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How different are Monetary Unions to national economies according to prices?

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How different are Monetary Unions to national economies according to prices?

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Abstract

Not that different. Based on a unique dataset of semi-annual microeconomic price levels of goods and services across and within countries for 1990:1-2018:2, we show that time-series volatility and cross-sectional dispersion of law-of-one-price deviations is similar for pairs of cities within the same country and within the European Monetary Union. Our empirical analysis reveals that inflation and nominal exchange rate volatility/dispersion across locations have a positive impact on the volatility/dispersion across locations of law-of-one-price deviations across the globe. Furthermore, dispersion of law-of-one-price deviations across goods falls when the relative inflation rate between these locations rises, suggesting that the degree of price adjustment in individual product markets within a country has an international component shaped by international trade and arbitrage considerations. According to this measure of price integration, economies within the monetary union are half-way to the level of integration characterizing national economies. Moreover, monetary union membership reduces the volatility of law-of-one-price deviations, taking member countries more than half-way towards the volatility levels characterizing national economies.

Keywords: Law-of-one-price, border effect, economic integration.

JEL Classification: F4.

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1 Introduction

How does membership in a monetary union affect prices for a given country? Is the distribution of Law-of-one-price (LOOP) deviations for cities belonging to a monetary union similar to cities located within the same country? Are the sources of variation in LOOP deviations similar for cities within a monetary union and for cities located within the same country? To what extent can the adjustment of relative prices across locations be explained by changes in nominal exchange rates or inflation? Answering these questions can help us understand the determinants and degree of integration between cities located within monetary unions as compared to cities located within the same country and relative to cities located in different countries across the globe.

We show that, according to prices, the European Monetary Union (EMU) can be better understood as a national economy than as separate individual economies. Using semi-annual microeconomic price levels for individual goods and services in cities located within and across countries during the period from 1990:1 to 2018:2, we show that both cross-sectional dispersion and time-series volatility of LOOP deviations are quite similar for pairs of cities within the EMU and pairs of cities within countries, and distinctly different than LOOP deviations across countries. We also show that the drop in LOOP deviations volatility in recent years coexists with a drop in the dispersion and volatility of inflation rates and a drop in the volatility of exchange rates across the globe.

Our paper relates to the literature focusing on the effects of the process of European unification on price differences. Imbs, Mumtaz, and Ravn (2010) show that EMU countries display lower price dispersion but not necessarily because of the single currency. Rogers (2007) finds that price dispersion for tradeable goods falls sharply across European cities from 1990 to 2004 and becomes close to that of the USA. Glushenkova and Zachariadis (2016) show that although price integration across EMU economies increases after the euro, this cannot be attributed directly to the launch of the euro but rather to the overall process of economic unification that begun in the 1990s. Our results are consistent with the above-mentioned papers. Similar to Rogers (2007), we show that dispersion of LOOP deviations across the EMU eleven original members is close to that of the USA, especially during the second half of the last decade.

A number of studies emphasize the importance of a "border effect" in hindering the process of international arbitrage, asserting that as a result of exchange rate volatility the existence of a national border hampers market integration (Parsley and Wei (1996), Mussa (1986), McCallum (1995), Engel and Rogers (1996)). Policies aiming at nominal exchange rate stability could stimulate price arbitrage thus reduce price differences. The literature suggests that the adoption of a common currency may facilitate trade in goods and services and increase capital flows (Bacchetta and van Wincoop (2000), Mundell (1961)), reduce transaction costs of trade (Rose (2000), Frankel and Rose (2002), Glick and Rose (2001), and Tenreyro (2002)), enforce commitment to price stability (Alesina and Barro (2002)), and synchronize business cycles across currency union members (Rose and Engel (2002)).

Our analysis shows that nominal exchange rate dispersion across locations/volatility has a positive impact on the dispersion across locations/volatility of LOOP deviations, suggesting that nominal exchange rates play an important role in shaping a "border" between national economies.[1] However, the role of nominal exchange rates in explaining price differences across countries might be overstated in the literature. Decomposing the variance of LOOP deviations reveals that a large part of the overall variation is related to long-run good-and-location-specific factors.[2]

Our subsequent regression analysis shows that monetary union membership reduces the volatility of LOOP deviations, taking member countries more than half the distance towards the volatility levels characterizing national economies. While part of the effect of EMU membership on the volatility of LOOP deviations is due to eliminating exchange rate volatility, EMU membership much like being in the same country has a separate effect on the volatility of LOOP deviations potentially due to the synchronisation of

[1] We also show that the dispersion of inflation (exchange rates) across locations has a bigger (smaller) impact on the dispersion of LOOP deviations for non-traded goods than for traded goods.

[2] Moreover, location-specific fixed effects account for only a small portion of the variation in LOOP deviations across eurozone member countries.

business cycles, structural similarities, and similar demand characteristics. Our results suggest that the latter explanation is no less important than the elimination of exchange rate volatility.

We also find that variation of LOOP deviations across goods falls when relative inflation between locations rises, suggesting that the degree of price adjustment in individual product markets within a country has an international component shaped by international trade and arbitrage considerations. EMU membership and being in the same country have a negative impact on the dispersion of LOOP deviations across goods, with cities in EMU member countries half-way to national economies in terms of this measure of price integration. This result persists with estimated magnitudes virtually unchanged after controlling for the effect of the nominal exchange rate on this measure of price integration, suggesting again that the impact of EMU membership on price integration is largely due to factors unrelated to the nominal exchange rate such as, e.g., product market characteristics.

In the next section, we describe our data. Following that, we compare distributions of LOOP deviations for different years and groups of pairwise comparisons and discuss changes in volatility and dispersion (across goods and across countries) of LOOP deviations for cities located within the same country, cities located in different countries that form a currency union, and cities in different countries that do not form a currency union. Sections 4 and 5 describe our variance decomposition and regression results, respectively, while the last section briefly concludes.

2 Data

We use a tailor made version of the Economist Intelligence Unit (EIU) city prices data available semi-annually for 179 goods and services across 93 countries in 152 cities, some of them within the same country, for the period from 1990:1 to 2018:2. For some of the goods, the EIU reports two observations per city: for a low price outlet (supermarkets) and for a medium price outlet. The EIU survey reports retail price data paid by a customer at the point of sale and therefore include sales tax. We supplement our price data with data on VAT/GST standard rates[3] to obtain free of sales tax prices. We conduct our analysis using these adjusted consumer prices that are net of tax. In all that follows, we present results using these adjusted prices.

We apply a number of restrictions to help us obtain a comparable sample of product items across countries and over time. First, we look at all price changes and remove goods with erroneous price movements, i.e. if there is a rise or fall in prices by more than 300%. We linearly interpolate data for prices missing in only one semester using the average of the prices at $t-1$ and $t+1$, similar to Parsley and Wei (2007). We control for outliers by eliminating individual prices that are at least five times bigger or smaller than the cross-city median price for that item in that year. Since data availability varies significantly across locations, for comparability purposes we keep only cities with at least 80% of the prices available. The 55 cities (spread over 28 countries) that meet this criterion are listed in Table 1. Finally, we restrict the number of items included in the sample by using a "90% cut-off" rule, which in practice means that an item is included only if it is recorded in at least 50 out of the 55 cities.[4] We end up with a sample of 189 items (119 unique goods and services) available in 55 cities located in 28 countries for the period 1990.1 to 2018.2. Detailed information on the 119 unique products, type of outlet where each good is sampled, and the number of cities where each good in each type of outlet is available, is summarized in Table A1 of the Online Appendix.

[3]The data on VAT/GST rates were mainly collected from multiple issues of the OECD Consumption Tax Trends available at `www.oecd-library.org/taxation/consumption-tax-trends_19990979`. For the US the retail sales taxes were obtained for each state from the Federation of Tax Administration available at `www.taxadmin.org/state-tax-agencies`.

[4]We also use a "100% cut-off" criterion, in which an item is included if it is recorded in all 55 locations. This restricts us to 50 items (37 unique goods and services). As there is no significant difference in the results for this narrower sample, we focus on the broader sample. The results for the narrow balanced sample are available by request.

Table 1: **Cities included in the sample**

World	**EZ11**	**US**
Adelaide, *Australia* (186)	Vienna, *Austria* (185)	Atlanta (181)
Brisbane, *Australia* (186)	Brussels, *Belgium* (187)	Boston (188)
Melbourne, *Australia* (185)	Helsinki, *Finland* (179)	Chicago (189)
Perth, *Australia* (187)	Lyon, *France* (185)	Cleveland (181)
Sydney, *Australia* (187)	Paris, *France* (188)	Houston (182)
Montreal, *Canada* (178)	Berlin, *Germany* (181)	Los Angeles (185)
Toronto, *Canada* (180)	Dusseldorf, *Germany* (187)	Miami (185)
Vancouver, *Canada* (184)	Frankfurt, *Germany* (183)	New York (183)
Santiago, *Chile* (166)	Hamburg, *Germany* (187)	Pittsburgh (185)
Copenhagen, *Denmark* (180)	Munich, *Germany* (186)	San Francisco (186)
Athens, *Greece* (175)	Dublin, *Ireland* (185)	Seattle (184)
Hong Kong, *Hong Kong* (174)	Milan, *Italy* (181)	Washington DC (187)
Tel Aviv, *Israel* (174)	Rome, *Italy* (187)	
Kuala Lumpur, *Malaysia* (176)	Luxembourg, *Luxembourg* (186)	
Auckland, *New Zealand* (186)	Amsterdam, *Netherlands* (188)	
Wellington, *New Zealand* (186)	Lisbon, *Portugal* (187)	
Singapore, *Singapore* (179)	Barcelona, *Spain* (187)	
Johannesburg, *South Africa* (180)	Madrid, *Spain* (188)	
Stockholm, *Sweden* (179)		
Geneva, *Switzerland* (186)		
Zurich, *Switzerland* (182)		
Bangkok, *Thailand* (170)		
Abu Dhabi, *UAE* (178)		
Dubai, *UAE* (172)		
London,*UK* (185)		

The number of product items in a particular city used for the analysis is presented in parenthesis.

3 Preliminary Analysis

We define price deviations between a pair of cities j and k for good i at time t as

$$q_{i,jk,t} = \ln(\frac{P_{i,j,t}E_{jk,t}}{P_{i,k,t}}), \tag{1}$$

where $P_{i,j,t}$ is the local-currency price of good i in city j at time t, and $E_{jk,t}$ is the nominal exchange rate between cities j and k at date t.

We start our analysis by looking at the kernel density estimates of pairwise LOOP deviations, pooling all goods and years together. Figure 1 plots distributions of LOOP deviations for three types of pairwise comparisons: cities located within the same coun-

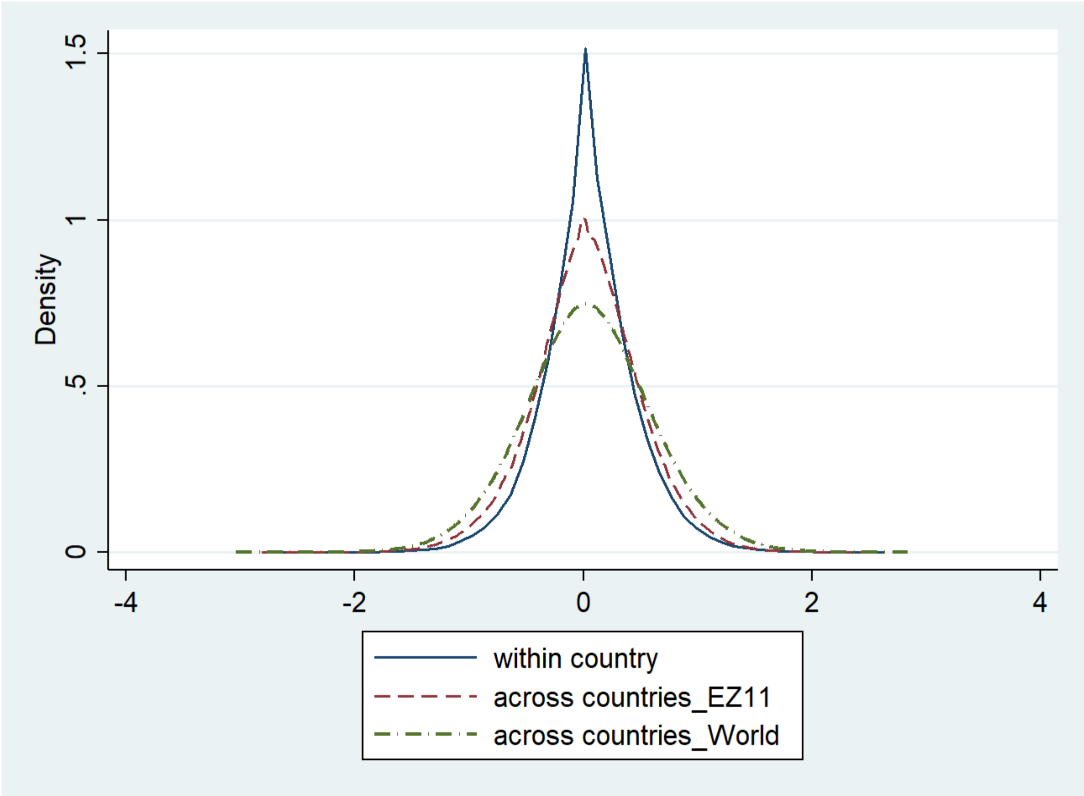

Figure 1: Distribution of LOOP deviations for different groups of pairwise comparisons

try, cities located in different countries that form a currency union (the eleven original eurozone member countries), and cities located in different countries that do not form a currency union. As can be seen in Figure 1, the distribution of LOOP deviations for monetary union members lies in between the density for within country comparison and that for across country comparisons, with the latter characterized by wider support and lower peak consistent with a lower degree of integration.

Figure 2 shows distributions of LOOP deviations in different years for various groups of city pairs. As we can see there, the lowest peak consistent with low degree of integration is associated with 1990 for the comparisons across the globe, while the highest degree of price integration is reached by year 2000 for all groups of city pairs. A visible drop in peakedness, especially for global and US comparisons, is observed by 2005 after which the degree of integration appears to keep deteriorating up until 2015 for the US and up until the second semester of 2018 for the EZ 11 original members and for comparisons across the globe.

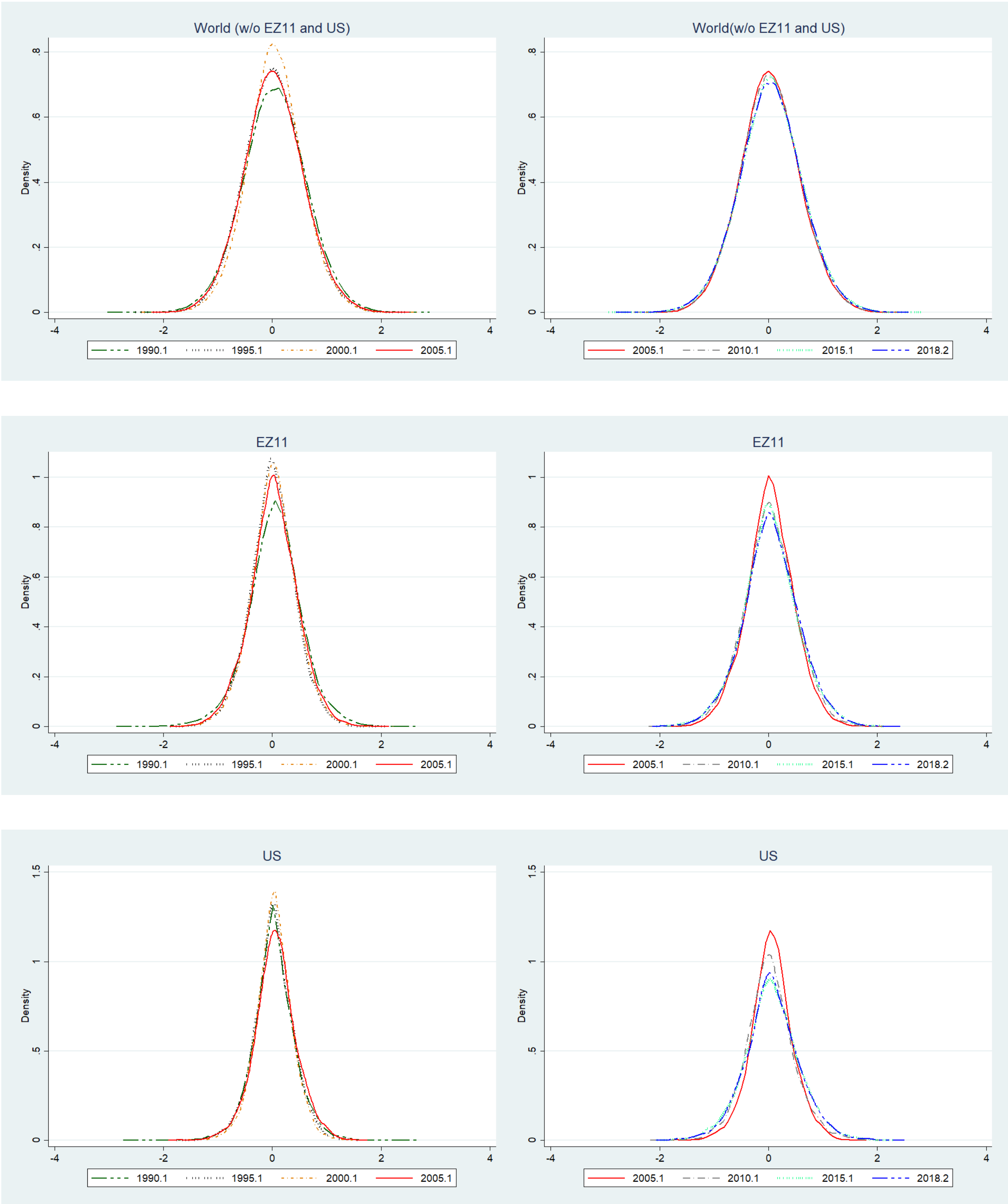

Figure 2: Distribution of LOOP deviations for different years and groups of pairwise comparisons

Time series volatility

We now consider the good-level time series volatility of LOOP deviations calculated as the standard deviation of LOOP deviations over time, $\sigma_{i,jk}(q_{i,jk,t}) = \sqrt{\frac{\sum_{t=1}^{T}(q_{i,jk,t}-\overline{q}_{i,jk})^2}{T-1}}$. Panel A of Table 2 shows mean (over locations) and standard deviation (across locations) of the time series volatility of LOOP deviations averaged over goods for the whole period under study and two sub-periods 1990:1-2008:1 and 2008:2-2018.2, prior to and after the arrival of the financial Crisis. As we can see there, mean volatility for the period 1990:1-2018:2 is higher for international LOOP deviations as compared to LOOP deviations within countries, within the US, or for the EZ 11, while the volatility within the US and within the original EMU members is nearly identical. These inferences hold for mean volatility both prior to and after the arrival of the financial Crisis.[5] In Table A2 of the Online Appendix we take a closer look at changes in the average volatility of LOOP deviations by considering various sub-periods. Similar patterns are observed for all sub-periods starting with 1990:1-1994:2 all the way to 2015:1-2018:2. Mean volatility is always higher for international LOOP deviations as compared to LOOP deviations within countries, within the US, or in the EZ 11. The volatility within the US and within the EZ 11 becomes nearly identical by the beginning of the 2000s. We also note that the standard deviation of the volatility measure across locations tends to be lower for comparisons across countries than for comparisons within countries for the period under study.[6] Finally, as becomes apparent from Table A2 of the Online Appendix, mean volatility has been falling over the past decade or so. One possibility we explore next, is that this phenomenon is associated with a reduction in the level and volatility of inflation in later years as compared to the early years of our sample.

In the second panel of Table 2, we report the mean (over locations) and standard deviation (across locations) of the time series volatility of good-level relative inflation

[5]The after-crisis mean volatility for the EZ 11 is even a bit lower relative to volatility within the US or to our broader within-country sample.

[6]However, this pattern varies over time. For instance, for the periods 1995.1-1999.2 and 2000.1-2004.2 the standard deviation of volatility across countries is higher than the standard deviation of volatility for the within country comparisons, while the opposite holds for 2005.1-2009.2.

Table 2: Mean (over city pairs) and standard deviation (across city pairs) of the averaged (over goods) time series volatility of LOOP deviations.

Panel A. Average Volatility of LOOP deviations

		Overall		Before and after crisis			
		1990.1-2018.2		1990.1-2008.1		2008.2-2018.2	
group of cities	N	mean	sd	mean	sd	mean	sd
US	66	0.287	0.026	0.242	0.019	0.205	0.020
within country	95	0.277	0.036	0.233	0.026	0.197	0.026
across countries (excl. EZ)	1250	0.324	0.027	0.280	0.026	0.228	0.027
across the EZ 11	140	0.286	0.016	0.243	0.015	0.192	0.027

Panel B. Average Volatility of Relative Inflation

		1990.1-2018.1		1990.1-2008.1		2008.2-2018.2	
group of cities	N	mean	sd	mean	sd	mean	sd
US	66	0.149	0.015	0.158	0.015	0.128	0.017
within country	95	0.146	0.016	0.153	0.017	0.126	0.018
across countries (excl. EZ)	1250	0.149	0.014	0.156	0.016	0.131	0.018
across the EZ 11	140	0.138	0.012	0.141	0.012	0.127	0.022

Panel C. Volatility of Exchange Rates

		1990.1-2018.2		1990.1-2008.1		2008.2-2018.2	
group of cities	N	mean	sd	mean	sd	mean	sd
across countries (excl. EZ)	1250	0.155	0.087	0.142	0.076	0.098	0.042

rates averaged over goods. Relative inflation is calculated as

$$\pi_{i,jk,t} = ln(\frac{P_{i,j,t}}{P_{i,j,t-1}}/\frac{P_{i,k,t}}{P_{i,k,t-1}}), \tag{2}$$

where $P_{i,j,t}$ is price of good i in country j at time t expressed in national currency. As we can see in Table 2, the mean volatility of relative inflation is lower for the EZ11 as compared to any other group of cities, and for the period since the financial Crisis, i.e. from 2008:2 to 2018:2, as compared to the period 1990:1 to 2008:1 preceding this. As evident in Table A2 of the Online Appendix, mean volatility of relative inflation is relatively lower in 2015:1-2018:2 and in 2010:1-2014:2 as compared to the sub-period immediately preceding these and as compared to the average over the period under study. This then might constitute part of the explanation as to why the volatility of LOOP deviations has been falling over the past decade or so. Moreover, as evident in Panel B of Table 2, the standard deviation across locations of this inflation volatility measure is elevated during the period since the arrival of the financial Crisis as compared to the earlier period from 1990:1 to 2008:1, especially for the EZ 11.

The last panel of Table 2 shows the mean (over locations) and standard deviation (across locations) of the time series volatility of nominal exchange rates for the cross-country comparisons. As we can see from Table 2, both the mean and standard deviation of nominal exchange rate volatility are lower in 2008.2-2018.2 compared to 1990.1-2008.1.

The three panels of Figure 3 show the distribution (across goods and bilateral comparisons) of the good-level time series volatility of LOOP deviations between cities for 1990:1-2008:1 and 2008:2-2018:2, for comparisons within the EZ, within the US, and across countries. For each of these three cases, there is a visible shift to the left of the mean of LOOP deviations in the sub-period since the arrival of the Crisis, accompanied with an increase in peakedness. Figure 4 shows this distribution for all sub-periods, where we observe a shift to the left, an increase in the peak, and shrinkage of the support of these distributions over time, with the first sub-period, 1990:1-1994:2, on the right-most having the highest mean, widest support, and lowest peak, and the last sub-period, 2015:1-2018:2, having the lowest mean, lowest support, and highest peak as compared to any other sub-period. Thus, the pattern observed in Figure 3 cannot be due to the arrival of the Crisis as this pattern had been in place even prior to it.

Dispersion across cities and dispersion across goods

Next, we calculate the dispersion of LOOP deviations across cities j and k at time t, $s_{i,t}$, as the standard deviation of the LOOP deviations across bilateral comparisons for each period t

$$s_{i,t} = \sqrt{\frac{\sum_{jk=1}^{N_{i,t}} (q_{i,jk,t} - \overline{q}_{i,t})^2}{N_{i,t} - 1}}, \tag{3}$$

where $\overline{q}_{i,t}$ is the mean of pairwise LOOP deviations $q_{i,jk,t}$ over all city pairs j and k, and $N_{i,t}$ is the number of city pairs where good i is available in period t. Figure 5 presents the evolution of average (over goods) dispersion of LOOP deviations across locations $\overline{s}_t^m = \frac{1}{M}\sum_{i=1}^{M} s_{i,t}^m$ for three groups of city pairs (m) – cities that are located within the same country (US), cities located in different countries that form a currency union

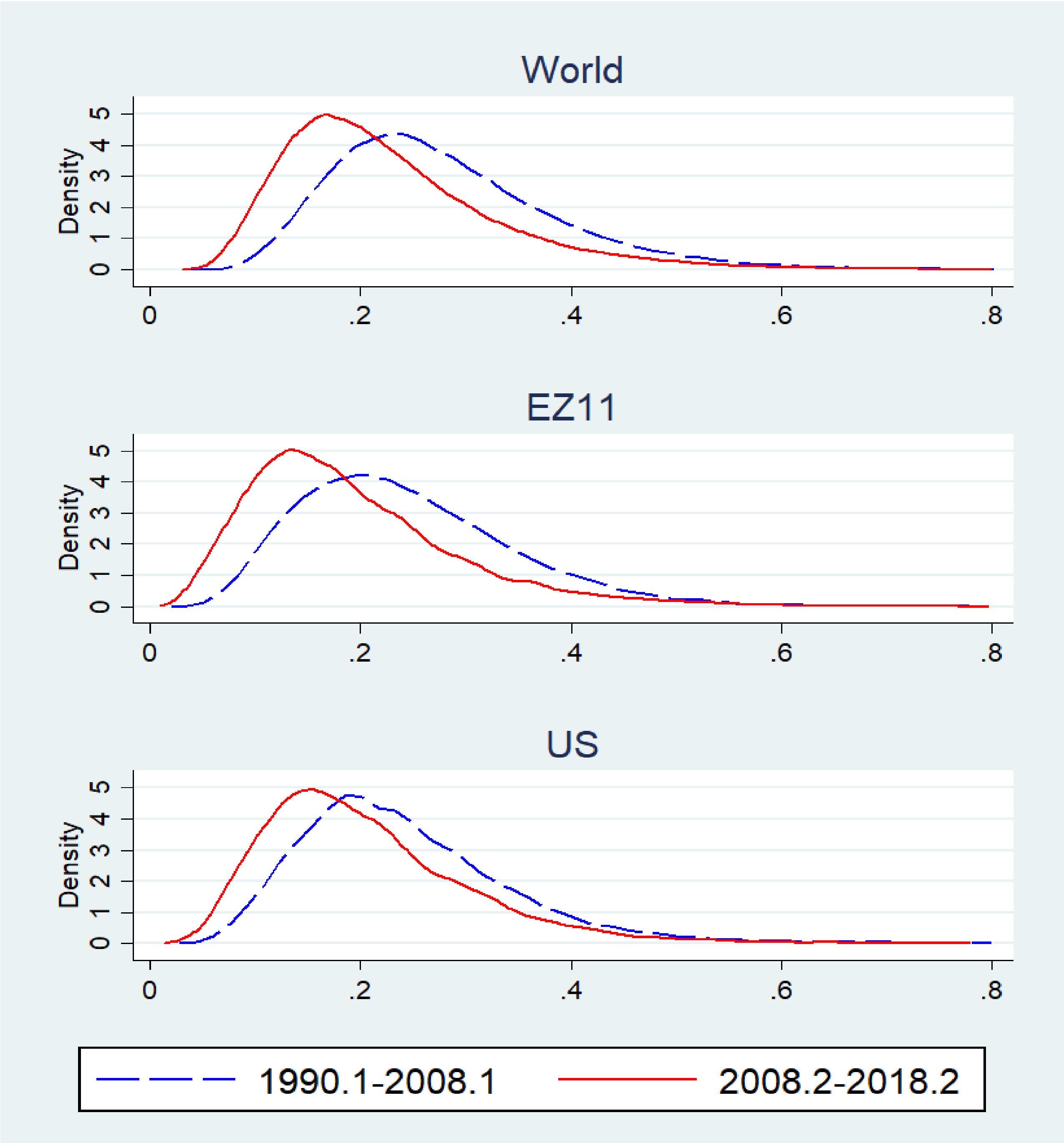

Figure 3: Distribution of the time-series volatility of LOOP deviations for each good and city pair, reported for city pairs across the globe, across the EZ 11, and for the US.

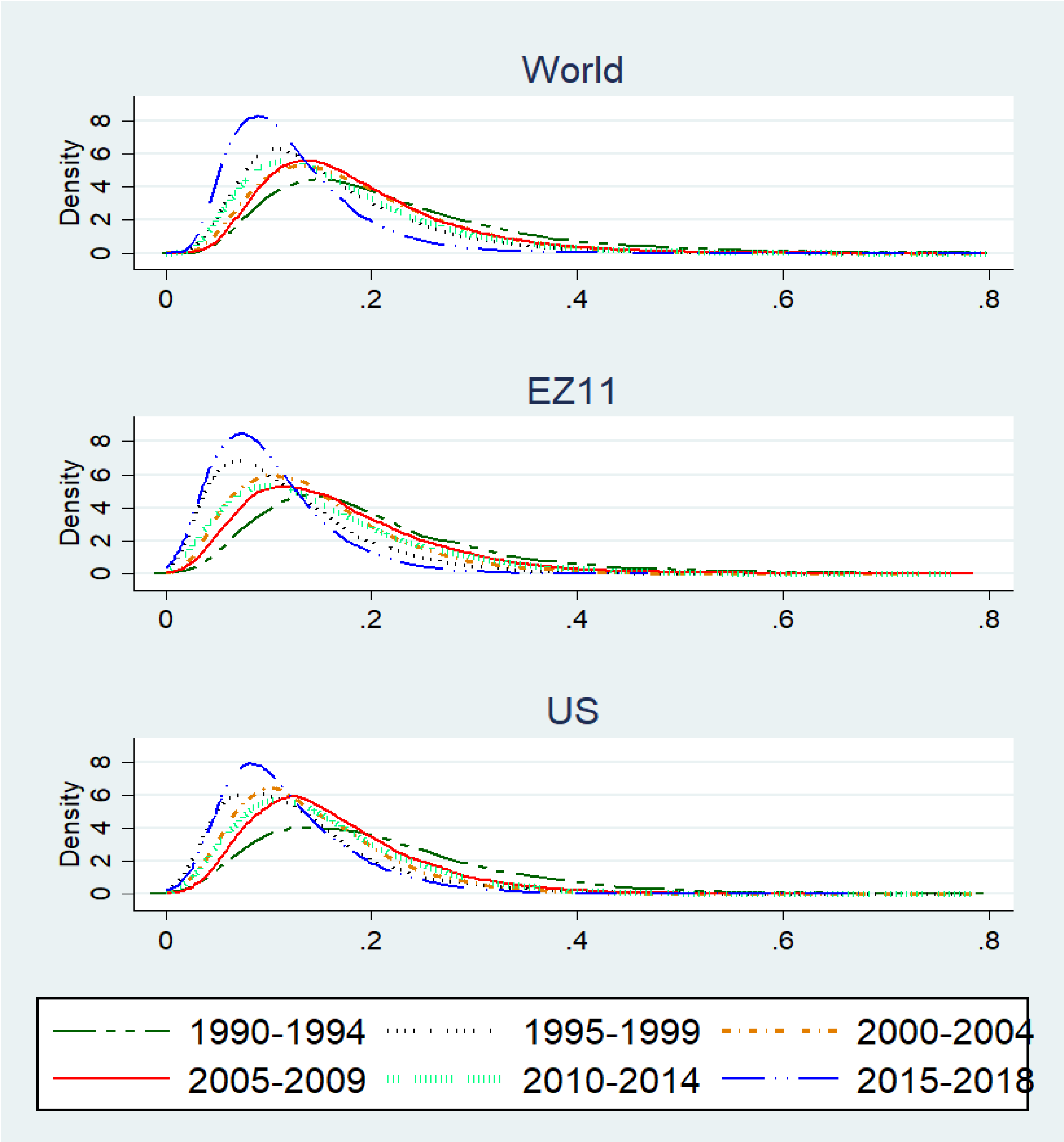

Figure 4: Distribution of the time-series volatility of LOOP deviations for each good and city pair, reported for city pairs across the globe, across the EZ 11, and for the US.

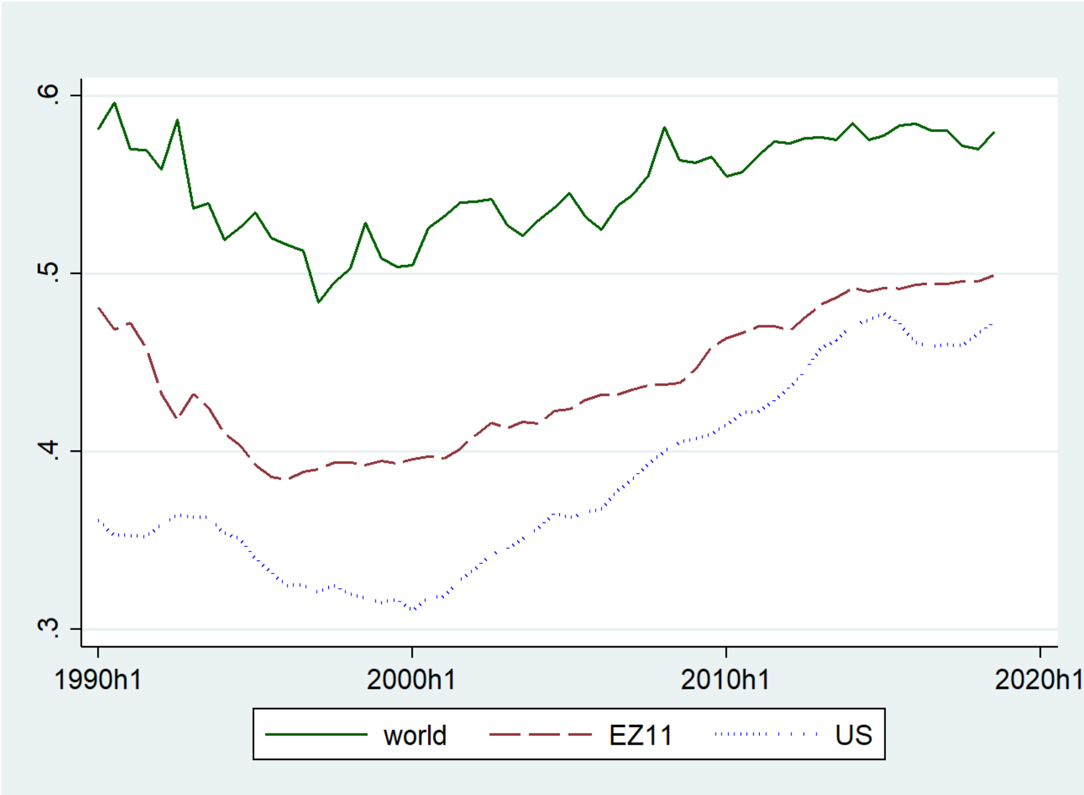

Figure 5: Mean over goods of dispersion of LOOP deviations across locations

(EZ 11), and cities located in different countries that do not form a currency union (i.e., excluding the EZ 11). As we can see in Figure 5, this measure of dispersion is always higher for LOOP deviations across countries as compared to LOOP deviations within the EZ 11 original members or within the US. The last two lie close to each other, especially so during the second half of the last decade. Moreover, this measure of dispersion exhibits a fall initially up until the late nineties, and then rises, especially in the case of the US but also for the EZ 11 and, less so, across the globe.

We also construct a measure of the dispersion of LOOP deviations across goods at time t, $s_{jk,t}$, as the standard deviation of LOOP deviations across goods for each period t

$$s_{jk,t} = \sqrt{\frac{\sum_{i=1}^{M_{jk,t}} (q_{i,jk,t} - \overline{q}_{jk,t})^2}{M_{jk,t} - 1}}, \tag{4}$$

where $\overline{q}_{jk,t}$ is the mean over all products of pairwise LOOP deviations $q_{i,jk,t}$ between city j and k, and $M_{jk,t}$ is the number of goods compared between cities j and k at

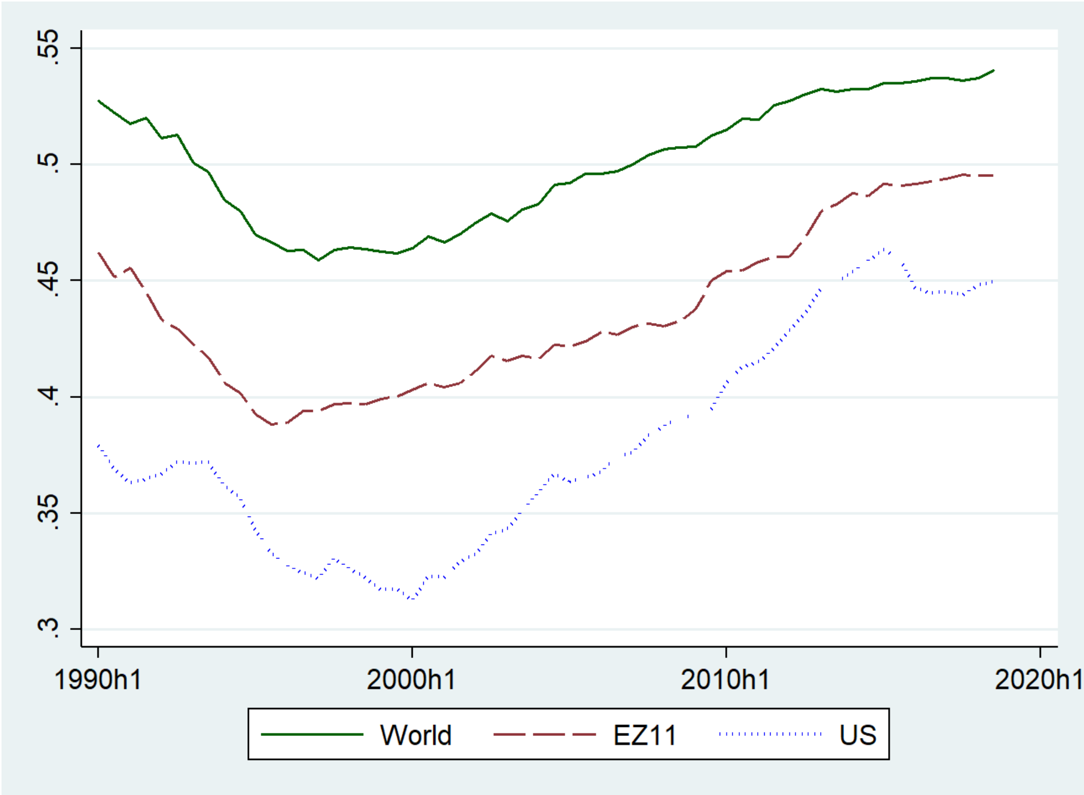

Figure 6: Mean over locations of dispersion of LOOP deviations across goods

time t. Figure 6 presents the evolution of average (over city pairs) dispersion of LOOP deviations across goods $\overline{s}_t^m = \frac{1}{N_m}\sum_{jk\in m} s_{jk,t}$ for cities that are located within the same country (US), cities located in different countries that form a currency union (EZ 11), and cities located in different countries that do not form a currency union (i.e., excluding the EZ 11). As we can see, perhaps surprisingly given that this measure pertains to dispersion across goods while the former pertains to dispersion across cities, Figure 6 strongly resembles the patterns observed in Figure 5. That is, first, international price comparisons across the globe are characterized by higher dispersion throughout the period as compared to comparisons within the EZ 11 or the US, second, the EZ 11 resemble the US especially by the second half of the last decade, and finally, the evolution of this measure of dispersion first falls up until the late nineties and then rises for all three types of price comparisons portrayed here and more steeply so for the US.

4 Variance decomposition

In this section, we attempt to assess the importance of the various sources of variation in LOOP deviations by decomposing the observed price dispersion into various components. The price differences may originate from three main sources. First, there may be differences across locations. If the city is more expensive on average than other cities, one would expect goods to be sold at a higher price in that city as compared to other cities (e.g. due to higher labor costs). The importance of this source of variation in LOOP deviations is captured by the *location component*. There might also be differences across equally expensive locations due to some product market characteristics, e.g. the degree of competition for that product in the local market. In this case, an identical product sold in two equally expensive (on average) locations may have different prices because one location is characterized by product market characteristics that render that particular product more expensive than in the other location. The importance of this source of variation in LOOP deviations is assessed by the *net good-specific location component*.

Second, there may be heterogeneity in the relative prices of different products within the same location. If so, one location may always charge a relatively higher price for one good and a relatively cheaper price for other goods. This source of variation in LOOP deviations is captured by the *net location-specific good component*. Moreover, there may be heterogeneity in the relative prices of different goods common for all locations, captured by the *good component*.

Third, the price difference for the same product compared between the same city-pair may change over time due to shocks that affect the prices of goods sold in different locations differently. The *time component* in our variance decomposition assesses the importance of such shocks.

We proceed by decomposing the observed price dispersion into the above mentioned sources of variation. First, the total variance of LOOP deviations, $q_{i,jk,t}$, could be presented as the sum of a location-and-good specific time component and a location-and-good component

$$Var_{i,jk,t}(q_{i,jk,t}) = E_{i,jk}(Var_t(q_{i,jk,t}|i,jk)) + Var_{i,jk}(E_t(q_{i,jk,t}|i,jk)). \quad (5)$$

Then, the second term, variance across city-pairs and goods of averaged over time LOOP deviations, can be further decomposed into a good-specific location component and a good component

$$Var_{i,jk}(E_t(q_{i,jk,t}|i,jk)) = E_i(Var_{jk}(E_t(q_{i,jk,t}|i,jk)|i)) + Var_i(E_{jk}(E_t(q_{i,jk,t}|i,jk)|i)), \quad (6)$$

or into a location-specific good component and a location component

$$Var_{i,jk}(E_t(q_{i,jk,t}|i,jk)) = E_{jk}(Var_i(E_t(q_{i,jk,t}|i,jk)|jk)) + Var_{jk}(E_i(E_t(q_{i,jk,t}|i,jk)|jk)). \quad (7)$$

Substituting (6) and (7) into (5) and rearranging terms, we obtain:

$$\begin{aligned} Var_{i,jk,t}(q_{i,jk,t}) = {} & E_{i,jk}(Var_t(q_{i,jk,t}|i,jk)) \\ & + Var_i(E_{jk}(E_t(q_{i,jk,t}|i,jk)|i)) + Var_{jk}(E_i(E_t(q_{i,jk,t}|i,jk)|jk)) \\ & + \frac{1}{2}[E_i(Var_{jk}(E_t(q_{i,jk,t}|i,jk)|i)) - Var_i(E_{jk}(E_t(q_{i,jk,t}|i,jk)|i)] \\ & + \frac{1}{2}[E_{jk}(Var_i(E_t(q_{i,jk,t}|i,jk)|jk)) - Var_{jk}(E_i(E_t(q_{i,jk,t}|i,jk)|jk))]. \end{aligned} \quad (8)$$

Following Crucini and Telmer (2012), we use notation $E_t(q_{i,jk,t}|i,jk)$ and $Var_t(q_{i,jk,t}|i,jk)$ to denote respectively the mean and variance over time of relative prices for good i between cities j and k. The first term in equation (8), $E_{i,jk}(Var_t(q_{i,jk,t}|i,jk))$, is the mean over goods and city-pairs of the volatility in LOOP deviations. We refer to this as the *time component* of variance in LOOP deviations. The second term in the decomposition, $Var_i(E_{jk}(E_t(q_{i,jk,t}|i,jk)|i))$, is the variance across goods of the average (over locations and time) relative prices. We refer to this as the *good component.* The third term on the right-had side of (8), $Var_{jk}(E_i(E_t(q_{i,jk,t}|i,jk)|jk))$, is the variance across city-pairs of the average (over goods and time) relative prices. This is the *location component* of variance in the LOP deviations.

Moreover, the term $[E_i(Var_{jk}(E_t(q_{i,jk,t}|i,jk)|i)) - Var_i(E_{jk}(E_t(q_{i,jk,t}|i,jk)|i)]$, is the mean over goods of the variance across city-pairs of LOOP deviations averaged over time minus the good component. We refer to this as the *net good-specific location component* of variance in LOOP deviations. Finally, the term $[E_{jk}(Var_i(E_t(q_{i,jk,t}|i,jk)|jk)) - Var_{jk}(E_i(E_t(q_{i,jk,t}|i,jk)|jk))]$, is the mean over locations of the variance across goods of LOOP deviations averaged over time minus the location component. We refer to this as the *net location-specific good component.*

Table 3 reports the results of the variance decomposition. Following the discussion in section 3, we report estimates of the variance decomposition for US city pairs, for cities located within the same country, for cities located in different countries that form a currency union, i.e., the EZ 11, and for cities located in different countries that do not form a currency union. First, we consider the total variance in LOOP deviations, which can capture the degree of price integration. Consistent with the shape of the distributions of LOOP deviations drawn in Figure 1, we find that the variance of LOOP deviations for monetary union members (0.218) lies in between the variance for within-country comparisons (0.162) and that for cross-country comparisons (0.315).

Table 3: **Decomposition of variance in LOOP deviations**

	Across countries (excl.EZ11)	US	Within country	Across the EZ11 countries
Total Variance	0.3146	0.1744	0.1622	0.2184
Time component	37.2%	54.4%	54.9%	43.0%
Location-Good component	62.8%	45.6%	45.1%	57.0%
Good component	0.5%	2.8%	1.7%	3.0%
Location component	12.9%	11.9%	10.4%	8.7%
Net good-specific location component	31.1%	20.4%	21.1%	25.5%
Net location-specific good component	18.7%	10.9%	12.2%	19.8%

Notes: The first row reports the total variance of LOOP deviations, $Var_{i,jk,t}(q_{i,jk,t})$. The second and third rows respectively report the ratio of the time component and of the location-and-good component to the total variance in LOOP deviations implied by equation (5). In the remaining rows, we decompose the location-and-good component into sub-components as in equations (6) and (7) and present the ratio of these sub-components to the total variance in LOOP deviations consistent with equation (8). Due to missing observations the sum of components is not always equal to 100%.

Table 3 shows that for international comparisons, 62.8% of the total variance in LOOP deviations is associated with the location-and-good-specific component, while 37.2% of the total variance can be explained by the time-specific component. The picture is yet different for cities belonging to the same country (or for cities within the US), where the time- and location-and-good specific components account for about 55% and 45% of the total dispersion in LOOP deviations, respectively. The results for cities located in different countries that form a currency union lie in between, with the time-specific component explaining 43% of the variance in LOP deviations, and the location-and-good-specific component accounting for 57% of the overall variance. These results suggest that the time series component and long-run good-and-location-specific factors play comparable roles in explaining the overall variance of LOOP deviations. It should also be noted that the time component plays a more important role within countries rather than across countries suggesting this is not mainly driven by nominal exchange rates but rather driven by other time-varying domestic factors. In the second part of this section we will further investigate the factors driving intertemporal price differences by decomposing the volatility of LOOP deviations.

Further decomposition of the location-and-good-specific component shows that the good component, which captures good-specific fixed effects, plays a very small role in explaining price differences, but interestingly the size of the good-component is quite similar for the comparisons within the US and across the EZ 11 countries, 2.8% and 3.0%, respectively. The location component, which is related to city-wide factors such as rent and wages, also accounts for a relatively small portion of variance in LOP deviations ranging from 8.7% for the comparisons across the EZ 11 to 12.9% for international comparisons across the other countries. Interestingly, the location component explains a somewhat smaller share of the total variation in LOOP deviations across the EZ 11 (8.7%) than across cities located within the same country (10.4% for cities located within the same country and 11.9% for US city-pairs).

More than 20% of the variance in LOOP deviations is explained by the good-specific location component. This suggest that a large portion of dispersion in LOOP deviations could be explained by location characteristics related to a specific product, such as the local degree of competition for that product. For cities located within the same country and for US cities, the share of this component in total variance is similar, at 21.1% and 20.4% respectively. For international comparisons, the share of the good-specific location component is significantly higher and equal to 31.1%. Again, the results for international comparisons across countries that form a currency union lie in between, with the good-specific location component explaining 25.5% of the total variance.

Finally, location-specific good factors, such as pricing strategies or search frictions, explain more than 10% of the total variance in LOOP deviations, with higher importance of this component for international comparisons than for intranational comparisons. For cities located in different countries that form a currency union (the EZ 11), the share of the location-specific good component in total variance equals 19.8%, which is close to the one for the comparisons across the rest of the globe, 18.7%, whereas for US cities, only 10.9% of the total variance in LOOP deviations is associated with this component.

Decomposition of the volatility of LOOP deviations

The above results suggest that time-series effects explain on average about half of the total variance in LOOP deviations. To better understand factors that drive intertemporal price differences, we further decompose the time-series variance (volatility) of LOOP deviations from equation (8). Using the same notation as above, we denote the volatility of LOOP deviations as $\sigma^2_{i,jk} \equiv Var_t(q_{i,jk,t}|i,jk)$. We apply the same decomposition method as before (the law of total variance) and express the good-and-location specific variance of $\sigma^2_{i,jk}$ as the sum of a location-specific component, a good-specific component, and their interactions[7]:

$$\begin{aligned} Var_{i,jk}(\sigma^2_{i,jk}) &= Var_i(E_{jk}(\sigma^2_{i,jk}|i)) + Var_{jk}(E_i(\sigma^2_{i,jk}|jk)) \\ &+ \frac{1}{2}[E_i(Var_{jk}(\sigma^2_{i,jk}|i)) - Var_i(E_{jk}(\sigma^2_{i,jk}|i))] \\ &+ \frac{1}{2}[E_{jk}(Var_i(\sigma^2_{i,jk}|jk)) - Var_{jk}(E_i(\sigma^2_{i,jk}|jk))]. \end{aligned} \tag{9}$$

[7]Appendix A provides details of how the identity (9) has been derived.

where $Var_i(E_{jk}(\sigma^2_{i,jk}|i))$ is the good-specific effect in the volatility of LOOP deviations, $Var_{jk}(E_i(\sigma^2_{i,jk}|jk))$ is the location-specific effect, $[E_i(Var_{jk}(\sigma^2_{i,jk}|i)) - Var_i(E_{jk}(\sigma^2_{i,jk}|i))]$ is the net good-specific location component, and $[E_{jk}(Var_i(\sigma^2_{i,jk}|jk)) - Var_{jk}(E_i(\sigma^2_{i,jk}|jk))]$ is the net location-specific good component. The results of the variance decomposition for the volatility of LOOP deviations are shown in Table 4.

Table 4: **Decomposition of the time-series variance of LOOP deviations**

	Across countries (excl.EZ11)	US	Within country	Across the EZ11 countries
Total Variance	0.0091	0.0072	0.0069	0.0069
Good component	14.3%	26.6%	20.4%	24.0%
Location Component	4.3%	4.4%	6.3%	1.5%
Net good-specific location component	35.9%	24.3%	30.3%	26.5%
Net location-specific good component	46.1%	45.7%	43.8%	48.4%

Notes: The first row reports total variance (across goods and location) of the volatility in LOOP deviations, $Var_{i,jk}(\sigma^2_{i,jk})$. The remaining rows report the share of each component to the total variance in the volatility of LOOP deviations as suggested by equation (9). Due to missing observations the sum of components is not always equal to 100%.

Strikingly, the variance of the volatility measure across the EZ 11 countries is identical to the variance across cities located within the same country, again suggesting that monetary unions are not that different from national economies. One might be interested whether this similarity could be explained by the common currency and therefore the absence of nominal exchange rate variation within a monetary union. To answer this question, we refer to the location-specific component presented in Table 4. For city-pairs across the EZ 11, the location component accounts for only 1.5%, which is much smaller than for within country comparisons (6.3%) and for the US (4.4%). This implies that location-specific shocks can explain only a thin portion of the volatility of LOOP deviations. At the same time, the small size of variance explained by location-specific effects for the EZ 11, implies that membership in the monetary union helps to reduce cross-country differences.

Looking at the good component, we find that it accounts on average for 21% of the variance in the volatility of LOOP deviations, with higher importance for comparisons within the US (26.6%) and across the EZ 11 (24%) and smaller role for other international comparisons (14.3%). Therefore, good-specific factors that are common for all locations play a more important role in explaining variation in the volatility of LOOP deviations than location-specific factors. This is consistent with the analysis in Crucini and Telmer (2012). Finally, the majority of the volatility of LOOP deviations is explained by the interaction of the good- and location-specific effects, with the net location-specific good component explaining on average a larger proportion of variation in the volatility of LOOP deviations than the net good-specific location component, 46% versus 30%, respectively.

The results of the two variance decomposition exercises presented above uncover a number of empirical regularities. First, a large part of the variation in cross-country LOOP deviations is associated with long-run good-and-location-specific factors. Importantly, membership in the monetary union allows countries to effectively reduce cross-country economic differences so that location-specific fixed effects explain a relatively small portion of the variation in LOOP deviations across the member countries.[8] Finally, good-specific location factors, related to the local characteristics of a specific product, such as the local degree of competition for that product, explain a lot of the variation. This explains on average about a quarter of the total variance in LOOP deviations.

5 Explaining the variance of LOOP deviations

In this section, we attempt to explain the time series volatility and cross-sectional dispersion (across locations, and across goods) of LOOP deviations. In particular, we consider the impact of membership in the monetary union, relative inflation, and other explanatory factors, on each of the components of price variance.

5.1 Explaining the time-series volatility of LOOP deviations

First, we analyze more formally the relation between time-series volatility of LOOP deviations (described in section 3) with inflation and nominal exchange rate volatility.

[8]This number is surprisingly even smaller than for intranational comparisons.

More specifically, we estimate the impact of relative inflation volatility ($\sigma_{i,jk}(\pi_{i,jk,t})$) and nominal exchange rate volatility ($\sigma_{i,jk}(e_{jk,t})$) on the volatility of LOOP deviations ($\sigma_{i,jk}(q_{i,jk,t})$) for good i across locations j and k.[9] Our baseline model is given as follows:

$$\sigma_{i,jk}(q_{i,jk,t}) = \beta_0 + \beta_1\sigma_{i,jk}(\pi_{i,jk,t}) + \beta_2\sigma_{i,jk}(e_{jk,t}) + \beta_3 EZ_{jk} + \beta_4 S_{jk} + \varepsilon_{i,jk} \tag{10}$$

where EZ_{jk} is a dummy that takes the value 1 if both cities j and k belong to any of the EZ 11 but not to the same country, and 0 if at least one of the locations in the comparison does not belong to the EZ 11. S_{ij} is a within-country dummy that takes the value 1 if locations j and k are within the same country and 0 if there is an international border between the locations. Estimation results are shown in Table 5.

We find that inflation and nominal exchange rate volatility significantly increase the volatility of LOOP deviations. Thus, this estimation exercise offers formal evidence as to the positive relation between the volatility of LOOP deviations with inflation and exchange rate volatility implied in Table 2 and the figures following it. More precisely, the estimated coefficient for inflation volatility is quite robust changing little, from 0.871 in the first column to 0.845 in the last column of Table 5, and remaining strongly significant at the 1% level throughout. The effect of nominal exchange rate volatility on the volatility of LOOP deviations is also positive and significant at the 1% level in all specifications, but much lower than the effect of inflation volatility with estimated coefficients varying from 0.105 in the first column to 0.041 in the last column.

The estimated coefficients for the EZ 11 dummy and the within-country dummy for the specification in column (3) which excludes the nominal exchange rate, are -0.032 and -0.043 respectively, suggesting that belonging to the monetary union has qualitatively similar effects on the volatility of LOOP deviations as belonging to the same country. The estimated coefficients for the EZ 11 dummy and the within-country dummy shown in column (4), net of the effect of the nominal exchange rate, are -0.027 and -0.036

[9] Relative inflation volatility is given by $\sigma_{i,jk}(\pi_{i,jk,t}) = \sqrt{\frac{\sum_{t=1}^{T}(\pi_{i,jk,t}-\overline{\pi}_{i,jk})^2}{T-1}}$, where $\pi_{i,jk,t}$ is relative inflation for good i between city-pair jk at time t defined in equation (2). For the nominal exchange rate we take logs, i.e. $e_{jk,t} = ln(E_{jk,t})$, as LOOP deviations and relative inflation are also in logs.

Table 5: **Explaining time-series volatility of LOOP deviations**

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)
Inflation vol.	0.871***	0.866***	0.867***	0.863***	0.850***	0.845***
	(0.032)	(0.033)	(0.033)	(0.033)	(0.033)	(0.032)
Nominal exch. rates vol.	0.105***	0.084***		0.041***		0.041***
	(0.009)	(0.009)		(0.011)		(0.011)
EZ11 dummy		-0.020***	-0.032***	-0.027***	-0.052***	-0.048***
		(0.003)	(0.003)	(0.003)	(0.006)	(0.006)
Within co. dummy			-0.043***	-0.036***	-0.061***	-0.055***
			(0.002)	(0.003)	(0.005)	(0.05)
Inflation vol.*EZ11					0.141***	0.143***
					(0.042)	(0.042)
Inflation vol.*within co.					0.127***	0.130***
					(0.029)	(0.029)
Constant	0.169***	0.175***	0.190***	0.184***	0.193***	0.187***
	(0.004)	(0.004)	(0.004)	(0.005)	(0.004)	(0.005)
Total Effect (EZ11)			-0.032***	-0.027***	-0.031***	-0.027***
			(0.003)	(0.003)	(0.003)	(0.003)
Total Effect (Within co.)			-0.043***	-0.036***	-0.042***	-0.036***
			(0.002)	(0.003)	(0.002)	(0.003)
Test for Equality			0.001	0.008	0.001	0.007
Observations	262,612	262,612	262,612	262,612	262,612	262,612
R-squared	0.258	0.260	0.264	0.265	0.265	0.265

Notes: *** p<0.01, ** p<0.05, * p<0.1. Clustered standard errors in parentheses. All models include good-fixed effects as explanatory variables. We report P-values for the null that the total effect of being within the EZ 11 and the total effect of belonging to the same country are equal.

respectively. Comparing the impact of belonging to the EZ in columns (3) versus (4) (-0.032 in column 3 versus -0.027 net of the effect of the exchange rate in column 4) suggests that while part of the effect of eurozone membership on the volatility of LOOP deviations is due to eliminating exchange rate volatility, being in the eurozone, much like being in the same country, has a separate (negative) affect on the volatility of LOOP deviations. This could relate to sharing a business cycle, structural similarities, or similar preferences and sentiments.

Adding interaction terms for the EZ 11 and within-country dummies with inflation volatility in the last two columns of Table 5, we find similar results. The respective estimated coefficients for the interaction term with the EZ dummy and the within country dummy are equal to 0.143 and 0.130 in column (6) (0.141 and 0.127 in column 5) with the direct effects very close to each other and equal to −0.048 and −0.055 (−0.052 and −0.061 in column 5) for the EZ 11 and within-country dummies respectively. Indeed, comparing direct effects for the EZ 11 and within-country dummies, we cannot reject the null of equality at any conventional level of significance, not even at the 10% level. P-values for the null that the estimated coefficient on the EZ 11 dummy equals the estimated coefficient on the within-country dummy presented in column (5) and column (6) of Table 5 are equal to 0.218 and 0.324, respectively. Importantly, again, the total effect of belonging to the EZ 11 (or belonging to the same country) is only slightly smaller in absolute magnitude in column (6) (net of the effect of the nominal exchange rate) as compared to column (5), −0.027 as compared to −0.031, suggesting that the nominal exchange rate is only (a small) part of what makes countries belonging to the monetary union similar in this dimension.

5.2 Explaining dispersion of LOOP deviations across locations

We now examine the relationship of the dispersion of LOOP deviations across locations ($s_{i,t}$), defined in section 3, with the dispersion of relative inflation across locations ($\sigma_{i,t}(\pi_{i,jk,t})$) and the dispersion of the exchange rate across locations ($\sigma_{i,t}(e_{jk,t})$). This is meant to help us understand the determinants of cross-location differences recorded in Figure 5. Our baseline model is as follows

$$s_{i,t} = \beta_0 + \beta_1 \sigma_{i,t}(\pi_{i,jk,t}) + \beta_2 \sigma_{i,t}(e_{jk,t}) + \beta_3 NT_i + \varepsilon_{i,t}, \tag{11}$$

where NT_i is a non-traded good dummy that takes the value 1 if the good is non-traded and 0 otherwise.[10]

In Table 6, we report regression results. First, we see that dispersion of inflation and dispersion of nominal exchange rates play similar roles in explaining dispersion of LOOP

[10] Our classification of the traded and non-traded goods follows Andrade and Zachariadis (2016).

Table 6: **Explaining dispersion of LOOP deviations across locations**

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)
Disp. of inflation	0.297***	0.307***	0.297***	0.296***	0.281***	0.286***
	(0.026)	(0.026)	(0.026)	(0.025)	(0.026)	(0.026)
Disp. of nom. Exch. Rates	0.307***	0.355***	0.305***	0.331***	0.309***	0.328***
	(0.050)	(0.050)	(0.045)	(0.048)	(0.045)	(0.049)
NT dummy			0.056**	0.374***	0.032	0.286*
			(0.027)	(0.171)	(0.033)	(0.170)
Disp. of erates*NT dummy				-0.212*		-0.164
				(0.113)		(0.110)
Disp. of inflation*NT dummy					0.228**	0.154
					(0.108)	(0.095)
Constant	0.027	-0.046	0.024	-0.015	0.019	-0.010
	(0.071)	(0.076)	(0.070)	(0.075)	(0.070)	(0.076)
Total Effect (NT)			0.056**	0.055**	0.064**	0.061***
			(0.027)	(0.023)	(0.027)	(0.023)
Total Effect (Inflation)	0.297***	0.307***	0.297***	0.296***	0.310***	0.305***
	(0.026)	(0.026)	(0.026)	(0.025)	(0.026)	(0.025)
Total Effect (Exch.rates)	0.307***	0.355***	0.305***	0.304***	0.309***	0.307***
	(0.050)	(0.050)	(0.045)	(0.044)	(0.045)	(0.044)
Test for Equality	0.807	0.320	0.861	0.856	0.988	0.961
Good-fixed effect	NO	YES	NO	NO	NO	NO
Observations	10,773	10,773	10,773	10,773	10,773	10,773
R-squared	0.113	0.114	0.113	0.116	0.116	0.118
Number of pid	189	189	189	189	189	189

Notes: *** p<0.01, ** p<0.05, * p<0.1. Robust standard errors in parentheses. Model (2) includes product-fixed effects as explanatory variables. We report P-values for the null that the total estimated effect of inflation dispersion equals the total estimated effect of exchange rate dispersion.

deviations across locations. In all models we cannot reject the null that the total effect of inflation dispersion on LOOP deviations is equal to that of exchange rate dispersion. The estimated coefficient on cross-location volatility of relative inflation is strongly significant and varies from 0.281 to 0.307, suggesting that part of the cross-location differences in relative prices can be explained by differences in relative inflation. As the variance of good-specific relative inflation rates across bilateral pairs rises, this leads to an increase in the dispersion of good-specific LOOP deviations across bilateral pairs. The coefficient for the dispersion of nominal exchange rates varies between 0.305

and 0.355 depending on which other variables are included in the regression, and is always statistically significant at the 1% level. This reinforces our finding that nominal exchange rates drive a "border" between national economies.

The impact of goods' non-tradedness on the cross-location variance of LOOP deviations is equal to 0.056 and is significant at the 5% level in column (3) of Table 6. This indicates that cross-sectional variation in LOOP deviations is bigger for non-traded goods than for traded goods. However, the coefficient of the direct effect of non-traded goods becomes insignificant when we include an interaction term between the non-traded goods dummy variable and the dispersion of inflation in column (5). The estimated coefficient for this interaction term is equal to 0.228, significant at the 5% level, implying that the dispersion of inflation has a bigger impact on the dispersion of LOOP deviations for non-traded goods (0.509) than for traded ones (0.281). This might arise due to the higher non-traded input content of non-traded goods which renders the domestic dispersion of inflation more relevant in inducing dispersion for such goods, while rendering exchange rate dispersion less relevant in inducing dispersion in non-traded as compared to traded goods. Hence the negative estimated coefficient for the interaction of non-traded goods with exchange rate dispersion across locations in column (4), implying dispersion of nominal exchanges rates plays a smaller role in explaining dispersion of LOOP deviation for non-traded goods (0.119) than for traded ones (0.331).

5.3 Explaining dispersion of LOOP deviations across goods

Finally, we investigate the determinants of the dispersion of LOOP deviations across goods, $s_{jk,t}$, defined in section 3. This is meant to help us understand the determinants of the dispersion across goods recorded in Figure 6. We estimate the following model:

$$s_{jk,t} = \beta_0 + \beta_1 \overline{\pi}_{jk,t} + \beta_2 e_{jk,t} + \beta_3 EZ_{jk} + \beta_4 S_{jk} + \beta_5 gdp_{jk,t} + \varepsilon_{jk,t}. \quad (12)$$

where, $\overline{\pi}_{jk,t}$ is average (over goods) relative (between locations j and k for each good i) inflation[11], $e_{jk,t}$ is the nominal exchange rate for location j relative to k, and $gdp_{jk,t}$ is the relative real income between locations j and k at time t.[12] Estimation results are presented in Table 7.

Table 7: **Explaining dispersion of LOOP deviations across goods**

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Average relative infl.	-0.024***	-0.024***	-0.023***	-0.024***	-0.020***	-0.019***	-0.022***	-0.023***
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.005)	(0.005)
Nominal exch.rate	0.005***	0.005***		0.005***	0.003**	0.003*		0.003**
	(0.002)	(0.002)		(0.002)	(0.002)	(0.002)		(0.002)
EZ11 dummy		-0.055***	-0.064***	-0.064***	-0.063***	-0.064***	-0.064***	-0.064***
		(0.004)	(0.003)	(0.003)	(0.004)	(0.004)	(0.004)	(0.004)
Within co. dummy			-0.132***	-0.132***	-0.132***	-0.132***	-0.131***	-0.132***
			(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)
Income differences					0.027***	0.031***	0.032***	0.031***
					(0.004)	(0.004)	(0.004)	(0.004)
Income diff.*EZ11						-0.068***	-0.068***	-0.068***
						(0.002)	(0.002)	(0.002)
Av. rel. Infl.*EZ11							0.022**	0.022**
							(0.008)	(0.008)
Av.rel. Infl*within co.							-0.008	-0.008
							(0.040)	(0.040)
Constant	0.505***	0.510***	0.519***	0.519***	0.519***	0.520***	0.520***	0.520***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Total Effect (EZ11)		-0.055***	-0.064***	-0.064***	-0.063***	-0.064***	-0.064***	-0.064***
		(0.004)	(0.003)	(0.003)	(0.004)	(0.004)	(0.004)	(0.003)
Total Effect (Within)			-0.132***	-0.132***	-0.132***	-0.132***	-0.132***	-0.132***
			(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)
Test for equality			0.000	0.000	0.000	0.000	0.000	0.000
Observations	84,645	84,645	84,645	84,645	84,645	84,645	84,645	84,645
R-squared	0.402	0.402	0.402	0.402	0.409	0.412	0.411	0.412
Number of ij	1,485	1,485	1,485	1,485	1,485	1,486	1,485	1,485

Notes: *** $p<0.01$, ** $p<0.05$, * $p<0.1$. Robust standard errors in parentheses. All models include time-fixed effects as explanatory variables. We report P-values for the null that total effect of being within the EZ 11 and total effect of belonging to the same country are equal.

We find that higher average relative inflation reduces the dispersion of LOOP deviations across goods. That is, variation across goods for LOOP deviations between locations j and k falls when the relative inflation rate between locations j and k rises. This suggests LOOP deviations for different goods become more similar to each other due to such changes in relative inflation between locations. This in turn implies that as the inflation in one of the locations increases relative to inflation in the other location, initially small LOOP deviations between these two locations increase faster than initially large LOOP deviations so that the variance of LOOP deviations across goods shrinks. This

[11] We first take good-specific relative inflation between locations j and k, $\pi_{i,jk,t}$, and then average it across all goods i available for a city-pair jk, i.e. the average over goods relative inflation calculated as $\overline{\pi}_{jk,t} = \frac{1}{M_{jk}} \sum_{i=1}^{M_{jk}} \pi_{i,jk,t} = \frac{1}{M_{jk}} \sum_{i=1}^{M_{jk}} ln(\frac{P_{i,j,t}}{P_{i,j,t-1}} / \frac{P_{i,k,t}}{P_{i,k,t-1}})$, where M_{jk} is the number of goods compared between cities j and k.

[12] We use PPP-adjusted real GDP per capita from the WDI. Relative income is obtained as $gdp_{jk,t} = ln(gdp_{j,t}/gdp_{k,t})$.

is consistent with the prices of goods that were initially relatively cheaper in location j relative to location k going up more than the prices of goods that were initially relatively more expensive in location j relative to k, during inflationary episodes. Thus, the degree of price adjustment in individual product markets within a country seems to have an international component shaped by international trade and arbitrage considerations.

We also find relatively small but statistically significant positive effect of nominal exchange rates on dispersion of LOOP deviations across goods, with an estimated coefficient varying between 0.003 and 0.005 depending on which other variables are included in the model. This suggests that movements in the nominal exchange rate between any two countries have an unequal affect on different product markets within the countries, and therefore cause an increase in the dispersion of LOOP deviations across goods.

The coefficient on the within-country dummy is negative and high, equaling around -0.13 in all models. If two locations belong to the same country, their product markets share similar characteristics, and therefore cross-good dispersion of LOOP deviations in this pair of cities is lower than for comparisons across countries. As the coefficient on the within-country dummy is much larger than coefficients on all other variables included in the regressions, our results also imply that belonging to the same country plays a more important role in explaining variation of LOOP deviations across goods as compared to other explanatory variables included in the model. This suggests that some unobserved product market characteristics may determine dispersion of LOOP deviations across goods. In particular, it implies that variation in the LOOP deviations across goods is mainly explained by characteristics of the individual product markets, such us preferences, which are similar for pairs of cities located within the same country but different across countries.

Similarly, the estimated coefficient for the EZ 11 dummy presented in column (3) is negative and equal to -0.064, suggesting that cross-good dispersion of LOOP deviations is lower for members of the Monetary Union as compared to non-EZ comparisons. This is then half-way[13] to a national economy in terms of reducing cross-goods dispersion in LOOP deviations. The magnitude of the coefficient does not change when we include the nominal exchange rate in the specification in column (4) relative to column (3), suggesting that the effect of EZ membership on the cross-good dispersion of LOOP deviations cannot be attributed to exchange rate differences, but rather to structural similarities.

Similarly, inclusion of cross-country income differences in the specification does not significantly affect the estimated coefficients for the EZ 11 and the within country dummies. The estimated coefficient on income differences presented in column (5) of Table 7 equals 0.027. One would expect locations with similar income to have a similar range of expensive and cheap goods, leading to lower dispersion of LOOP deviations across goods for such location pairs. This is consistent with non-homothetic preferences, where consumers' preferences are affected by their income.

Finally, adding interactions of average relative inflation with the EZ 11 and the within-country dummies in columns (7) and (8) of Table 7, we find that the estimated coefficients for the interaction term with the EZ dummy is equal to 0.022 and the direct effect of relative inflation is equal to -0.023 (-0.022 in column 7), suggesting that average relative inflation plays a very small role in reducing dispersion of LOP deviations across goods for eurozone countries.

6 Conclusion

We have shown that monetary unions might not be that different from national economies according to prices, as the EMU is in fact better understood as a national economy than as separate ones. Specifically, we have shown that both cross-sectional dispersion and time-series volatility of LOOP deviations is quite similar for pairs of cities within a

[13] P-values for the null that the estimated coefficient on the EZ 11 dummy equals half of the estimated coefficient on the within-country dummy presented in Table 7 are larger than 0.1 in all models, varying from 0.555 in model (5) to 0.640 in model (8).

country as compared to pairs of cities within the EMU and distinctly different than LOOP deviations across countries. A natural question arising here is the role of the nominal exchange rate in hindering the process of price integration.

We recorded a drop in LOOP deviations volatility in recent years coexisting with a drop in the dispersion and volatility of inflation rates and a drop in the volatility of exchange rates across the globe. Our analysis has shown that nominal exchange rate volatility/dispersion across locations has a positive impact on the volatility/dispersion across locations of LOOP deviations. This suggests that nominal exchange rate volatility plays a role in shaping a "border" between national economies across the glove. However, our variance decomposition exercise showed that the role of nominal exchange rates in explaining price differences across countries might be overstated.

Our regression analysis has illustrated that being in a monetary union reduces the volatility of LOOP deviations to a degree that takes member countries more than half the distance towards the volatility levels characterizing national economies. While part of the effect of EMU membership on the volatility of LOOP deviations is due to eliminating exchange rate volatility, we found that being in the EMU, much like being in the same country, appears to have a separate effect on the volatility of LOOP deviations potentially due to business cycle synchronisation, structural similarities and similar demand characteristics.

Moreover, we found that variation of LOOP deviations across goods falls when relative inflation between locations rises, implying that the degree of price adjustment in individual product markets within a country has an international component shaped by international trade and arbitrage considerations. According to this measure of price integration, cities located across the monetary union member countries are half-way to national economies. These results are net of the effect of the nominal exchange rate, suggesting again that monetary union membership, much like being in the same country, has a distinct effect on integration that is no less important than that of a common currency.

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Online Appendix

A Details of variance decomposition

In this appendix we provide details of variance decomposition for volatility of LOOP deviations presented in section 4. Let $\sigma^2_{i,jk}$ denote volatility of LOOP deviations, i.e. $\sigma^2_{i,jk} \equiv Var_t(q_{i,jk,t}|i, jk)$. Using the law of total variance, we can express variance (across goods and city-pairs) of volatility in two ways:

$$Var_{i,jk}(\sigma^2_{i,jk}) = E_i(Var_{jk}(\sigma^2_{i,jk}|i)) + Var_i(E_{jk}(\sigma^2_{i,jk}|i)), \tag{A1}$$

or

$$Var_{i,jk}(\sigma^2_{i,jk}) = E_{jk}(Var_i(\sigma^2_{i,jk}|jk)) + Var_{jk}(E_i(\sigma^2_{i,jk}|jk)). \tag{A2}$$

Combining (A1) and (A2), we get the following identity

$$\begin{aligned} Var_{i,jk}(\sigma^2_{i,jk}) = \frac{1}{2}[&E_i(Var_{jk}(\sigma^2_{i,jk}|i)) + Var_i(E_{jk}(\sigma^2_{i,jk}|i)) \\ &+ E_{jk}(Var_i(\sigma^2_{i,jk}|jk)) + Var_{jk}(E_i(\sigma^2_{i,jk}|jk))]. \end{aligned} \tag{A3}$$

Further rearranging the terms we obtain the variance decomposition equation used in section 4:

$$\begin{aligned} Var_{i,jk}(\sigma^2_{i,jk}) = &Var_i(E_{jk}(\sigma^2_{i,jk}|i)) + Var_{jk}(E_i(\sigma^2_{i,jk}|jk)) \\ &+ \frac{1}{2}[E_i(Var_{jk}(\sigma^2_{i,jk}|i)) - Var_i(E_{jk}(\sigma^2_{i,jk}|i))] \\ &+ \frac{1}{2}[E_{jk}(Var_i(\sigma^2_{i,jk}|jk)) - Var_{jk}(E_i(\sigma^2_{i,jk}|jk))]. \end{aligned} \tag{A4}$$

We refer to the components as follows:

- $Var_i(E_{jk}(\sigma^2_{i,jk}|i))$ - good component.
- $Var_{jk}(E_i(\sigma^2_{i,jk}|jk))$ - location component.
- $E_i(Var_{jk}(\sigma^2_{i,jk}|i))$ - good-specific location component.
- $E_{jk}(Var_i(\sigma^2_{i,jk}|jk))$ - location-specific good component.
- $[E_i(Var_{jk}(\sigma^2_{i,jk}|i)) - Var_i(E_{jk}(\sigma^2_{i,jk}|i))]$ - net good-specific location component.
- $[E_{jk}(Var_i(\sigma^2_{i,jk}|jk)) - Var_{jk}(E_i(\sigma^2_{i,jk}|jk))]$ - net location-specific good component.

Note that the difference between the good-specific location component and the location component equals the difference between the location-specific good component and the good component, i.e.

$$E_i(Var_{jk}(\sigma^2_{i,jk})) - Var_{jk}(E_i(\sigma^2_{i,jk})) = E_{jk}(Var_i(\sigma^2_{i,jk})) - Var_i(E_{jk}(\sigma^2_{i,jk})). \tag{A5}$$

Therefore, the variance of volatility of LOOP deviations could be decomposed simply into the good-specific component, location-specific component, and a residual:

$$\begin{aligned} Var_{i,jk}(\sigma^2_{i,jk}) &= Var_i(E_{jk}(\sigma^2_{i,jk})) + Var_{jk}(E_i(\sigma^2_{i,jk})) \\ &+ \frac{1}{2}[E_i(Var_{jk}(\sigma^2_{i,jk})) - Var_{jk}(E_i(\sigma^2_{i,jk})) + E_{jk}(Var_i(\sigma^2_{i,jk})) - Var_i(E_{jk}(\sigma^2_{i,jk}))] \\ &= Var_i(E_{jk}(\sigma^2_{i,jk})) + Var_{jk}(E_i(\sigma^2_{i,jk})) + [E_i(Var_{jk}(\sigma^2_{i,jk})) - Var_{jk}(E_i(\sigma^2_{i,jk}))] \\ &= Var_i(E_{jk}(\sigma^2_{i,jk})) + Var_{jk}(E_i(\sigma^2_{i,jk})) + [E_{jk}(Var_i(\sigma^2_{i,jk})) - Var_i(E_{jk}(\sigma^2_{i,jk}))]. \end{aligned} \tag{A6}$$

We refer to the terms $[E_i(Var_{jk}(\sigma^2_{i,jk})) - Var_{jk}(E_i(\sigma^2_{i,jk}))]$ and $[E_{jk}(Var_i(\sigma^2_{i,jk})) - Var_i(E_{jk}(\sigma^2_{i,jk}))]$ as the residual that captures interaction of the location- and the good-specific effects. The results of decomposition (A6) are same as from "2-factor ANOVA".

Table A1: **List of goods included in the sample**

NON-TRADED GOODS

Item name	N
Babysitter's rate per hour	53
Business trip, typical daily cost	55
Cost of a tune up (but no major repairs)	54
Cost of developing 36 colour pictures	50
Daily local newspaper	52
Dry cleaning, man's suit	53
Dry cleaning, trousers	55
Dry cleaning, woman's dress	54
Electricity, monthly bill	53
Four best seats at cinema	51
Hilton-type hotel, single room, 1 night incl. breakfast	55
Hire car, weekly rate for lowest price	54
Hire car, weekly rate for moderate price	51
Hourly rate for domestic cleaning help	51
Laundry (one shirt)	54
Man's haircut (tips included)	55
Moderate hotel, single room, 1 night incl. breakfast	55
One good seat at cinema	51
Taxi: airport to city centre	54
Taxi: initial meter charge	51
Three course dinner for four people	55
Unfurnished residential apartment: 2 bedrooms	53
Unfurnished residential apartment: 3 bedrooms	50
Woman's cut & blow dry (tips included)	55

TRADED GOODS

Available in both a supermarket and a mid-price store

Item name	N_s/N_m
Bacon (1 kg)	52/53
Batteries (two, size D/LR20)	52/53
Beef: filet mignon (1 kg)	50/52
Beef: ground or minced (1 kg)	52/54
Beef: roast (1 kg)	50/52
Beef: steak, entrecote (1 kg)	53/54
Beef: stewing, shoulder (1 kg)	51/54
Beer, local brand (1 l)	52/54
Beer, top quality (330 ml)	53/54
Butter, 500 g	55/55
Carrots (1 kg)	51/52
Cheese, imported (500 g)	53/54
Chicken: fresh (1 kg)	54/52
Cigarettes, Marlboro (pack of 20)	53/53
Coca-Cola (1 l)	55/55

TRADED GOODS (continued)

Item name	N_s/N_m
Cocoa (250 g)	51/52
Cornflakes (375 g)	54/55
Dishwashing liquid (750 ml)	55/55
Drinking chocolate (500 g)	54/54
Electric toaster (for two slices)	54/53
Facial tissues (box of 100)	55/55
Flour, white (1 kg)	53/55
Frozen fish fingers (1 kg)	50/51
Frying pan (Teflon or good equivalent)	50/52
Gin, Gilbey's or equivalent (700 ml)	51/55
Ground coffee (500 g)	53/54
Hand lotion (125 ml)	50/51
Instant coffee (125 g)	55/55
Laundry detergent (3 l)	54/55
Lettuce (one)	53/54
Lipstick (deluxe type)	53/53
Margarine, 500g	55/55
Milk, pasteurised (1 l)	53/53
Mineral water (1 l)	52/52
Olive oil (1 l)	55/55
Orange juice (1 l)	54/54
Oranges (1 kg)	52/53
Peaches, canned (500 g)	55/55
Peanut or corn oil (1 l)	52/54
Peas, canned (250 g)	50/50
Pork: chops (1 kg)	52/53
Potatoes (2 kg)	51/52
Razor blades (five pieces)	52/54
Scotch whisky, six years old (700 ml)	52/55
Shampoo & conditioner in one (400 ml)	54/50
Sliced pineapples, canned (500 g)	54/55
Soap (100 g)	54/55
Spaghetti (1 kg)	55/55
Sugar, white (1 kg)	54/54
Tea bags (25 bags)	52/52
Toilet tissue (two rolls)	54/55
Tomatoes, canned (250 g)	55/55
Tonic water (200 ml)	53/54
Toothpaste with fluoride (120 g)	55/55
White bread, 1 kg	54/54
White rice, 1 kg	52/53
Wine, common table (1 l)	53/54
Wine, superior quality (700 ml)	52/53

TRADED GOODS (continued)

Available in both a chain and a mid-price store

Item name	N_c/N_m
Boy's dress trousers	51/53
Business shirt, white	55/55
Business suit, two piece, medium weight	54/54
Child's jeans	55/55
Child's shoes, dresswear	52/53
Dress, ready to wear, daytime	53/53
Girl's dress	52/54
Men's shoes, business wear	55/54
Socks, wool mixture	54/55
Tights, panty hose	53/53
Women's shoes, town	53/53
Child's shoes, sportswear	53/55

Available in one type of stores

Item name	N
Bananas (1 kg) (mid-priced store)	51
Boy's jacket, smart (mid-priced/branded store)	50
Cognac, French VSOP (700 ml) (mid-priced store)	54
Compact car (1300-1799 cc) (low)	55
Compact disc album (average)	54
Deluxe car (2500 cc upwards) (low)	55
Family car (1800-2499 cc) (low)	54
Fresh fish (1 kg) (mid-priced store)	53
Ham: whole (1 kg) (mid-priced store)	51
International foreign daily newspaper (average)	51
International weekly news magazine (Time) (average)	55
Kodak colour film (36 exposures) (average)	52
Lamb: chops (1 kg) (mid-priced store)	51
Lemons (1 kg) (mid-priced store)	51
Liqueur, Cointreau (700 ml) (mid-priced store)	53
Low priced car (900-1299 cc) (low)	53
Onions (1 kg) (mid-priced store)	51
Paperback novel (at bookstore) (average)	53
Pork: loin (1 kg) (mid-priced store)	51
Regular unleaded petrol (1 l) (average)	53
Television, colour (66 cm) (average)	55
Tomatoes (1 kg) (mid-priced store)	50
Vermouth, Martini & Rossi (1 l) (mid-priced store)	53
Wine, fine quality (700 ml) (mid-priced store)	52
Women's cardigan sweater (mid-priced/branded store)	53

Notes: This table reports the goods included in the analysis, the types of outlets where goods were sampled, and the number of cities where each good in each type of store is available, N. In case where an item is available in two types of stores, we separately present the number of cities for which the goods is available in supermarkets, in chain stores, and in mid-price stores, denoting them as N_s, N_c and N_m, respectively.

Table A2: Mean (over city pairs) and standard deviation (across city pairs) of the averaged (over goods) time series volatility of LOP deviations by years.

Panel A. Average Volatility of LOOP deviations

	1990.1-1994.2		1995.1-1999.2		2000.1-2004.2		2005.1-2009.2		2010.1-2014.2		2015.1-2018.2	
group of cities	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd
US	0.207	0.024	0.136	0.013	0.143	0.018	0.163	0.021	0.154	0.021	0.118	0.020
within country	0.197	0.029	0.129	0.016	0.140	0.019	0.161	0.024	0.151	0.022	0.112	0.020
across countries (excl. EZ)	0.219	0.027	0.160	0.026	0.182	0.031	0.184	0.021	0.170	0.024	0.121	0.019
across EZ11 countries	0.199	0.025	0.119	0.012	0.146	0.013	0.166	0.016	0.154	0.027	0.100	0.018

Panel B. Average Volatility of Relative Inflation

	1990.1-1994.2		1995.1-1999.2		2000.1-2004.2		2005.1-2009.2		2010.1-2014.2		2015.1-2018.2	
group of cities	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd
US	0.215	0.027	0.115	0.009	0.117	0.017	0.145	0.025	0.131	0.021	0.094	0.014
within country	0.206	0.030	0.110	0.011	0.115	0.018	0.143	0.024	0.131	0.021	0.092	0.014
across countries (excl. EZ)	0.208	0.029	0.112	0.016	0.122	0.017	0.144	0.020	0.138	0.023	0.093	0.013
across EZ11 countries	0.179	0.024	0.097	0.010	0.117	0.015	0.142	0.019	0.134	0.028	0.087	0.017

Panel C. Volatility of Exchange Rates

	1990.1-1994.2		1995.1-1999.2		2000.1-2004.2		2005.1-2009.2		2010.1-2014.2		2015.1-2018.2	
group of cities	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd
across countries (excl. EZ)	0.086	0.051	0.086	0.043	0.100	0.051	0.073	0.034	0.052	0.033	0.047	0.020