CHAPTER 6

Law of One Price

6.1 The Law of One Price Cannot Be Rejected: Two Tests Based on the Tradable/Nontradable Price Ratio

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6.1.1 Introduction

The law of one price for tradable commodities is an essential ingredient in the body of knowledge known as international economics. Without the imposition of this law, there would not even be the traditional "pure theory" of international trade. Without this law, much of the "monetary theory," too, would have to be reconstructed.

Yet, the empirical evidence does not support the law of one price. On the contrary, with the exception of tests involving narrowly defined, extremely homogeneous commodities, the law has been universally rejected in econometric and other testing.

The premise of this paper is that the reason for the failure of the law of one price in empirical testing is the disaggregative approach almost uniformly followed. An aggregative technique is superior on several

L. H. Officer, *Essays in Economic History*,
https://doi.org/10.1007/978-3-030-95925-8_6

grounds: theoretically, because it accounts for cross-commodity substitution in production and consumption; statistically, because it avoids the difficult task of matching individual products across countries; and econometrically, because it commits no specification errors.

Therefore, rather than striving for commodity homogeneity among countries, I use a broad sectoral classification of tradables versus nontradables. An equation is developed involving purchasing power parity (PPP), the exchange rate, and the nontradable/tradable price ratio in each country. This relationship is used to perform two novel tests of the law of one price: first, equality of the prices of tradables and nontradables for a given country; second, equality of the price of tradables across countries. If the first test is successful, then the law of one price for tradables can be extended to a law of one price for all commodities, both tradables and nontradables.

In Sect. 6.1.2 the law of one price is formally expressed and the reasons for deviations from the law discussed. Section 6.1.3 surveys the empirical literature on the law of one price, and Sect. 6.1.4 generates the model to be used in the present, aggregate, testing of the law. Using data developed in Sect. 6.1.5, the equality of the prices of tradables and nontradables is tested in Sect. 6.1.6 and equality of the price of tradables across countries in Sect. 6.1.7. Tests of the validity of the aggregative approach are described in Sect. 6.1.8, and concluding comments of the study are made in Sect. 6.1.9, followed by an appendix on the data.

6.1.2 Law of One Price

The law of one price for tradables states that there is a unique price of a tradable commodity irrespective of the country of output, where the respective home-currency prices of the commodity are expressed in a common currency via market exchange rates. If one abstracts from the inevitable index-number problems of aggregation, this law, if applicable at the disaggregative level, would farther hold for aggregates of tradable commodities, in particular, the totality of tradables. For the law of one price to be extended from tradables to all commodities, one requires the further relationship that, for each country, the price level of tradables is equal to that of nontradables.

For the law of one price of tradables to be valid, a sufficient condition is that the markets involved be purely and perfectly competitive (in the Chamberlinian sense). This would assure the existence of perfect arbitrage. Further, if the commodities in a market comparison are not identical, elasticities of substitution in production and/or consumption must nevertheless be high. To extend the validity of the law to nontradables, tradables and nontradables should again have substantial substitution possibilities with respect to each other in production and/or consumption.

Looked at from the opposite standpoint, what are the elements that give rise to deviations from the law of one price? These forces are threefold. First, the purity of competition may be lacking. The existence of monopoly and oligopoly can cause divergences from the law for two reasons: (i) the monopolist may practice price discrimination in the domestic and foreign markets (see Ripley 1974; Goldstein and Officer 1979; Crouhy-Veyrac et al. 1982); (ii) oligopolists, in fulfillment of a desire for price stability, may absorb the impact of a changing exchange rate in their profits, so that the price of tradables does not move with the exchange rate to maintain the law of one price (see Dunn 1970, 1973). Second, the phenomenon of product differentiation can reduce the substitutability of manufactured goods of different countries, even for products within the same commodity category (see Kravis and Lipsey 1971, 1978; Norman 1975; Isard 1977b). Third, at an aggregate level, the price of tradables may have differing weighting patterns (that is, differing commodity compositions) in the countries involved (see Isard 1977a; Kravis and Lipsey; 1978; Goldstein and Officer 1979; Crouhy-Veyrac et al. 1982).

6.1.3 *Critique of Empirical Literature*

Like all economic theories, the law of one price can hold only to an approximate degree in the real world. Still, even while allowing for random errors as well as for the systematic factors making for deviations from the law, the law of one price should be expected to hold empirically to a considerable extent; for its foundations—competitive conditions and high elasticities—are the basic requisites of a well-functioning economic system. In this light, it would be surprising—and demoralizing for the domestic and international economy—if the law of one price tended to be rejected by the evidence. And yet, incredibly, of the sixteen empirical studies on the issue of which I am aware, thirteen have negative implications for the law of one price.[1] Of the remainder, two (Genberg 1975; Rosenberg 1977) can be construed as supporting the law of one price; while the third (Crouhy-Veyrac et al. 1982) validates the law only for what the authors call "two pilot cases" as distinct from "the main evidence." Indeed, only for primary products priced on international commodity exchanges has the law of one price received consistent validation (by Genberg and Crouhy-Veyrac and others). In the remaining study (Rosenberg) in which the law of one price receives support, the commodities are precisely defined steel products made homogeneous now by manufacturing design rather than by nature.

When products have any differentiation at all, the law of one price ceases to receive support. It is my contention that the reason is the decision to compare commodities at disaggregative levels, this decision made by all the authors involved. Only one existing test of the law of one price is at the level of aggregate tradables. Kravis and Lipsey (1978, p. 222) conclude that differences in tradables prices are "not trivial even among the industrial countries." However, the range of the price level for tradables is less than half that for nontradables, suggesting that this test, on balance, is not that unfavorable regarding the law of one price.

It is the position of this paper not only that the appropriate level at which to test the law of one price is that of aggregate tradables (and nontradables) but also that a formal model should be used to derive an estimable equation, permitting comparison of results "with versus without" imposition of the law of one price (the latter not performed by Kravis and Lipsey). In contrast, the conventional treatment is commodity disaggregation combined with comparisons via ad hoc observation or simple correlation or regression analysis. The conventional approach has several weaknesses that bias results against the law of one price:

(i) The law of one price in practice might emanate from more complex substitutions in production and consumption than those of a bilateral nature, that are inherent in disaggregative testing. The complex substitutions, not captured in disaggregative testing, are incorporated in an aggregative approach such as that of the present paper. Further, because the conventional, disaggregative approach involves testing for purely bilateral, one-on-one substitution, the data must be made commensurate across countries: each product examined must be made homogeneous or comparable over all sources of supply—an extremely difficult task given both the nature of many manufactured goods and the specific peculiarities of each country's official statistics. This problem does not at all exist in the aggregative approach.

(ii) The existence of transport, insurance, information, and other transactions costs, together with trade restrictions, and of changes in these elements, implies that conventional disaggregative testing (as well as the aggregate-level testing carried out by Kravis and Lipsey 1978) is too severe on the law of one price.[2] Testing the null hypothesis of unity for the common-currency domestic/foreign price ratio of a commodity biases the finding in favor of rejecting the law. Rather, each of the end points, or "commodity points," delimited by the transactions costs and trade restrictions or their changes and within which the law of one price is valid, must be the subject of the null hypothesis. This procedure has not been followed in any testing to date. The problem itself does not even arise in the aggregate-level testing of the present study, as the "null hypothesis" is tested not directly but only indirectly.

(iii) Those authors that regress the domestic country's price index on the foreign price index and the exchange rate as separate independent variables are probably committing a specification error. The reasons why there might be a different response to a change in the one rather than the other explanatory variable are quite subsidiary to the main issue of the law of one price (see Crouhy-Veyrac et al. 1982, pp. 331–332), Empirically, Crouhy-Veyrac and others (1982) find that decomposing the explanatory variable worsens their regressions considerably. These arguments and findings suggest that the negative results of Curtis (1971), Bordo and Choudhri (1976), Kravis and Lipsey (1977), and Richardson (1978) are all suspect, as these authors specify a decomposition of the explanatory variable.

6.1.4 A Model of PPP and the Tradable/Nontradable Price Ratio

6.1.4.1 Derivation of PPP/Exchange-Rate Relationship

In this section a model is developed to test the law of one price in a way quite different from the traditional approach. The totality of production, or gross domestic product (GDP), is divided into two categories, tradables and nontradables, for both a domestic country (i) and a base country (b). The purchasing power parity, or relative price levels, of the countries is defined in terms of the prices of tradables and nontradables:

$$\mathrm{PPP}^i \equiv \frac{\mathrm{WT}^i \cdot \mathrm{PT}^i + \mathrm{WN}^i \cdot \mathrm{PN}^i}{\mathrm{WT}^b \cdot \mathrm{PT}^b + \mathrm{WN}^b \cdot \mathrm{PN}^b} \tag{6.1}$$

where

$$\mathrm{WT}^j + \mathrm{WN}^j \equiv 1 \quad j = i, b \tag{6.2}$$

with the following notation:

PPP^i = purchasing power parity for country i, no. of units of i's currency per unit of base currency
PT^j = price level of tradables in country j, with a weight of WT^j in the overall price level; $j = i, b$
PN^j = price level of nontradables in country j, with a weight of WN^j in the overall price level; $j = i, b$
R^i = exchange rate for country i's currency, no. of units of i's currency per unit of base currency.

PPP theory suggests that a country's own production pattern is the optimal weighting scheme for its price level, and the country-specific weights in Eq. (6.1) reflect this fact.[3] Each country's price level is a weighted average of commodity prices in the country, with own-country production (expenditure) weights.

At the adopted level of aggregation the law of one price for tradables is:

$$\mathrm{R}^i = \mathrm{PT}^i / \mathrm{PT}^b \tag{6.3}$$

Combining Eqs. (6.1) and (6.3), one obtains:

$$\mathrm{PPP}^i \big/ R^i \equiv \frac{\mathrm{WT}^i + \mathrm{WN}^i \cdot \left(\mathrm{PN}^i \big/ \mathrm{PT}^i\right)}{\mathrm{WT}^b + \mathrm{WN}^b \cdot \left(\mathrm{PN}^b \big/ \mathrm{PT}^b\right)} \tag{6.4}$$

subject, of course, to Eq. (6.2). Equation (6.4) then involves the purchasing power parity, the exchange rate, the nontradable/tradable price ratio in the two countries ($\mathrm{PN}^i/\mathrm{PT}^i$ and $\mathrm{PN}^b/\mathrm{PT}^b$), and the weight of tradables in the countries' respective price levels.

6.1.4.2 Generation of Estimable Equation

Thus far the analysis has dealt with a single time period. The problem with Eq. (6.4), therefore, is that the two nontradable/tradable price variables are ratios of price levels rather than of period-to-period indexes and therefore are nonobservable; nor have such data been constructed except in normalized form, rendering them useless for Eq. (6.4) (see, for example, Kravis et al. 1982, pp. 193–196). For an estimable equation, one can have this nonobservable variable just for the base country; for there is only one such country, while i ranges over N domestic countries, with N the sample size.

The unknown $\mathrm{PN}^i/\mathrm{PT}^i$ is eliminated by considering two time periods, a "current period," t, and "base period," o, respectively subscripting variables as such, rearranging Eq. (6.4), and taking the ratio of the equations in the two periods. Then, after considerable algebraic manipulation, one obtains:

$$\left(\mathrm{PPP}^i/R^t\right)_t = \frac{A^i + B^i \cdot \beta}{C^i + D^i \cdot \beta}, \tag{6.5}$$

where

$$A^i \equiv \left(\mathrm{WT}^i/\mathrm{WN}^i\right)_t + I^i\left[\left(\mathrm{PPP}^i/R^i\right)_o\left(\mathrm{WT}^b/\mathrm{WN}^i\right)_o - \left(\mathrm{WT}^i/\mathrm{WN}^i\right)_o\right],$$

$$B^i \equiv \left(I^i/I^b\right)\left(\mathrm{PPP}^i/R^i\right)_o\left(\mathrm{WN}^b/\mathrm{WN}^i\right)_o,$$

$$C^i \equiv \left(\mathrm{WT}^b/\mathrm{WN}^i\right)_t,$$

$$D^i \equiv \left(\mathrm{WN}^b/\mathrm{WN}^i\right)_t,$$

$$I^j \equiv (\mathrm{PN}/\mathrm{PT})_t^j/(\mathrm{PN}/\mathrm{PT})_0^j \quad j = i, b,$$

$$\beta \equiv (\mathrm{PN}/\mathrm{PT})_t^b.$$

Noting that the I^j variables are ratios of period-to-period nontradable/tradable price ratios (or, equivalently, ratios of a nontradable price index to a tradable price index), these variables are observable or, more precisely, calculable. In fact, data can be obtained for all variables in Eq. (6.5) with the exception of $\left(\mathrm{PN}/\mathrm{PT}\right)_t^b$, or β, the nontradable/tradable price ratio in the base country. The first test of the law of one price is now apparent. One specifies an error structure for Eq. (6.5), a base country, b, and a current period, t, and assembles data to construct the variables A^i, B^i, C^i, D^i, I^i, l^b for a sample of N domestic countries, that is, $i = 1, \ldots, N$.[4] The parameter β is then estimated econometrically from this observation matrix. Assuming that the law of one price for tradables [Eq. (6.3)] holds, this parameter is the ratio of the price level of nontradables to that of tradables. If its estimate is not significantly different from unity, while significantly different from zero, then tradables and nontradables for a given country (or at least for the base country) are good substitutes; it could not be rejected that a law of one price for tradables widens to a law of one price for commodities generally.

The second test of the law of one price is of the equality of the price of tradables across countries, that is, whether Eq. (6.3) holds empirically. The technique is to drop Eq. (6.3) from the model, thus permitting a comparison of results including versus excluding the law of one price for tradables.

6.1.4.3 *Limitations of PPP Concept*

The testing procedure thus described, while devoid of the limitations of the disaggregative approach, is not without its costs. In order to obtain an estimable Eq. (6.5), PPP had to be defined in an unconventional way and in two respects. The weights for the countries' price levels are not only country-specific but also expenditure rather than quantity based. While the own-country weighting is justified in terms of PPP theory, the two weighting properties together imply that purchasing power parity, the countries' relative price levels [Eq. (6.1)], is not a true price index in the sense that it can be re-expressed as a meaningful function of price relatives. It is possible, therefore, that PPP as defined is sensitive to a change in the unit of measurement of a commodity. Fortunately, it is arguable that the problem is not serious, in part because it is legitimate to impose the base country's unit of measurement in the base period on all countries and both periods. Then a proportionate change in measurement units across all commodities would not affect the PPPs. Also, the PPPs are now single-valued, though only with respect to the customary measurement units of the base country. The extent of residual ambiguities in the PPP concept would be an empirical question, but one that is irrelevant for this study. The reason is that PPPs defined as in Eq. (6.1) are unobservable and resort must be had to conventional PPPs that are normal price indexes.

Similar limitations apply to the ratio of the price level of nontradables to that of tradables within a country, and hence to testing for equality of the prices of tradables and nontradables. In this case, the issue is resolved through the ratio appearing only as an estimable parameter in the model.

6.1.5 The Sample

6.1.5.1 Selection of PPP Measure

With PPP defined as in Eq. (6.1) unavailable, Irving Fisher's ideal index number is selected as the PPP measure. As the geometric mean of the Laspeyres (base-country-weighted) and Paasche (domestic-country-weighted) indexes, the Fisher index has the property of "equi-characteristicity," that is, equal consideration is given to the weighting pattern of each country. In contrast, the Laspeyres and Paasche indexes each have the well-known bias of a relatively lower price level for the country whose weights are used. Looked at another way, Eq. (6.1) defines the price level for each country in terms of its own weighting pattern. The Laspeyres and Paasche indexes each satisfy this criterion for one country and contradict it for the other; the logical compromise is Fisher's ideal index.

6.1.5.2 Selection of PN/PT Measure

Consider Eq. (6.1), which defines the overall price level for each country as a weighted average of its tradable and nontradable components, PT and PN, respectively. What better measure of the overall price level could there be than the GDP price level, which aggregates the prices of all domestic production, that is, the total of tradable and nontradable output, with weights proportional to domestic output of tradables and nontradables, respectively? Switching to index numbers, the GDP deflator, PGDP, is the same weighted average of price-index equivalents of PT and PN. Since PGDP is constructed as the ratio of current-priced to constant-priced aggregate output (GDP), the price deflators for tradable and nontradable output—denoted as $\hat{\text{P}}\text{T}$ and $\hat{\text{P}}\text{N}$, respectively—are obtained along the same lines, with the output of tradables (nontradables) defined as that part of GDP originating in the tradable (nontradable) sector of the economy. It remains only to allocate industries to the tradable and nontradable sectors. The tradable sector is taken to consist of (1) agriculture, hunting, forestry, and fishing, (2) mining and quarrying, and (3) manufacturing, while the nontradable sector is composed of all other industries in which GDP originates.[5] Then the nontradable/tradable price-index ratio, I^J, is $\hat{P}N / \hat{P}T$.[6] This variable provides an obvious and logically compatible nontradable/tradable weighting pattern (WN, WT), namely, the proportion of constant-priced output originating in the (nontradable, tradable) sector.

6.1.5.3 Selection of Sample

The sample size is delimited by the availability of two sets of data: PPP measures (to construct the PPP/*R* variables) and output by industry of origin (to construct the $\hat{P}N / \hat{P}T$ variables). Available data on economy-wide PPP indexes are most extensive for the United States as the country of comparison; so it is the logical choice for base country. Restricting the search for PPP data to those at an economy-wide level (GDP, GNP, and NNP, in that order of preference) and that are Fisher indexes with the United States as the common base country, 1975 is the year ("current year") for which by far the largest number of data points, at 34, is obtainable. Of these countries, eighteen have at least one other year (a "base year") of PPP data satisfying the above criteria, while four fulfill the criteria in all respects except one: the foreign country against which comparison is made is not the United States. These four remain in the sample by obtaining the base-year PPP via a linking process (see data appendix). The other twelve countries are dropped from the sample, and two further countries are eliminated because of a lack of availability of tradable/nontradable data to construct the $\hat{P}N / \hat{P}T$ variable, resulting in a final sample size of twenty.

Several countries in the sample have more than one base year for which both the PPP and tradable/nontradable data are available. A unique base year is obtained by selecting the one furthest in the past, in order to provide a maximum time span over which to test the law of one price. The resulting 20-country sample is summarized in Part A of Table 6.1, with the country, base year, and value of the PPP/*R* variable in base and current periods shown in the first four columns.

Table 6.1 PPP/R data and residuals from its estimates

Country	*Base year*	*PPP/R*		*Residuals*[b]		
		Current year[a]	*Base year*	*Equation*	*PGDP method*	*Naive model*
A. Sample size of 20						
U.K	1950	0.8627	0.7114	0.0199	0.1498	−0.1513
Belgium	1955	1.1469	0.8182	−0.1368	0.0962	−0.3287
Denmark	1950	1.2909	0.7117	−0.3477	0.2357	−0.5793
France	1950	1.1028	0.7545	−0.1041	0.0022	−0.3483
Germany	1950	1.1706	0.7318	−0.2609	0.3517	−0.4388
Italy	1950	0.8657	0.6980	0.0830	0.2063	−0.1677
Netherlands	1970	1.1811	0.7770	−0.1437	0.0828	−0.4041
Hungary	1967	0.6041	0.7453	0.1009	0.0150	0.1412
Poland	1965	0.7716	0.7333	0.0090	−0.1444	−0.0383
Japan	1967	0.9364	0.6544	−0.0436	0.0219	−0.2819
Brazil	1968	0.6642	0.5124	−0.0195	−0.0853	−0.1518
Colombia	1970	0.4054	0.4392	0.2040	0.0442	0.0337
Mexico	1968	0.5736	0.4884	0.0545	0.0519	−0.0852
Uruguay	1968	0.5485	0.3957	0.0031	−0.0407	−0.1528
Iran	1970	0.6660	0.4779	−0.0130	0.2968	−0.1882
Kenya	1967	0.5519	0.5502	0.1283	0.0166	−0.0017
India	1967	0.3364	0.3609	0.0875	0.0146	0.0245
Korea	1970	0.4537	0.5635	0.3052	0.1686	0.1098
Philippines	1970	0.4383	0.4013	0.1456	0.0378	−0.0370
Thailand	1963	0.4510	0.2489	−0.0717	−0.1798	−0.2021
B. Sample size of 2						
Norway	1950	0.7858	0.6825	−0.0302	0.0012	−0.1033
Canada	1950	0.9072	0.8476	0.0324	−0.0139	−0.0597

[a]Year of predicted PPP/*R*. 1975 for all countries in 20-country sample; 1955 for Norway and 1965 for Canada
[b]Estimated *minus* actual PPP/*R*

6.1.6 Test of Equality of Prices of Tradables and Nontradables

6.1.6.1 Estimation Technique

All variables in Eq. (6.5) are observable, with the exception of $(\text{PN}/\text{PT})_t^b$ the price-level ratio in the base country in the current period, that is, the parameter β. Assuming an additive error term that is independently and identically distributed for all observations, nonlinear least-squares is an appropriate method, providing a consistent and asymptotically normally distributed estimate of β, and this is the technique adopted.[7]

Table 6.2 Estimates of regression equation

Equation number	$\hat{\alpha}$	$\hat{\beta}$	*Correlation coefficient*[a]	*Log-likelihood ratio*[b]
1	0.17 (4.59)	0.84 (3.96)	0.89	43.69
2	–	1.24 (2.47)	0.86	35.88

[a]Correlation of actual and fitted dependent variable
[b]Restriction $\beta = 0$

6.1.6.2 *Estimation of Equation (6.5)*

Because the countries composing the sample do not have a common base period, a better fit of Eq. (6.5) could be obtained by including a constant term, α, and the resulting regression is presented as Equation number 1 in Table 6.2, where $\hat{\alpha}$ and $\hat{\beta}$ are the nonlinear least-squares estimates of α and β, respectively, with their t-values in parentheses. Now, $\hat{\beta}$ is the estimate of $(\mathrm{PN}/\mathrm{PT})_t^b$, the nontradable/tradable price-level ratio in the United States in 1975. According to two statistics—the t-test (with values 3.96 and -0.74) and the log-likelihood-ratio test (with values 43.69 and 0.48)—β is both significantly different from zero at extremely low levels of significance (less than one tenth of one percent) and not significantly different from unity at extremely high levels of significance (above 40%). Furthermore, the point estimate of β, at 0.84, is itself not far away from unity. Therefore one cannot reject the hypothesis that the price levels of tradables and nontradables were equal for the United States in 1975.

Division of $\hat{\beta} = 0.84$, the estimated U.S. nontradable/tradable price-level ratio in 1975, by the corresponding U.S. price-index ratio, I^{b}, for "base periods" at five-year intervals between 1950 and 1980 yields a time series of the U.S. nontradable/tradable price-level ratio, PN/PT, as shown in the second column of Table 6.3. While historically PN/PT has been rising, by 1970–1980 it stabilized not far from unity.

6.1.6.3 *Performance of Equation Outside of Sample*

There are two countries, Norway and Canada, for which appropriate PPP data, while not available for 1975, exist for two or more other years.[8] The requisite tradable/nontradable data are also available, resulting in a two-country sample outside the original sample and exhibited in Part B of Table 6.1 (first four columns). It would be inappropriate to use Equation number 1 to predict "current-period" PPP/R for Norway and

Table 6.3 Time series of U.S. nontradable/tradable price-level ratio

Year	*Based on*	
	Equation 6.1	*Equation 6.2*
1950	0.63	0.93
1955	0.67	0.98
1960	0.69	1.02
1965	0.77	1.13
1970	0.85	1.25
1975	0.84	1.24
1980	0.84	1.23

Canada in 1955 and 1965, respectively (their current periods), because that regression has a constant term predicated on the current year 1975 and a specific conglomeration of base years. The better procedure is to drop the constant and re-estimate the equation, with the result exhibited as Equation number 2 in Table 6.2. Applying the U.S. nontradable/tradable price-index ratio, l^b, to $\hat{\beta} = 1.24$, as was done above for $\hat{\beta} = 0.84$, one obtains another time series of the U.S. absolute price-level ratio, PN/PT, as shown in the third column of Table 6.3. Plugging in the appropriate values of A^i, B^i, C^i, D^i, l^i, I^b for i = (Norway, Canada), t = (1955, 1965), and o = (1950, 1950), where $\hat{\beta}$ = (0.98, 1.13), the result is the predicted PPP/R in period t via the equation. The forecast error (difference between the estimated and actual PPP/R) is shown in column 5 of Table 6.1 (last two rows, for Norway and Canada). The absolute error amounts to only 3.84% of the true PPP/R for Norway and 3.57% for Canada.

6.1.7 Test of Equality of Prices of Tradables Across Countries

6.1.7.1 Motivation of Test Procedure

The law of one price for tradables is tested by considering Eq. (6.5) as forecasting the dependent variable $(\text{PPP}^i/R^i)_t$, the PPP/exchange-rate ratio for the domestic country in 1975. As Eq. (6.5) embodies the law of one price [Eq. (6.3)], an alternative predictor of $(\text{PPP}^i/R^i)_t$ is obtained by dropping Eq. (6.3) from the model. If the estimates from the two predictors—the first of which does, the second of which does not incorporate the law of one price—are sufficiently close, then the law of one price cannot be rejected. As an indicator of closeness, a third predictor of $(\text{PPP}^i/R^i)_t$ is developed, based on a naive model. For the law of one price to be supported, Eq. (6.5)'s prediction of PPP/R must be close to the estimate of the model excluding Eq. (6.3) but far from the prediction of the naive model.

*6.1.7.2 Alternative Methods of Predicting PPP/*R

Equation (6.5) is interpreted as predicting the PPP/R ratio in period t given the ratio in period o and subject to the law of one price, Eq. (6.3), holding in both periods. To set up a test of the law of one price, Eq. (6.3) is dropped but the rest of the model retained. Consider the GDP deflator defined in terms of the prices of tradables and nontradables:

$$\text{PGDP}_t^j \equiv \frac{\text{WT}_t^j \cdot \text{PT}_t^j + \text{WN}_t^j \cdot \text{PN}_t^j}{\text{WT}_t^j \cdot \text{PT}_o^j + \text{WN}_t^j \cdot \text{PN}_o^j} \quad j = i, b \tag{6.6}$$

where

$\text{PGDP}^j{}_t$ = GDP deflator for country j in period t relative to period o $j = i, b$

Then $\text{PPP}^i{}_t$ may be approximated by

$$\left(\text{PGDP}_t^i/\text{PGDP}_t^b\right) \cdot \text{PPP}_o^i \tag{6.7}$$

and $(\text{PPP}^i/R^i)_t$ estimated as

$$\left[\left(\text{PGDP}_t^i/\text{PGDP}_t^b\right) \cdot \text{PPP}_o^i\right]/R_t^i \tag{6.8}$$

Note that, as the GDP deflator is a current-weighted price index, expressions (6.7) and (6.8) are only approximations to $\text{PPP}^i{}_t$ and $(\text{PPP}^i/R^i)_t$, respectively. Were the denominator of the right-hand side of Eq. (6.6) to involve $(\text{WT}^j{}_o, \text{WN}^j{}_o)$ in place of $(\text{WT}^j{}_t, \text{WN}^j{}_t)$, then (6.7) and (6.8) would be identically equal to $\text{PPP}^i{}_t$ and $(\text{PPP}^i/R^i)_t$.

This approach to estimation of the PPP/R ratio in period t may be called the "PGDP" method in opposition to the "equation" method, based on Eq. (6.5). The PGDP method is used to obtain predictions of PPP/R in the current period for each of the twenty countries in the original sample and the two countries in the second sample. Defining the residual as the difference between the estimated and actual PPP/R, this error is listed for the equation method (that is, the estimates via Equation numbers 1 and 2 (in Table 6.2) for the twenty-country and two-country samples, respectively) and the PGDP technique in columns 5 and 6, respectively, of Table 6.1. Which method could be expected a priori to lead to the better forecast? To answer the question, consider the various sources of error.

(i) According to Eq. (6.1), the price levels composing PPP are to be defined with country-specific weights. Instead, a compromise measure, the Fisher index, is used. This substitution applies to both techniques.

(ii) Several data problems also affect both approaches. Since the GDP deflator is obtained in practice as the ratio of current-priced to constant-priced GDP, any change in the base period of the constant-priced series (even though corrected via linking on the basis of an overlap) will disturb the PGDP series and therefore the PGDP-method prediction. So will a switch to a new system of national accounts not carried back to base period o. The same data problems apply to the equation method, however, because crucial to the method is the computation of tradables and nontradables "deflators" using national-accounts data. Further, the PPP and PGDP series may not be comparable conceptually; but again the same caveat applies to the PPP and nontradable/tradable price-index series.

(iii) The PGDP method assumes that the weights (WT, WN) for the current period apply also to the base period. The equation method allows for differences in the (WT, WN) weights in the two periods. This is an advantage of the equation approach only if the tradable/nontradable division of output that it adopts is sufficiently consonant with reality.

(iv) As a direct result of imposing the law of one price, the equation technique explicitly incorporates the nontradable/tradable price-index ratio in the domestic and base countries. Nothing is gained in prediction by this complication. There is an unnecessary complexity in the equation's forecast compared to the PGDP predictor. On the average, one would expect such complexity to bring about a greater magnitude of forecast error.

Table 6.4 Average errors from estimates of PPP/*R*

Sample size	*Percent of mean true PPP/R*					
	Average of absolute errors			*Average of squared errors*		
	Equation method	*PGDP method*	*Naive model*	*Equation method*	*PGDP method*	*Naive model*
20	15.19	14.93	25.74	2.98	2.97	8.11
2	3.70	0.89	9.63	0.12	0.01	0.84

Interestingly, the equation method has the smaller residual (in absolute value) for as many as 8 of the 22 forecasts, as shown in columns 5 and 6 of Table 6.1. The comparison is suggestive that the law of one price cannot be rejected. The conclusion is reinforced by computation of the average absolute errors and average squared errors (each expressed as a percentage of the mean true PPP/*R*) in Table 6.4. For the twenty-country sample, the error level is relatively high and the equation technique has average error extremely close to the PGDP method. For the two-country sample, the gap between the errors is wider, but the level of the errors is much smaller. So the errors resulting from the two methods appear to be quite close. Still, "how close is close?"

6.1.7.3 Comparison with Naive Model

Consider yet a third method of estimating $(\mathrm{PPP}^i/R^i)_t$—a naive model that ignores all price changes between the base and current period and predicts PPP_t by PPP_o, thus estimating $(\mathrm{PPP}^i/R^i)_t$ as $\mathrm{PPP}^i{}_o/R^i{}_t$.

The residuals from the naive model are listed in the final column of Table 6.1 and the resulting average errors presented in Table 6.4 along with those of the other two techniques. On the average, for each sample, the residuals rank as follows (and as expected) in absolute value (smallest first): PGDP method, equation method, naive model. For each average-error measure (absolute and squared) and each sample, define an "error-difference ratio" as follows:

(Equation-Method Error *minus* PGDP-Method Error)/(Naive-Model Error *minus* Equation-Method Error).

Table 6.5 Error-difference ratios

Sample size	*Based on*			
	Absolute errors		*Squared errors*	
	Ratio	*Inverse*	*Ratio*	*Inverse*
20	0.02	40.58	0.002	513.00
2	0.47	2.11	0.15	6.55

This ratio provides a heuristic test of the law of one price. If its value is unity, the equation average residual is equidistant between those of the other two techniques, providing neither positive nor negative evidence for the law of one price. If the ratio exceeds unity, this has a negative implication for the law of one price. Below unity, the law of one price is supported. The lower the value of the ratio, the greater the evidence for the law of one price. Taking the inverse of the ratio, the significance of deviations from unity is reversed. Now the higher the ratio (providing it is above unity), the more support there is for the law.

Table 6.5 presents the error-difference ratios and their inverses. While the test itself has no statistical significance, the ratios are sufficiently far below unity (or, the inverse ratios sufficiently far above unity)—especially for the twenty-country sample—that the following conclusion can reasonably be drawn: the law of one price cannot be rejected on the basis of the evidence presented in this study.

6.1.8 Validity of Tradable/Nontradable Distinction

If the allocation of goods into the tradable and nontradable sectors is largely arbitrary, then the evidence in favor of the law of one price becomes suspect. Suppose that the tradable/nontradable distinction involves little more than a random allocation of commodities into the two sectors. The implication for the finding that prices of tradables and nontradables are equal is that, with each sector receiving a random allocation of goods, of course their price levels would be approximately the same. However, the result that prices of tradables are equal across countries is supportive of the law of one price even if the tradable sector is composed of a random group of commodities.

For the law of one price to be extended from tradables to all commodities, then, one must demonstrate that the tradable/nontradable distinction made in Sect. 6.1.5 has firm empirical foundation. Prior investigations have provided such support via the following results. First, based on input–output data, the ratios of both imports and exports to domestic sales are substantially higher for the tradable than the nontradable sector. Second, cross-country correlations of inflation rates or price indexes are higher for tradables than nontradables. Third, import price indexes are more highly correlated with price indexes of tradables than of nontradables. Fourth, as explanatory variables in a formal model of import demand, the price index of nontradables is uniformly nonsignificant whereas that of tradables is significant in a majority of cases. (See Goldstein and Officer 1979, pp. 421–422; Goldstein et al. 1980, pp. 193–196.).

To supplement these previous investigations, a test based specifically on the model of the present study is appropriate. Perhaps the most serious deficiency of the adopted (or indeed any) tradable/nontradable dichotomy is that the level of aggregation of existing data may be too high to permit a clear classification of industries into one sector or the other. In allocating a full industry to the category in which the preponderance of its sub-industries belongs, some of its output inevitably becomes included in the wrong sector. The most obvious example is services, which, while allocated totally to the nontradable sector, clearly have a tradable component, as the balance-of-payments table for any country shows.

Letting the export of services as a percentage of the production of nontradables represent the "tradable component" of the nontradable sector, are the prediction errors of Eq. (6.5) correlated with this component? If so, then the tradable/nontradable distinction is incorrect and Eq. (6.5) misspecified, calling into question the favorable findings for the law of one price based on this equation and reported in Sects. 6.1.6 and 6.1.7.

The following regression equation was estimated cross-sectionally over seventeen domestic countries (with Hungary, Poland, and Iran excluded due to data limitations):

$$\underset{}{Y} = \underset{(1.78)}{0.08} + \underset{(1.11)}{0.0056\mathrm{X}} \quad \overline{R}^2 = 0.01,$$

where

Υ = absolute value of residuals from Eq. (6.5) estimated as Equation number 1, listed in column 5 of Table 6.1
X = percentage of nontradables output that is exported, average of base year and 1975.

If services are illegitimately excluded from the tradable sector, then the slope of the regression should be significantly positive. Though positive, the slope is nonsignificant and the explanatory power of the regression is poor. The evidence, therefore, is that services are properly classified as nontradables, given a tradable/nontradable dichotomy.

6.1.9 Concluding Comments

Conventional testing of the law of one price involves considerable disaggregation of commodities, and modelling not going beyond linear regression in sophistication. Results of this approach are decidedly unfavorable to the law of one price once products have any element of differentiation.

In this paper a novel technique was introduced. The law of one price was tested using a breakdown of commodities at an aggregation no lower than that of tradables versus nontradables. Using the tradable/nontradable dichotomy, a model was developed that tested the law both domestically (that the prices of tradables and nontradables are equal) and internationally (that the price of tradables is identical across countries). In both cases the law of one price received strong support.

The positive results of the aggregative approach of this paper contrast with the negative findings of the disaggregative technique. While each approach has its own limitations, no study has found the weaknesses of the disaggregative framework to be unimportant, and there is reason to believe that the biases of this framework are unfavorable to the law of one price. In contrast, the present study demonstrates that the limitations of the aggregative approach do not affect its positive findings for the law of one price.

Appendix: The Data

1. Purchasing Power Parities—The only measures accepted were those based on direct price comparisons or on extrapolations of such measures via detailed extrapolations of components of GDP (rather than simple extrapolation via GDP deflators). Data

sources (by year) are as follows. 1975: Kravis and others (1982); 1950 (except Canada) and 1955: Gilbert and associates (1958); 1970: Kravis and others (1978); 1967:Kravis and others (1975); 1965 (Poland): Wiles (1971); 1950 and 1965 (Canada):Walters (1968); 1968 (Brazil, Mexico, Uruguay): Salazar-Carrillo (1978), with Colombia as base country, converted to United States as base via Colombia/U.S. 1968/1970 GDP deflator applied to Colombia/U.S. 1970 PPP; 1963 (Thailand): Usher (1968), with United Kingdom as base country, converted to United States as base via U.K./U.S. 1963/1967 GDP deflator applied to U.K./U.S. PPP for 1967.

2. Exchange Rates—International Monetary Fund (1980 and 1982 Yearbooks), series *af* (inverse of *ah* for United Kingdom) preferred, otherwise series *rf*. Poland and Hungary: *Pick's Currency Yearbook*, various issues; Poland: "effective official rate;" Hungary: "capitalistic tourist/noncommercial rate" (daily average computed for 1975).
3. Tradable/Nontradable Data—OECD (various issues); United Nations (various issues). Where segments of series are non- comparable, the earlier segment is linked to the later using a conversion ratio calculated from the earliest year of overlap.
4. GDP Deflator—International Monetary Fund (*Supplement on Price Statistics, 1981*). Hungary and Poland: United Nations (various issues).
5. Exports—Goods-and-services combined: International Monetary-Fund (1980 Yearbook), line 90c. Italy: 1950 obtained from OECD, *Statistics of National Accounts 1950–1961* on basis of overlap. Goods: International Monetary Fund (1980 Yearbook), line 70. Uruguay: line 70, d—in dollars, converted to domestic currency using exchange rate *rf*. India: International Monetary Fund (March 1971 and April 1979)—to obtain data for year beginning April 1, consistent with PPP, tradable/nontradable, and goods and services exports data. Services: Obtained by subtraction.

Notes

1. The thirteen studies are Bordo and Choudhri (1976), Curtis (1971), Dunn (1970, 1973), Isard (1977a, b), Kravis and Lipsey (1971, 1977, 1978), Norman (1975), Ormerod (1980), Richardson (1978), and Ripley (1974).

2. A similar point, with the exclusion of information costs, is made by Crouhy-Veyrac and others (1982).
3. It can be argued that a unit-factor-cost concept is the most appropriate methodology for PPP (Houthakker 1962, pp. 293–294). Now, under certain assumptions, a unit-factor-cost concept of PPP is equivalent to a PPP based on price levels that are a production-weighted average of commodity prices in each country (Houthakker 1962, p. 296; Officer 1974, pp. 871–872; 1976a, pp. 11–12; 1978, p. 564).
4. Of course, error terms are best incorporated structurally, i.e., included in Eqs. (6.3) and (6.4) and thence in Eq. (6.5). This pure procedure is not followed here for mathematical simplicity and because the estimation technique adopted is not thereby affected (see Sect. 6.1.6). Note also that for the parameter β to be estimable from the data, all observations must have the same current period, though their base periods can differ.
5. These industries are electricity, gas, and water; construction; wholesale and retail trade; restaurants and hotels; transportation, storage, and communication; finance, insurance, real estate, and business services; government services; and other producers of services.
6. For a thorough development of this measure, a discussion of its limitations, and empirical testing of the appropriateness of the $\hat{P}T$, $\hat{P}N$ series in general and the tradable/nontradable industry breakdown in particular, see Goldstein and Officer (1979) and Goldstein, Khan, and Officer (1980). The present study is not the first in which the $\hat{P}T$ and $\hat{P}N$ variables are elements in econometric testing (as distinct from being the subject of such testing). Predecessors are Officer (1976b), Goldstein and Officer (1979), Goldstein, Khan, and Officer (1980), and Stone (1982).
7. See Judge and others (1980, pp. 725–727). For curve-fitting purposes, it is acceptable to define the "error" simply as the difference between the left-hand and right-hand sides of Eq. (6.5), thereby justifying nonlinear least-squares. If one wished to obtain the additional, maximum-likelihood, properties of asymptotic unbiasedness, asymptotic efficiency, and sufficiency, then not only must a specific distribution of any error term be imposed but also the errors must enter Eq. (6.5) via Eqs. (6.3) and (6.4) structurally. The maximum-likelihood estimate would become quite complex.
8. For Canada, several years of PPP estimates are available, and the "base" and "current" years are chosen so as to maximize the intervening time period.

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