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# Europe Without Borders? The Effect of the Euro on Price Convergence

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Has the introduction of the Euro reduced the economic significance of national borders across the Euro Area? This article extends Engel and Rogers well known work on border effects to cities across Western Europe over the period 1995–2004. Although cross-border prices across the Euro Area are still more volatile than within-country prices, the importance of the border has diminished since the euro was introduced in 1999. The impact of the common currency on the border effect varies by country size, with the largest decreases occurring between larger Euro countries. Although cross-border price volatility has not changed between the United Kingdom and large Euro countries, volatility has actually increased between the small Euro countries and the United Kingdom. These results are consistent with the fact that exchange rates are more likely to adjust to price differentials between small countries than between large countries.

**Keywords:** *law of one price; border effects; European Monetary Union*

National borders have effectively disappeared and, along with them, the economic logic that made them useful lines of demarcation in the first place.

—Kenichi Ohmae (1990) in the *Borderless World*

## Introduction

Much has been made about increased globalization in the international economy. Free trade zones such as the North American Free Trade Agreement (NAFTA) and currency unions such as the Euro Area (EA) have purportedly reduced the economic

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significance of national borders. As trade and investment flows increase, markets will become less segmented. Has this really occurred, though? According to the story above, we should at least begin to observe convergence to the law of one price, where the same good sells for the same price regardless of location.

Although theoretically appealing, the law of one price has consistently failed the test when put to the data. Studies such as Isard (1977), Giovannini (1988), and Knetter (1989, 1993) show that prices for even highly tradable and homogeneous goods fail to equalize across locations. Other studies have found that prices between locations fail to even move in the same direction. An implication of the law of one price is that if prices for the same good across locations do move in the same direction, then real exchange rates constructed from these price series should exhibit mean reversion. Rogers and Jenkins (1995) and Jenkins (1997) construct real exchange rates for commodity prices and reject mean reversion for the vast majority of these cases.<sup>1</sup>

Why is it that such an economically plausible theory fails to hold up to real-world analysis? Two culprits that emerge are transport costs and market segmentation caused by national borders. Transport costs limit the arbitrage opportunities that drive the law of one price.<sup>2</sup> Arbitrageurs are willing to exploit large price differences, but the presence of transport costs prevents them from trading on smaller differences. O'Connell and Wei (1997) find evidence of this limited arbitrage by estimating a threshold model, with prices converging more rapidly for large initial price differences than for small differences.

Parsley and Wei (1996) find that convergence rates to the law of one price are significantly higher between cities within the United States than those found in cross-border studies. So why do borders matter? The presence of trade barriers can limit arbitrage in much the same way as transport costs, but this still does not explain the importance of borders within free trade zones such as the EU or NAFTA. Another possibility is that residents of one country may have an affinity for domestically produced goods, the "home bias" in trade.<sup>3</sup> Differential tax schemes across countries may matter, as well as language and cultural differences. Finally, there may be national standards that create natural market segmentation such as right-side steering wheels, 220-volt outlets, or warranties that are only valid within the country of purchase.

Has the introduction of the Euro eliminated the importance of national borders across the EA? Although the adoption of a common currency is not going to change the linguistic or cultural differences that could be segmenting markets, it does eliminate the border as a line demarcating currency usage within the EA. Because multiple currencies create transaction costs, the elimination of these currencies should increase arbitrage opportunities, narrowing price differentials. Devereux, Engel, and Tille (2003) argue that prior to the adoption of a common currency, menu costs limited price changes in response to exchange rate movements. For example, a U.S.-based firm selling in Europe facing twelve different currencies would need to

have twelve different pricing rules.<sup>4</sup> If, however, the firm only faced one currency, then they would only need to have one pricing rule and as a result, prices would be more sensitive to differences in local markets.

Prices convergence may also increase with greater coordination of business cycles across countries within the EA. Increased trade between Euro countries as well as a common monetary policy for all member states suggests that economic shocks are less likely to be localized within a country's borders than before. Before the formation of the European Monetary Union (EMU), countries were able to pursue their own monetary policies, displaying varying tolerances for inflation.<sup>5</sup> As a result, prices within a country were affected by a common factor that did not necessarily affect prices in other nations. With a common monetary policy for all EA countries, this national level price determinant is removed.

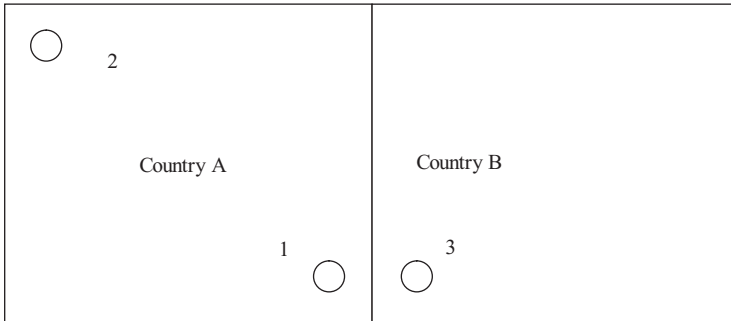
Existing empirical studies have been split on the impact of the euro on price convergence.<sup>6</sup> While still a relatively new line of research, we can point to two studies that have driven the debate. Engel and Rogers (2004) look at cost of living prices taken from the Economist Intelligence Unit across eighteen cities and find no evidence that the euro has led to greater price convergence. However, a study by Allington, Kattuman, and Waldman (2005) looking at a wide range of goods finds that price dispersion has fallen significantly more across the EA than between the EA and non-EA countries.

My article finds that price convergence has increased between the "large" Euro countries but remained unchanged between the smaller Euro countries. This result is consistent with the fact that prior to the introduction of the euro, small country exchange rates were essentially fixed to the large Euro countries (primarily Germany). The same was not the case for the larger Euro countries who did see a real reduction in trade barriers with the formation of the monetary union in 1999.

The chief advantage of the article is that it gathers fairly high-frequency (monthly) data on a much wider range of locations (over 200) than previous studies. Having a large number of locations within countries with frequently updated prices is essential to getting accurate estimates of how much more volatile prices are across borders than within them. A wider range of locations comes at the price of limited coverage of goods. The price data I use comes from the U.S. State Department's daily per diem rates, 1995–2004, on lodging and meals. These price series have two major weaknesses compared to the commodity prices generally used in this literature. First, they are two highly nontradable goods (albeit with tradable components). I argue that while looking at nontradables will produce an upper bound estimate of price divergence across borders, any evidence that price convergence has increased since the introduction of the euro gleaned from these prices is likely to be a lower bound estimate.

The second weakness with this data set is that prices are highly aggregated and perhaps not comparable across locations. I argue that this problem is mitigated somewhat by the standards used to gather prices, which explicitly attempt to compare

**Figure 1**  
**Cities Separated by Distance and Border**



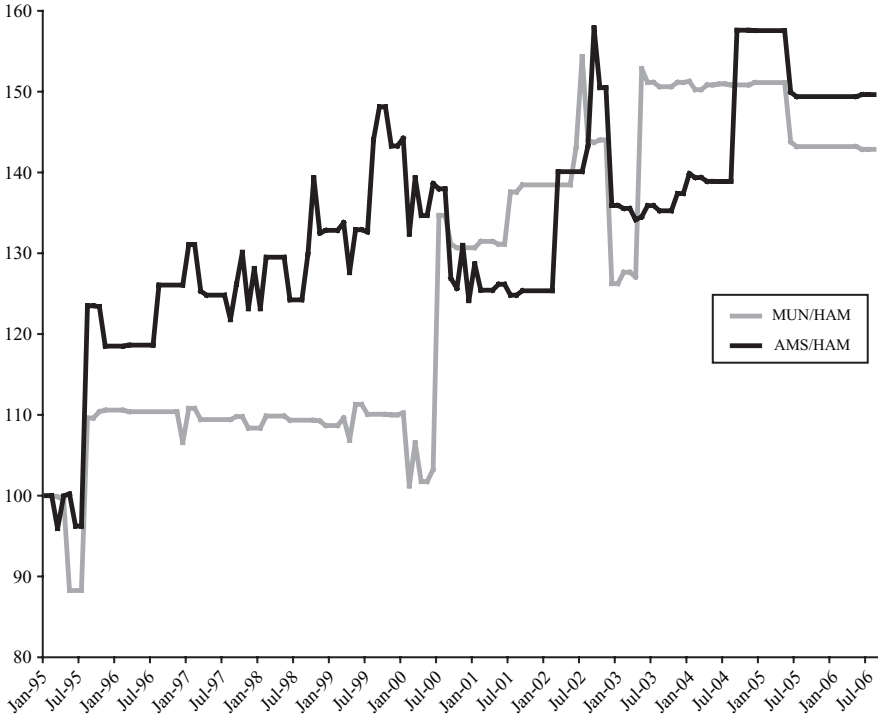
similar goods across locations. Second, the economic shock argument discussed above will still hold at higher levels of aggregation. Finally, the prices of aggregated goods are determined in part by components traded between countries. As the prices of these components converge, then we should begin to see price convergence for even highly aggregated goods.

### Hypothetical Model

Before proceeding with the analysis, it may be useful to place the empirical methodology in the context of a hypothetical model world depicted in Figure 1. There are two countries in the world (A and B) and three cities. Cities 1 and 2 are in country A, while city 3 is in country B.

Let the price of a good in city  $j$  ( $j = 1, 2, 3$ ) be  $p_j$  and the relative price between cities  $i$  and  $j$  be  $p_{ij} = p_i/p_j$ . Do national borders affect prices? Examining the relative price between cities 1 and 2 against the relative price between 1 and 3 sheds light on this question. Note that cities 1 and 3 are closer together than cities 1 and 2. Without the border, we should expect  $p_{13}$  to exhibit greater stability than  $p_{12}$ , all else being equal. Is this really the case? Engel and Rogers (1996) look at this very issue using price data for United States and Canadian cities. They find that while distance certainly affects relative price volatility, the effect pales in comparison to the presence of a border between locations. A conservative estimate states that crossing the border is equivalent to over 2,800 kilometers of distance between locations in the same country. In the context of this model,  $p_{13}$  may in fact be more volatile than  $p_{12}$  if the border effect dominates the distance effect.

**Figure 2**  
**Relative prices for Amsterdam, Hamburg, and Munich**



Distances: Amsterdam (NLD) to Hamburg (GER) = 366 km  
Munich (GER) to Hamburg (GER) = 611 km

A casual examination of the data suggests that while the border plays a significant role across the EA, its effect has diminished since the introduction of the euro. Figure 2 plots two relative price indexes—the Munich-Hamburg relative price and the Amsterdam-Hamburg relative price. Although the first relative price is between two cities in the same country, the second is between two cities that are closer together. The Munich-Hamburg relative price displays greater stability than the Amsterdam-Hamburg price, indicating that the border between Germany and the Netherlands does in fact matter. Beginning around 1999, this difference is considerably less pronounced, perhaps reflecting the introduction of the euro.<sup>7</sup> One of the main contributions of this article is to find firm empirical support for this casual observation.

The rest of this article seeks to answer the following question: are national borders across the European Union an impediment to price convergence, and if so, how has their effect diminished since the adoption of the euro? The section on Border Effect presents the empirical methodology for assessing the importance of the border effect, drawing on Engel and Rogers (1996), and more recent refinements to this strand of literature. The section on Data describes the unique data set used in this study, addressing both its strengths and weaknesses. The section on Baseline Results discusses the empirical results and their implications, and the last section concludes.

## The Border Effect

For ease of exposition, assume that there are only two countries, home (h) and foreign (f). Let the relative price between two cities  $i$  and  $j$  separated by a border be

$$p_{ij,t}^c = p_{i,t} - p_{j,t} \quad (1)$$

where  $p_{i,t}$  and  $p_{j,t}$  are log prices. The relative price between cities  $k$  and  $l$  within the same country is given by the following:

$$p_{kl,t}^w = p_{k,t} - p_{l,t} \quad (2)$$

Pooling all city pairs together, the excess volatility of cross-border prices over within-country prices is as follows:<sup>8</sup>

$$\Phi = \text{Avg}[\text{Var}(p_{ij,t}^c)] - \text{Avg}[\text{Var}(p_{kl,t}^w)] \quad (3)$$

A large value for  $\Phi$  indicates that on average, relative prices across a border are more volatile than those within countries on either side of a border. To test whether national borders segment markets, we simply test whether  $\Phi = 0$ .

## A Comparison to Engel and Rogers (1996)

In their 1996 study examining the border effect between the United States and Canada, Engel and Rogers propose the following econometric specification:<sup>9</sup>

$$q_{ij} = \alpha D_{ij} + \beta X_{ij} + \sum_{k=1}^K \gamma_k C_k + u_{ij} \quad (4)$$

$D_{ij}$  is the log distance between locations  $i$  and  $j$ ,  $X_{ij}$  is a dummy variable equal to 1 if locations  $i$  and  $j$  are separated by a border, and  $C_k$  is a location-specific dummy variable for all  $K = 201$  cities in the sample. Inclusion of  $C_k$  picks up any time-constant idiosyncratic fixed effects not picked up by distance or the border. The coefficient on

the border dummy  $X_{ij}$  is an estimate of excess cross-border price volatility  $\Phi$ , holding distance, national borders, and city-specific fixed effects constant.

The dependent variable is the relative price volatility between two cities. Several methods may be used to measure this variable. One candidate is the standard deviation of the first-differenced relative price is defined as follows:

$$p_{ij,t} = (p_{i,t} - p_{j,t}) - (p_{i,t-1} - p_{j,t-1}) \tag{5}$$

and

$$q_{ij} = \left( \frac{1}{T-1} \sum_{t=1}^T (p_{ij,t} - \bar{p}_{ij})^2 \right)^{\frac{1}{2}} \tag{6}$$

A drawback to using this measure is that it assumes the relative price has a unit root. Engel and Rogers suggest modeling the relative price as an AR (autoregressive) (equation 6) process of order 6 with twelve monthly dummies. Relative price volatility would then be estimated as the standard deviation of the twelve-month ahead forecast error. With my data set, there are no qualitative difference in results using either measure.<sup>10</sup> For ease of reproduction, the results using the volatility measure given by (equation 6) will be reported hereafter.

### Idiosyncratic Shocks

This article focuses on the excess volatility of cross-border prices. Implicitly assumed is that cross-border prices exhibit less comovement than within-country prices. As a refinement to their original methodology, Engel and Rogers (1998) suggest examining relative prices in terms of their common and idiosyncratic shocks. Assume log prices can be modeled as the following:

$$\begin{aligned} p_{i,t} &= v_{i,t} - w_t \\ p_{j,t} &= v_{j,t} - w_t \end{aligned}$$

The log price in city  $i$  is affected by a shock common to all cities ( $w_t$ ) and a shock specific to each city  $i$  ( $v_{i,t}$ ). The correlation between log prices is:

$$\text{Corr}(p_{i,t}, p_{j,t}) = \frac{\text{Var}(w)}{\sqrt{\text{Var}(v_i) + \text{Var}(w)} \sqrt{\text{Var}(v_j) + \text{Var}(w)}} \tag{7}$$

Looking at (equation 7), it is clear that an increase in  $\text{Var}(v_i)$ , the variance of the idiosyncratic shock in city  $i$ , will cause the price correlation between cities  $i$  and  $j$  to decrease. In other words, the two prices will move more closely together when most of the variation in each price series is due to a common factor.

How much can this hypothesis explain relative price volatility? To see this, we must isolate the innovation part of price changes from the deterministic. This is accomplished by fitting a higher-order autoregressive process with monthly dummies to each price series. The covariance of price shocks was then taken to be the average pair-wise covariance between the residuals from each fitted price series.<sup>11</sup> To determine the importance of the differential price shock hypothesis in explaining relative price variation, the regression in (equation 4) is augmented to:

$$q_{ij} = \alpha D_{ij} + \beta X_{ij} + \sum_{k=1}^K \gamma_k C_k + \delta SCV_{i,j} + u_{ij} \quad (8)$$

where  $SCV_{ij}$  is the price shock covariance between cities  $i$  and  $j$ . As this variable increases in magnitude, we should observe greater correlation between prices and lower relative price volatility. By including this variable, the estimated distance and border effects will have been filtered from any differential response to shocks between cities.

### Uneven Sampling Bias

Is the border effect a statistical artifact of the samples used to estimate it? Cheung and Lai (2006) show that if the sample includes an unequal number of locations across borders, then any estimated border effects may be biased. Recall the definition of excess cross-border price volatility between two countries presented in (equation 3)

$$\Phi = \text{Avg}[\text{Var}(p_{ij,t}^c)] - \text{Avg}[\text{Var}(p_{kl,t}^w)]$$

When computing  $\text{Avg}[\text{Var}(p_{ij,t}^c)]$ , every cross-border pair contains one observation from each country on either side of the border. The average variance of within-country pairs across all countries in the sample, however, will be a weighted average, with the weights defined as the share of total locations within a particular country. Thus, if we over-sample a country that has relatively low within-country price variation, we run the risk of overestimating the excess volatility of prices across borders.

Let  $n_h$  be the number of locations sampled in the home country and  $n_f$  be the number sampled in the foreign country. Cheung and Lai (2006) show that when there is even sampling ( $n_h = n_f$ ), the expected excess variation of cross-border prices is:

$$E(\Phi) = E[\text{Var}(p_{ij}^c)] - \frac{E[\text{Var}(p_{kl}^h)] + E[\text{Var}(p_{mn}^f)]}{2} \quad (9)$$

When there is uneven sampling ( $n_h \neq n_f$ ), the expected border effect (excess cross-border variation) is:

$$E(\Phi^*) = E[\text{Var}(p_{ij}^c)] - \frac{n_h E[\text{Var}(p_{kl}^h)] + n_f E[\text{Var}(p_{mn}^f)]}{n_h + n_f} \tag{10}$$

If the border effect under even sampling is used as a benchmark, then the expected bias from uneven sampling is given by:

$$E(\Phi^* - \Phi) = \frac{n_f - n_h}{n_f + n_h} \frac{E[\text{Var}(p_{kl}^h)] - E[\text{Var}(p_{mn}^f)]}{2} \tag{11}$$

To see how uneven sampling may predictably bias estimates of the border effect, suppose that we over-sample the home country ( $n_h > n_f$ ) and that relative prices within the home country are more volatile than those within the foreign country. Looking at (equation 11), we see that we would actually be underestimating the true border effect. If we were to over-sample the foreign country, we would be overestimating the border effect by giving too much weight to the nation with low within-country price variation.

### The Data

To estimate border effects in Europe before and after the introduction of the euro, I use a data set of per diem rates (in U.S. dollars), 1995-2004, published by the U.S. State Department for employees living abroad.<sup>12</sup> The rates are broken down into two categories as follows: “lodging” and “meals and incidental expenses.” The total per diem is the sum of these two rates. The price series thus applies to highly nontradable goods. We should therefore expect to see greater price dispersion here than would be for more tradable goods. However, these goods do have traded intermediate components and the theory being tested is that prices move in the same direction, not that they fully equalize between locations.

Thus, a major drawback to using this price series is that any estimated border effects are likely to be upper bound estimates, given limited arbitrage. However, the weakness in the data of estimating the border effect at a given point in time is exactly its strength in estimating the change in the border effect following the introduction of the euro. With limited arbitrage, any estimate of a reduced border effect using these prices will thus be a lower bound. We can be more confident about any evidence of Euro zone price convergence following the introduction of the euro with this data set than estimates obtained from a data set using more tradable goods. A more thorough explanation and justification for the use of nontradables to measure changes in the border effect is given in Appendix C.

The second weakness with this data set is that it uses highly aggregated goods that are not uniform across locations. The law of one price states that through trade, prices for the same good traded in different locations should converge. If goods are

different, then there is less reason to expect prices to converge. While a valid criticism, I argue that we may still observe price convergence for three reasons. First, the standards used to collect prices make a concerted effort to compare similar items across locations. The U.S. State Department requires foreign posts to submit a detailed report on living costs covering the three most frequently used hotels and the cost of breakfast, lunch, and dinner at the three most frequently used restaurant in each post.<sup>13</sup> Those completing the report are instructed to select moderately priced hotels that meet common standards on size, cleanliness, and security. The price survey also incorporates differences in taxes, whether meals are included in the lodging rate, and whether there are seasonal differences in rates. For meals, each report lists detailed information on the cost of breakfast, lunch, and dinner across multiple restaurants in each post. For example, the breakfast survey asks for the typical cost of a breakfast consisting of bacon, two eggs, juice, toast, and coffee or tea exclusive of taxes and tips. The lunch and dinner surveys are even more detailed with different categories for beef, chicken, fish, soup, and salad. Thus, the price surveys make an effort to make highly aggregated categories like lodging and meals comparable across locations.

Even if these goods are not directly tradable across locations, we may still see price convergence if a common currency increases the coordination of business cycles. Prior to the introduction of the euro, countries were able to pursue independent monetary policy and displayed varying tolerances for inflation. An economic shock that affected all countries in the region could have differing responses by monetary policy makers, with imperfect capital mobility allowing for different interest rates across the region. With a common monetary policy, all countries will have the same monetary response to an economic shock, thus removing one national level determinant of price dispersion.

Finally, even highly aggregated goods have common disaggregated components. Although a meal in Paris may not really be comparable to a meal in Naples, the two products share many common traded components. If the introduction of the euro causes the prices of these components to converge, then we should see at least partial convergence of the aggregate prices.

The data set covers monthly price observations from January 1995 through December 2004 for 201 cities in sixteen countries. Data was collected for cities that had uninterrupted coverage over the entire sample period and any city with seasonal prices for lodging or meals (typically resort destinations) was dropped from the data set.<sup>14</sup> The dependent variable is a function of the relative price, which requires city pairs. In general, it is necessary to calculate  $N(N - 1)/2$  relative price volatilities. This is because we not only need to calculate the relative price variances but the covariance as well. For example, even after computing the London/Paris and London/Rome relative price variances, we still need to compute the Paris/Rome relative price volatility (to compute the covariance between the two previous relative price series). There are 201 cities in the sample, requiring estimation of a total of 20,100 relative price volatilities. A summary of the data is presented in Table 1.

**Table 1**  
**Summary Statistics for Same-Country Pairs**

	Cities	City Pairs	Avg. Distance (km)	Avg. St.Dev ( $\times 1,000$ )
Austria	4	6	214.1	30.9
Belgium	15	105	80.0	21.7
Denmark	1	–	–	–
Finland	1	–	–	–
France	16	120	393.1	40.7
Germany	65	2,080	285.2	40.6
Ireland	3	3	127.0	46.6
Italy	22	231	347.7	44.3
Luxembourg	1	–	–	–
Netherlands	10	45	54.4	41.8
Norway	1	–	–	–
Portugal	2	1	274.4	70.4
Spain	22	231	588.7	31.6
Sweden	1	–	–	–
Switzerland	3	3	149.0	37.1
United Kingdom	34	561	270.6	32.8
Cross-border Pairs	–	16,714	953.0	50.3
Total	201	20,100	834.7	48.3

Note: The number of cities is defined as the number of cities within each country, whereas the number of city pairs is the number of distinct pairs that can be formed within each country (equal to  $N(N-1)/2$  where  $N$  is the number of cities in each country). Avg. Distance is the average physical distance between same-country cities and Avg. St. Dev is the average standard deviation of the log-first differenced relative prices (per diem rates) of within-country city pairs computed across monthly observations covering 1995–2004.

The first column lists the number of cities in each country, and the second column gives the total number of distinct city-pairs in each country. For example, there are four cities in Austria that form six unique city pairs within Austria. There is only one city in Finland sampled, meaning that there are no city pairs within Finland (although 200 cross-border city pairs can be formed with Helsinki). The third column lists the average distance between locations in each country. Distance is calculated for each location as the great circle distance between city pairs.<sup>15</sup> The fourth column lists the average standard deviation of the relative price (defined by the daily per diem rate). A cursory examination indicates higher cross-border price volatility, although it is unclear whether this is directly attributable to aspects of the border or to the greater distance between cross-border pairs.

### Baseline Results

To isolate the border effect from distance, I estimate the simple regression model in (equation 4) by Ordinary Least Squares (OLS). Estimates from my data set and

**Table 2**  
**Benchmark Results Relative to Engel and Rogers (1996)**

	Log Distance	Border	Border Width (km)	Adjusted $R^2$
Per diem	2.06 (0.19)	11.35 (0.26)	120	0.89
E.R. "pooled estimates"	1.06 (0.33)	11.9 (0.42)	1,676	0.77
Lodging	2.58 (0.23)	10.12 (0.30)	31	0.88
E.R. "shelter"	0.84 (0.18)	9.42 (0.21)	3,990	0.93
Meals	2.06 (0.16)	10.68 (0.23)	99	0.87
E.R. "food away from home"	0.18 (0.89)	9.71 (0.11)	367	0.97

Note: Estimates of (equation 4) in the text. Heteroskedasticity consistent standard errors reported in parentheses. All coefficients have been multiplied by  $10^3$  for clarity. Estimates starting with "E.R." are from Table 3 of Engel and Rogers (1996). All coefficients are significant at the 1 percent level. The width of the border is defined as the number of kilometers in distance needed to replicate the effect of crossing the border for two locations within the same country. It is computed as  $\exp\{\beta/[\alpha + 1.645 \times \text{SE}(\alpha)]\}$ , where  $\alpha$  is the coefficient on distance and  $\beta$  is the estimated border effect. We use the 95 percent confidence interval upper-bound estimate of the distance effect as in Engel and Rogers (1996) to get conservative estimates of the border width.

those obtained for similar goods in Engel and Rogers (1996) are presented in Table 2. Both distance and the border prove to be significant determinants of relative price volatility, supporting the original Engel and Rogers results for the United States and Canada. However, the impact of the border relative to distance (the "width" of the border) is much smaller with this data set. Engel and Rogers conservatively estimate that crossing the border is equivalent to over 2,800 km of distance for same country cities, while I estimate a border less than a tenth as large. Note, however, that this is not necessarily because of a smaller role of national borders but rather a larger role for distance (representing transport costs) in Western Europe. Said differently, the marginal effect of a kilometer of distance on relative price volatility between two European cities is greater than the marginal effect between two United States or two Canadian cities. This result suggests that relative price volatility between Berlin and Frankfurt should actually be higher than that between New York and Washington, DC, given that these city pairs have about the same distance between them. That markets appear to be more segmented within Europe than within the United States or Canada is a somewhat surprising result.

Using Engel and Rogers (1996) methodology, both distance and the border have a significant impact on relative price volatility. How much of this is a real linkage and how much is specification error? In the last section, two potential problems with the original specification were introduced—the presence of idiosyncratic price shocks and uneven sampling bias. To account for idiosyncratic price shocks, I include a measure of the covariance between price shocks for all relative price series. The potential bias caused by uneven sampling has a simple solution: resample all countries so that they have an equal number of cities. To maintain a wide range of

**Table 3**  
**Summary Statistics for the Even Sample**

	Cities	City Pairs	Avg. Distance (km)	Avg. St.Dev ( $\times 1,000$ )
Belgium	10	45	101.5	20.3
France	10	45	514.8	45.9
Germany	10	45	391.6	49.7
Italy	10	45	552.1	52.6
Netherlands	10	45	44.9	41.8
Spain	10	45	628.0	28.3
United Kingdom	10	45	346.4	49.2
Cross-border Pairs	–	2,100	1,206.6	51.8
Total	70	2,415	1,097.3	50.4

Note: See Table 1 for a description of each column. The ten cities in each country were selected based on average population over the period 1995–2004.

countries, the ten largest cities (as measured by average population over the sample period) were selected for each country. If a country did not have ten cities in the original sample, it was dropped. The new even sample covers the ten largest cities in each of the following countries: Belgium, France, Germany, Italy, the Netherlands, Spain, and the United Kingdom. From these seventy cities, we can construct 2,415 distinct city pairs. Of these, 315 are within-country pairs and 2,100 are cross-border pairs.

Another potential problem with the original sample is the distance estimate, which fails to account for geography. Rather than use great circle distance for the even sample, I compute actual driving distances between the centers of the 2,100 city-pairs using data from Google Maps. These distances more accurately reflect trade costs, although the empirical estimates are not qualitatively different using either distance measure. Summary statistics for the even sample are presented in Table 3.

The even sample preserves the cross-country heterogeneity that made the data set appealing in the first place. Countries differ both in terms of geographic size and population density. Unfortunately, we are left with only one country not adopting the euro in 1999 (the United Kingdom), but some useful inferences may still be made. A cursory examination of the even sample reveals a positive correlation between distance and relative price volatility, and suggests that cross-border prices are more volatile than those within countries.

Table 4 lists the OLS estimation results for the original specification given by (equation 4) and the refined specification in (equation 8), using both the uneven and the even samples. The evidence suggests that uneven sampling of locations has created an upward bias in estimates of the border effect, as the magnitude of the border effect is lower with the even sample. The border is, however, still a statistically significant determinant of relative price volatility. Cities located further apart tend to have higher relative price volatility, whereas those who have more common

**Table 4**  
**Uneven Sampling and Idiosyncratic Shocks**

	All Cities I	Even Sample I	All Cities II	Even Sample II
Distance	2.06* (0.19)	0.06 (0.33)	0.87* (0.10)	0.13 (0.22)
Border	11.35* (0.296)	10.55* (0.75)	5.58* (0.17)	4.68* (0.43)
SCV	—	—	-23.75*(0.33)	-21.03* (0.77)
Border width (km)	120	>20,000	3,990	13,550
Adjusted $R^2$	0.89	0.90	0.95	0.95
Observations	20,100	2,415	20,100	2,415

Note: Estimates of (equation 4) and (equation 8) in the text for per diem rates (sum of lodging and meals). Significance at the 5 percent level indicated by \* as determined by robust standard errors reported in parentheses. All coefficients have been multiplied by  $10^3$  for clarity. Specification I regresses relative price volatility on log distance, the border variable, and city fixed effects. Specification II adds the covariance of idiosyncratic price shocks for each city pair. The even sample includes the ten largest cities in each of seven countries. SCV = shock covariance.

responses to price shocks tend to have more stable relative prices. Once unique price shocks have been accounted for, the border is still significant, but the distance effect falls in both magnitude and significance. This would seem to indicate that the distance effect had been picking up differences in market conditions between locations.

## The Effects of Monetary Union

The results in the last section confirmed that cross-border relative prices are more volatile than those within a country, even after controlling for distance, idiosyncratic shocks, and uneven sampling bias. National borders are economically significant for a number of reasons, such as defining the boundaries of currency usage and monetary policy. Are borders still economically significant after they cease to define these boundaries? The results in this section suggest that while cross-border price volatility remains higher than within-country volatility, there has been a significant reduction across the countries that adopted the euro and ceded monetary policy to the European Central Bank (ECB).

We can estimate how border and distance effects have changed since the inception of the euro by taking advantage of the fact that both the distance and the presence of a border between cities do not change over time. Recall the econometric specification given by (8):

$$q_{ij} = \alpha D_{ij} + \beta X_{ij} + \sum_{k=1}^K \gamma_k C_k + \delta SCV_{ij} + u_{ij}$$

We can split the sample into pre- and post-euro periods:

**Table 5**  
**Differential Border and Distance Effects**

	All Countries	EA Pairs Only
Change in border effect	1.60 (0.89)	0.20 (0.89)
Change in distance effect	-1.91* (0.36)	-1.87* (0.34)

Note: Significance at the 1 percent level given by \*. Estimates of equation (14) in the text, regressing the change in relative price volatility between the post- and pre-euro periods on log distance, the border, price shock covariance, and city fixed effects using the even sample of locations across seven countries. EA pairs refers to city pairs located within the EA (essentially excluding any city pair formed by at least one United Kingdom city). Heteroskedasticity consistent standard errors reported in parentheses. EA = Euro Area.

$$q_{ij}^{pre} = \alpha^{pre} D_{ij} + \beta^{pre} X_{ij} + \sum_{k=1}^K \gamma_k^{pre} C_k + \delta^{pre} SCV_{ij}^{pre} + u_{ij}^{pre} \tag{12}$$

$$q_{ij}^{post} = \alpha^{post} D_{ij} + \beta^{post} X_{ij} + \sum_{k=1}^K \gamma_k^{post} C_k + \delta^{post} SCV_{ij}^{post} + u_{ij}^{post} \tag{13}$$

Distance, border, and city fixed effects do not change over time. We can subtract (equation 12) from (equation 13) to obtain the following:

$$q_{ij}^{post} - q_{ij}^{pre} = (\alpha^{post} - \alpha^{pre}) D_{ij} + (\beta^{post} - \beta^{pre}) X_{ij} + \sum_{k=1}^K (\gamma_k^{post} - \gamma_k^{pre}) C_k + (\delta^{post} SCV_{ij}^{post} - \delta^{pre} SCV_{ij}^{pre}) + (u_{ij}^{post} - u_{ij}^{pre}) \tag{14}$$

If there has been no change in the distance or border effects between the pre- and post-euro periods, then the estimated coefficients on distance and the border above should be zero. If the introduction of the euro has reduced the significance of these effects, then the estimates should be negative and vice versa.

Table 5 gives OLS estimates of (equation 14) for both the entire even sample and for city pairs located within the EA. For both groups, the border effect did not significantly change between the pre- and post-euro periods. Interestingly, the importance of distance in explaining relative price volatility has fallen significantly for both groups, indicating a reduction in arbitrage barriers.

The results above indicate that the adoption of the euro has not had any significant impact on cross-border price volatility. However, these estimates are from a sample pooled across a heterogeneous group of countries. It may be useful to look at the effect of monetary union on a country-by-country basis. Table 6 provides estimates of the border effect prior to the introduction of the euro (equation 12) and the differential volatility specification (equation 14) for all country pairs in the even sample.

**Table 6**  
**Change in the Border and Distance Effects, Country Pairs**

			Border Effect, Pre-Euro	$\Delta$ Border Effect	$\Delta$ Distance Effect
Large-large	United Kingdom	France	4.75*** (1.19)	0.20 (2.62)	0.35 (1.68)
	United Kingdom	Germany	8.43*** (1.49)	3.92 (3.81)	3.89* (1.93)
	United Kingdom	Italy	6.33*** (1.53)	0.85 (3.12)	0.14 (1/58)
Large-small	United Kingdom	Belgium	3.85*** (1.17)	12.94*** (2.56)	0.85 (0.78)
	United Kingdom	Netherlands	3.55** (1.65)	5.08* (3.06)	1.57 (1.54)
	United Kingdom	Spain	3.50* (1.39)	5.79* (3.48)	1.12 (1.53)
Large-large	France	Germany	8.47*** (1.05)	-5.02*** (1.72)	-0.17 (1.40)
	France	Italy	9.10*** (1.01)	-4.72** (1.88)	-1.98 (1.35)
	Germany	Italy	8.87*** (1.36)	-4.08* (2.03)	-2.56 (1.75)
Large-small	France	Belgium	6.19*** (1.14)	2.10 (1.63)	-1.79** (0.74)
	France	Netherlands	1.91 (2.26)	2.05 (3.08)	-2.96** (1.39)
	France	Spain	5.50*** (1.05)	-2.38 (1.82)	0.22 (1.47)
	Germany	Belgium	4.22*** (1.34)	0.32 (1.46)	0.56 (0.98)
	Germany	Netherlands	4.59** (2.04)	-1.32 (2.58)	0.94 (1.87)
	Germany	Spain	4.32** (1.75)	0.21 (2.34)	-0.48 (1.56)
	Italy	Belgium	6.07*** (1.73)	1.13 (1.72)	-1.21 (0.75)
	Italy	Netherlands	3.89 (3.06)	3.44 (3.50)	1.60 (1.49)
	Italy	Spain	5.62*** (1.29)	-0.37 (1.99)	-0.47 (1.51)
Small-small	Belgium	Netherlands	0.61 (1.50)	3.31** (1.49)	-1.43 (0.97)
	Belgium	Spain	4.56*** (1.66)	-4.39** (1.72)	-1.17 (0.77)
	Netherlands	Spain	0.61 (3.54)	-0.30 (4.19)	-1.76 (1.65)

Note: Estimates of equations (12) and (14) on a country-by-country basis. Significance at the 1, 5, and 10 percent levels given by \*\*\*, \*\*, and \*, respectively. Country size is based on Gross National Product (GNP). For columns five and six, a negative coefficient indicates a decrease in the border or distance effects following the introduction of the euro, whereas a positive coefficient indicates an increase. All estimates are from the specification using an even number of cities in each country and actual driving distances between locations. Heteroskedasticity consistent standard errors reported in parentheses.

The estimation results are grouped by country size and euro status.<sup>16</sup> The first three rows show that there has been no discernible change in excess cross-border price variation between the United Kingdom and the three large Euro countries. The coefficients on the change in border effect are all positive, indicating an increase in market segmentation, but not significantly different from zero. Distance has become a more significant factor in determining price dispersion between Germany and the United Kingdom but not for the other two country pairs. The next three rows highlight the explicit cost of the United Kingdom not adopting the euro: less integration with the small open economies of the Euro zone. National borders have grown in significance between cities in the United Kingdom and those in Belgium, the Netherlands, and Spain. Excess cross-border price variation between the United Kingdom and Belgium has increased by 336 percent since the introduction of the

euro. Although less dramatic, I estimate increases of 143 and 165 percent for cross-border prices with the Netherlands and Spain. These results may suggest that markets in these small EA nations have turned away from the United Kingdom since the introduction of the euro.

Excess cross-border price variation has fallen between the large countries in the EA. Estimating (equation 12) for France and Germany, the border coefficient is 8.47. The change in the border coefficient for France and Germany following the introduction of the euro is  $-5.02$ , a decline of nearly 60 percent. In other words, cross-border relative prices between France and Germany have become 60 percent less volatile relative to within-country prices since the introduction of the euro. Border effects between France and Italy and Germany and Italy declines similar magnitudes. This decrease in the economic significance of national borders suggests that the movement to a common currency was effective at integrating markets across these borders. The reduction in the border effect also suggests an implicit cost to the United Kingdom of not adopting the euro: greater market integration with its main trading partners.

The border effect does not appear to have changed between the large and small EA countries. One possible explanation for this is even before the introduction of the euro, the smaller EA countries had currencies and monetary policies closely tied to the larger EA nations. The remaining border effect could be because of such things as differing national standards or home biases that are less affected by having a common currency. Looking at the impact of the euro on border effects across the small EA countries, the results are mixed. Cross-border price volatility has actually increased between Belgium and the Netherlands, while that between Belgium and Spain has fallen. Although somewhat counterintuitive, this result actually makes sense if the adoption of a common currency has reduced trade barriers between Belgium and Spain. Some trade between Belgium and the Netherlands may have been diverted to Spain after the introduction of the euro. As a result, two highly synchronized economies drifted apart somewhat to increase coordination with a distal third nation.

Why have the effects of the EA on cross-border price volatility differed across countries? One possible explanation is differences in market power in the foreign exchange market. Consider, for example, the issue of incomplete exchange rate pass through. Theoretically, differences in prices between locations should pass through to exchange rates (or vice versa) in each location, eliminating arbitrage opportunities. However, exchange rates between small countries are more likely to adjust to price differences than exchange rates between larger nations. Thus, exchange rate differences are more likely to be translated into price differences in large countries. The elimination of multiple exchange rates should therefore have a larger effect between the larger countries, exactly the result found by this study.

So why was there an increase in cross-border price volatility between the United Kingdom and the small Euro countries, but no similar increase between the United

Kingdom and the large Euro countries? One possible explanation could be that the value of the euro on the foreign exchange market is predominantly determined by the large EA countries. Thus, the larger nations did not see as significant a change in their exchange rate with the United Kingdom as the smaller EA countries. As a result of the relatively larger realignment, the smaller EA countries experienced greater market divergence with the United Kingdom.

## Conclusions

Proponents of monetary union argue that it will usher in a new age of price stability and economic prosperity across the currency area. Has this really occurred in the admittedly short history of the euro? Has price volatility fallen across the EA, and if so, has this been because of the formation of a monetary union? The results in this article suggest that the effects of the euro on cross-border price volatility depend on the sizes of the countries on either side of the border. Within the EA, larger countries have experienced a decrease in price variability, perhaps because of incomplete exchange rate pass through before the adoption of a common currency. Cross-border price volatility between these countries and the United Kingdom has not changed, but cross-border prices have become more volatile between the United Kingdom and smaller EA nations.

Several policy implications with regard to European countries outside of the EA (most notably the United Kingdom) emerge from this study. Stable cross-border prices are important for several reasons. First, stable prices across borders promote both trade and investment by reducing risk. Second, the potential problem of asymmetric monetary policy is mitigated if prices are stable across the monetary union. The results in this study suggest that these benefits have accrued to France, Germany, and Italy, but not for the smaller EA members. That national borders have declined in significance for these larger nations may suggest that the euro has been effective at integrating markets for these countries.

The results in this study present evidence of greater price stability across the EA, particularly for the larger EA members. The main limitation of this study is in the price series used. Clearly, lodging and meals are two goods (or rather services) that are nontradable. The kind of goods for which we would expect to see prices converge following the adoption of a common currency are tradable goods. Thus, this price series is suspect for any study trying to estimate the importance of national borders at a given point in time. The results in Tables 2 and 4 should therefore be taken with a grain of salt. The greatest weakness of the data set turns into its greatest strength, however, when looking at changes in the border effect. Prices of highly traded goods should be the first to respond to the single currency, with nontradable goods prices taking longer to adjust to this policy shift. Any evidence of a reduced border effect found by examining nontradable goods prices must then be considered to be lower

bound estimate of the true amount of market convergence brought about by the adoption of a single currency.

## Notes

1. Technically, these studies reject mean reversion by failing to reject a unit root. The hypothesis tests employed in these studies are subject to the low power critique of standard unit root tests. More powerful unit root tests such as those introduced by Elliott, Rothenberg, and Stock (1996) and Pesavento (2004) have lent greater support to mean reversion, albeit at a very slow pace.

2. These costs are not insignificant. Davis (1998) estimates transport costs as a percentage of imports in the United States to be 4.8 percent, a higher cost than import tariffs. Limao and Venables (2001) provide evidence that these costs are significantly trade reducing, with the elasticity of trade to transport costs at  $-2.5$  percent.

3. For example, McCallum (1995), Helliwell (1996).

4. This could apply to a firm selling any type of good whose price (or the prices of its inputs) are quoted in dollars.

5. Imperfect capital mobility can allow interest rates to vary across the region.

6. See chapter 3.4 in Baldwin (2006) for a more thorough review of the literature on the euro's impact on trade pricing.

7. Similar patterns hold for other relative prices. For example, the Strasbourg to Bordeaux relative price displays much more stability than the Strasbourg to Frankfurt relative price prior to 1999 despite the fact that Strasbourg is 800 km closer to Frankfurt than to Bordeaux. After the introduction of the Euro in 1999, the relative volatility of the cross-border price series declines markedly.

8.  $\text{Var}()$  in this case refers to the variance operator.

9. Note that this specification is essentially a gravity equation, proven to be quite successful in estimates of international trade (cf. Bergstrand 1985).

10. I also used the mean absolute deviation as a measure for relative price volatility. The sign and significance of the border effects did not change, although the distance effect was of smaller magnitude. This may be attributed to the nonlinear relationship between distance and relative price volatility.

11. Specifically, each price series was estimated with a sixth-order AR process with twelve monthly dummies. Using a data dependent lag selection method with Akaike Information Criteria (AIC), the optimal lag length was between four and six over all price series. To err on the side of caution, six lags were used for all prices.

12. The choice of this data set over other sources of price data on cities in Europe (such as the Economist Intelligence Unit data on living expenses) was made because of the large number of cities within each country. Significant within-country heterogeneity is essential to getting accurate estimates of the border effect. Having a large number of cities comes at the costs of fewer goods, however. Given that the emphasis of this article is on price volatility, it seems better to have more locations and fewer goods than vice versa.

13. The survey completed by each post is Form DS-2026, available at <http://www.usa-federal-forms.com/usa-fedforms-dos-ds-other/usdos-other-ds-2026-nonfillable.pdf>.

14. Seasonal prices are identified directly in the State Department database and generally refer to popular tourist destinations with high seasons.

15. This calculation is made by first approximating the shape of the earth as spherical. Then, once the geographic coordinates are converted into radians, the distance between cities 1 and 2 is calculated from the following formula for computing the surface distance (in kilometers) between two points on a sphere:  $6378 \times \arccos[\sin(\text{lat}1) \times \sin(\text{lat}2) + \cos(\text{lat}1) \times \cos(\text{lat}2) \times \cos(\text{lon}2 - \text{lon}1)]$ , where  $\text{lat}_{\{i\}}$  and  $\text{lon}_{\{i\}}$  are the latitude and longitude for city  $i$  in radians. This approximation is fairly accurate, generally within

thirty kilometers of the actual distance between locations. The city center is chosen as the reference point for latitude and longitude coordinates, and geographic features such as mountains and rivers are not taken into consideration.

16. A country's "size" classification is a somewhat arbitrary measure based on GDP. There are six EA countries in the even sample, so the three countries with the highest Gross Domestic Product (GDP) (France, Germany, and Italy) are deemed to be large, whereas the three lowest GDP countries (Belgium, the Netherlands, and Spain) are classified as small. The size groupings are solely for clarity and the reader is encouraged to examine the estimates on a country-by-country basis.

17. See the exhaustive study by Baldwin (2006) for a review of the trade impact of currency unions.

## Appendix A

### List of Cities, Full Sample

Country	City	Country	City
Austria	Innsbruck	Germany	Esslingen
	Linz		Frankfurt am Main
	Salzburg		Fuerth
	Vienna		Garmisch-Partenkirchen
Belgium	Antwerp		Germering
	Bertrix		Giebelstadt
	Brugge		Hamburg
	Brussels		Hannover
	Diegem		Heidelberg
	Florennes		Herongen
	Ghent		Herrsching
	Gosselies		Herzogenaurach
	Herstal		Hoescht
	Leuven		Ingolstadt
	Liege		Kaiserslautern-Landkreis
	Mons		Kalkar
	Oostende		Kitzingen
	Shape/Chievres		Koenigswinter
Zaventem		Konstanz	
Denmark	Copenhagen		Kornwestheim
			Leipzig
Finland	Helsinki		Ludwigsburg
			Moenchen-Gladbach
			Munich
France	Aix-en-Provence		Nellingen
		Bordeaux	New Ulm
		Clermont-Ferrand	Niederbachem
		Lyon	Nürnberg
		Marignane	Oberammergau
		Marseille	Offenbach
		Rhoendorf	

*(continued)*

**Appendix A (continued)**

Country	City	Country	City
	Metz		Roedelheim
	Montpellier		Rostock Warnemünde
	Mulhouse		Saarbrücken
	Nancy		Schwabach
	Nice		Schwerin
	Paris		Sembach
	Strasbourg		Sindelfingen
	Suresnes		Starnberg
	Toulouse		Stuttgart
			Sylt Island
Germany	Aachen		Tübin gen
	Bad Honnef		Twisteden
	Berlin		Ulm
	Böblingen		Wahn
	Bonames		Würzburg
	Bonn		Zirndorf
	Bremen		
	Chemnitz	Ireland	Adare
	Cologne		Dublin
	Delmenhorst		Limerick
	Dresden		
	Düsseldorf	Italy	Bari
	Echt erdingen		Bologna
	Erfu rt		Ferrara
	Erlangen		Florence
	Eschborn		Genoa
	Ess en		La Spezia
Italy	Milan	Switzerlan d	Bern
	Modena		Geneva
	Naples		Zurich
	Palermo		
	Pisa	United Kingdom	Aberdeen
	Ravenna		Beacons field
	Reggio Emilia		Belfast
	Rimini		Birmingham
	Rome		Bournemouth
	Siena		Brighton
	Taormina		Bristol
	Trieste		Bury St. Edmonds
	Turin		Cambridge
	Venice		Canterbury
	Verona		Cardiff
	Vicenza		Caversham
			Crawley

(continued)

**Appendix A (continued)**

Country	City	Country	City
Luxembourg	Luxembourg		Dover
			Edinburgh
The Netherlands	Amsterdam		Ft. Halstead
	The Hague		Gat wick
	Leiden		Glasgow
	Lisse		Harrogate
	Noordwijkt		High Wycombe
	Papendrech		Horley
	Rotterdam		Inverness
	Schiphol		Liverpool
	Utrecht		London
	Ypenburg		Manchester
			Men with Hill
Norway	Oslo		Nottingham
			Oxford
Portugal	Lisbon		Plymouth
	Oporto		Poole
			Portsmouth
Spain	Barcelona		Reading
	Bilbao		Southampton
	Fuengirola		Winchester
	Gerona		
	Getafe		
	La Coruña		
	Leri da		
	Logroño		
	Madrid		
	Malaga		
	Marbella		
	Oviedo		
	San Sebastian		
	Santander		
	Santiago de Co mpostela		
	Seville		
	Tarragona		
	Torreon		
	Torremolinos		
	Valencia		
	Vitoria		
	Zaragoza		

## Appendix B

### List of Cities, Even Sample

Country	City	Country	City
Belgium	Antwerp	Netherlands	Amsterdam
	Brugge		The Hague
	Brussels		Leiden
	Ghent		Lisse
	Herstal		Noordwijk
	Leuven		Papendrecht
	Liege		Rotterdam
	Mons		Schiphol
	Oostende		Utrecht
	Zaventem		Ypenburg
France	Aix-en-Provence	Spain	Barcelona
	Bordeaux		Bilbao
	Clermont-Ferrand		La Coruña
	Lyon		Madrid
	Marseille		Malaga
	Montpellier		Oviedo
	Nice		Seville
	Paris		Valencia
	Strasbourg		Vitoria
	Toulouse		Zaragoza
Germany	Berlin	United Kingdom	Birmingham
	Bremen		Bristol
	Cologne		Cardiff
	Düsseldorf		Edinburgh
	Essen		Glasgow
	Frankfurt am Main		Liverpool
	Hamburg		London
	Hannover		Manchester
	Munich		Nottingham
	Stuttgart		Plymouth
Italy	Bari		
	Bologna		
	Florence		
	Genoa		
	Milan		
	Naples		
	Palermo		
	Rome		
	Turin		
Venice			

## Appendix C

### Justification for Using Nontradables

Assume that each good in city  $i$  has both traded and nontraded components such that:

$$p_{i,t} = (1 - \alpha)p_{i,t}^T + \alpha p_{i,t}^N \quad (\text{A1})$$

The price of the final good in city  $i$  is a function of the prices of the traded (T) and nontraded (N) intermediate components and the share of the nontraded good price ( $\alpha$ ) in the final price. Let the relative price between two cities ( $i$  and  $j$ ) separated by a border be:

$$p_{ij,t}^c = [(1 - \alpha)p_{i,t}^T + \alpha p_{i,t}^N] - [(1 - \alpha)p_{j,t}^T + \alpha p_{j,t}^N] \quad (\text{A2})$$

Similarly, the relative price between two cities ( $i$  and  $k$ ) within the same country is:

$$p_{ik,t}^w = [(1 - \alpha)p_{i,t}^T + \alpha p_{i,t}^N] - [(1 - \alpha)p_{k,t}^T + \alpha p_{k,t}^N] \quad (\text{A3})$$

The border effect is defined as the pooled excess volatility of cross-country relative prices over within-country relative prices:

$$\Phi = \text{Avg}[\text{Var}(p_{ij}^c) - \text{Var}(p_{ik}^w)] \quad (\text{A4})$$

Assume that cities  $i$ ,  $j$ , and  $k$  are representative of the sample (enabling us to drop the average term) and substitute the traded and nontraded components of each price:

$$\Phi = (1 - \alpha)^2 [\text{Var}(p_{ij}^{cT}) - \text{Var}(p_{ik}^{wT})] + \alpha^2 [\text{Var}(p_{ij}^{cN}) - \text{Var}(p_{ik}^{wN})] \quad (\text{A5})$$

Assume  $[\text{Var}(p_{ij}^{cT}) - \text{Var}(p_{ik}^{wT})] < [\text{Var}(p_{ij}^{cN}) - \text{Var}(p_{ik}^{wN})]$ . In other words, the excess volatility of cross-border relative prices will be smaller for tradables than nontradables. This makes sense, as arbitrage should lead to more price convergence for traded goods. Thus, the more tradable a good (smaller  $\alpha$ ), the smaller the expected border effect.

In this study, we are clearly using highly nontradable goods (large  $\alpha$ ). We should observe larger border effects with these goods than we would if we were looking at commodity prices, for example. If we are using purely nontradables ( $\alpha = 1$ ), then the border effect breaks down to:

$$\Phi^{(\alpha=1)} = \text{Avg}[\text{Var}(p_{ij}^{cN}) - \text{Var}(p_{ik}^{wN})] \quad (\text{A6})$$

Without trade, there is little impetus for cross-border and within-country prices to converge. Therefore, the border effect is at a maximum for nontradable goods. However, the central question of this article is how the formation of the Euro zone has *changed* the economic significance of national borders. Using nontraded goods will

provide a lower limit estimate for the reduction in the border effect. Consider the border effect before and after the formation of the Euro zone:

$$\Phi_{\text{pre}} = (1 - \alpha)^2 [\text{Var}(p_{ij,\text{pre}}^{cT}) - \text{Var}(p_{ik,\text{pre}}^{wT})] + \alpha^2 [\text{Var}(p_{ij,\text{pre}}^{cN}) - \text{Var}(p_{ik,\text{pre}}^{wN})] \quad (\text{A7})$$

$$\Phi_{\text{post}} = (1 - \alpha)^2 [\text{Var}(p_{ij,\text{post}}^{cT}) - \text{Var}(p_{ik,\text{post}}^{wT})] + \alpha^2 [\text{Var}(p_{ij,\text{post}}^{cN}) - \text{Var}(p_{ik,\text{post}}^{wN})] \quad (\text{A8})$$

The change in the border effect is given by:

$$\begin{aligned} \Phi_{\text{post}} - \Phi_{\text{pre}} = & (1 - \alpha)^2 \left\{ [\text{Var}(p_{ij,\text{post}}^{cT}) - \text{Var}(p_{ik,\text{post}}^{wT})] - [\text{Var}(p_{ij,\text{pre}}^{cT}) - \text{Var}(p_{ik,\text{pre}}^{wT})] \right\} \\ & + \alpha^2 \left\{ [\text{Var}(p_{ij,\text{post}}^{cN}) - \text{Var}(p_{ik,\text{post}}^{wN})] - [\text{Var}(p_{ij,\text{pre}}^{cN}) - \text{Var}(p_{ik,\text{pre}}^{wN})] \right\} \end{aligned} \quad (\text{A9})$$

How will the formation of the Euro zone affect this term? The elimination of multiple currencies will have the strongest effect on trade. Several studies have found evidence of increased trade (and subsequent price convergence) following the formation of a currency union.<sup>17</sup> The impact on nontraded goods is less clear. Although the coordination of monetary policy may help to harmonize nontraded goods prices across borders, there is no trade mechanism to exploit cross-country price differences. Consider a purely nontraded good ( $\alpha = 1$ ). The differential border effect is entirely dependent on nontraded goods:

$$\Phi_{\text{post}}^{\alpha=1} - \Phi_{\text{pre}}^{\alpha=1} = [\text{Var}(p_{ij,\text{post}}^{cN}) - \text{Var}(p_{ik,\text{post}}^{wN})] - [\text{Var}(p_{ij,\text{pre}}^{cN}) - \text{Var}(p_{ik,\text{pre}}^{wN})] \quad (\text{A10})$$

Compare this to a purely traded good ( $\alpha = 0$ ):

$$\Phi_{\text{post}}^{\alpha=0} - \Phi_{\text{pre}}^{\alpha=0} = [\text{Var}(p_{ij,\text{post}}^{cT}) - \text{Var}(p_{ik,\text{post}}^{wT})] - [\text{Var}(p_{ij,\text{pre}}^{cT}) - \text{Var}(p_{ik,\text{pre}}^{wT})] \quad (\text{A11})$$

If we assume that the formation of the Euro zone will cause traded goods prices to converge more than nontraded goods prices, then clearly equation A11 will be larger than equation A10. As what we are estimating looks a lot more like equation A10 than equation A11, any evidence of a reduced border effect is likely to be a lower bound.

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