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Abstract

Factor price equality across countries is an important implication of the Heckscher-Ohlin-Samuelson model of international trade. Although an influential theoretical result, the model has received surprisingly little empirical support. Burgman and Geppert (1993) argue that this might be due to the neglect of the non- stationarity property of the time series under consideration. Using a cointegration approach, they find strong evidence pointing towards a long-run relationship between factor prices in six major industrialized countries. The present paper shows, however, that there is only limited evidence of cointegration once the finite sample bias is taken into account. Moreover, there is only weak evidence of a significant cointegrating relationship when real (rather than nominal) labor cost data are used. There is some indication of long-run co-movements of real factor prices when using the statistically more powerful bivariate tests rather than a multivariate framework.

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1. Introduction

Factor price equality across countries with sufficiently similar factor endowments is an important implication of the Heckscher-Ohlin-Samuelson model of international trade. The *Factor Price Equality theorem* states that countries producing the same product mix with similar technologies and the same product prices must have the same factor prices for the same factors. While factor prices might differ between countries that find themselves within different *cones of diversification*, they should be the same when factor endowments are such that all countries select the same range of goods to produce (Leamer 1995). Even though the factor price equalization theorem only holds under a relatively strong set of assumptions, the theorem (as well as the underlying Heckscher-Ohlin-Samuelson model) has shaped economists' beliefs regarding the interaction of free trade and factor markets since the late 1940s. The empirical evidence in support of the factor prices equalization theorem, however, remains surprisingly ambiguous even for the highly integrated markets of OECD countries (see e.g. Davis et al. 1997). Bernard et al. (2001) have recently provided evidence that absolute factor price equalization does not hold between different US regions, i.e. that "the US contains multiple cones of diversification" (ibid., p. 2).

There are two explanations for the failure of the empirical literature to provide evidence in support of the factor price equalization predictions of the Heckscher-Ohlin-Samuelson model. One reason could be that the *assumptions* underlying the result are not met empirically. For instance, Rayp (1998) finds no evidence for a long-term trade equilibrium between France, Belgium, and the Netherlands using intra-German data as a benchmark. Since existence of such an equilibrium is a pre-condition for factor price equalization, this finding is interpreted as proof against the Heckscher-Ohlin-Samuelson argument.[1] A second

[1] However, the rejection of a particular assumption in its pure form might not be sufficient to reject the prediction that factor prices tend to equalize over time – in particular among highly integrated economies. For

possible explanation of the lack for empirical evidence is given in Burgman and Geppert (1993). They point out that much of the empirical literature so far has neglected the non-stationarity property of the time series under consideration. Indeed, using a cointegration approach more suitable for non-stationary, integrated time series, Burgman and Geppert (1993) find strong evidence pointing towards a long-run relationship between unit labor costs in the six major industrialized countries Canada, France, Germany, Japan, Great Britain, and the U.S. In particular, they report existence of four stationary cointegrating relationships between the unit labor costs of these countries. This finding is interpreted as evidence in favor of the Heckscher-Ohlin-Samuelson model. They conclude that "wages across the six countries studied are closely tied together, as predicted by factor price equalization." (ibid., p. 484).

So has the empirical failure of the factor price equalization theorem been overcome? The present paper reconsiders the results of the Burgman and Geppert (1993) under two aspects. First, Burgman and Geppert's (1993) sample covers only 40 annual observations from 1950 to 1989. As pointed out by the authors, their empirical results are therefore subject to finite sample bias, which is prevalent in small samples and when the number of variables is relatively large. Using the finite sample bias corrections developed by Cheung and Lai (1993, 1995) we find much weaker evidence for non-stationarity and cointegration in the unit labor costs of the six countries under analysis.[2] This is also true in our extended data set covering the period 1950-1998. Second, Burgman and Geppert (1993) rely on nominal unit labor cost data, converted into U.S. dollars, rather than real data in national currencies. However, this approach may not be appropriate when there are frequent deviations of exchange rates from purchasing power parities and the law of one price does not hold. In this paper we use both nominal and real data and contrast the results.

instance, Kemp and Okawa (1997) show that under certain conditions, factor price equalization might prevail even in the presence of imperfect competition.

In the following, we show that controlling for the finite sample bias, using real data, and working with series denominated in national currency there is only very limited evidence for factor price equalization. We find, however, that there is some indication of long-run co-movements of real factor prices on the bilateral level. In this sense our paper can be interpreted as reconciling the more supportive results of Burgman and Geppert (1993) with the more critical findings of Rayp (1998).

The paper is organized as follows. Section 2 will present preliminary analysis of the data, while section 3 discusses formal stationarity tests. The main part of the paper is section 4, which encompasses a test of co-integration. Section 5 concludes.

2. Preliminary analysis

All data are provided by the U.S. Bureau of Labor Statistics. This includes nominal unit labor costs denominated in U.S. dollars and in national currencies as well as the consumption price indices. The data set includes six countries (Canada, France, Germany, Japan, Great Britain, and the U.S.) and annual observations covering the period 1950 to 1998.

[Figures 1 and 2 about here]

Figure 1 shows the *nominal* unit labor costs converted into *U.S. dollars* using purchasing power parities for the six countries in our sample between 1950 and 1998. This is the data used by Burgman and Geppert (1993), except that our data set includes eight additional observations 1990-98 for each country. At first glance, Figure 1 suggests that the nominal time series are indeed highly correlated with each other. There are, however, two potential problems with this interpretation.

[2] As the paper of Cheung and Lai appeared in the same year as the one by Burgman and Geppert, a computationally easy finite sample adjustment procedure was not available to them.

First, as already hinted in the previous section, using unit labor cost converted to a *common currency* based on purchasing power parities might not be appropriate when actual exchange rates deviate from these parities. More importantly, when the test for factor prize equalization takes the special form of a test for cointegration or co-movement of time series rather than convergence of levels, it might also be superfluous. In fact, one of the advantages of the time series approach is that it avoids the complications associated with a comparison of levels across countries. Second, using nominal rather than real data might not be appropriate. It is worthwhile recalling that the concept of factor price equalizations (and thus, by extension, the concept of factor price co-movements) is one defined in real rather than nominal terms. The Heckscher-Ohlin-Samuelson model implies that the capital-labor ratios and therefore real productivity and real factor prices are equalized across countries.[3]

Taking into account both arguments, Figure 2 presents the six times series in *real* terms based on national currency. Empirically, real unit labor costs can be computed from the time series in national currency and the respective consumer price indices. The changes caused by switching from nominal to real figures are quite dramatic. Visual inspection suggests that some of the series are closer to being stationary than non-stationary. This would imply that these time series are not suitable for a cointegration exercise. The overall picture is also less suggestive of strong co-movements in the time series. In the following, the preliminary visual impression will be tested formally.

3. Unit root tests

The concept of cointegration implies that the non-stationary component of a wage series is common across countries. A first step in the procedure is therefore to test for a unit root in each individual series. If a series does not have a unit root, the concept of cointegration

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[3] An extension to the equality of nominal factor prices requires purchasing power parity to hold perfectly.

becomes meaningless. We employ the augmented Dickey and Fuller (ADF) test, which allows for both an intercept and a time trend, to determine whether there is a unit root in the data series.

Let X_{it} be the unit labor cost index of country i (with i = Canada, France, Germany, Japan, the U.K., and the U.S.) at time t. The ADF test is based on the regression equation:

$$\Delta X_{it} = \mu_0 + \mu_1 t + \alpha X_{it-1} + \beta_1 \Delta X_{it-1} + \ldots + \beta_p \Delta X_{it-p} + \varepsilon_t \,, \qquad (1)$$

where Δ is the first difference operator and $\varepsilon_t \sim iid(0,ó_\varepsilon^2)$ is an error term. The Akaike information criterion (AIC) is used to determine p, the lag parameter. Results of applying the ADF test to the data are shown in Table 1.

[Table 1 about here]

As we are dealing with a limited data set of annual data, drawing inference from the test statistics needs to take into consideration the *finite sample properties* of the estimator. With only 48 data points we need to adjust the asymptotic critical values tabulated by Dickey and Fuller (1979). Using the critical values suggested by Cheung and Lai (1995), we find that we cannot reject the null hypothesis of a unit root in any country for the nominal wages series either measured in national currency units or in U.S. dollars. Despite the small-sample correction, the latter result is in line with the finding reported in Burgman and Geppert (1993, Table 1). In the real series, however, we reject the null of a unit root in the case of Germany and Japan. These two countries are therefore excluded from the subsequent cointegration exercise based on real unit labor costs.

4. Cointegration tests

In order to test for the presence of a common long term trend in the wage dynamics we employ the Johansen (1991) procedure. Our test follows closely the work by Burgman and

Geppert (1993), which first applied the Johansen method to unit labor cost data. Again we have to correct for the finite sample size when drawing inference. A second issue is that, in this case, the finite sample problem is magnified by the fact that we are applying a multivariate test and thus have more parameters to estimate. The largest system estimated has 6 variables and only 48 numbers of observation (or 47 effective numbers of observation). A third problem is that the number of lags included in the testing procedure reduces the efficiency of the estimation. Cheung and Lai (1993) suggest the following scaling factor to be applied to the asymptotic critical values, which takes account of the three points raised above:

$$SF = \frac{T}{T - nk}, \tag{2}$$

where SF denotes scaling factor, T is the sample size, n is the number of variables and k is the number of lags. In the case of the six dimensional system, 48 observations and two lags, as suggested by the AIC and Schwarz information criterion (SIC), the asymptotic critical values thus need to be higher by a factor of 1.34 – a quite substantial increase, given the close decision commonly made in cointegration exercises. The estimation results of the Eigenvalue as well as the Maximum Eigenvalue (Max. Eig.) and Trace statistics are reported in Table 2.

[Table 2 about here]

If we were *not* to take account of the finite sample bias, the left-hand side of the table would provide evidence comparable to that reported by Burgman and Geppert (1993). Based on *asymptotic* critical values and on our somewhat extended sample period, we would find three cointegrating vectors.[4] However, if we apply the *finite sample* adjustment, only one of the cointegrating vectors is significant (see Table 2).[5] Both asymptotic and finite sample

[4] Note that the results are somewhat different as our sample contains eight more years of observations. Restricting the sample to the period 1950-89 and not correcting for the finite sample bias, we can exactly reproduce the Burgman and Geppert (1993) result of four cointegrating vectors.
[5] The same is true for the series expressed in the national currency units (not reported, available on request).

critical values are reported in the appendix. The result stresses the importance of controlling for limitations in the size of the data set used for cointegration tests as pointed out by Burgman and Geppert (1993). More importantly, it questions the claim that the movements of nominal unit labor costs in the six major industrialized economies are very much in line. In fact, only one cointegrating vector suggests that there are five common long run trends, driving the unit labor cost series in the long run – a quite diverse dynamic behavior. The coefficient estimates for the cointegrating vestors (with the US-coefficient standardized to one) as well as the standard α coefficients are reported in the lower half of the table. The latter are usually interpreted as the average speed of adjustment back toward the cointegrating vector after a deviation.[6]

As argued in the preceding section, a test of factor price equalization is more adequately based on real, rather than on nominal data. Turning to real labor unit costs, however, we find more reason to doubt that the predictions of the Heckscher-Ohlin-Samuelson model hold. Based on conventional levels of significance, there is only one cointegrating vector in the real time series and thus three common long run trends (see column three in Table 2).[7] This is true for *both* the asymptotic and finite sample critical values. The results are less favorable for factor price equalization than with nominal data, since under asymptotic critical values with nominal data there were three significant vectors (see above). Regarding the results based on finite sample critical values, note that the level of significance is fairly low compared to the nominal result reported above. If we were to raise the statistical threshold to the more conservative 2.5 percent level, as some authors suggest (Osterwald-Lenum 1992, Cheung and Lai 1993), we could not reject the null hypothesis of *no*

[6] Despite the difference in sample length, these results are broadly comparable with the ones reported by Burgman and Geppert (1993).
[7] Recall that, in the real labor cost series, the null of a unit root was rejected in the case of Germany and Japan (see Table 1). The remaining sample consists of Canada, France, Great Britain, and the US.

cointegration in the four non-stationary times series at all.[8] In other words, there is indeed very little evidence of significant co-movement in real labor costs across the major industrialized economies in our sample.

[Table 3 about here]

Is the case for factor price equalization therefore now closed? A possible way to counter the above conclusion is to exploit the efficiency gains of moving to bivariate systems. While this approach loses information contained in the multivariate procedure, it partly resolves the issue of the small power of the multivariate cointegration test. Table 3 presents the cointegration test statistics for the six bivariate country pairs in the four country sample of (non-stationary) real unit labor costs. Out of six, only two do not allow rejection of the null hypothesis when the finite sample bias is controlled for.[9] In particular, we find evidence in favor of real unit labor cost equalization between the U.S. and Canada and (somewhat less strong) between the U.S. and France. Overall, the small number of significant country pairs supports the findings of the multilateral model. One a more speculative note, one is tempted to add that the statistically stronger finding of cointegration between the U.S. and Canada could equally be due to the relatively higher degree of factor mobility between these two North-American countries.

5. Conclusions

Absolute factor price equalization across countries is a key prediction of the Heckscher-Ohlin-Samuleson model of international trade, one of the more influential "workhorse" models in economics. Despite its theoretical might, the factor price equalization hypothesis has received surprisingly little empirical support. In an important exception to the rule,

[8] The one cointegrating vector found in the nominal series is significant even at the one percent level.
[9] Both cointegrating vectors are significant at the one percent level.

Burgman and Geppert (1993) argue that this might be due to the neglect of the non-stationarity of the time series under consideration. And indeed, applying a cointegration approach to (nominal) unit labor costs in six major industrialized countries (Canada, France, Germany, Japan, Great Britain, and the U.S.), they find evidence of long-run factor price co-movement. This finding can be interpreted as being in line with equalization of factor prices amongst these countries.

The present paper, however, finds that there is only very limited evidence of cointegration once the finite sample bias is taken into account. Moreover, only weak significant cointegration remains when real instead of nominal labor cost data are used. This is partially due to the fact that not all real labor cost series are non-stationary and thus suitable for a cointegration exercise. There is, however, somewhat stronger indication of longer-run co-movement of real factor prices on the bilateral level (for instance, between the U.S. and Canada).

While the majority of results presented here are clearly not in line with factor price equalization, future research could find it useful to consider more closely *bilateral (real) factor price movements*. A more systematic identification of country pairs or regions might also allow a better discrimination between goods and factor movements as possible determinants of such co-movements. Another area for future research has been pointed out by Bernard et al. (2001), who suggest looking at *relative factor price equality* instead of absolute equality. Integrating such a set-up into the co-integration approach followed in the present paper – while not a trivial task – would, in principle, increase the test’s robustness with regard to unobserved regional differences in productivity, factor quality, and technology. All in all, the search for empirical evidence for the Heckscher-Ohlin-Samuleson model remains a promising field for further research.

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Appendix

Asymptotic and finite sample critical values

	Trace Statistic		Max. Eig. Statistic	
	ACV	FSCV	ACV	FSCV
n-r = 6	82.49	110.70	36.36	48.72
n-r = 5	59.46	75.51	30.04	38.15
n-r = 4	39.89	48.06	23.80	28.67
n-r = 3	24.31	27.85	17.89	20.50
n-r = 2	12.53	13.70	11.44	12.50
n-r = 1	3.84	3.91	3.84	3.91

Note: FSCV according to Cheung and Lai (1993) are contrasted to the ACV by Osterwald-Lenum (1992) for a system with 6 variables, 2 lags and 47 effective observations.

Figure 1: Nominal unit labor cost in U.S. dollars (standardized)

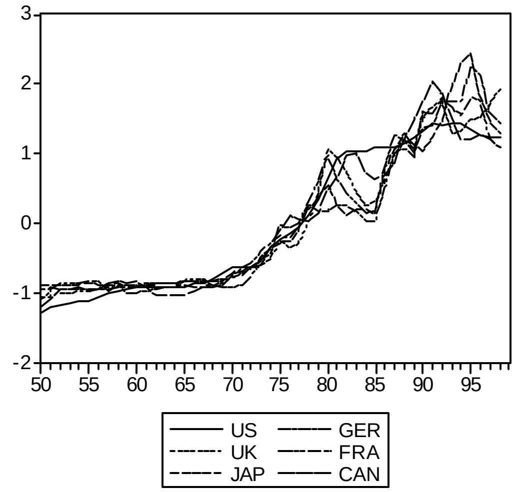

Figure 2: Real unit labor cost in national currency units (standardized)

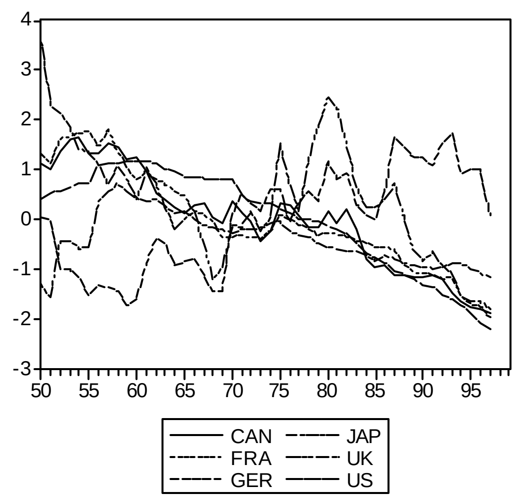

Table 1: Unit Root Test Results

	Nominal (U.S.$)		Real (n.c.)	
	Test Stat.	P-value	Test Stat.	P-value
CAN	-1.75	(0.75)	-3.22	(0.09)
FRA	-2.77	(0.22)	-1.38	(0.88)
GER	-2.32	(0.45)	-3.98 +	(0.01)
JAP	-2.80	(0.21)	-3.86 +	(0.02)
UK	-2.15	(0.55)	-1.02	(0.94)
USA	-2.28	(0.47)	-1.27	(0.90)

Note: The lag parameters were set to two lags. Qualitatively there are no differences for the range of 1-4 lags. The significance of the statistics is evaluated according to the finite sample critical values (FSCV) reported in Cheung and Lai (1995). "+" indicates significance at the five percent level, given FSCVs. P-values are reported in parenthesis. The unit root hypothesis is rejected for their first differences of the series in all cases.

Table 2. Cointegration Test Results (multivariate)

H(0)	Nominal (U.S.$)			Real (n.c.)		
	Eigenvalue	Max. Eig.	Trace Stat.	Eigenvalue	Max. Eig.	Trace Stat.
r = 0	0.69	71.85* +	152.00* +	0.57	34.66* +	52.51* +
r 1	0.63	35.83*	80.15*	0.33	12.00	17.85
r 2	0.39	24.83*	44.31*	0.25	5.78	5.58
r 3	0.28	10.23	19.48	0.03	0.06	0.06
r 4	0.19	6.33	9.25			
r 5	0.00	2.91	2.91			

Cointegrating vectors and α matrices:

	USA	UK	FRA	CAN	JAP	GER
Vector (nominal)	1	2.50	-0.062	-3.126	3.187	-3.312
α	-0.215	0.720	0.197	-0.016	0.701	0.539
Vector (real)	1	1.772	0.545	-0.772		
α	-0.034	0.146	0.009	0.163		

Note: The Eigenvalue, the Maximum Eigenvalue (Max. Eig.) Statistic, and the Trace Statistic are computed from the multivariate system consisting of the six and four countries. We only include time series that display a unit root. Two lags are selected as the optimal lag structure by both the AIC and SIC criterion. "*" indicates significance at the five percent level according to *asymptotic* critical values (ACV) and "+" denotes significance at the five percent level according to FSCV. Finite sample critical values are computed as suggested by Cheung and Lai (1993) (see appendix).

Table 3. Cointegration Test Results (bivariate)

	H(0)	Eigenvalue	Max. Eig.	Trace Stat.
USA/CAN	r = 0	0.50	30.76* +	31.20* +
	r 1	0.01	0.43	0.43
USA/FRA	r = 0	0.39	22.41* +	22.76* +
	r 1	0.01	0.35	0.35
USA/UK	r = 0	0.14	7.11	9.30
	r 1	0.04	2.19	2.19
UK/CAN	r = 0	0.13	6.30	7.75
	r 1	0.03	1.44	1.44
UK/FRA	r = 0	0.13	6.81	6.91
	r 1	0.00	0.09	0.09
CAN/FRA	r = 0	0.19	9.59	9.71
	r 1	0.00	0.12	0.12

Cointegrating vectors and α matrices:

	USA	CAN	USA	FRA
Vector	1	-1.95	1	-2.09
α	-0.112	0.163	-0.114	0.086

Note: The Eigenvalue, the Maximum Eigenvalue (Max. Eig.) Statistic, and the Trace Statistic are computed from the multivariate system consisting of the six and four countries. We only include time series that display a unit root. Two lags are selected as the optimal lag structure by both the AIC and SIC criterion. “*” indicates significance at the five percent level according to ACV and “+” denotes significance at the five percent level according to FSCV. Finite sample critical values are computed as suggested by Cheung and Lai (1993) (see appendix).