autoregressive coefficient and half-life:

3. The cities in our sample are: Atlanta, Boston, Chicago, Cincinnati, Cleveland, Detroit, Houston, Kansas City, Los Angeles, Minneapolis, New York, Philadelphia, Pittsburg, Portland, San Francisco, Seattle, and St. Louis.

4. To make our results comparable with those of Cecchetti et al. (2002), we also use their data set that includes annual CPI data for 19 U.S. cities from 1918 to 1995. The data set is available from Professor Nelson C. Mark's homepage: http://www.nd.edu/~nmark/. In addition to the cities listed in the previous footnote, their sample includes Baltimore and Washington, D.C., for which the BLS discontinued publishing separate series since 1997.

5. In the international PPP literature, this relative price would be equivalent to the real exchange rate. Although a numeraire currency is chosen for calculating real exchange rate, we use the average city CPI, an approach previously adopted by Cecchetti et al. (2002) and Chen and Devereux (2003).

a downward bias due to small sample size and an upward bias due to the moving average error term introduced by time aggregation of data.

We implement a fixed effects panel generalized least squares (GLS) estimation technique as described in Phillips and Sul (2004). In contrast to the least squares dummy variable (LSDV) method, this technique increases the efficiency of the estimates by controlling for cross-sectional dependence. To sketch an outline of the procedure, suppose relative price in city i follows an AR(1) process:

$$r_{i,t} = \alpha_i + \rho_i r_{i,t-1} + u_{i,t}, \tag{2}$$

where α_i is a city-specific constant; $i = 1, 2, \ldots, n$; and $t = 1, 2, \ldots, T$. In the absence of time aggregation, the errors are generated by a single factor structure,

$$u_{i,t} = \delta_i \theta_t + \varepsilon_{i,t}, \tag{3}$$

where δ_is are factor loadings, θ_t is the common shock, and $\varepsilon_{i,t}$s are serially and mutually independent. The factor loadings and the error covariance matrix are estimated by iterative method of moments, and the estimated covariance matrix is then used to obtain the feasible GLS estimate of ρ.

However, in the presence of time aggregation the regression error has a moving average (MA) structure. Suppose $u_{i,t}$ follows an MA(1) process:

$$u_{i,t} = \upsilon_{i,t} + \gamma \upsilon_{i,t-1} \quad \text{and} \quad \upsilon_{i,t} = \delta_i \theta_t + \varepsilon_{i,t}. \tag{4}$$

In this specification, the estimated covariance matrix—which is used to transform the variables to obtain the feasible GLS estimate of ρ—includes both the contemporaneous and the long-run covariance. This estimated autoregressive coefficient is then adjusted for the Nickell bias, the time aggregation bias, and the combined Nickell and time aggregation bias as discussed in Choi et al. (2006).[6] These bias-corrected estimates of autoregressive coefficient are used to obtain various unbiased estimates of the half-life to price index convergence among the U.S. cities.

2. RESULTS

Table 1 presents the results of our homogeneity test. In the first column we report the estimated Wald statistics for our data set as well for the data set used by Cecchetti et al. (2002). The second column shows the corresponding critical chi-squared values at the 5% significance level. A comparison of columns 1 and 2 indicates that we cannot reject the null of homogeneity. Thus, the dynamic behavior of relative prices does not vary significantly across the U.S. cities and the panel estimate of the

6. Time aggregation of the data introduces an interaction between the Nickell bias and the time aggregation bias, which requires additional adjustment in the estimation of the autoregressive coefficient. For a discussion, see Choi et al. (2006). The combined Nickell and time aggregation bias correction incorporates this adjustment.

TABLE 1

HOMOGENEITY TEST RESULTS

	Estimated test statistics (1)	5% critical value ($\chi^2_{n-1,0.05}$) (2)
Relative prices in 17 cities (sample period: 1918–2006)	12.28	26.30
Relative prices in 19 cities (sample period: 1918–95)	17.46	28.87

NOTE: The null hypothesis is H_0: $\rho_1 = \rho_2 = \cdots = \rho_n$ where ρ_i is the AR(1) coefficient of relative price in city i. Under the null, the estimated test statistic follows a chi-squared distribution with $n - 1$ degrees of freedom. The Wald test is described in Choi et al. (2004).

TABLE 2

PANEL FEASIBLE GLS ESTIMATION OF ρ AND IMPLIED HALF-LIFE

	No bias corrections		Nickell bias corrected		Time aggregation bias corrected		Nickell and time aggregation bias corrected	
	$\hat{\rho}$ (1)	Half-life (2)	$\hat{\rho}$ (3)	Half-life (4)	$\hat{\rho}$ (5)	Half-life (6)	$\hat{\rho}$ (7)	Half-life (8)
Relative prices in 17 cities (sample period: 1918–2006)	0.929	9.41	0.950	13.51	0.887	5.78	0.912	7.53
Relative prices in 19 cities (sample period: 1918–95)	0.916 (0.894, 0.883)	7.90	0.947 (0.922, 0.931)	12.73 (8.535, 9.695)	0.877	5.28	0.906	7.02

NOTE: The values in parentheses are Levin–Lin and Im–Pesaran–Shin estimates of ρ and the corresponding values of half-life, respectively, as reported by Cecchetti et al. (2002).

autoregressive coefficient is not likely to be biased upward. It implies that pooling of data is appropriate.

Table 2 presents our estimates of the autoregressive coefficient along with the implied half-life with no bias correction and with various types of bias corrections. The first two columns give us the estimated values of ρ and associated half-life with no bias correction.[7] Columns 3 and 4 report the estimated ρ and corresponding half-life when only the Nickell bias is corrected. Our estimate shows that the Nickell bias corrected half-life is more than 13 years. It is slightly shorter when we use the Cecchetti et al. (2002) data set. The estimates of ρ and associated half-life when only the time aggregation bias is corrected are presented in columns 5 and 6. The half-life is more than 5 years. Finally, when corrections are made for the combined Nickell and time aggregation bias, the half-life turns out to be about 7.5 years.

7. The difference between the current estimates of ρ and those of Cecchetti et al. (2002) (see row 2 of Table 2) can be ascribed to the differences in the estimation methods. Note that our estimation method exploits the cross-sectional covariance structure of the observations to control for cross-sectional dependence. In contrast, inclusion of a common time effect to account for cross-sectional dependence in Cecchetti et al. works only asymptotically as n increases.

3. CONCLUSION

Using annual CPI data for 17 U.S. cities from 1918 to 2006, this paper estimates the half-life to price index convergence, correcting for the time aggregation bias as well as the small-sample bias that typically arise in panel data estimation. To our knowledge, the half-life of 7.5 years is the best estimate available for city price index convergence in the United States. However, this result still implies slow convergence by international PPP standards, the explanation for which is beyond the scope of this short article.

LITERATURE CITED

Carrion-i-Silvestre, Josep L., Tomas del Barrio, and Enrique Lopez-Bazo. (2004) "Evidence on the Purchasing Power Parity in a Panel of Cities." *Applied Economics,* 36, 961–6.

Cecchetti, Stephen G., Nelson C. Mark, and Robert Sonora. (2002) "Price Convergence among United States Cities." *International Economic Review,* 43, 1081–98.

Chen, L. L., and J. Devereux. (2003) "What Can US City Price Tell Us about Purchasing Power Parity?" *Journal of International Money and Finance,* 22, 213–22.

Choi, Chi-Young, Nelson C. Mark, and Donggyu Sul. (2004) "Bias Reduction by Recursive Mean Adjustment in Dynamic Panel Data Models." Manuscript, University of Auckland.

Choi, Chi-Young, Nelson C. Mark, and Donggyu Sul. (2006) "Unbiased Estimation of the Half-Life to PPP Convergence in Panel Data." *Journal of Money, Credit and Banking,* 38, 921–38.

Culver, Sarah E., and David H. Papell. (1999) "Panel Evidence of Purchasing Power Parity Using Intranational and International Data." Mimeo, University of Houston.

Engel, Charles, and John H. Rogers (1996) "How Wide Is the Border?" *American Economic Review,* 86, 1112–25.

Im, Kyung So, M. H. Pesaran, and Yongcheol Shin. (1997) "Testing for Unit Roots in Heterogeneous Panels." Working Paper, University of Cambridge.

Koo, Jahyeong, Keith R. Phillips, and Fiona D. Sigalla. (2000) "Measuring Regional Cost of Living." *Journal of Business & Economic Statistics,* 18, 127–36.

Levin, A., and C. F. Lin. (1993) "Unit Root Tests in Panel Data: New Results." Manuscript, Board of Governors of the Federal Reserve System, Washington, DC.

Nickell, Stephen. (1981) "Biases in Dynamic Models with Fixed Effects." *Econometrica,* 49, 1417–26.

Parsley, David C., and Shang-Jin Wei. (1996) "Convergence to the Law of One Price without Trade Barriers or Currency Fluctuations." *Quarterly Journal of Economics,* 111, 1211–36.

Phillips, Peter C. B., and Donggyu Sul. (2004) "Bias in Dynamic Panel Estimation with Fixed Effects, Incidental Trends and Cross Section Dependence." Manuscript, University of Auckland.

Sonora, Robert J. (2005) "City CPI Convergence in Mexico." *Review of Development Economics,* 9, 359–67.