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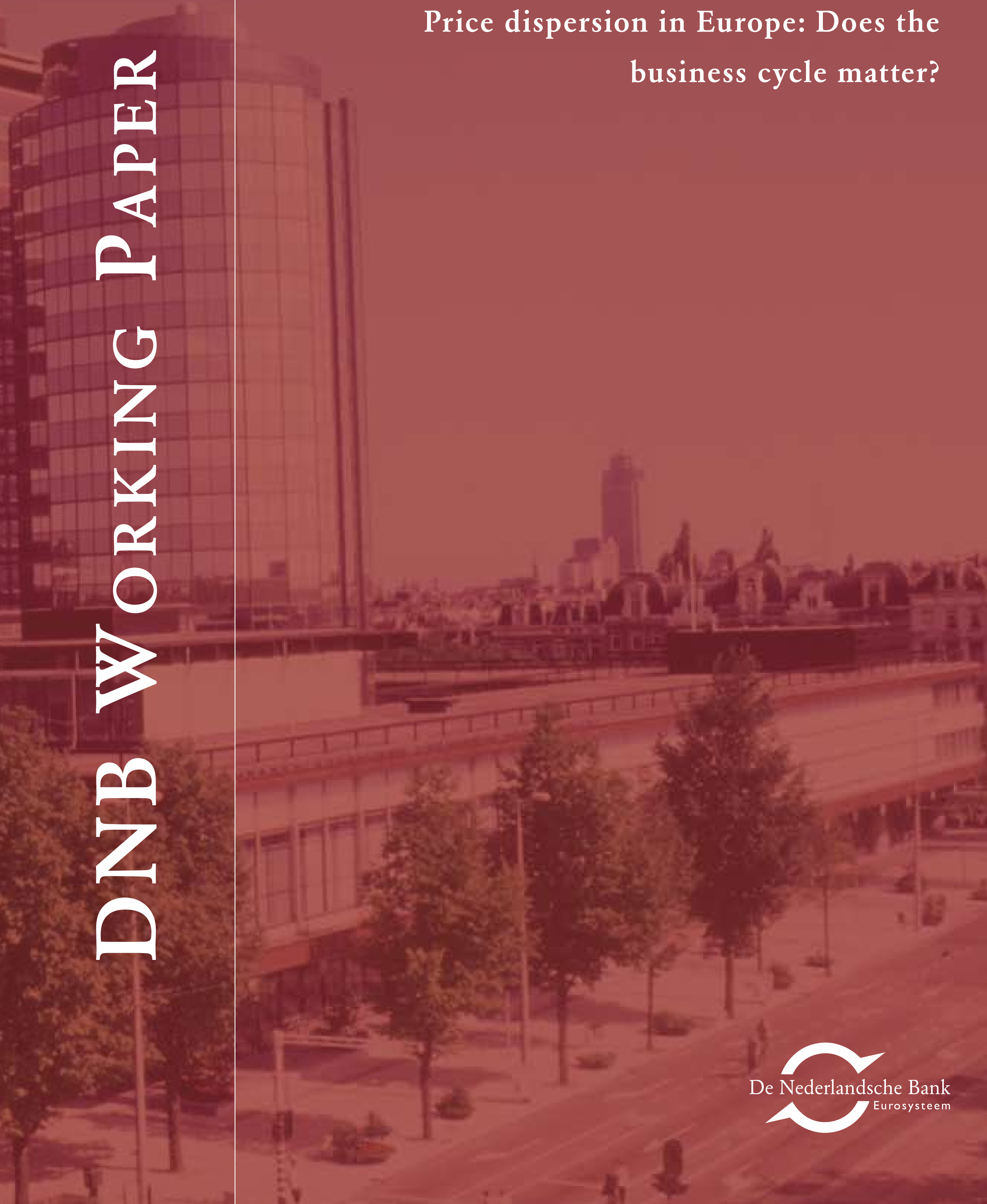

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Marco Hoeberichts and Ad Stokman *

* Views expressed are those of the authors and do not necessarily reflect official positions of De Nederlandsche Bank.

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Abstract

We analyze the effect of the business cycle on price dispersion in Europe. Five decades of price level dispersion data for Europe enable us to distinguish short-term influences from long-term influences like market integration. We find that at the business cycle frequency, price dispersion across EMU member countries over the 1960 - 2009 period is significantly lower during economic downturns. This confirms on a macroeconomic level the evidence from micro and survey studies that markets become more competitive with falling demand, reducing deviations from the Law of One Price. Our model replicates most of the major drops in price level dispersion during severe economic recessions of the early 1970s, 1980s and 1990s, as well as the small change during the recent financial crisis.

JEL codes: E31, E50, F15, F41

Key words: economic integration, price level convergence, Law of One Price, EMU, business cycle

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1. Introduction

Empirical research on price differences across borders has provided many explanations for the behaviour of international price dispersion. Engel and Rogers (1996, 2001) mention trade barriers, transportation costs, non-traded inputs and variable nominal exchange rates under sticky prices as possible sources for the failure of the law of one price. Rogers (2007) finds falling price dispersion for traded goods in Europe prior to 1999 and suggests that progress towards a single market and adoption of a single currency might be responsible. Faber and Stokman (2009) find that indirect tax rate harmonization, convergence of non-traded input costs, and convergence of traded input costs explain the long-run behaviour of price dispersion in Europe. More recently, Berka and Devereux (2010), using a panel for a large number of European countries over the 1995-2007 period, find substantial dispersion of price levels with little sign that dispersion is diminishing over time. We analyze price dispersion across European countries over a much longer period (1960-2009). This long period enables us to focus on the effect of the business cycle on the dynamic behaviour of price differences. Our main finding is that price dispersion is reduced during severe economic downturns.

There is ample empirical evidence that economic agents' behaviour changes in an economic recession. Research conducted by European central banks cooperating in the Eurosystem's Inflation Persistence Network (IPN) studied firms' price setting behaviour (see e.g. Fabiani *et al*, 2006). One important finding is that firms report that negative demand shocks are more likely to lead to price adjustments than positive demand shocks. This result comes from a survey conducted in nine countries and covering more than 10,000 firms across different sizes and industries and appears to apply in all countries participating in the research project. Another research project by European central banks on wage dynamics asked almost 15,000 firms in 15 European countries about their reaction to a hypothetical drop in demand. Evidence from this survey shows that, after a substantial reduction in demand, more than 90% of firms will try to reduce cost e.g. by negotiating terms with their suppliers (see e.g. Dhyne and Druant, 2010). The same question was asked again in early 2009, when for most firms a drop in demand had materialized as a result of the crisis. This follow-up survey confirmed the results found when the firms answered the hypothetical question[1] suggesting that firms in their role as buyers of inputs become more price sensitive during a recession. Firms also indicate that their customers become more price-sensitive during economic downturns.

The effect of the business cycle on price dynamics has been studied before. Field and Pagoulatos (1997) find evidence for a procyclical elasticity of demand in general but for countercyclical behaviour for the price elasticity of demand during recessions. This finding is consistent with a lower

[1] See Table 5.3 in "Wage dynamics in Europe: Final report of the wage dynamics network (wdn)", ECB (2009)

mark up during recessions. Gerardi and Shapiro (2009) provide evidence for the airline industry that competition reduces price dispersion.

Although we focus on *changes* in price dispersion and its relationship with the business cycle, our study is related to papers explaining price dispersion as an equilibrium phenomenon. Salop and Stiglitz (1977) develop a theoretical model of price discrimination across informed and uninformed buyers. In their model, some firms will target informed buyers and charge a low price, whereas other target uninformed buyers and charge a high price. Baylis and Perloff (2002) find empirical evidence for this theory in their study on pricing patterns for internet shops selling electronic devices. We link this result with the finding that, on average, buyers are more price-sensitive during recessions. This suggests that, during a recession, high-price firms will not be able to maintain their high price. These firms are only able to keep their high price in an environment with uninformed buyers. During recessions, the fraction of uninformed buyers is lower, leaving less room for high-price firms to survive. In an experimental study of price dispersion Morgan *et al* (2006) find that increases in the fraction of informed consumers leads to more competitive pricing for all consumers.

We use a dataset on European price levels that is based on standard HICP data for the former EMU-11 members that are available from 1960. To compare levels of HICP across countries, we apply a similar methodology as Chen and Devereux (2003) for US and OECD city CPIs. From these price level data, we compute a time-series of our dispersion measure. Using an error-correction framework, we isolate the short-run dynamics of price dispersion from the long-run determinants. The long-run behaviour is explained by openness, exchange rate volatility and income dispersion. In the equation for the short-run dynamics, we also include a business cycle indicator. A standard indicator for recession periods appears to be an important determinant of the short-run dynamics of price dispersion. The results confirm that the dynamic behaviour of price dispersion across 11 EMU countries is systematically affected by our recession indicator.

The paper is organized as follows. In Section 2 we set up the framework for our analysis. Section 3 discusses our dataset. Section 4 shows the results of the estimation and Section 5 concludes.

2. Conceptual framework

Definition of price level dispersion

In this section, we introduce the price level dispersion measure and theoretical framework. A basket of products in country *j* at time *t* has price level P_{jt}. Price levels from all n countries are expressed in the same currency. Price level dispersion at time *t* is measured by the cross-country standard deviation of $\log P_{jt}$ (short notation $\sigma(x_t) = \sigma(\log X_{jt} \mid t)$:

$$\sigma(p_t) = \sigma(\log P_{jt} \mid t) = \sqrt{\frac{1}{n}\sum_{j=1}^{n}(\log P_{jt} - \frac{1}{n}\sum_{i=1}^{n}\log P_{it})^2} \tag{1}$$

Determinants price level dispersion

The two main ingredients for modeling price level dispersion are

(1) The production technology. Following Crucini *et al* (2005), production is described by a Cobb-Douglas technology with a traded and non-traded input factor. This distinction is crucial for analyzing price differences between countries as tradable goods open the possibility of arbitrage;

(2) The type of market in which products are traded. We assume that there is monopolistic competition, implying that firms set final good prices as a mark-up over costs. In a recent large scale survey among European companies, mark up pricing over costs was found to be the dominant approach to price setting (Fabiani *et al*, 2007). In the long run, firms adopt desired mark-ups that are fixed. In the short run, mark-ups are supposed to be flexible.

In all countries under consideration, the bundle of goods is produced by the same Cobb Douglas technology with constant returns to scale, combining a non-traded input with a traded input:

$$P_{jt} = \beta_j W_{jt}^{\alpha} Q_{jt}^{1-\alpha} \tag{2}$$

where α is the share of non-traded inputs required for production, W_{jt} the price of the non-traded intermediate input and Q_{jt} the price of the traded intermediate input in country *j* at time *t*. The mark-up β_j is a function of the price elasticity of demand in country *j*. In line with recent fact finding by Christopoulou and Vermeulen (2008) on mark-ups in Europe and the US, we assume that mark-up β_j is stable in the long run, but may vary across countries. From Eq. 2 one may derive Eq. 3 that proves to be a good approximation of the long-run relationship between the price dispersion level and its determinants (for details see Faber and Stokman, 2009).

$$\sigma(p_t) = \sigma(\beta) + \alpha\sigma(w_t) + (1-\alpha)\sigma(q_t) \tag{3}$$

In our further analysis arbitrage costs are broken down in exchange rate volatility (vol_t) and openness of a country group ($open_t$) which summarizes the development over time of all other trade costs like transportation costs, (non-)tariffs barriers and information costs (Rogoff, 1996):

$$\sigma(q_t) = f(vol_t(+), open_t(-)) = \partial_0 + \partial_1 vol_t + \partial_2 open_t \qquad (4)$$

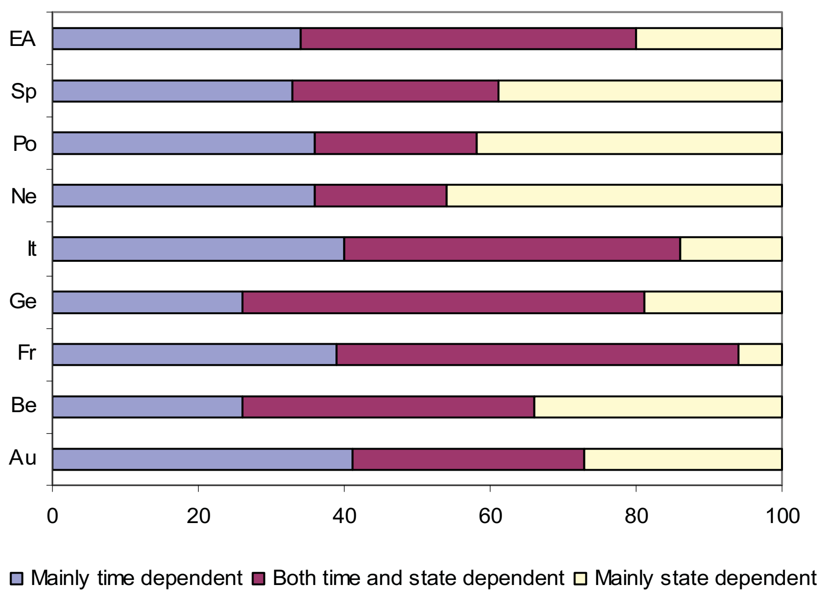
Substituting Eq. 4 into Eq. 3, we get the following relationship for price level dispersion

$$\sigma(p_t) = \sigma(\beta) + \alpha\sigma(w_t) + (1-\alpha)[\partial_0 + \partial_1 vol_t + \partial_2 open_t] \qquad (5)$$

Eq. 5 provides us with an analytical tool to identify the long-term factors driving price level dispersion This framework is also our bench mark to study possible regularities in price dispersion dynamics.

IPN and WDN survey results suggest that on average one third of individual firms in the Euro area mainly adopt time-dependent price-reviewing rules, and two thirds a mixture of time and state-dependent rules (see Figure 1). This means that with large enough relevant common shocks, many firms in the Euro area will review their prices and may decide to change them. Wage setting is to a substantial degree institutionalized and wages are often agreed upon at regular, predetermined intervals. With time-dependent wages and state-dependent prices, mark-ups are state dependent in the short-run. Therefore, when studying price-dispersion dynamics, we need to extent the base model with time varying country-level mark-ups. Our proposition is that under worsening business cycle conditions, consumers become more price-sensitive, markets become more competitive, and both mark-up and price spreads become smaller. The more alike business cycle conditions are across countries, the better we are able to identify such an effect.

Fig 1 Price reviewing rules (percentages)



Source Fabiani *et al* (2006)

3. Data

Price level data

From 1995 on, EUROSTAT publishes absolute HICP levels for EU Member States. HICP *indices* are available back to 1960.[2] To compare levels of HICP across European countries for years preceding 1995, we apply a similar methodology as that used by Chen and Devereux (2003) for US and OECD city CPIs. Firstly, all indices are converted into a common currency (DM or euro) using yearly averages of market exchange rates. Next, the HICP indices are converted into absolute price levels by using the absolute price levels for 1995.[3] Chen and Devereux (2003) and Faber and Stokman (2009) show that this approximation of the underlying absolute values of HICP is reliable. Price deviations for a broad basket of goods may be subject to summation bias, that is, different price level movements in HICP categories, which may cancel each other out or dominate. Aggregation bias is shown not to be a serious problem. We combine the constructed HICP levels for the 1960 – 1994 period with the EUROSTAT absolute HICP levels from 1995 – 2009. By doing so, we obtain a consistent dataset covering the 1960 – 2009 period. Figure 2 depicts the development of the absolute price levels in the countries that started off EMU in 1999. Over time, the Finnish absolute price level was the highest among this group (only recently passed by the Irish absolute price level) and the Portuguese price level the lowest. Figure 3 shows that price dispersion more than halved in EMU-11.

Supplemental data

Following the model specification, additional data are required for non-traded input costs, exchange rate volatility, openness, the share of non-traded inputs and the business cycle. To approximate the costs of non-traded input (W_{jt}), we take the per capita gross domestic (or region) product (GDP) at factor costs converted to common units using PPP measures.[4] Long-term European exchange rate volatility (vol_t) is measured by the standard deviation of all monthly changes in the exchange rate of a country against the German mark in one year, averaged over all countries in the group and over eight years.[5] For openness we take the average goods trade within the EU-15 region as a share of GDP. The business cycle indicator in this paper is the volume of industrial production in the euro area relative to its trend.

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[2] Source: OECD Economic Outlook (Number 75, June 2004).
[3] Source: Eurostat Chronos.
[4] Source: OECD Economic Outlook and additional data from the World Development Indicators database. (Europe) / Bureau of Economic Analysis (US). A correction is made for the German reunification.
[5] Source: IMF IFS and Reinhart and Rogoff (2004).

Fig 2 Absolute consumer price levels EMU member countries
(logs)

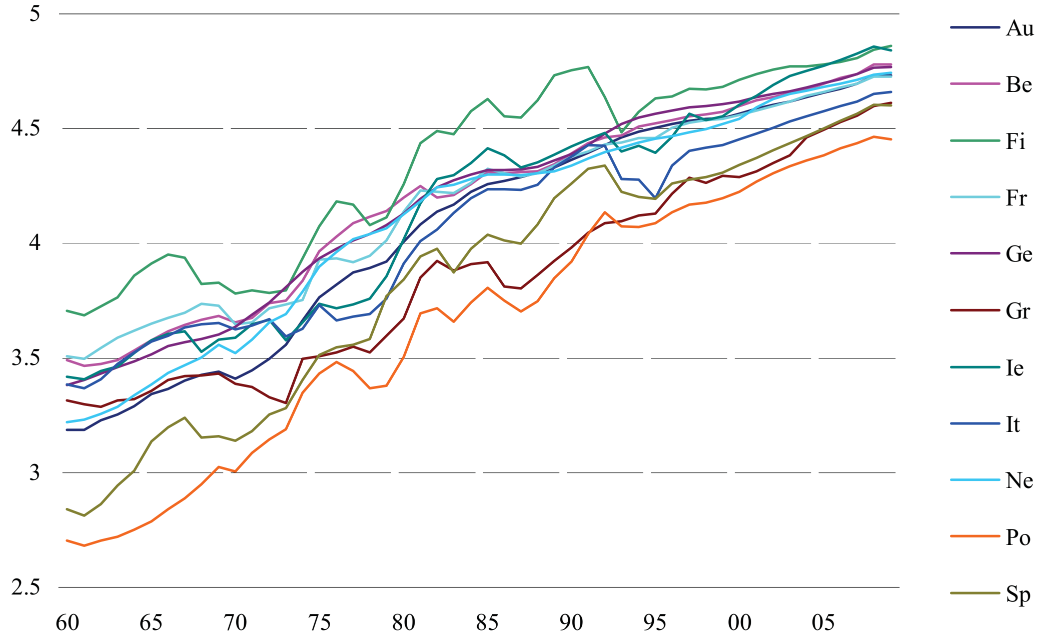
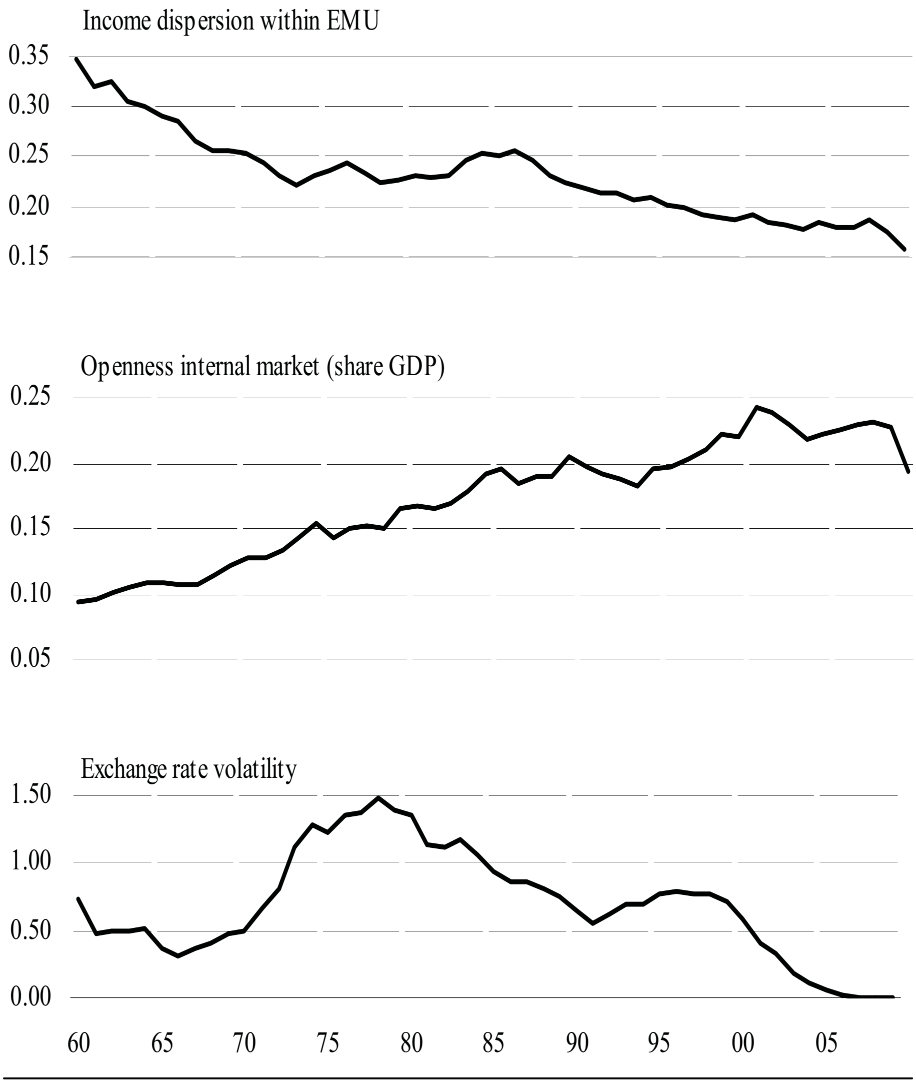


Fig. 3 Price level dispersion

According to Figure 3, three episodes can be distinguished: 1960-73 was a period of rapid decline in price level dispersion, 1974-87 was an episode of stagnation, and 1988-2009 was an episode in which price level convergence regained momentum. After the introduction of the euro in 1999, the overall price-dispersion level among the eleven original EMU member countries initially remained unchanged, but has been on a declining trend again from 2003 onwards. Faber and Stokman (2009) make a calculation of the main factors driving long-run developments in price dispersion. Convergence of non-traded input costs and convergence of traded input costs (in the form of exchange rate stability and increased internal market openness) all made a substantial contribution (Figure 4). The unprecedented drop in price level dispersion in the early 1990s, however, still needs to be explained. In Section 4, we take a closer look at the short-term dynamics in price level dispersion.

Fig. 4 Determinants of price level dispersion



4. Estimation results

The starting point of the analysis is Eq. 5 in which the price level dispersion rate is explained by income dispersion as a proxy for non-tradable input costs spreads, and openness and exchange rate volatility as a measure for the spread in tradable input costs across EMU member countries. This is the base model. In the extended model, a European business cycle indicator is added. In order to identify the dynamics in price level dispersion, a two-step procedure is applied. In the first step, the Johansen co-integration methodology is adopted to determine the underlying longer-term steady state relationships. In the second step, the dynamic part is estimated.

Annual data are available from 1960 up to and including 2009. The model is estimated for the full sample 1960-2009. As a robustness check, we also estimate the model for samples ending in 1998 and in 2006, thereby eliminating the impact of EMU and the recent financial crisis respectively. We obtain very similar results when we use these smaller samples.

All variables under consideration have a unit root of order 1 (Table 1). To test whether price level dispersion, income dispersion, openness and exchange rate volatility form a co-integrating relation, we apply the Johansen maximum likelihood procedure. Details of the rank tests are included in Annex A. The co-integration rank test suggests the presence of one co-integrating relation at the 2% level of significance. All three estimated parameters have the expected signs: openness lowers price level dispersion, exchange rate volatility increases price dispersion and income dispersion is positively related to price level dispersion (Table 2). The estimated share α of non-traded input costs in the production of consumption goods ranges from 0.6 in 1960-1998 to 0.7 in 1960-2009. This is near to what might be expected from a production accounting approach (see for example Maier, 2004). It is also in line with Berka and Devereux (2010) who find that real exchange rates in Europe are closely tied to relative levels of GDP per capita. Their study is based on a rich monthly dataset from 1985 to 2007 covering a large number of consumer goods for 31 European countries.

Table 1 ADF unit root test statistics

	1960-2009	
	Level	First difference
$\sigma(p_t)$	-2.94 (0.16)	- 5.38 (0.00)
$\sigma(w_t)$	-2.27 (0.44)	-6.23 (0.00)
vol_t	-1.65 (0.76)	-4.55 (0.00)
$open_t$	-1.78 (0.39)	-5.27 (0.00)

p-values between brackets

Table 2 Estimated steady state elasticities $\sigma(p_t)$

coefficient of	1960-1998	1960-2006	1960-2009
$\sigma(w_t)$	0.60 (0.19)	0.66 (0.15)	0.70 (0.15)
$open_t$	-0.46 (0.16)	-0.46 (0.15)	-0.44 (0.14)
vol_t	0.034 (0.010)	0.037 (0.007)	0.036 (0.006)
Johansen test			
- trace test	1 co-integrating relation **	1 co-integrating relation *	1 co-integrating relation *
- eigenvalue test	1 co-integrating relation **	1 co-integrating relation *	1 co-integrating relation *

Intercept (no trend) in CE and test VAR
Standard errors between brackets
* = 1% significance level ** = 2% significance level

Figure 5 shows that the price dispersion level among EMU countries may deviate substantially from the steady state level. Interestingly, large departures occurred under a variety of exchange rate regimes: it occurred in the 1960s during the Bretton Woods episode with fixed exchange rates relative to the US dollar, and in the 1970s with floating exchange rates (an arrangement called "the snake"). But also in the 1980s and 1990s under the EMS with stable exchange rates adjustable within limited boundaries. In recent years, price dispersion levels remained more in line with steady state levels.

Fig. 5 Steady state price level dispersion in EMU

Particularly in the late 1980s, departures from the steady state were large. In the early 1990s this came to an end when price dispersion displayed an unprecedented large drop. Rogers (2007) noticed that the drop took place around the completion of the Single Market in 1992. From the long term perspective we take here, it appears that price dispersion squeezing is not unique for the early 1990s. Also in the early 1970s and early 1980s, for example, price dispersion dropped markedly towards levels well below the steady state, indicating that factors other than institutional ones might have been at work. In Section 1, we saw that under weakening economic conditions, consumers become more price-sensitive and markets become more competitive. As a consequence, price differences become smaller. Yet, according to Figure 5, some profound business cycle downturns, notably the one that emerged during the recent global financial crisis, seem not to have affected price differentials within Europe, unless such an effect was offset by compensating forces

The estimated parameters are not very sensitive to the choice of the sample period. This does not mean that the introduction of the euro has no lasting effect on the long term level of price dispersion. Several empirical studies provide evidence that the euro has stimulated cross border trade. In our model, increased openness leads to narrower price differential among EMU countries.

Now we are in a position to investigate the dynamics of price level dispersion more closely. We include the 1960-2009 estimated co-integration parameters from Table 2 in the error correction specification of Eq. 6 below. Departures from equilibrium induce price level dispersion to move back towards its steady state path. If d_0 is small, mean reversion takes place at a slow rate. If d_0 is close to 1, mean reversion takes place almost instantaneously. Eq. 6 represents the base model. Business cycle indicators are added in Eq. 8 (extended model).

Base model, error correction specification

$$\Delta\sigma(p_t) = c_0 + c_1\Delta\sigma(p_{t-1}) + c_2\Delta\sigma(w_{t-i}) + c_3\Delta open_{t-j} + c_4\Delta vol_{t-k} - d_0\ ecm_{t-1} \qquad \text{i,j,k=0, 1} \tag{6}$$

$$ecm_t = \sigma(p_t) - 0.09 - 0.70\ \sigma(w_t) + 0.44\, open_t - 0.036\, vol_t \tag{7}$$

Extended model, error correction specification

$$\Delta\sigma(p_t) = c_0 + c_1\Delta\sigma(p_{t-1}) + \ldots\ldots\ldots\ldots\ldots + c_5\Delta bus_t - d_0\ ecm_{t-1} \tag{8}$$

First we take a closer look at the estimation results for the base model. In the short run, the constant, the autoregressive component and the one-year lagged exchange rate volatility are significant (Table 3, column 1). The sign of the lagged change in exchange rate volatility is opposite to that of the long-term parameter, reflecting that exchange rate volatility affects steady state price level dispersion with approximately a one-year delay instead of no delay. The estimated error correction coefficient of 0.50 implies that the half life of mean reversion is about one year, which is high for empirical studies using aggregate price level data. The massive fall in price dispersion in the early 1990s is only partially captured by the base model. This is not the only episode with large negative outliers in the residuals.

Sizable unexplained drops in price dispersion also show up in the 1970s, early 1980s and mid-1990s. As a consequence, normality and unskewedness of the residuals are rejected at the 5% significance level. In column 2 of Table 3, all insignificant parameters are set to zero.

These findings suggest that other channels are at work. In Section 1 we presented theoretical arguments and micro-, experimental and survey evidence why business cycles - and particularly business cycle downturns - may lead to drops in price dispersion at the macro level. In the following this will be tested, first by making no explicit distinction in up- and downturns (symmetric response), and next by allowing for asymmetric responses. As country business cycles within EMU are tightly connected (see Annex B for a visual inspection), the euro area business cycle indicator bus_t is expected to sufficiently represent the state of the economies under consideration. Table 3 shows that changes in the European business cycle indicator, whether measured by Δbus or by a dummy (1 for upturns and -1 for downturns), are not significant. See Table 3, column 3 and 4 respectively.

Next, we allow for asymmetry by labeling changes in the European business cycle indicator as *relatively weak* if the absolute value of Δbus is smaller than half the standard deviation of Δbus, and *relatively strong* if the absolute change is larger. This choice provides us with an economically meaningful partitioning of business cycle changes, as well as with a division into roughly four equally sized parts (see Figure 6). The estimation results do not rely on precisely where the line is drawn between relatively strong and relatively weak.

		No. of years
∂bus^{++}	1 for years with relatively strong economic upturn in the euro zone, 0 otherwise	11
∂bus^{+}	1 for years with relatively weak economic upturn in the euro zone, 0 otherwise	14
∂bus^{-}	1 for years with relatively weak economic downturn in the euro zone, 0 otherwise	13
∂bus^{--}	1 for years with relatively strong economic downturn in the euro zone, 0 otherwise	12

Fig. 6 Euro area business cycle episodes

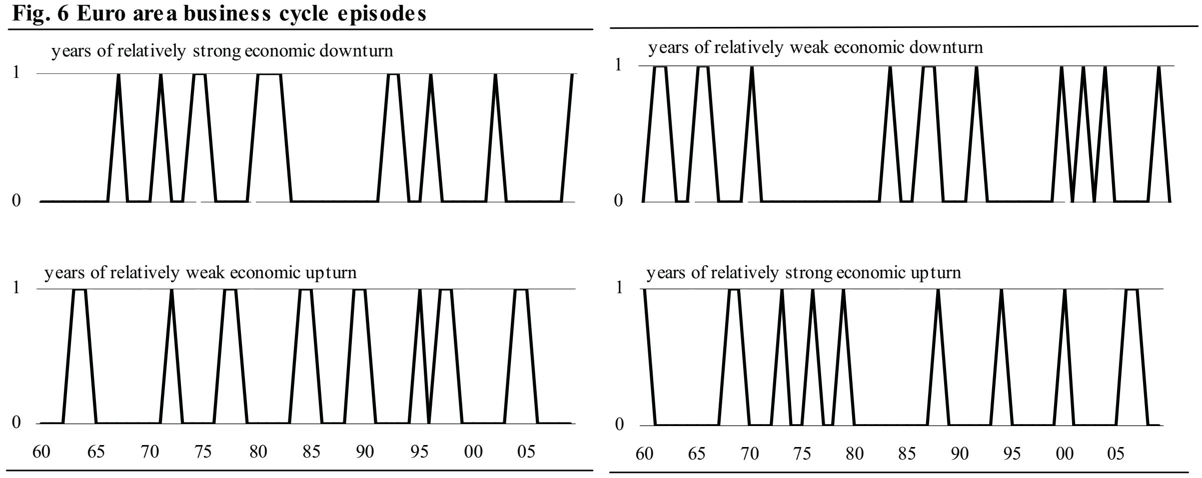


Table 3 Summary estimation results

	Base model		Extended model *1962-2009*					. *1962-2006*
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8) .
ecm_{t-1}	0.495	0.494	0.493	0.497	0.520	0.552	0.544	0.541
	(5.3)	(5.9)	(5.8)	(6.0)	(6.8)	(7.9)	(7.7)	(7.7)
constant	-0.003	-0.003	-0.003	-0.003	-0.000	0.001	0.001	0.001
	(1.9)	(2.0)	(1.9)	(2.1)	(0.1)	(0.9)	(1.0)	(0.7)
$\Delta\sigma(p_{t-1})$	0.305	0.307	0.305	0.268	0.196	0.208	0.217	0.208
	(2.7)	(2.8)	(2.6)	(2.4)	(1.9)	(2.2)	(2.3)	(2.2)
$\Delta\sigma(w_{t-1})$	-0.000	-	-	-	-	-	-	-
	(0.0)							
$\Delta open_{t-1}$	0.192	-	-	-	-	-	-	-
	(0.9)							
Δvol_{t-1}	-0.040	-0.0370	-0.037	-0.042	-0.032	-0.029	-0.030	-0.030
	(2.6)	(2.6)	(2.5)	(2.9)	(2.4)	(2.4)	(2.5)	(2.4)
$\Delta open_t$	-	-	-	-	-	-0.409	-0.450	-0.415
						(2.9)	(3.1)	(2.9)
Δbus_t	-	-	0.000	-	-	-	-	-
			(0.1)					
∂bus_t^{++}	-	-	-	0.002 a	-0.002	-	-	-
				(1.6)	(0.7)			
∂bus_t^{+}	-	-	-	0.002 a	-0.000 b	-	-	-
				(-)	(0.2)			
∂bus_t^{-}	-	-	-	-0.002 a	0.000 b	-	-	-
				(-)	(-)			
∂bus_t^{--}	-	-	-	-0.002 a	-0.011	-0.014	-	-0.014
				(-)	(3.6)	(4.7)		(4.7)
dum6084 ∂bus_t^{--} **	-	-	-	-	-	-	-0.012	-
							(3.4)	
(1-dum6084) ∂bus_t^{--}	-	-	-	-	-	-	-0.017	-
							(4.0)	
$\overline{R^2}$	0.42	0.43	0.42	0.45	0.54	0.62	0.62	0.61
LM(1) *	0.85	0.69	0.69	0.59	0.83	0.90	0.89	0.83
LM(2) *	0.17	0.16	0.16	0.27	0.27	0.27	0.21	0.32
LM(4) *	0.46	0.44	0.44	0.61	0.46	0.50	0.34	0.58
Norm *	0.05	0.04	0.04	0.36	0.80	0.95	0.94	0.95
Chow break (1984) *	0.99	0.96	0.98	0.98	0.91	0.80	-	0.77
Chow forecast (2006) *	0.78	0.83	0.76	0.69	0.29	0.85	0.77	-

Note t-values between brackets
* p-values
** d6084=1 for 1960-1984 and 0 elsewhere.
a symmetry restriction I: effect business cycle decline = - effect business cycle rise
b symmetry restriction II: effect modest business cycle decline = - effect modest business cycle rise

The estimation results show that ∂bus^{--} is highly significant and has the expected sign: price level dispersion within Europe is being squeezed markedly during economic downturns (columns 5 and 6), particularly during more severe economic downturns. By contrast, aggregate price level dispersion rates are not systematically affected during economic upswings. Turning back to the original determinants from the base model, current changes in openness are significant now (column 6).[6] The parameter estimate has the same sign and about the same size as in the long term. This means that current changes in openness immediately translate into a new steady level of price dispersion in Europe. As already has been noticed, exchange rate volatility has a delayed impact on the steady state.

To summarize, in a year with significantly deteriorating economic conditions, price level dispersion will drop on average by an estimated 1.4 percentage points. Other things being equal, three successive years of significant business cycle downturn like in the early 1980s will be accompanied by a price dispersion squeeze of over 4 percentage points. Can the model explain the big fall in price level dispersion between 1987 and 1993? Of a total drop of 9 percentage points between 1987 and 1993, one third can be attributed to a decrease in the underlying steady state level and one third to business cycle contraction, leaving one third unexplained. Surprisingly, the recent economic downturn, stemming from the financial crisis, has left price level dispersion untouched. According to the model, the downward effect from the recession was offset by the big drop in international trade.

Robustness

We performed several robustness tests (in- and out-of-sample). In the *first* test, ∂bus_t^{--} has been split up into two equal episodes: 1960-1984 including 7 years of recession and 1985-2009 with 5 recession years (see Table 3, column 7). The effect is somewhat larger in the recent episode, but the difference is not significant.

Secondly, if we re-estimate the model leaving out recent years of the financial crisis, the parameter estimates remain very much the same. This holds for both the long-term parameters and the short-term parameters in the model. An out-of-sample forecast based on the 1960-2006 model tracks the 2007-2009 level of price dispersion closely. A *third* way of illustrating the stability of the model is by performing a so-called dynamic simulation. In a dynamic simulation, one starts with observed values of $\sigma(p_t)$, in our case for the years 1960 and 1961, and calculates all successive values of price dispersion using Eq. 8, replacing observed lagged values of price dispersion by the simulated values of price dispersion. After a few years all successive values of the price level dispersion are almost completely driven by the explanatory variables in the model. The result of this exercise is Figure 7,

[6] As $\Delta open_t$ and Δbus_t are weakly exogenous, current values may be included in the right-hand side of the dynamical part of the equation .

which shows that the model gives a good description of the price dispersion history of Europe, even for the years around the completion of the Single Market, although some part remains unexplained.

Fourth, replacement of our current recession dummy for Europe by a lagged dummy or by a US recession dummy (having five out of twelve recession years in common with Europe) yields insignificant parameter estimates (See Tables 4a and 4b). This suggests that current European business cycle conditions are relevant for price dispersion drops.

Fig. 7 Dynamically simulated price level dispersion EMU

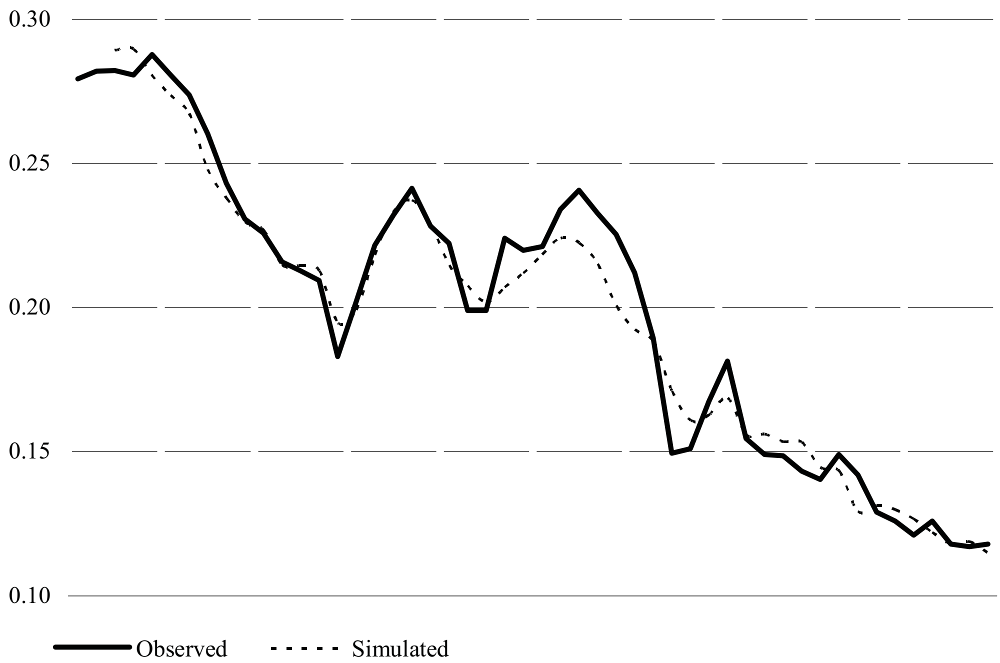


Table 4a Can *current* US downturns explain price dispersion squeezing in Europe?

	Recession dummy Europe	Recession dummy US
∂bus_{t}^{--}	-0.014	0.001
	(4.7)	(0.2)
$\overline{R^2}$	0.62	0.42

Note t-values between brackets

From the twelve years we identify as years of relatively strong business cycle downturns, Europe and the US share five.

Table 4b Can *lagged* US downturns explain price dispersion squeezing in Europe?

	Recession dummy Europe	Recession dummy US
∂bus_{t-1}^{--}	0.001	-0.005
	(0.3)	(1.4)
$\overline{R^2}$	0.42	0.45

As a *final* check, we ignore long-term developments by simply de-trending all four non-stationary variables from the base model with an HP-filter, and run an OLS regression on the first difference of the de-trended variables and the business cycle dummies (See Annex C). This procedure delivers the same insights. Of course, our original model is much richer in its simultaneous description of long-term and short-term channels.

All in all, the introduction of a recession indicator helps to improve the description of European price level dispersion substantially.

5. Concluding remarks

Half a century of price level dispersion data enables us to identify the presence of a business cycle component in price dispersion movements. We find that small variations in the European business cycle leave the price dispersion level unaffected. In case of stronger business cycle downturns, however, the effects are substantial. We link our finding of reduced price dispersion during recessions to evidence from microeconomic and survey studies showing a higher degree of competition during economic downturns. Fabiani *et al*. (2006) find that two thirds of firms in the euro area apply a price-setting rule with state-dependent elements, implying that these firms adjust their prices when a large-enough shock occurs. For many firms, a recession beyond a certain threshold, with a large fall in demand, will be such a shock, inducing them to lower their prices. This finding is consistent with more competition and downward flexible prices during strong economic downturns.

By analyzing international price dispersion at business cycle frequency, we fill the gap between studies on determinants of the long-run trend behaviour of price dispersion like trade barriers and the short-term fluctuations like the sticky consumer prices with volatile exchange rates analyzed in Engel and Rogers (2001).

The robustness checks confirm that this result does not depend on specific episodes like the start of EMU or the recent financial crisis. Interestingly, our model is capable of explaining most of the massive drop in price level dispersion in the early 1990s, as well as the small change during the recent financial crisis.

Our results reveal an important non-linearity in the dynamic behaviour of price dispersion. In spite of abundant evidence from empirical microeconomic studies, surveys and experimental research that agents' behavior in bad times is not just the mirror image of their behaviour in good times, the macroeconomic consequences of non-linear behaviour receive little attention. We link our findings to buyers' higher price sensitivity during recessions. Changes in price sensitivity are very relevant for monetary policy making. An interesting research agenda would be to incorporate switches in price sensitivity in our macroeconomic models.

ANNEX A Trace and maximum eigenvalue tests for co-integration

The first step in the Johansen approach involves testing for the cointegration rank *r*. To compute these tests one needs to choose the maximum lag length p in the vector autoregressive model. Table B1 for 1960-2009 and Table B2 for 1960-2006 below summarize the results of the cointegrating rank tests for lag lengths up to and including 3, allowing for the presence of an intercept in both the CE and test VAR. At the 5% level, the null hypothesis of no cointegrating relationship is rejected, irrespective the size of *p*. According to the maximum eigenvalue test (trace test) the null hypothesis of one (at most one) co-integrating relation cannot be rejected.

Table A1 Co-integration tests 1960-2009

Hypothesized no. of CEs		Test statistic *Lags intervals p in first differences*			
Null hypothesis	Alternative	p=1	p=2	p=3	5% critical value
		Trace statistic			
$H_0 : r = 0$ *	$H_1 : r \geq 1$	63.06	54.64	59.59	47.86
$H_0 : r \leq 1$	$H_1 : r \geq 2$	24.66	21.71	25.84	29.80
$H_0 : r \leq 2$	$H_1 : r \geq 3$	12.28	10.40	9.65	15.49
$H_0 : r \leq 3$	$H_1 : r \geq 4$	2.55	1.72	1.85	3.84
		Max eigenvalue statistic			
$H_0 : r = 0$ *	$H_1 : r = 1$	38.40	32.92	33.74	27.58
$H_0 : r \leq 1$	$H_1 : r = 2$	12.38	11.31	16.19	21.13
$H_0 : r \leq 2$	$H_1 : r = 3$	9.73	8.68	7.80	14.26
$H_0 : r \leq 3$	$H_1 : r = 4$	2.55	1.71	1.85	3.84

Intercept (no trend) in CE and test VAR * denotes rejection of the hypothesis at the 0.05 level

Table A2 Co-integration tests 1960-2006

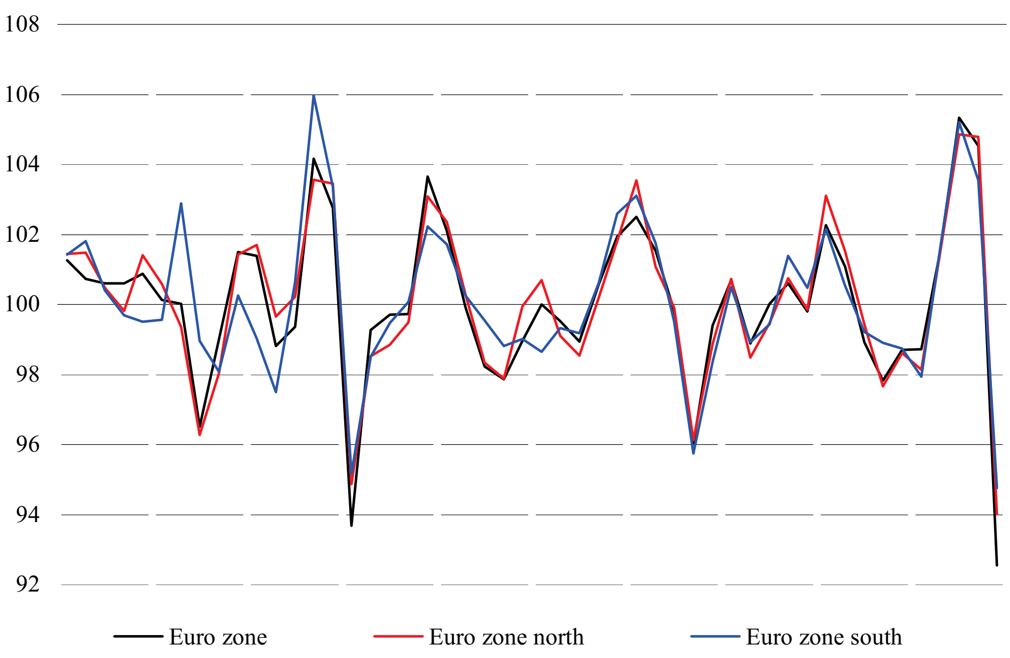
Hypothesized no. of CEs		Test statistic *Lags intervals p in first differences*			
Null hypothesis	Alternative	p=1	p=2	p=3	5% critical value
		Trace statistic			
$H_0 : r = 0$ *	$H_1 : r \geq 1$	57.76	49.87	51.06	47.86
$H_0 : r \leq 1$	$H_1 : r \geq 2$	20.78	18.15	21.90	29.80
$H_0 : r \leq 2$	$H_1 : r \geq 3$	8.90	7.89	7.33	15.49
$H_0 : r \leq 3$	$H_1 : r \geq 4$	0.02	0.003	0.002	3.84
		Max eigenvalue statistic			
$H_0 : r = 0$ *	$H_1 : r = 1$	36.98	31.72	29.16	27.58
$H_0 : r \leq 1$	$H_1 : r = 2$	11.88	10.26	14.57	21.13
$H_0 : r \leq 2$	$H_1 : r = 3$	8.88	7.89	7.32	14.26
$H_0 : r \leq 3$	$H_1 : r = 4$	0.02	0.003	0.002	3.84

Intercept (no trend) in CE and test VAR * denotes rejection of the hypothesis at the 0.05 level

Tables B1 and B2 show that there is little sensitivity with respect to the choice of the maximum lag length *p*. On the basis of the Akaike and Schwarz information criterion, p=1 is the most appropriate length in the vector autoregressions.

In small samples, the properties of the rank test statistics may differ substantially from the asymptotic properties. As a result, the tests are generally biased towards finding co-integration too often when asymptotic critical values are used. If we adopt a commonly used small sample correction suggested by Ahn and Reinsel (1990) and Reimers (1992), the existence of one co-integrating relation can still not be rejected. This is not surprising. In terms of the number of observations the sample size might be considered small, but in terms of the time span this is not the case. Half a century of European price developments is more than adequate to pass the statistical tests. Extending the model with a deterministic trend in the CE does not alter the findings. The accompanying parameter estimate is insignificant at the 5% level.

ANNEX B Co-movement business cycles within Euro area



ANNEX C Estimation with de-trended variables (HP-filter)

$\Delta \hat{\sigma}(p_t)$: yearly change in de-trended price level dispersion

$\Delta \hat{\sigma}(w_{t-1})$: yearly change in de-trended income dispersion

$\Delta \hat{open}_t$: yearly change in de-trended openness

$\Delta \hat{vol}_t$: yearly change in de-trended measure of exchange rate volatility

$\Delta \hat{\sigma}(p_t)$		Estimation period 1962-2009
Determinants		
constant		0.003
		(1.5)
$\Delta \hat{\sigma}(w_{t-1})$		0.559
		(2.4)
$\Delta \hat{open}_t$		-0.303
		(1.3)
$\Delta \hat{vol}_t$		0.045
		(2.0)
∂bus_t^{++}		0.001
		(0.3)
∂bus_t^{+}		0.000
		(0.1)
∂bus_t^{-}		-0.000
		(-)
∂bus_t^{--}		-0.014
		(3.5)
$\overline{R^2}$		0,22
LM(1)	*	0.53
LM(2)	*	0.13
LM(4)	*	0.16
Norm	*	0.83
Chow Break (1984)	*	0.42
Chow forecast (2006)	*	0.64

t-values between brackets

* p-values

References

Ahn, S., and G. Reinsel, (1990), Estimation for partially nonstationary autoregressive models, *Journal of the American Statistical Association*, 85, 813-823

Berka, M., and M. Devereux, (2010), What determines European real exchange rates?, *NBER Working Paper* No. 15753

Baylis, K. and J.M. Perloff, (2002), Price dispersion on the internet: Good firms and bad firms, *Review of Industrial Organization*, 21, 305-324

Chen, L., and M. Devereux. (2003), What can US city price data tell us about purchasing power parity? *Journal of International Money and Finance*, 22, 213-22

Christopoulou, R., and P. Vermeulen, (2008), Mark ups in the euro area and the US over the period 1981-2004 - a comparison of 50 sectors, *ECB Working Paper Series*, No. 856

Crucini, M. J., Telmer, C., and Zachariadis, M. (2005), Understanding European real exchange rates, *American Economic Review*, 95, 3, 724-738

Dhyne, E., and Druant, M. (2010), Wages, labor or prices: how do firms react to shocks? *ECB Working Paper Series*, No. 1224

ECB (2009), Wage dynamics in Europe: Final report of the wage dynamics network (wdn), http://www.ecb.int/home/pdf/wdn_finalreport_dec2009.pdf

Engel, C., and Rogers, J. H. (1996), How wide is the border?, *American Economic Review*, 86(5), 1112-25

Engel, C., and Rogers, J. H. (2001), Deviations from purchasing power parity: causes and welfare costs, *Journal of International Economics*, 55(1), 29-57

Faber, R.P., and A.C.J. Stokman, (2009), A short history of price level convergence in Europe, *Journal of Money Credit and Banking*, 41, 2-3, 461-477

Fabiani S., Druant, Hernando, Kwapil, Landau, Loupias, Martins, Matha, Sabbatini, Stahl, Stokman, (2006), What firms' surveys tell us about price-setting behavior in the euro area, *International Journal of Central Banking,* 2, 3, 3-47

Fabiani S., C. Loupias, F. Martins, R. Sabbatini (eds.), (2007), Pricing decisions in the euro area: How firms set prices and why, *Oxford University Press.*

Field, M.K., and E. Pagoulatos, (1997), The cyclical behavior of price elasticities of demand, *Southern Economic Journal,* 64, 1, 118-129

Gerardi, K.S., and A.H. Shapiro, (2009), Does competition reduce price dispersion? New evidence from the airline industry, *Journal of Political Economy*, vol 117, no 1, 1-37

Maier, P. (2004), EMU enlargement, inflation and adjustment of tradable goods prices: What to expect, DNB Working Paper No. 10

Morgan, J. , H.Orzen and M. Sefton, (2006), An experimental study of price dispersion, *Games and Economic Behavior*, 54, 134-158

Reinhart, C., and K. Rogoff, (2004), The modern history of exchange rate arrangements: a reinterpretation, *Quarterly Journal of Economics*, 119, 1, 1-48

Reimers, H.-E., (1992), Comparison of tests for multivariate cointegration, *Statistical Papers*, 33, 335-359.

Rogers, J.H., (2007), Monetary union, price level convergence, and inflation: How close is Europe to the USA?, *Journal of Monetary Economics*, 54, 3, 785-796

Rogoff, K.. (1996) "The purchasing power parity puzzle." *Journal of Economic Literature*, 34, 647-68

Salop, S. and J. Stiglitz, (1977), Bargains and ripoffs: a model of monopolistically competitive price dispersion, *The Review of Economic Studies*, 44, 493-510

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