The Behaviour of Relative Prices in the European Union: A Sectoral Analysis*

Natalie Chen†
ECARES, Université Libre de Bruxelles

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Abstract

Using multivariate unit root test methods, this paper investigates the Purchasing Power Parity (PPP) hypothesis at the sectoral level across six European countries over the last seventeen years. Evidence of mean reversion toward PPP is found for the relative prices of some sectors and countries. Mean reversion in relative prices is explained by cross-country and cross-sectoral characteristics such as the distance between countries, non-tariff barriers, research and development, advertising and industrial concentration. Nominal exchange rate volatility does not have any significant effect on mean reversion in relative prices.

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†ECARES, Université Libre de Bruxelles - CP139 - 50, av. FD Roosevelt, 1050, Brussels, Belgium, tel: 32-2-650.38.60, fax: 32-2-650.40.12, e-mail: nchen@ulb.ac.be, http://www.ecares.org/

1 Introduction

The comparison of prices across countries is one of several possible ways of investigating the extent of market integration. In particular, the finding that the prices of similar goods, expressed in a common currency, fail to equalize between locations, is an indication that the markets are not perfectly integrated.

Various factors are usually identified as preventing the prices of similar products to be equal across countries. Among these are the geographical separation of markets and differences in consumer tastes or in product quality. On the one hand, countries are more likely to trade with neighbours because transportation costs are lower, thus facilitating arbitrage, but on the other hand, crossing borders may become expensive because of the existence of tariffs and trade restrictions. However, arbitrage, which is expected to favour price convergence between locations, is only possible if consumers are both willing and able to transfer their demand between suppliers of different countries. This ability to engage in arbitrage is mainly a function of its cost and of the existence of regulatory barriers, whereas the willingness to engage in arbitrage depends upon the preferences of consumers and the perceived quality of the products.

The effect of nominal exchange rates is also to be stressed. If the prices of goods are sticky in local currencies (which is usually the case), a highly volatile nominal exchange rate between two countries will produce highly volatile relative prices of similar goods across the two same countries. Finally, from a microeconomic, market structure, perspective, the discriminatory pricing behaviour of firms with market power is another potential source of price dispersion.

The case study of the European Union is of particular interest because price differentials are usually expected to be small between Member States. First, this is because they are located close to each other and they have succeeded in dismantling many restrictions on trade, allowing arbitrage to become more efficient; the situation has been further improved with the implementation of the Single Market Programme (SMP), launched in the mid-1980s.

Second, since March 1979, European Member States chose to stabilize their exchange rates by participating in the Exchange Rate Mechanism (ERM) of the European Monetary System (EMS). Under this system, nominal exchange rates remain fixed within a narrow band, but with potential for periodic adjustment or realignment. The recent introduction of Monetary Union, which includes a common currency, the Euro, will increase price transparency and should therefore further influence the behaviour of cross-country prices. The comparison of prices across borders will become easier, allowing for lower price dispersion between countries, and transaction costs related to making purchases abroad will also be significantly reduced.

On the whole, the benefits of the SMP, through the removal of non-tariff barriers, the establishment of Monetary Union and the introduction of the Euro, should decrease the cost of cross-border trade within the European Union and hence facilitate arbitrage activities.

Focusing on six European countries, this analysis is based on industrial prices, disaggregated at the sectoral level, between January 1981 and December 1997. The paper addresses three key questions. Over the period in question, what is the extent of market integration reached by these European countries? Are there any significant differences in the behaviour of prices across industrial sectors? Finally, what is the relative importance of the various factors, identified above, in explaining the behaviour of prices across countries and sectors?

The analysis is undertaken in two stages. First, the objective is to investigate the behaviour of industrial prices across these European countries. The failure of the Law Of One Price (LOOP) and of the Purchasing Power Parity (PPP) theoretical concepts is usually recognized as evidence that markets are not completely integrated. Testing for the empirical validity of these concepts closely relates to investigating the presence of unit roots in relative prices. If the unit root hypothesis can be rejected, relative prices are mean reverting and PPP is said to hold in the long run. Drawing on recent literature on PPP, unit root tests are implemented over panel data, and the presence of serial and cross-sectional correlations between relative price series is carefully taken into account. In addition, using disaggregated data at the sectoral level and considering all possible country pairs in the sample, the present paper allows the estimated speeds of mean reversion to be different across industrial sectors and countries.

The second part of the analysis uses the results obtained from these multivariate unit root estimations to investigate the relative importance of various elements which may explain mean reversion of relative prices, across sectors and countries. On the one hand, the analysis considers country type variables such as nominal exchange rate volatility and the geographical separation of markets (measured by both the distance between locations and the presence of a common border). On the other hand, the role of sectoral characteristics such as the extent of vertical differentiation (which characterizes the nature of competition), the degree of industrial concentration (which reflects potential market power) and the existence of non-tariff barriers, is also taken into account.

The paper is organized as follows: section 2 reviews the basic concepts of the LOOP and PPP literature as well as some of the most relevant empirical results obtained in this research area; section 3 describes the data and provides some summary statistics; the econometric methodology implemented in order to test for unit roots in panel data is formalized in section 4 where our results are also examined; section 5 is devoted to determine the importance of various elements in explaining mean reversion in relative prices across sectors and countries, and section 6 summarizes and concludes.

2 Framework

We begin by reviewing the main theoretical concepts used in the literature in order to analyse the price behaviour of a given good or basket of goods in different markets. Some of the most relevant empirical results obtained in this area are also explored.

Denote by $p_t(k)$ and $p_t^*(k)$ the (logarithm of) price of good k at time-t in domestic and foreign currency respectively and by e_t the (logarithm of) domestic price of foreign currency (nominal exchange rate). The Law Of One Price (LOOP) states that, in integrated markets,

$$p_t(k) = p_t^*(k) + e_t \tag{1}$$

should hold for any good k. This concept relies upon a simple arbitrage argument which suggests that, abstracting from tariffs and transportation costs, trade in goods should allow prices, expressed in a common currency, to equalize across countries. If the LOOP holds for any single good, then it should also hold for baskets of identical goods. However, even if the LOOP is not confirmed for each individual good, it could still be valid for a basket of goods since the individual deviations from the LOOP could compensate each other in the basket.

The Purchasing Power Parity (PPP), which is a generalization of the LOOP, states that once converted to a common currency, national price levels should be identical. There are two common versions of PPP. *Absolute* PPP requires:

$$p_t = p_t^* + e_t \tag{2}$$

where p_t and p_t^* respectively denote the (logarithm of) domestic and foreign aggregate price level at time-t. *Relative* PPP only requires the rate of growth in the exchange rate to compensate the differential between the rates of growth in prices:

$$\Delta p_t = \Delta p_t^* + \Delta e_t \tag{3}$$

where Δ is the difference operator. Empirical PPP and LOOP studies[1] are however subject to a number of data problems. First, it is usually impossible to select identical goods across countries: many items produced in a country often do not have near-perfect substitutes in the other countries. Second, aggregate price indices, such as consumer or wholesale price indices, are conceptually similar across countries but may nevertheless be calculated differently. In addition, when looking at time series there is the problem of introducing new goods in the basket, which implies changing the relative weights of the components of the basket. Finally, since the only data generally available are in the form of price indices relative to a base-year, nothing can be inferred about the validity of the LOOP or of the PPP for that particular year. As a consequence, most researchers prefer to rely on the relative, rather than on the absolute version, of PPP because it allows for a constant price differential across countries.

The starting point for most empirical studies is the real exchange rate which is the nominal exchange rate deflated by the ratio of national prices. The (logarithm of) real exchange rate, denoted q_t, is:

$$q_t = p_t^* + e_t - p_t \tag{4}$$

and is a measure of the deviations from PPP. It is acknowledged today that short run deviations from PPP are usually large and volatile. Therefore, recent studies investigate the validity of this concept in the long run. One way to test for long run – relative – PPP is to determine whether the hypothesis of a unit root in the real exchange rate q_t can be rejected. Univariate unit root methods rely on Dickey-Fuller tests, based on the regression:

$$\Delta q_t = \alpha + \beta q_{t-1} + \varepsilon_t \tag{5}$$

[1] For a recent survey of the literature, see Froot and Rogoff (1995) and Rogoff (1996).

where α and β are parameters and ε_t is a disturbance term. The null hypothesis, $\beta = 0$, implies that q_t contains a unit root (the deviations from PPP are permanent) whereas the alternative, $\beta < 0$, indicates that there is mean reversion in q_t and hence that PPP holds in the long run (the deviations from PPP are temporary, so there is a tendency for the real exchange rate to revert to its mean value). Under the alternative, β can be interpreted as the rate of decay of deviations from PPP per time period, and allows to calculate the corresponding half-life which represents the expected number of time periods for these deviations to decay by 50%. The closer β is to zero, the longer the estimated half-life of a shock. Consensus estimates put this half-life between three and five years among industrialized countries, emphasizing the slow speed of reversion (persistence) of relative prices.

A large body of the early literature was unable to find evidence against the unit root hypothesis. This is because unit root tests are characterized by low statistical power to reject the null hypothesis in small samples, making it difficult to distinguish between a unit root and a stationary series mean reverting very slowly. Recently, some studies tried to circumvent the problem by looking at very long horizon data sets, but this approach is often criticized because it neglects the effects of a possible structural change in real exchange rates between fixed (before the Bretton Woods collapse) and floating rate periods. Engel (2000) also argues that when a random variable evolves according to the sum of two processes (a stationary but persistent component and a non-stationary component), unit root tests are incorrectly sized when implemented over long horizon data sets.

Another way to increase the power of unit root tests is to introduce cross-section variation in the data, involving the use of panel samples in which the real exchange rates of various countries are all computed with respect to a benchmark country. Since Levin and Lin (1992) first introduced unit root tests applicable to panel data under the assumption of i.i.d. disturbances, there has been an increasing interest in testing for long run PPP by panel data methods[2]. Drawing on the work of Abuaf and Jorion (1990), O'Connell (1998) however shows that the limiting distributions derived by Levin and

[2]Among others, Abuaf and Jorion (1990), Wei and Parsley (1995), Frankel and Rose (1996), Jorion and Sweeney (1996), Cumby (1996), Papell (1997), Taylor and Sarno (1998), Papell and Theodoridis (1998), Flôres, Jorion, Preumont and Szafarz (1999), Wu and Wu (1998), Cheung, Chinn and Fujii (1999) and Cecchetti, Mark and Sonora (2000) find evidence of PPP whereas Engel, Hendrickson and Rogers (1997) and O'Connell (1998) do not.

Lin (1992) are not appropriate because they ignore the additional information which is contained in the contemporaneous correlations between real exchange rates. Indeed, in panel samples, real exchange rates are correlated by construction because they share two common components: the nominal exchange rate and the price index of the benchmark country. Generalizing the Levin and Lin (1992) model to control for contemporaneous correlations in the panel, O'Connell (1998) shows that it is still possible to implement powerful panel unit root tests. Flôres, Jorion, Preumont and Szafarz (1999) lend support to the utility of exploiting cross-correlations in multivariate tests, but also demonstrate that power can be further increased by allowing the mean reversion coefficient to differ across countries in the panel. Finally, Papell (1997) argues that ignoring serial correlation in real exchange rates may also distort the results.

If the empirical validity of the PPP and LOOP hypotheses is very instructive in assessing the extent of market integration between countries, the aim of providing some explanation as to the outcomes should also trigger any economist's curiosity. In particular, the purpose of another strand of the literature is to explain the deviations from the LOOP. Using the price indices of disaggregated consumer goods in various countries and cities, Engel and Rogers (1996, 1998, 2000) show that nominal exchange rate volatility has a great power in explaining the failures of the LOOP, reflecting the importance of nominal price stickiness. Distance (which is a proxy for the cost of arbitrage activities) also contributes to price dispersion. One of their main findings is the role of the border as an additional contributor to cross-country price dispersion because, maintaining both distance and the nominal exchange rate constant, price differentials appear to be stronger between two cities when they are separated by a national border (see also Wei and Parsley (1995, 1996, 1999)).

Finally, some other researchers have arrived to a better understanding of the sources of persistence in the deviations from PPP. Convergence toward PPP is shown to be faster between locations that are closer together (Campa and Wolf (1997) and Cecchetti, Mark and Sonora (2000)). Campa and Wolf (1997) also show that a larger market size accelerates the rate of PPP reversion, but surprisingly, they also find that greater bilateral trade leads to slower reversion, contradicting the goods-arbitrage based view of long run PPP. This result is however not isolated since Cheung, Chinn and Fujii (1999) report that the more open an economy is to international trade, the more persistent is its real exchange rate. These authors also highlight that nominal exchange rate volatility, as well as an imperfectly competitive market structure, play a significant role in explaining the persistence of sectoral PPP deviations.

3 The Data and Descriptive Statistics

Researchers are faced with a dilemma concerning the nature of the price index to use in their empirical work. Consumer price indices usually contain a non-traded goods component because of the retailing services that bring the goods to the market (shipping costs, insurance during the transport, taxes, distribution etc). Some researchers argue that these consumer indices are appropriate because they include the prices of goods which are relevant to the typical consumer. However, it is also thought that the existence of this non-traded component may explain the frequent rejection of the PPP hypothesis, so other researchers prefer to use producer or wholesale price indices which cover a higher proportion of tradeable goods.

The data used in this study were obtained from Eurostat, the Statistical Office of the European Union. In order to minimize the role of non-traded components, and hence to abstract from the Balassa-Samuelson effect, domestic output price indices (for industrial sectors), in Ecu, are chosen for the analysis. Most existing studies usually use aggregate, national level price data[3]. In this paper, price indices are disaggregated at the 3-digit Nace rev.1 level[4] for most European countries between January 1981 and December 1997, giving 204 monthly observations. All price indices are equal to 100 in June 1995. Monthly bilateral exchange rates are end of period values.

We excluded from the analysis countries with an insufficient number of observations. The data for six remaining countries, Germany, Belgium, France, Italy, Spain and the Netherlands, allow to construct a balanced panel sample including 17 sectors.

For a given month t and a given sector k, relative prices, denoted $q_{ijk,t}$, are computed as the (logarithm of) ratio of the price index $p_{ik,t}$ of each country i to the price index $p_{jk,t}$ of country j $(i \neq j)$. That is, $q_{ijk,t} = \ln(\frac{p_{ik,t}}{p_{jk,t}})$, where

[3]Exceptions are Canzoneri, Cumby and Diba (1999), Wei and Parsley (1995, 1996), Cheung, Chinn and Fujii (1999) and Fleissig and Strauss (2000) who use disaggregated data at the sectoral level.

[4]Nace rev.1 is the General Industrial Classification of Economic Activities within the European Union.

$p_{ik,t}$ and $p_{jk,t}$ are both expressed in Ecu.

Table 1 contains summary statistics. We measure volatility by the standard deviation of a series between February 1981 and December 1997. The top line of the table reports, for all country pairs (with 6 countries, there are $6\binom{5}{2} = 15$ different country pairs), the volatility of nominal exchange rates, $vol_{ij} = std(\Delta \ln(e_{ij,t}))$ where $e_{ij,t}$ is the bilateral exchange rate between countries i and j. On the whole, nominal exchange rates do not appear to be strongly volatile. The lowest volatilities over the period are obtained between Germany, the Netherlands, France and Belgium, with Germany and the Netherlands displaying the lowest one (equal to 0.296%). The standard deviations of the nominal exchange rates for Spain, and then for Italy (with respect to other countries), are somewhat higher, with the strongest one being obtained between Spain and Italy (equal to 1.97%). However, in contrast to Germany, France, Belgium and the Netherlands, which participated in the ERM during the whole period under consideration, Spain only joined the ERM in June 1989 and Italy's participation was suspended in September 1992.

The next rows contain the volatility, over the same period, of relative prices $q_{ijk,t}$ for all sectors and country pairs, that is $std(\Delta q_{ijk,t})$. Despite the large differences in the degree of volatility of relative prices across sectors, nominal exchange rate volatility seems to account for some of the behaviour of relative prices across countries. For instance, whatever the sector considered, relative prices are systematically more volatile between Spain and the Netherlands than between the Netherlands and Germany. This reflects, to a certain extent, stickiness in nominal prices.

Besides, the relative prices for some particular sectors, whatever the country considered, are systematically more volatile compared to other ones (compare for instance textiles (17.4) and computers (30.0)). This is an indication that not only are country-type factors required to explain the behaviour of prices, but that the role of sectoral characteristics is also important.

4 Testing for Unit Roots

The first part of this section describes the econometric methodology implemented to test for the presence of unit roots in panel samples of relative prices computed for various country pairs and sectors. In most studies, the joint null hypothesis states that all the series considered in the panel are unit root processes. Consequently, non rejection of the null does not tell anything about whether some of these series are in fact stationary. In this paper, the tests allow the speed of mean reversion to differ across industries and country pairs, allowing us to determine whether the unit root hypothesis can be separately rejected for each of the series. These tests are thus not panel unit root tests in the conventional sense (where the speed of mean reversion is restricted to being the same for all series in the panel), but is instead more akin to a seemingly unrelated regressions (SUR) approach. In addition, in order to further increase the power of the test the existence of both serial and contemporaneous correlations is carefully taken into account by the procedure. The results are examined in the second part of this section.

4.1 Methodology

Most multivariate unit root test studies usually compute relative prices with respect to a benchmark country (one exception is Engel, Hendrickson and Rogers (1997)). However, extending the sample to all possible country pairs allows a much larger country dimension[5]. But, as shown by Engel *et al.* (1997), when including all country pairs and estimating different speeds of reversion, there is no simple univariate representation for each of the relative price series. In particular, it can be shown that the right way to model the vector of relative prices is not to model each element as a function of lags only of itself, but to write each variable as a function of its own lags and the lags of the other variables. But in that case, the notion of unit roots and speeds of convergence is ambiguous.

Besides, since we do not constrain the mean reversion coefficients to be the same across series, the only cross-equation restriction used here is the contemporaneous cross-correlation of the residuals. However, the cost of doing such a joint estimation is that a huge variance-covariance matrix has to be estimated. In our case, with 15 country pairs and 17 sectors, there would be 255 equations and $255\left(\frac{254}{2}\right) = 32.385$ off-diagonal elements to estimate. The difficulty of getting precise estimates of these many terms may therefore outweigh the potential gain in power to be obtained from pooling.

[5]Many studies find that PPP holds better when the German mark (or more generally, European currencies), rather than the US dollar, is used as the benchmark (Wei and Parsley (1995), Jorion and Sweeney (1996), Papell (1997), Papell and Theodoridis (1998) and Wu and Wu (1998) among others). This problem is avoided here since all possible country pairs are considered.

In this paper, the tests are therefore implemented over country pair specific samples in which sectors are all pooled together. In that case, each sample only has 17 series (17 sectors), and the cross-correlations for a given country pair are higher[6]. This approach also prevents us from modelling each relative price series as a function of its own lags and of the lags of the other series, facilitating the interpretation of the estimated mean reversion coefficients.

The following econometric procedure is applied to each of the 15 country pair samples each including 17 sectors. A multivariate unit root test, which allows for different speeds of mean reversion for each of the relative price series, is specified as:

$$\Delta q_{k,t} = \alpha_k + \beta_k q_{k,t-1} + \varepsilon_{k,t} \tag{6}$$

where, for each of the 15 country pair samples, $q_{k,t}$ is the relative price of sector k, $k = 1, ..., K$, $t = 1, ..., T$ where K and T respectively denote the total number of sectors (17) and time periods (203), and $\varepsilon_{k,t}$ is a disturbance term. For simplicity, the country pair indices ij are now omitted. The sector specific constants α_k are included in the regression because price indices, rather than absolute price levels, are used to carry out the test. For $k = 1, ..., K$ and $t = 1, ..., T$, the null (the relative price series $q_{k,t}$ is a unit root process) and alternative hypotheses are formalized as:

$$H_0 \;:\; \Delta q_{k,t} = \varepsilon_{k,t} \tag{7}$$

$$H_1 \;:\; \Delta q_{k,t} = \alpha_k + \beta_k q_{k,t-1} + \varepsilon_{k,t} \tag{8}$$

In (8), the β_k's are the mean reversion parameters and $\beta_k < 0$.

As already mentioned, it is important to control for the existence of contemporaneous correlation within each panel. The exploitation of the information contained in these correlations (together with the estimation of different speeds of mean reversion) should therefore allow to increase the power of the test. Consequently, Seemingly Unrelated Regressions (SUR) are implemented for estimation.

First, in order to control for serial correlation in the disturbance terms under the null, each of the $\varepsilon_{k,t}$'s in the panel are fitted by autoregressive AR(p) models where p, the optimal number of lags, is selected using the Schwartz criterion. That is:

$$\varepsilon_{k,t} = \phi_{1,k}\varepsilon_{k,t-1} + ... + \phi_{p,k}\varepsilon_{k,t-p} + \nu_{k,t} \tag{9}$$

[6]We thank an anonymous referee for that suggestion.

for each $k = 1, ..., K$, $t = 1, ..., T$ and where the $\{\phi_{n,k}\}_{n=1}^{p}$ are the estimated lag coefficients[7]. Equation (9) can similarly be written as $\phi_k(L)\,\varepsilon_{k,t} = \nu_{k,t}$. The variance-covariance matrix Ω is then computed from the K series of residuals $\nu_{k,t}$, that is $\Omega = E(\nu_{k,t}\nu'_{k,t})$ and is of dimension $[K \times K]$. Note that O'Connell (1998) considers the disturbance terms to be generated, under the null, by a restricted VAR(p) process where the serial correlation properties of all the series in the panel are assumed to be identical. However, our finding of different lag lengths (and estimated coefficients) across the relative price series in each panel provides little support for such a restriction.

Having estimated the serial and cross-sectional correlation properties of the $\varepsilon_{k,t}$'s under the null, the dependent and explanatory variables in equation (6), $\Delta q_{k,t}$ and $q_{k,t-1}$, are each transformed by their corresponding lag polynomial $\phi_k(L)$ to produce some new series denoted $\Delta q^*_{k,t}$ and $q^*_{k,t-1}$. These transformed variables $\Delta q^*_{k,t}$ and $q^*_{k,t-1}$ are then simply replaced in equation (6) which, together with the variance-covariance matrix Ω, is estimated by SUR to yield the mean reversion parameters $\hat{\beta}_k$ and their corresponding test statistics $t_{\beta_k} = \hat{\beta}_k/\sigma_{\beta_k}$, where σ_{β_k} is the standard error for the estimate of β_k. For each panel sample, there are K (17) parameters β_k to be estimated.

Because the standard Dickey-Fuller tables do not apply in this multivariate context, the critical values of the distribution of the test statistics t_{β_k}, for each sector k in the panel, are tabulated by parametric bootstrap: for given values of K and T, 5000 panels of relative prices are generated under the null, all series indexed k being constrained to have the same serial ($\{\phi_{n,k}\}_{n=1}^{p}$) and cross-sectional (Ω) properties as the ones previously estimated from the data. The p-values corresponding to each of the estimated coefficients are also calculated.

4.2 The Results

The results from estimating equation (6) separately for each country pair are reported in table 2. Since the estimated coefficients are (mostly) negative, they should, a priori, be indicative of mean reversion.

When looking at the various p-values which report the significance level at which the unit root hypothesis can be rejected, the relative prices for some countries and sectors appear as stationary processes over the period.

[7]The comparison of the various AR(p) processes is done for values of p running from 0 to 36, corresponding to a period of three years with monthly data. The estimated lag lengths and coefficients (not reported) vary between one and nine months.

However, in order to determine the number of mean reverting series in each panel, size-adjusted critical values, as determined by the so-called Bonferroni bounds, are used. In this case, each test is conducted individually at the α/N level (where N is the number of tests, $N = 17$, and $\alpha = 10\%$) so that the set of N tests have a joint size not greater than α. For each country pair, the proportion of sectors for which relative prices are mean reverting toward PPP, before and after the use of these size-adjusted critical values, are reported in table 3:

Table 3 : Proportion of sectors converging toward PPP (%)

	France	Germany	Belgium	Netherlands	Italy	Spain
France	-	18 (6)	53 (12)	12 (6)	35 (0)	18 (0)
Germany	-	-	23 (12)	23 (12)	18 (0)	18 (0)
Belgium	-	-	-	29 (6)	35 (6)	23 (6)
Netherlands	-	-	-	-	6 (6)	18 (6)
Italy	-	-	-	-	-	18 (6)
Spain	-	-	-	-	-	-

Notes: For each country pair, the table reports the share of sectors for which the unit root hypothesis can be rejected at the 10% level, before and after (in brackets) the use of Bonferroni bounds.

Focusing on the results obtained with the Bonferroni bounds, Belgium and the Netherlands both display some evidence of mean reversion toward all the other countries considered. In addition, they exhibit the largest number of sectors for which the unit root hypothesis can be rejected. On the whole, the largest number of cases in which relative prices revert toward their mean are obtained between Germany, France, Belgium and the Netherlands. These countries were however expected to have already reached some degree of market integration over the period since they belong to the six countries[8] (the EU-6) which signed the Treaty of Rome in 1957, establishing the European Economic Community (EEC).

By contrast, for Italy and Spain there is relatively less evidence against the unit root hypothesis. This result could follow from the fact that the volatility of these countries' nominal exchange rates is stronger then the ones observed between Belgium, France, Germany or the Netherlands. However,

[8] The six founding countries of the EEC are Belgium, France, Germany, Italy, Luxemburg and the Netherlands.

since Italy also belongs to the EU-6, better results could have been expected for that country as compared to Spain which only joined the European Union in 1986.

Our results can also be compared to the trade intensity prevailing between these countries. For instance, the 1990 ratio of the sum of exports and imports to value added, in manufacturing industries, is equal to 1.41 between Germany and Belgium, 1.39 between Germany and the Netherlands and 1.14 between France and Belgium. In contrast, this ratio is only equal to 0.23, 0.21, 0.26 and 0.35 between France and Spain, Germany and Spain, France and Italy and Germany and Italy respectively. These findings mostly coincide with the ones obtained in terms of mean reversion: Germany, France, Belgium and the Netherlands, which trade intensively with each other, also display evidence of mean reversion, and are hence relatively integrated whereas Spain and Italy are in the opposite situation.

Our findings from a sectoral point of view are also interesting. In the cases of the relative prices for textiles (17.4), footwear (19.3), carpentry (20.3), wooden containers (20.4), paper and articles of paper (21.1 and 21.2), detergents (24.5), metals (27.4) and office machinery and computers (30.0), mean reversion is never reported for any of the country pairs. On the contrary, the sectors for which the unit root hypothesis is rejected are chemicals (24.1), paints (24.3), rubber (25.1), plastic (25.2), glass (26.1), bricks (26.4), cement and articles of cement (26.5 and 26.6).

We now turn to the analysis of the speed of convergence toward PPP which is based on the persistence parameters, the β_k's. Since the estimated serial correlation coefficients may be biased down (see Cecchetti *et al.* (2000)), we bias-adjust the β_k's estimates using the formula suggested by Nickell (1981). From these adjusted mean reversion coefficients denoted $\tilde{\beta}_k$, we then compute the adjusted half-lives of divergences from PPP which are given by $\ln(0.5)/\ln\left(1+\tilde{\beta}_k\right)$. Restricting to the cases for which the unit root hypothesis can be rejected at the 10% level (after the use of the Bonferroni bounds), the fastest move to mean reversion, corresponding to an adjusted half-life of four months, relates to the manufacture of plastic (25.2) between Belgium and Spain. In contrast, the slowest speed of mean reversion is obtained between Italy and Belgium for the manufacture of bricks (26.4) with an adjusted half-life of approximately 27 months (more than two years). These convergence rates toward PPP are therefore faster (and the half-lives shorter) than those usually recorded. For instance, Wei and Parsley (1995) show that, in the case of the EMS countries, 51 months are necessary for the deviations from PPP to be reduced to half. Our findings are more in line with those of Cumby (1996) who studies (across 14 countries between 1986 and 1996) the prices of Big Mac hamburgers, and finds a half-life for the deviations from PPP of just under one year. However, when considering the whole set of estimates for all country pairs and sectors, persistence in relative prices, as well as the adjusted half-lives, increases considerably.

Finally, the estimates of a constrained (single) mean reversion coefficient for each of the country pair samples are reported in table 4. Only between Belgium and France is this coefficient significantly different from zero (at the 5% level). These results are in contrast with some other panel studies which also focus on European countries without distinguishing between the countries which are converging toward PPP and the ones which are not. For instance, the unit root hypothesis is strongly rejected by Jorion and Sweeney (1996) in a panel of seven European currencies (including Switzerland) between 1973 and 1993, by Papell (1997) in a panel of European Member States between 1973 and 1994 and by Wu and Wu (1998) for both the European Union and the EMS countries between 1973 and 1997. One exception is Papell (1997) who is unable to reject the null hypothesis in the case of seven countries of the EMS. However, in contrast to the present paper, these empirical studies all rely upon aggregate price data and compute their real exchange rates with respect to a benchmark country.

To summarize, the use of disaggregated data at the sectoral level, the inclusion of all possible country pairs in the sample and the estimation of heterogeneous speeds of mean reversion prove informative. Indeed, mean reversion is more frequently reported for the Netherlands, Germany, Belgium and France while relative prices for certain sectors, no matter which country pair is considered, appear to mean revert systematically more often than other sectors. Accordingly, both country and sectoral characteristics appear important in explaining the behaviour of relative prices over the period. Recall that the importance of investigating both types of factors was already emphasized when analysing table 1. However, in contrast to these descriptive statistics which were computed from univariate processes, the results of this section are obtained in a multivariate setting.

Before moving to the next section, it is worth observing that the main shortcoming of this empirical study is the short time span of data available. Despite the enlargement of the samples by using monthly and cross-sectional data, seventeen years of data may well be sufficient to detect differences in the behaviour of prices across sectors and countries, but perhaps not enough to find additional statistical significance against the unit root hypothesis.

5 Explaining Mean Reversion

The results analysed in the preceding section show that evidence of PPP could be reported more frequently for some countries and sectors than for others. In addition, the speeds of reversion toward PPP, based on the estimated mean reversion parameters, appear to be very different across country pairs and sectors. An important question is now to determine empirically how this particular price behaviour may be related to the set of factors which are usually identified as being responsible for the deviations from PPP and for their persistence.

The theoretical model presented by Wei and Parsley (1995), which is in the same spirit as the one in Engel and Rogers (1996), serves as a guide to motivate our basic empirical specifications. In this model, price dispersion is positively related to the distance between locations because shipping costs, which impede arbitrage activities, increase with distance. Nominal exchange rate volatility contributes to price dispersion as well, reflecting that prices are relatively sticky in local currencies. Finally, their model also shows that the behaviour of relative prices depends on the physical properties and market structure of the product in question. However, these authors concentrate on the volatility of relative prices over a period whereas here, the objective is to explain persistence in relative prices. Particular attention is paid to the role of nominal exchange rate volatility, the geographical separation of markets and of sectoral characteristics (Campa and Wolf (1997), Cheung *et al.* (1999) and Cecchetti *et al.* (2000)).

To examine these questions, three alternative measures of relative price persistence are computed. First, we aim to explain our persistence parameters, the β_k's obtained for all country pairs ij and sectors k. The closer β_k is to zero, the more persistent is the sectoral real exchange rate and the slower is the speed of parity reversion. A logistic transformation of the p-values, as well as the t-ratios associated with the persistence parameters, are also investigated.

Three different samples (corresponding to each dependent variable to be explained) are derived from the results obtained in the previous section. Each of them, which is purely cross-sectional, contains $I\left(\frac{I-1}{2}\right) \times K = 255$

observations where, as before, I and K respectively denote the total number of countries (6) and sectors (17).

The next two sections are devoted to our analysis. The first section motivates the choice of country level factors in explaining persistence in relative prices. The second further extends the analysis by considering the role of sectoral characteristics in affecting the mean reversion properties of relative prices. The results are reported in the third section.

5.1 The Country Level

When comparing the behaviour of prices across countries, nominal exchange rate volatility, which can be interpreted as a proxy for the exchange rate uncertainty that price-setters face, needs to be considered. For instance, Delgado (1991) shows that this variability raises the level of uncertainty, and hence intensifies price stickiness. In other words, firms become less willing to adjust their prices since the exchange rate may move back again later on. Wei and Parsley (1995, 1999) and Engel and Rogers (1996, 1998, 2000) also find that nominal exchange rate volatility is significant in explaining the failure of PPP across countries, while Cheung *et al.* (1999) show that volatility slows the speed of reversion. Accordingly, nominal exchange rate volatility, vol_{ij}, which is measured by the standard deviation, between February 1981 and December 1997, of the first log differences of the nominal exchange rate between countries i and j, is expected to slow the adjustment toward PPP.

As acknowledged by Engel and Rogers (1996, 1998, 2000) and Wei and Parsley (1995, 1999), prices may not equalize between locations because of shipping costs. In addition, Campa and Wolf (1997) find that a greater geographical distance, which proxies for unobservable transportation costs, results in a slower PPP reversion. The logarithm of distance, $dist_{ij}$, between the capitals of country i and country j is therefore computed, and is expected to have a negative impact on the speed of reversion toward PPP. These costs should rather be distinguished by sector since they may depend on the physical characteristics of the products in each sector, but this is not possible because of data unavailability.

A further way to capture other possible determinants of transportation costs is to compute a dummy variable, $bord_{ij}$, which takes the value one when the country i shares a common border with country j and zero otherwise. This variable, which is similar to the one considered by Wei and Parsley (1995), is expected to have a positive impact over the speed of reversion because arbitrage and trading activities should be easier between countries close to each other, inducing firms to adjust their prices. It is worth pointing out that the interpretation of this variable is not the same as in Engel and Rogers (1996, 2000), where prices are compared within, and across, countries and where the border dummy variable reflects the fact that price dispersion is higher between two cities when they are separated by a national border.

It is worth noting that Campa and Wolf (1997) cast some doubt on the arbitrage explanation since they show that deviations from PPP and trade flows are virtually uncorrelated in either direction. Instead, they argue that mean reversion may be induced by policy actions such as realignments in nominal exchange rates, which imply an immediate reversion of relative prices toward their mean. This observation is important because during most of the period analysed, the six countries considered in the present paper participated in the Exchange Rate Mechanism in which nominal exchange rates were to remain within narrow bands. However, the effects of the various nominal exchange rate realignments, which occurred in the ERM, cannot be investigated in the context of this model since our samples are purely cross-sectional and therefore do not contain any temporal dimension.

Before moving to the next section, the strong collinearity between these country level variables has to be underlined. The correlations between nominal exchange rate volatility, on the one hand, and the border and distance variables, on the other hand, are large (respectively equal to -0.52 and 0.75). A priori, it seems obvious that countries closer together should display lower exchange rate volatility[9], but these correlations are stronger than those usually reported (Engel and Rogers (1998) find a 0.49 correlation between distance and the standard deviation of monthly exchange rates). The inclusion of exchange rate volatility, distance and the border dummy variable, together in a single regression, should accordingly be precluded.

5.2 The Sectoral Level

The previous section has motivated the choice of country level variables in explaining persistence in relative prices. In this section, the aim is to investigate the role of sectoral characteristics.

[9]The closest countries are to each other, the higher their trade share between them. This trade intensity may therefore have a stabilizing impact over bilateral exchange rates in order to avoid large swings in trade flows.

It is conjectured that trade barriers act much like transportation costs in creating wedges between the prices of traded goods in different locations. This issue is therefore examined by considering a measure of non-tariff barriers, ntb_k, a qualitative variable taking the value one if sector k is subject to non-tariff barriers and zero otherwise (Buigues, Ilzkovitz and Lebrun (1990)). These barriers should have a negative impact on the speed of mean reversion since they impede arbitrage activities.

Engel and Rogers (1998) also point to the fact that monopoly power, reflecting the ability of firms to price discriminate, should be considered in explaining price dispersion across industries. In the same context, Cheung *et al.* (1999) empirically test if differences in sectoral real exchange rate persistence systematically arise from differences in market structure; more specifically, they consider the hypothesis that industries with a less competitive market structure have more persistent sectoral real exchange rates. Using the price cost-margin across industries and countries to approximate the profitability of an industry, Cheung *et al.* (1999) find some evidence in favour of their hypothesis.

In order to analyse the effects of market power on the persistence of sectoral PPP deviations, the (logarithm of the) five firm concentration ratio, $conc_k$, which represents the combined production of the five largest producers in the industry as a share of total EU-12 production, is considered (Davies and Lyons (1996)). In our context, the more concentrated an industry, the more likely its relative prices should be persistent.

Another way to reflect the structure of an industry is to characterize the nature of competition via the degree of product differentiation. For instance, an industry is better characterized as monopolistically competitive than perfectly competitive if firms supply some differentiated products that are imperfect substitutes to each other. Cheung *et al.* (1999) use the Grubel-Lloyd intra-industry trade index to reflect the extent of market power due to product differentiation. Consistent with prediction, sectors subject to substantial intra-industry trade tend to have more persistent sectoral PPP deviations.

If firms vertically differentiate their products, one can also expect them to invest in R&D or advertising. Since these investments can create barriers to entry or can be used by firms to vertically fragment the market (and hence limit competition), market power is expected to be stronger in sectors where the nature of competition is mainly based on the perceived quality of the product. Accordingly, to capture vertical differentiation of the products, we consider two variables: (adv_k) is equal to one when sector k is subject to a high intensity in advertising and zero otherwise (Davies and Lyons (1996)), and (rd_k) is the R&D intensity ratio (the share of R&D expenditure in production, averaged across Germany, France, the Netherlands, Italy and Spain in 1993, Eurostat). Both variables are expected to adversely affect the speed of mean reversion toward PPP.

5.3 The Results

Having explained the choice of various country and sectoral level variables, we now analyse the relationship between these variables and persistence in relative prices. The regression specification is given by:

$$\begin{aligned} pers_{ij,k} &= c + \beta_1.country_{ij} + \beta_2.(ntb_k) + \beta_3.\ln(conc_k) \\ &\quad +\beta_4.\ln(rd_k) + \beta_5.(adv_k) + \varepsilon \end{aligned} \tag{10}$$

where, for all country pairs ij $(i \neq j)$ and all sectors k, the dependent variable, $pers_{ij,k}$, in turn denotes the persistence parameters (the β_k's), a logistic transformation of the p-values and the test statistics corresponding to each of the mean reversion coefficients. An increase in the mean reversion coefficients (with $\beta_k < 0$) indicates an increase in persistence; similarly, an increase in the p-values or in the test statistics (where $t_{\beta_k} < 0$) is associated with more persistence. Because they are strongly correlated, the country level variables $country_{ij} = [vol_{ij},\ \ln(dist_{ij}),\ bord_{ij}]$ are included separately into the regressions. The results of explaining the persistence parameters, the p-values and the test statistics are respectively reported in tables 5, 6 and 7.

Is there any evidence that the adjustment in relative prices is impeded by distance? From the first column in table 4, the estimated slope coefficient of distance, which is positive and significant at the 10% level, indicates that convergence is indeed slower between countries of greater spatial separation. In other words, this reflects that higher transport costs reduce arbitrage between locations. From tables 5 and 6, distance also appears to increase the p-values and the test statistics corresponding to the persistence coefficients. On the whole, these findings are qualitatively consistent with Campa and Wolf (1997) and Cecchetti *et al.* (2000) but also with Engel and Rogers (1996, 1998, 2000) and Wei and Parsley (1995, 1999). Engel and Rogers

(1996, 1998, 2000) however argue that distance may also matter for reasons other than shipping costs. In particular, they point to the fact that places farther apart may have dissimilar cost structures and that the behaviour of prices is closely influenced by wages. Finally, Cheung *et al.* (1999) find that the estimated coefficient of distance is not significant in explaining persistence and has the wrong sign. But, as acknowledged by these authors, the effect of geographical distance on the speed of reversion remains ambiguous, unlike its effect on the size of PPP deviations.

The results relating to the border are displayed in the second column of each table. Despite their negative signs, the estimated coefficients do not support the hypothesis that arbitrage accelerates the speed of reversion (because they are not statistically different from zero). Note that in Wei and Parsley (1995), the estimated coefficient of that dummy variable is not significantly different from zero either (and hence does not influence, in their case, price dispersion).

Finally, when considering the effects of nominal exchange rate volatility (reported in the third columns of each table), the coefficients are positive in all cases, indicating that a higher volatility tends to slow the speed of adjustment toward PPP, but none of these coefficients is significantly different from zero. This result is in contrast with that of Cheung *et al.* (1999) who find that an increased exchange rate volatility leads to a slower parity reversion.

As to the effects of non-tariff barriers on the persistence parameters (table 4), the estimated coefficients are positive and significant. On the whole, the persistence parameters are, on average, 0.009 higher for the sectors affected by non-tariff barriers as compared to other sectors, supporting the idea that these barriers tend to slow the adjustment toward PPP. This variable is however not significant in explaining the p-values or the test statistics. For the sake of comparison, note that Engel and Rogers (1998) find that high barriers induce lower price dispersion. The two authors however remain skeptical about that puzzling result.

In terms of the effects of industrial concentration, the estimated coefficients of $conc_k$ are significant and positive in all specifications, a finding which is consistent with the notion that the adjustment in relative prices is slowed by the extent of market power. As expected, vertical differentiation of the products is also associated with a slower speed of reversion toward PPP. The estimated coefficients of the R&D and advertising variables are positive and significant in all cases. These results are consistent with priors and with

Cheung *et al.* (1999) and Cecchetti *et al.* (2000).

On the whole, most findings are in accordance with the other empirical results obtained in this research area: when focusing on European Union Member States, the geographical segmentation of markets, non-tariff-barriers, industrial concentration and the vertical differentiation of the products appear as significant determinants of cross-country and cross-industry price behaviour. No significant effect of nominal exchange rate volatility could however be put in evidence.

6 Concluding Remarks

The approach used in this paper to measure the extent of market integration in six European countries between January 1981 and December 1997, consisted of examining and explaining the behaviour of prices at the sectoral level. In theory, the failure of LOOP and PPP between locations is an indication that markets are not completely integrated. Accordingly, the purpose of this paper was to investigate empirically the PPP hypothesis at the sectoral level, and to provide some explanations for the observed differences across sectors and countries.

Long run PPP is empirically validated if the unit root hypothesis can be rejected, implying that relative prices revert to their mean values. The choice of panel data, as compared to simple time series, allows to exploit the additional information contained in the contemporaneous correlations between the series. Therefore, the first part of the paper aimed to establish whether the presence of unit roots could be detected in panel samples of relative prices computed across countries and sectors, the existence of serial and contemporaneous correlations being carefully taken into account in the econometric procedure.

When constraining the mean reversion coefficient to be identical across the series, only weak evidence against the unit root hypothesis could be found. In contrast, when estimating heterogeneous speeds of mean reversion toward PPP for each sector included in each country pair sample, the unit root hypothesis could indeed be rejected in some cases. In particular, mean reversion in the relative prices of France, Germany, Belgium and the Netherlands is reported more frequently than for Spain or for Italy, suggesting that the first four countries are more integrated with each other. These four countries were indeed expected to be relatively integrated since they belong to the six countries which established the EEC. In contrast, the results for Italy remain disappointing. Moreover, certain sectors, no matter for which country pair, appear as mean reverting more often than other sectors. Finally, given the fact that the estimated half-lives lie between four months and two years, the speeds of reversion toward PPP are faster than those reported in most other studies.

The second part of the empirical work aimed to provide some explanations as to the different behaviours of relative prices across sectors and countries. Distance between locations, non-tariff barriers at the sectoral level, vertical differentiation (measured by both the sectoral intensity in advertising and in R&D) and concentration all appear, as expected, to slow the adjustment of relative prices across countries and sectors. The effect of nominal exchange rate volatility on the speed of mean reversion was not significantly different from zero.

In a recent survey of international price behaviour, Rogoff (1996, p.665) concludes that "international goods markets, though becoming more integrated all the time, remain quite segmented, with large trading frictions across a broad range of goods. These frictions may be due to transportation costs, threatened or actual tariffs, non-tariff barriers, information costs, or lack of labour mobility. As a consequence of various adjustment costs, there is a large buffer within which nominal exchange rates can move without producing an immediate proportional response in relative domestic prices. International goods markets are highly integrated, but not yet nearly as integrated as domestic goods markets".

On the whole, the present study finds support for this conclusion in the European context. However, the recent establishment of Monetary Union, through the introduction of the Euro, is expected to further influence the behaviour of prices across countries and industries. In particular, Monetary Union will make markets more transparent, thereby affecting the behaviour of both consumers and producers. On the one hand, consumers will more easily be able to switch to cheaper products sold in foreign markets, allowing to increase arbitrage between locations. On the other hand, producers may be threatened to decrease their discriminatory price-setting practices on their home markets, and therefore opt for a defensive strategy such as investing in product differentiation (which, in the context of this paper, is shown to slow the speed of reversion). This increased transparency may also encourage firms to enter other EU markets, thereby reducing the concentration of industries at the national level (and hence allow to speed reversion in relative prices). Finally, note that nominal exchange rate volatility (which, in the context of this paper, does not significantly affect the behaviour of relative prices) will be completely eliminated with the arrival of the Euro.

In sum, in the context of international price behaviour, the recent introduction of Monetary Union opens the way to a new and potentially rewarding direction for future research.

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Table 1: Volatility of nominal exchange rates and of relative prices across sectors and countries (%)

Sector / country pair	FR-DE	BE-DE	IT-DE	ES-DE	NL-DE	BE-FR	IT-FR	ES-FR	NL-FR	IT-BE
Exchange rate	0.896	0.730	1.840	1.804	0.296	0.921	1.814	1.810	0.879	1.892
Textiles (17.4)	1.09	1.31	1.83	1.61	0.56	1.47	1.88	1.71	1.14	2.19
Footwear (19.3)	1.38	1.52	1.81	1.56	0.69	1.90	2.18	1.78	1.52	2.18
Carpentry (20.3)	1.04	1.05	1.80	1.79	0.63	1.14	1.80	1.80	1.08	1.99
Wooden containers (20.4)	1.24	1.69	1.80	1.78	0.82	1.89	1.71	1.74	1.31	2.34
Paper (21.1)	0.96	1.31	1.95	2.16	0.97	1.44	1.78	2.05	1.20	2.15
Articles of paper (21.2)	1.01	1.17	1.72	1.67	0.56	1.34	1.79	1.72	1.10	1.89
Chemicals (24.1)	1.31	1.03	1.96	1.65	1.32	1.37	2.07	1.85	1.59	2.22
Paints (24.3)	1.40	2.30	1.91	2.03	1.13	2.19	1.79	1.88	1.18	2.70
Detergents (24.5)	1.15	1.10	1.77	1.67	0.71	1.31	1.76	1.65	1.07	1.83
Rubber (25.1)	1.29	1.79	1.99	2.01	1.14	1.64	1.76	1.78	1.07	1.96
Plastic (25.2)	1.13	1.10	1.81	1.78	0.96	1.14	1.66	1.66	1.09	1.67
Glass (26.1)	1.19	0.97	1.99	1.69	0.92	1.21	1.94	1.73	1.37	1.96
Bricks (26.4)	1.10	1.74	1.89	1.75	1.30	1.82	1.88	1.79	1.55	2.37
Cement (26.5)	1.20	1.58	2.16	2.04	0.91	1.78	2.29	2.20	1.29	2.34
Articles of cement (26.6)	1.03	0.95	1.85	1.65	0.63	1.24	1.83	1.66	1.00	1.95
Metals (27.4)	1.40	4.00	2.23	2.36	2.02	4.07	2.07	2.21	1.89	4.50
Computers (30.0)	3.64	1.14	2.33	2.28	1.56	3.68	3.93	4.06	3.77	2.56
Average	1.33	1.51	1.93	1.85	0.99	1.80	2.01	1.96	1.42	2.28

(continued on next page)

Table 1 (continued)

Sector / country pair	ES-BE	NL-BE	ES-IT	NL-IT	ES-NL	average
Exchange rate	1.797	0.721	1.970	1.858	1.763	
Textiles (17.4)	1.89	1.43	1.82	1.93	1.65	1.57
Footwear (19.3)	1.90	1.66	1.88	1.88	1.60	1.70
Carpentry (20.3)	1.94	1.15	1.94	1.75	1.80	1.51
Wooden containers (20.4)	2.24	1.70	1.94	1.85	1.80	1.72
Paper (21.1)	2.47	1.53	2.38	2.06	2.22	1.77
Articles of paper (21.2)	1.89	1.23	1.89	1.76	1.64	1.49
Chemicals (24.1)	1.76	1.48	2.04	2.28	1.88	1.72
Paints (24.3)	2.55	2.17	1.93	1.88	1.80	1.92
Detergents (24.5)	1.65	1.00	1.76	1.76	1.52	1.45
Rubber (25.1)	2.18	1.41	1.90	1.74	1.79	1.70
Plastic (25.2)	1.59	0.90	1.73	1.75	1.65	1.44
Glass (26.1)	1.82	1.15	2.03	2.09	1.91	1.60
Bricks (26.4)	2.16	1.93	2.00	2.27	2.05	1.84
Cement (26.5)	2.33	1.50	2.43	2.14	1.98	1.88
Articles of cement (26.6)	1.69	1.07	1.80	1.86	1.67	1.46
Metals (27.4)	4.47	4.22	2.82	2.11	2.56	2.86
Computers (30.0)	2.16	1.77	2.94	2.83	2.51	2.74
Average	2.16	1.61	2.07	2.00	1.88	

Notes: Volatility is defined as the standard deviation of a series between February 1981 and December 1997. The top row of the table gives the volatility of (monthly) nominal exchange rates, that is $std\left(\Delta \ln\left(e_{ij,t}\right)\right)$ where $e_{ij,t}$ is the bilateral exchange rate between the two currencies of each country pair ij. Other column entries give, for each country pair ij $(i \neq j)$ the volatility of relative prices for each sector k, $std\left(\Delta q_{k,t}\right)$.

Table 2: Multivariate unit root tests. Mean reversion coefficients and p-values in square brackets

Sector / country pair	FR-DE	BE-DE	IT-DE	ES-DE	NL-DE	BE-FR	IT-FR	ES-FR	NL-FR	IT-BE
Textiles (17.4)	−0.028 [0.042]	−0.017 [0.679]	−0.026 [0.410]	−0.009 [0.778]	−0.046 [0.114]	−0.053 [0.073]	−0.082 [0.031]	−0.010 [0.589]	−0.018 [0.516]	−0.095 [0.029]
Footwear (19.3)	−0.006 [0.742]	−0.014 [0.737]	−0.005 [0.900]	−0.054 [0.151]	−0.064 [0.055]	−0.005 [0.848]	−0.017 [0.495]	−0.005 [0.833]	−0.008 [0.613]	−0.004 [0.908]
Carpentry (20.3)	−0.065 [0.045]	−0.022 [0.261]	−0.012 [0.733]	−0.003 [0.913]	−0.024 [0.333]	−0.085 [0.018]	−0.025 [0.507]	−0.004 [0.895]	−0.031 [0.372]	−0.031 [0.201]
Wooden containers (20.4)	−0.009 [0.836]	−0.036 [0.315]	−0.013 [0.743]	−0.008 [0.830]	−0.047 [0.209]	−0.083 [0.038]	−0.067 [0.090]	−0.108 [0.015]	−0.005 [0.893]	−0.064 [0.098]
Paper (21.1)	−0.017 [0.708]	−0.034 [0.472]	−0.034 [0.449]	−0.040 [0.286]	−0.001 [0.949]	−0.084 [0.042]	−0.054 [0.153]	−0.032 [0.414]	−0.016 [0.608]	−0.043 [0.283]
Articles of paper (21.2)	−0.019 [0.706]	−0.049 [0.235]	−0.008 [0.859]	−0.008 [0.753]	−0.012 [0.758]	−0.076 [0.049]	−0.072 [0.062]	−0.012 [0.578]	−0.077 [0.040]	−0.041 [0.304]
Chemicals (24.1)	−0.025 [0.578]	−0.026 [0.414]	−0.013 [0.819]	−0.020 [0.625]	-0.117^{c} [0.005]	−0.078 [0.033]	−0.121 [0.011]	−0.059 [0.087]	-0.120^{c} [0.005]	−0.064 [0.075]
Paints (24.3)	-0.079^{c} [0.005]	−0.025 [0.585]	−0.098 [0.036]	−0.063 [0.102]	−0.014 [0.745]	−0.021 [0.632]	−0.088 [0.033]	−0.072 [0.071]	−0.013 [0.800]	−0.033 [0.383]
Detergents (24.5)	−0.015 [0.685]	−0.068 [0.094]	−0.056 [0.037]	−0.013 [0.737]	−0.031 [0.384]	−0.042 [0.246]	0.001 [0.960]	−0.005 [0.861]	−0.010 [0.784]	−0.045 [0.139]
Rubber (25.1)	−0.051 [0.215]	-0.056^{b} [0.001]	0.000 [0.957]	−0.013 [0.764]	-0.094^{c} [0.005]	-0.104^{b} [0.002]	0.005 [0.988]	−0.008 [0.844]	−0.057 [0.149]	−0.016 [0.419]
Plastic (25.2)	−0.014 [0.703]	−0.029 [0.501]	−0.027 [0.504]	−0.007 [0.847]	−0.080 [0.016]	−0.057 [0.124]	−0.039 [0.248]	−0.030 [0.541]	−0.050 [0.202]	−0.008 [0.841]
Glass (26.1)	−0.067 [0.115]	−0.067 [0.164]	−0.047 [0.320]	0.000 [0.958]	−0.007 [0.845]	-0.092^{b} [0.002]	−0.057 [0.125]	−0.015 [0.697]	−0.001 [0.950]	−0.056 [0.145]
Bricks (26.4)	−0.012 [0.813]	−0.046 [0.071]	−0.013 [0.610]	0.000 [0.957]	0.006 [0.992]	−0.026 [0.244]	0.000 [0.951]	0.003 [0.985]	−0.020 [0.510]	-0.038^{c} [0.005]
Cement (26.5)	−0.013 [0.738]	−0.050 [0.168]	−0.049 [0.134]	−0.091 [0.024]	−0.046 [0.211]	−0.031 [0.447]	−0.018 [0.632]	−0.020 [0.646]	−0.028 [0.550]	−0.085 [0.033]
Articles of cement (26.6)	−0.009 [0.789]	-0.081^{b} [0.001]	−0.032 [0.399]	−0.068 [0.077]	−0.045 [0.139]	−0.015 [0.721]	−0.035 [0.342]	−0.053 [0.151]	−0.008 [0.801]	−0.032 [0.396]
Metals (27.4)	−0.025 [0.383]	−0.060 [0.114]	−0.073 [0.074]	−0.064 [0.100]	−0.021 [0.451]	−0.084 [0.032]	−0.086 [0.032]	−0.051 [0.174]	−0.026 [0.316]	−0.081 [0.047]
Computers (30.0)	0.004 [0.970]	0.004 [0.999]	−0.014 [0.534]	−0.013 [0.626]	−0.062 [0.117]	0.003 [0.959]	0.008 [0.995]	0.009 [0.999]	0.002 [0.948]	−0.002 [0.901]

(continued on next page)

Table 2 (continued)

Sector / country pair	ES-BE	NL-BE	ES-IT	NL-IT	ES-NL
Textiles (17.4)	−0.007 [0.825]	−0.012 [0.770]	−0.004 [0.866]	−0.035 [0.341]	−0.016 [0.657]
Footwear (19.3)	−0.015 [0.733]	−0.059 [0.147]	−0.016 [0.653]	−0.008 [0.836]	−0.101 [0.018]
Carpentry (20.3)	−0.077 [0.013]	−0.085 [0.011]	−0.018 [0.609]	−0.013 [0.737]	−0.020 [0.619]
Wooden containers (20.4)	−0.055 [0.154]	−0.045 [0.204]	−0.030 [0.416]	−0.062 [0.171]	−0.030 [0.464]
Paper (21.1)	−0.060 [0.113]	−0.026 [0.410]	−0.045 [0.209]	−0.041 [0.112]	−0.027 [0.406]
Articles of paper (21.2)	−0.013 [0.616]	−0.080 [0.048]	−0.025 [0.359]	−0.018 [0.663]	−0.009 [0.715]
Chemicals (24.1)	−0.030 [0.300]	−0.048 [0.203]	−0.094 [0.023]	-0.131^{c} [0.006]	−0.041 [0.235]
Paints (24.3)	−0.011 [0.796]	−0.032 [0.436]	−0.045 [0.301]	−0.035 [0.335]	−0.022 [0.604]
Detergents (24.5)	−0.011 [0.786]	−0.007 [0.871]	−0.014 [0.572]	−0.032 [0.329]	−0.018 [0.588]
Rubber (25.1)	−0.029 [0.258]	-0.083^{b} [0.002]	−0.055 [0.170]	0.002 [0.981]	−0.011 [0.786]
Plastic (25.2)	-0.177^{b} [0.001]	−0.046 [0.261]	−0.003 [0.878]	−0.048 [0.167]	−0.031 [0.316]
Glass (26.1)	−0.028 [0.409]	−0.002 [0.944]	−0.025 [0.550]	−0.021 [0.757]	−0.003 [0.920]
Bricks (26.4)	−0.015 [0.402]	−0.015 [0.676]	−0.008 [0.783]	−0.002 [0.925]	0.002 [0.977]
Cement (26.5)	−0.079 [0.024]	−0.025 [0.505]	−0.039 [0.276]	−0.031 [0.340]	-0.135^{b} [0.002]
Articles of cement (26.6)	−0.054 [0.120]	−0.095 [0.013]	-0.088^{b} [0.001]	−0.029 [0.444]	−0.081 [0.059]
Metals (27.4)	−0.091 [0.030]	−0.066 [0.079]	−0.099 [0.022]	−0.015 [0.569]	−0.045 [0.160]
Computers (30.0)	0.005 [0.994]	0.000 [0.958]	−0.012 [0.431]	−0.019 [0.469]	−0.013 [0.699]

Notes: ^{a}, ^{b}, ^{c} denote asymptotic significance at the 10%, 5% and 1% levels after the use of Bonferroni bounds. For each country pair specific sample, mean reversion coefficients are obtained from multivariate unit root estimation of equation (6) in the text, $\Delta q_{k,t} = \alpha_k + \beta_k q_{k,t-1} + \varepsilon_{k,t}$, where k=1,...,17 and t=1981:2,...,1997:12. The tests allow for serial and contemporaneous correlation. p-values are obtained by parametric bootstrap (see the text).

Table 4: Restricted multivariate unit root tests

Country pair	FR-DE	BE-DE	IT-DE	ES-DE	NL-DE
$\hat{\beta}$	-0.015	-0.009	-0.018	-0.010	-0.017
t_β	-4.876	-3.523	-5.252	-3.642	-5.203
10% critical	-6.090	-6.214	-6.179	-6.203	-6.190
Sample	BE-FR	IT-FR	ES-FR	NL-FR	IT-BE
$\hat{\beta}$	-0.026^b	-0.014	-0.007	-0.014	-0.018
t_β	-6.584	-4.109	-2.903	-4.502	-5.908
10% critical	-6.084	-6.099	-6.100	-6.001	-6.182
Sample	ES-BE	NL-BE	ES-IT	NL-IT	ES-NL
$\hat{\beta}$	-0.018	-0.017	-0.016	-0.016	-0.016
t_β	-5.448	-5.081	-5.472	-4.908	-4.823
10% critical	-6.234	-6.246	-6.159	-6.211	-6.201

Notes: For each country pair specific sample, mean reversion coefficients $\hat{\beta}$ and test statistics t_β are obtained from multivariate unit root estimation of $\Delta q_{k,t} = \alpha_k + \beta q_{k,t-1} + \varepsilon_{k,t}$ where β is identical across all series in the panel. Critical values are obtained by parametric bootstrap (see the text). ^{a}, ^{b}, ^{c} denote asymptotic significance at the 10%, 5% and 1% levels respectively.

Table 5: Persistence in relative prices (dependent variable: mean reversion coefficients)

	Regression 1	Regression 2	Regression 3
c	-0.093^a [−4.75]	-0.055^a [−9.71]	-0.061^a [−9.51]
$dist_{ij}$	0.005^c [1.82]	-	-
$bord_{ij}$	-	-0.003 [−0.81]	-
vol_{ij}	-	-	0.003 [0.90]
ntb_k	0.009^b [2.29]	0.009^b [2.27]	0.009^b [2.27]
$conc_k$	0.0004^a [3.11]	0.0004^a [3.08]	0.0004^a [3.11]
rd_k	0.006^a [2.85]	0.006^a [2.85]	0.006^a [2.87]
adv_k	0.013^b [2.37]	0.013^b [2.35]	0.013^b [2.36]
$Adj - R^2$	0.097	0.088	0.088

Table 6: Persistence in relative prices (dependent variable: logistic transformation of the p-values corresponding to each of the mean reversion coefficients)

	Regression 1	Regression 2	Regression 3
c	-4.815^a [−3.23]	-1.979^a [−5.10]	-2.443^a [−5.40]
$dist_{ij}$	0.422^c [1.82]	-	-
$bord_{ij}$	-	-0.097 [−0.34]	-
vol_{ij}	-	-	0.295 [1.10]
ntb_k	0.444 [1.34]	0.444 [1.32]	0.444 [1.33]
$conc_k$	0.039^a [3.30]	0.039^a [3.27]	0.039^a [3.30]
rd_k	0.404^a [3.00]	0.404^a [3.01]	0.404^a [3.03]
adv_k	1.086^a [2.69]	1.086^a [2.67]	1.086^a [2.70]
$Adj - R^2$	0.109	0.096	0.101

Table 7: Persistence in relative prices (dependent variable: test statistics corresponding to each of the mean reversion coefficients)

	Regression 1	Regression 2	Regression 3
c	-3.642^a [−5.77]	-2.370^a [−14.70]	-2.564^a [−13.26]
$dist_{ij}$	0.189^c [1.93]	-	-
$bord_{ij}$	-	-0.048 [−0.39]	-
vol_{ij}	-	-	0.120 [1.04]
ntb_k	0.223 [1.54]	0.223 [1.52]	0.223 [1.52]
$conc_k$	0.018^a [3.51]	0.018^a [3.48]	0.018^a [3.51]
rd_k	0.173^a [3.02]	0.173^a [3.03]	0.173^a [3.04]
adv_k	0.456^a [2.62]	0.456^a [2.59]	0.456^a [2.62]
$Adj - R^2$	0.118	0.105	0.108

Notes to tables 5, 6 and 7: Models are estimated over cross-section samples where the number of observations is n=255. Standard errors are heteroskedastic consistent (White). For a definition of the variables, see the text. ^{a}, ^{b}, ^{c} denote asymptotic significance at the 10%, 5% and 1% levels respectively.