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## Working Paper

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# Inflation, Price Dispersion and Market Integration through the Lens of a Monetary Search Model

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# Inflation, Price Dispersion and Market Integration through the Lens of a Monetary Search Model

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## Abstract

Recent monetary search models emphasize that the real effects of inflation via its impact on price dispersion depend on the level of search costs and, thus, on the level of market integration. For less integrated markets, the inflation-price dispersion nexus is predicted to be asymmetrically V-shaped which implies an optimal inflation rate above zero. For highly integrated markets, however, theory suggests that the impact of inflation on price dispersion disappears. Employing price data of the European Union member states, this paper is the first that empirically tests these implications of monetary search theory.

*Keywords:* Inflation; Relative price variability; Monetary search models; European market integration.

*JEL classification:* E31, C23

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# 1 Introduction

In macroeconomic theory, the impact of inflation on price dispersion is a major channel of real effects of inflation. According to menu-cost (Benabou, 1992) or Lucas-type misperception models (Barro, 1976) inflation increases relative price variability (RPV), distorts the information content of prices, and, thereby, impedes the efficient allocation of resources. Both types of models imply a monotonous inflation-RPV nexus in which inflation always lowers welfare. As a consequence, the early empirical evidence is typically based on linear regressions of RPV on the rate of inflation (see e.g. Debelle and Lamont, 1997, and Jaramillo, 1999).

Recent monetary search models predict that the impact of inflation on price dispersion and welfare is more complex. According to Head and Kumar (2005), both the inflation-RPV and the inflation-welfare nexus are asymmetrically V-shaped provided that search costs are sufficiently high. As a consequence, the optimal rate of inflation for economies with high search costs is above zero. In case of very low search costs, however, the relationship between inflation and RPV breaks down. These theoretical implications for the inflation-RPV nexus have never been tested empirically. Assuming that search costs decrease when markets become more integrated, the current paper fills this gap by estimating the relationship between inflation and RPV for sub-groups of European countries with different degrees of goods market integration.

Contradicting the predictions of standard menu-cost or misperception models, recent empirical evidence suggests that the relation between inflation and RPV is non-linear, see e.g. Fielding and Mizen (2008) and Bick and Nautz (2008). A first attempt to explicitly test the implications of the Head and Kumar (2005) model is given by Caglayan et al. (2008). Using price observations from bazaars, convenience stores, and supermarkets in Turkey, they confirm a V-shaped relationship between inflation and RPV. However, their data set does not allow to explore the role of market integration for the inflation-RPV nexus.

Monetary search models are designed for countries with low or moderate inflation rates (see Head and Kumar, 2005, p.535). Therefore, members of the European Union (EU) are natural candidates for an empirical test of these models. Although European integration has made considerable progress on average, notable differences in goods market integration across Europe have remained. The following analysis compares two groups of countries. The first group contains the highly integrated Euro-area countries where a common currency contributes to keep search costs low. The second group contains the rather heterogeneous group of all 27 EU member states where markets are less integrated and, thus, search costs should be significantly higher compared to Euro-area countries, see Engel and Rogers (2004) and Parsley and Wei (2008).

Our empirical results show that the impact of inflation on price dispersion is non-linear and crucially depends on the level of goods market integration. In particular, the evidence supports both predictions of the monetary search model. On the one hand, the empirical relation between inflation and price dispersion is asymmetrically V-shaped in the less integrated EU-27 economy suggesting an optimal annual inflation rate of about 3%. On the other hand, there is no significant impact of inflation on price dispersion for the highly integrated Euro-area markets.

The rest of the paper is organized as follows. Section 2 briefly reviews the Head and Kumar (2005) monetary search model and derives testable implications for the empirical relationship between inflation and RPV. Section 3 introduces the data and specifies the price variability and inflation measures. Section 4 presents the empirical results obtained for the inflation-RPV nexus of the EU27 and the Euro-area countries. Section 5 discusses the robustness of the results and Section 6 concludes.

## 2 The Monetary Search Model

### 2.1 Inflation, Price Dispersion and Welfare Costs

The Head and Kumar (2005) monetary search model emphasizes that buyers have only incomplete information about the prices offered by different sellers. In this model, the impact of inflation on price dispersion and welfare is determined by two opposing effects. On the one hand, higher expected inflation lowers the value of fiat money, which increases demand for goods and, thereby, sellers' market power.<sup>1</sup> Since market power differs across sellers, higher expected inflation leads to higher price dispersion. On the other hand, higher expected inflation also raises the gains of search which adds two further dimensions to its effect on welfare. First, the search induced by inflation is costly. And second, because it induces search, inflation increases buyers' information and, thereby, weakens sellers' market power. Therefore, inflation may have also welfare-improving effects by reducing the dispersion of prices. As a result, the sign of the overall effect of inflation on price dispersion and welfare is not obvious.

In order to shed more light on the overall effect of inflation on price dispersion and welfare, we solved the monetary search model by Head and Kumar (2005) numerically. Detailed presentations of the model and the simulation exercise are provided in Appendix A1.

Figure 1 displays the benchmark simulation for inflation's impact on welfare and price dispersion.<sup>2</sup> The figure shows that at low inflation rates the reduction of market power resulting from increased search intensity in response to an increase in inflation is sufficient to decrease price dispersion and to raise welfare (i.e. welfare costs decrease).

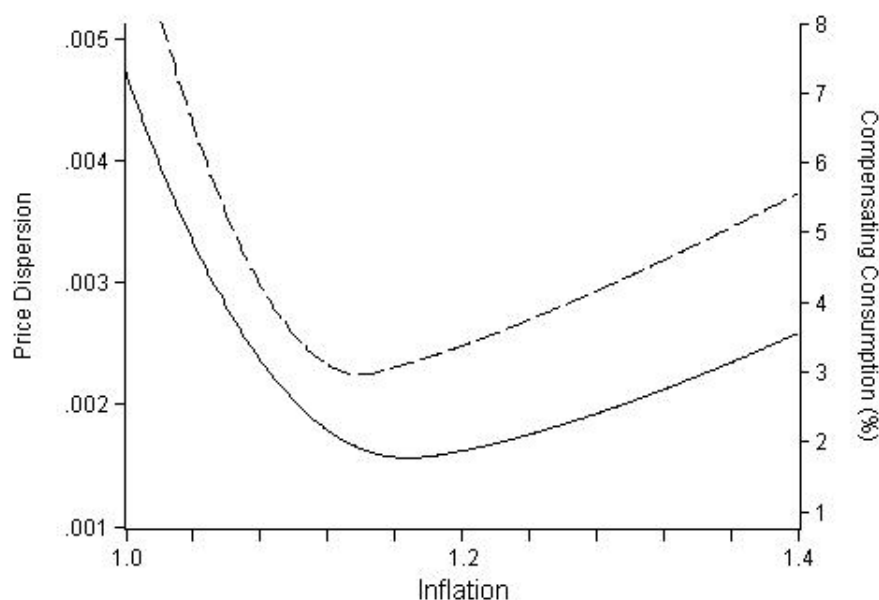
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<sup>1</sup>Note that the only source of inflation is the growth of the money stock. Thus, inflation is unambiguously overall inflation and should not be interpreted as the growth rate of the price level of a specific category of goods. Since households maximize their expected utility, they care about expected future money growth, i.e. *expected overall inflation*.

<sup>2</sup>The welfare cost of inflation is measured by the quantity of consumption required to give a representative household the same utility as she would receive in the optimum (without asymmetric information) as a percentage of optimum consumption.

However, when inflation exceeds a critical value, the search-increasing effect of inflation gets negligible and the welfare distorting effect of inflation on sellers' market power eventually dominates. As a result, the relationship between expected inflation and price dispersion can be captured by an asymmetric V-shaped specification where the vertex occurs at positive levels of inflation. Note that the welfare maximizing inflation rate  $\Pi^*$ , which is determined by the minimum of the welfare cost curve, is located below but very close to the vertex of the inflation-RPV nexus. Accordingly, this vertex may serve as a proxy for  $\Pi^*$ .

Figure 1: Inflation, price dispersion, and welfare



Notes: The figure shows the impact of expected inflation on price dispersion and welfare as predicted by the monetary search model introduced by Head and Kumar (2005). Price Dispersion (solid line - left scale); Compensating Consumption (%) (dashed line - right scale). For more details, see Appendix A1.

In the appendix, we show that V-shaped effects of inflation require search costs to be sufficiently high. Since the level of search costs should be negatively related to the degree of market integration, this leads to our first empirically testable implication of the monetary search model:

**Hypothesis 1:** *Consider the monetary search model of Head and Kumar (2005). Provided that the degree of market integration in an economy is sufficiently low, the relationship between expected inflation and RPV is asymmetrically V-shaped with a non-zero optimal rate of inflation.*

A first attempt to test this hypothesis is given by Caglayan et al. (2008) who found, however, a *symmetric* V-shaped relationship between price dispersion and expected inflation in Turkey.

## 2.2 Search Costs and Market Integration

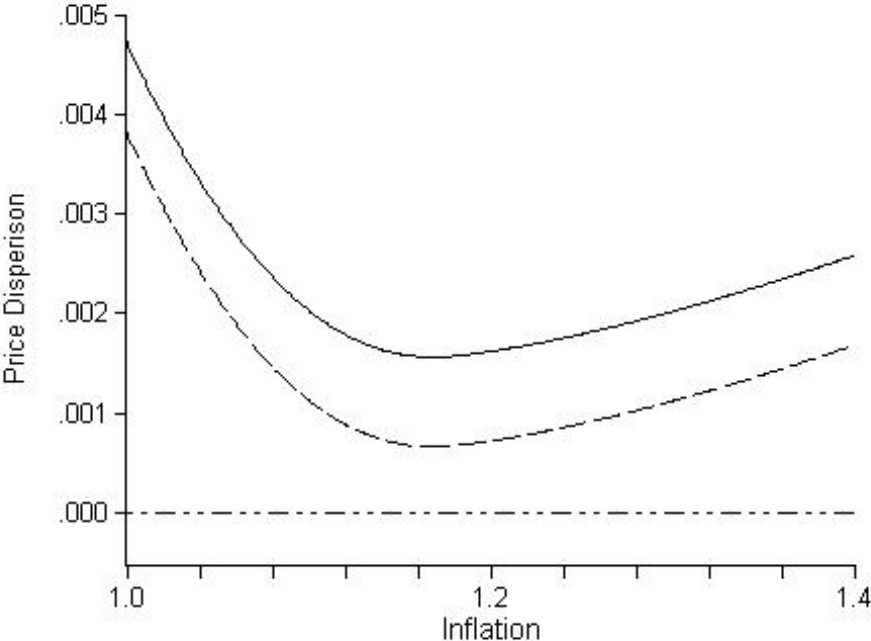
In the benchmark simulation presented above, the model has been solved for parameter values typically used in the literature. In particular, search costs have been calibrated to achieve an average mark-up of prices over marginal costs of 10%, see e.g. Gali et al. (2001). However, due to the ongoing market integration in the Euro-area, mark-ups may have declined over the recent years.

To shed more light on the role of search costs for the real effects of inflation, we computed additional model simulations with varying levels of search costs. The upper graph in Figure 2 displays the asymmetric V-shaped linkage between inflation and RPV for the benchmark simulation. In the middle graph search costs are lower, but still high enough to generate real effects of inflation. Compared to the benchmark the inflation-RPV nexus shifts downwards: With lower search costs the proportion of buyers observing only one price quote decreases, simply because buyers pay less search costs for any given level of search intensity. It follows that sellers market power diminishes resulting in a lower level of price dispersion at all inflation rates. The lower graph which equals the zero line depicts the inflation-RPV nexus for a low search cost market. Here, search costs fall below a critical threshold and inflation has no effects on price dispersion. If search costs fall below the threshold, all buyers optimally observe more than one price quote. In the absence of shocks and under the assumption



of constant marginal costs across sellers, the only possible price distribution is then concentrated at the marginal cost price such that price dispersion equals zero. In this case, the distorting effect of inflation on price dispersion vanishes and the classical dichotomy holds.<sup>3</sup>

Figure 2: The inflation-RPV nexus and the role of search costs



Notes: Figure plots price dispersion versus inflation for varying levels of search costs: i) high search costs (upper graph) ii) moderate search costs (middle graph) and iii) low search costs (lower graph). See Appendix A1 and Figure 1 for more details.

We summarize this prediction of Head and Kumar (2005) as follows:

**Hypothesis 2** *For a highly integrated market, where search costs are sufficiently low, there is no significant impact of expected inflation on the dispersion of prices.*

<sup>3</sup>For a detailed description of the different model simulations, see Appendix A1 where we also give a more technical discussion of the Head and Kumar monetary search model.

## 2.3 Market Integration in the European Union

According to the predictions of Head and Kumar (2005) and the hypotheses stated above, market integration crucially affects the relationship between inflation and price dispersion. In the following, both hypotheses will be tested using panel data from two subgroups of EU member states characterized by different levels of market integration. For Euro-area countries, on the one hand, much progress on the issue of market integration and price transparency has been made with the Single Market Program of 1992 and the introduction of the Euro in 1999. Using price data across different Euro-area countries, Engel and Rogers (2004) find evidence for an advanced integration of Eurozone consumer markets caused by the efforts to reduce economic barriers initiated in the 1990s. Furthermore, Parsley and Wei (2008) show that market integration among the countries in the Eurozone is uniformly higher compared to non-Euro countries. Therefore, the Euro-area should represent a highly integrated market where search costs are low. On the other hand, the EU 27 economy consists of a very heterogeneous group of countries and exhibits a lower degree of market integration.<sup>4</sup>

## 3 Data and Measurement

Many empirical contributions analyzed the impact of inflation on *intermarket* relative price variability (RPV), see e.g. Debelle and Lamont (1997), Jaramillo (1999), and Becker and Nautz (2009). *Intermarket* RPV is typically defined as the standard deviation of the rates of inflation of various products of goods and services around the average inflation rate in a given city or country. By contrast, the *intramarket* side

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<sup>4</sup>Austria, Belgium, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal and Spain are grouped together in Euro-area, whereas the EU-27 group consists of the Euro-area countries plus Bulgaria, Czech Republic, Denmark, Estonia, Cyprus, Latvia, Lithuania, Hungary, Malta, Poland, Romania, Slovenia, Slovakia, Sweden and United Kingdom. Although Slovenia, Cyprus and Malta adopted the Euro in 2007 and 2008, respectively, we do not include them into the Euro-area group, because our sample already starts in 1996. This implicates that Slovenia, Cyprus and Malta did not participate in the EMU for the major part of our sample period. Alternatively, one can split the countries into a Euro-area group and a non-Euro group. The qualitative results presented in this paper do not depend on this splitting scheme.

(deviations of individual product specific inflation rates with respect to the product average inflation rate across cities or countries) seems to be underresearched.<sup>5</sup> In the following empirical study, the focus shall be on price variability in Europe within the *intramarket* side because search models are specifically designed to account for price dispersion within a given market.

We use monthly data for various subcategories of the Harmonized Index of Consumer Prices (HICP) provided by the Eurostat database. The data set runs from January 1996 to August 2008. It includes observations of the twelve major HICP subcategories for all 27 EU member states.<sup>6</sup> *Intramarket* relative price variability is defined as:

$$RPV_{it} = \left[ \sum_{j=1}^N w_{jt} (\pi_{ijt} - \pi_{it})^2 \right]^{0.5}, \quad (1)$$

where  $\pi_{ijt}$  is the rate of change in the price index of the  $i$ th subcategory in country  $j$  at time period  $t$  and  $\pi_{it}$  is the average rate of change in product category  $i$ 's price index ( $\pi_{it} = \sum_{j=1}^N w_{jt} \pi_{ijt}$ ).  $w_{jt}$  is the weight of country  $j$  at time  $t$  in the overall HICP index ( $\sum_{j=1}^N w_{jt} = 1$ ) and  $N$  refers to the number of countries under consideration.

Overall HICP inflation is denoted by  $\Pi_t = \sum_{j=1}^N w_{jt} \Pi_{jt}$ , where  $\Pi_{jt}$  is overall inflation in country  $j$  in time period  $t$ . Table 4 in Appendix A2 presents some summary statistics on the RPV and inflation measures, see also Figures 3 and 4. Panel Unit root tests indicate that all inflation and RPV measures are stationary.<sup>7</sup>

Theories on the relation between inflation and RPV emphasize the different roles of expected and unexpected inflation. In line with the empirical literature, we base our measures of expected inflation on a time series representation of inflation. Specifically,

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<sup>5</sup>Notable exceptions include Lach and Tsiddon (1992), Reinsdorf (1994), Fielding and Mizen (2000), and Caglayan et al. (2008).

<sup>6</sup>These HICP subcategories are: food and non-alcoholic beverages (CP01); alcoholic beverages, tobacco and narcotics (CP02); clothing and footwear (CP03); housing, water, electricity, gas and other fuels (CP04); furnishing, household equipment and routine maintenance of the house (CP05); health (CP06); transport (CP07); communication (CP08); recreation and culture (CP09); education (CP10); restaurants and hotels (CP11); miscellaneous goods and services (CP12). Data series are seasonally adjusted using the Census X11 procedure.

<sup>7</sup>Results of the Panel Unit Root tests are not presented but are available on request.

we estimate an AR(12) model for  $\pi_{it}$  and  $\Pi_t$ .<sup>8</sup> Expected inflation is derived as the one period-ahead inflation forecast while unexpected inflation is the resulting forecast error. Note that beating the forecasting performance of univariate time series models of inflation is not an easy task, particularly over a monthly forecast horizon, see e.g. Elliott and Timmermann (2008).

## 4 Empirical Results

### 4.1 The Empirical Model

This Section studies the implications given by the Head and Kumar monetary search model. Since expected inflation in the Head and Kumar model stems from growth in the stock of fiat money our analysis focuses on overall expected inflation ( $\Pi^e$ ). Furthermore, to control for the predictions of menu-cost and signal extraction models, we follow the empirical literature on the *intramarket* inflation-RPV relationship (see e.g. Lach and Tsiddon, 1992) and include the absolute values of expected ( $\pi_i^e$ ) and unexpected ( $\pi_i - \pi_i^e$ ) product specific inflation into our fixed-effects panel equation:

$$RPV_{it} = \alpha_i + \lambda_t + \beta_1 |\pi_{it}^e| + \beta_2 |(\pi_{it} - \pi_{it}^e)| + \beta_3 |\Pi_t^e - a| + \beta_4 D_t |\Pi_t^e - a| + \epsilon_{it} \quad (2)$$

According to Hypothesis 1, the relationship between overall expected inflation and price dispersion can be captured via a V-shaped specification where the vertex occurs at positive levels of expected HICP inflation. Following Caglayan et al. (2008), we therefore include  $|\Pi_t^e - a|$  (with  $a \geq 0$ ) into our regression model. For  $a > 0$  the vertex of the V-shaped inflation-RPV relation shifts away from the origin towards positive values of expected overall inflation. Theory suggests that the response of RPV to expected inflation is asymmetric. The asymmetry is captured by the term  $D_t |\Pi_t^e - a|$  where  $D_t$  is a dummy variable which equals one when  $\Pi_t < a$  and zero otherwise.

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<sup>8</sup>Additionally to the autoregressive parts in the  $\pi_{it}$  forecast model, we also include past values of overall HICP inflation (up to 3 lags).

Accordingly, for levels of inflation below  $a$  the slope of the V-shaped inflation-RPV nexus equals  $\beta_3 + \beta_4$ . Whereas for inflation rates above  $a$ , the marginal impact of inflation on RPV is given by  $\beta_3$ . Finally, our specification includes a product fixed effect which controls for product heterogeneity and monthly time dummies. In line with Caglayan et al. (2008), the model is estimated by means of minimizing the sum of squared residuals  $SSR$  using a grid search procedure for  $a$ .<sup>9</sup> Recall from Section 2 that the parameter value of  $a$  identifies the vertex of the inflation-RPV nexus which can be used as a proxy for the optimal welfare maximizing inflation rate  $\Pi^*$ .

## 4.2 Inflation and Price Dispersion in a Less Integrated Market

The estimation results for the EU 27 economy are shown in the first column of Table 1. As predicted by menu-cost and misperception models, we find a significant positive effect of expected and unexpected product specific inflation on price dispersion. More interestingly, however, the estimated vertex  $a$  in the inflation-RPV nexus is greater than zero resulting in a right shift of the V-shaped inflation-RPV nexus. For the huge, and probably less integrated, EU 27 market, the null hypothesis  $a = 0$  is rejected at the 1% significance level. Moreover, both inflation coefficients,  $\hat{\beta}_3$  and  $\hat{\beta}_4$ , are highly significant and plausibly signed. Thus, in line with Hypothesis 1, the estimated relationship between inflation and price dispersion is asymmetrically V-shaped. Note that the estimated vertex,  $a^* = 0.0025$ , implies that the optimal annual inflation rate for the EU-27 economy should be about 3% which is close to the European Central Bank's definition of price stability.

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<sup>9</sup>The starting point of our grid search is  $a = 0$ . Subsequently, we increase  $a$  in increments of 0.00025 up to  $a = 0.0075$ . Note that the average values of monthly overall inflation for our two country samples are 0.001723 and 0.002703 (0.021 and 0.032 in annual terms), respectively (see Table 4). So,  $a = 0.0075$  seems to be a reasonable endpoint.

Table 1: Inflation and Relative Price Variability in the European Union:  
An empirical test of the Head and Kumar monetary search model

	$RPV_{it} = \alpha_i + \lambda_t + \beta_1 \pi_{it}^e  + \beta_2 (\pi_{it} - \pi_{it}^e) $ $+ \beta_3 \Pi_t^e - a  + \beta_4D_t \Pi_t^e - a  + \epsilon_{it}$	
	<i>EU – 27</i>	<i>Euro – area</i>
$\hat{\beta}_1$	1.616** (0.183)	0.333** (0.022)
$\hat{\beta}_2$	0.560** (0.041)	0.283** (0.004)
$\hat{\beta}_3$	0.343** (0.082)	0.023 (0.029)
$\hat{\beta}_4$	0.543** (0.251)	0.132 (0.131)
$a^*$	0.00250	0
$H_0 : a = 0$	7.891 [0.00]	–
Obs	1632	1632
Product Groups	12	12
Countries	27	12

Notes: Expected and unexpected inflation series are based on an AR forecast model (see Section 3.1).  $a^*$  is an estimated parameter minimizing the sum of squared residuals. Heteroskedasticity-consistent standard errors in parentheses, p-values in brackets.  $D_t$  is a dummy variable equal to 1 when  $\Pi_t^e < a$  and zero otherwise. \*, \*\* indicate significance at the 5% and 1% significance level. Following Hansen (1999) a bootstrap procedure was used to obtain p-values for testing  $H_0: a=0$ . Sample: 05/1997-08/2008.

### 4.3 Inflation and RPV in a Highly Integrated Market

The second column of Table 1 presents the estimation results for the Euro-area panel, a textbook example for a highly integrated market. Compared to the EU 27 estimation, the effect of overall expected inflation changes substantially. First of all, the optimal  $a$  in the Euro-area is equal to zero. Furthermore, the parameter estimates on  $\beta_3$  and  $\beta_4$  are not statistically different from zero. In fact, no real effects of expected HICP inflation on price dispersion can be found for the Euro-area.<sup>10</sup> According to Hypothesis 2, the estimated break down of the inflation-RPV nexus for the highly integrated Euro-area market is predicted by the monetary search model.

## 5 Changes in the Level of Market Integration over Time

The results presented in the previous section indicate the importance of the degree of market integration for the relationship between inflation and price dispersion in Europe. Apparently, there is little room for discussion whether Euro-area countries are more integrated compared to all EU-27 member states. Yet, there may exist changes in the level of European market integration over time. This section accounts for possible variations in the degrees of market integration within a country group by splitting the sample periods according to major political changes.

### 5.1 The Effect of the 2004 EU Enlargement

On the first of May 2004, the European Union saw its biggest enlargement to date when ten countries joined the EU. This may have had significant consequences for market integration within the acceding countries. To analyze the effect of the 2004 EU enlargement on market integration and, thereby, on the relationship between inflation

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<sup>10</sup>Adding a measure of overall unexpected inflation ( $\Pi - \Pi^e$ ) to Equation (2) does not influence these results. The parameter estimates on overall unexpected inflation are insignificant in all models. Moreover, for a panel consisting of EU-15 countries (Euro-area plus Denmark, Sweden, and the United Kingdom) the results do not qualitatively differ from those presented for the Euro-area.

and price dispersion, we introduce a new country panel, called acc-2004, which includes all countries involved in the 2004 EU enlargement. Thus, acc-2004 consists of Czech Republic, Estonia, Cyprus, Latvia, Lithuania, Hungary, Malta, Poland, Slovenia, and Slovakia.

Table 2: Inflation and Relative Price Variability:  
The EU enlargement in 2004

	$RPV_{it} = \alpha_i + \lambda_t + \beta_1  \pi_{it}^e  + \beta_2  (\pi_{it} - \pi_{it}^e) $ $+ \beta_3  \Pi_t^e - a  + \beta_4 D_t  \Pi_t^e - a  + \epsilon_{it}$	
	05/1997-04/2004	05/2004-08/2008
$\hat{\beta}_1$	1.104** (0.146)	0.327* (0.148)
$\hat{\beta}_2$	0.458** (0.157)	0.262** (0.016)
$\hat{\beta}_3$	0.341** (0.102)	0.154 (0.116)
$\hat{\beta}_4$	0.308** (0.078)	0.226 (0.334)
$a^*$	0.00575	0.00335
$H_0 : a = 0$	7.363 [0.01]	0.759 [0.53]
Obs	1008	624
Product Groups	12	12
Countries	10	10

Notes: Acceding countries panel used. See Table 1 for further explanations.

The results for the pre- and post-05/2004 regressions of the acceding countries panel are shown in Table 2. Again, in line with menu cost and misperception models the impact of expected and unexpected product specific inflation is highly significant. This holds for the pre- and post-2004 period. However, there are notable differences with respect to overall expected inflation. In the pre-2004 regression, we find evidence of a significant asymmetric V-shaped relation between overall expected inflation and RPV,



where the vertex occurs at positive levels of inflation. More precisely, the estimated optimal inflation rate is close to 6.9% in annual terms which clearly exceeds the optimal inflation rate estimated for the complete panel of 27 EU countries. Higher optimal inflation rates in the acceding countries group which primarily consists of less developed Eastern European countries might be explained by higher productivity growth rates, see e.g. Égert et al. (2003). By contrast, the results for the post-2004 period indicate no significant relationship between overall expected inflation and price dispersion in the acc-2004 panel. In particular, the null hypothesis  $a = 0$  can not be rejected.

From the perspective of the Head and Kumar monetary search model, these results suggest that there are substantial variations in market integration over time. Eastern European markets are more integrated in the post-2004 period which causes the distorting effects of HICP inflation on price dispersion to disappear.

## 5.2 The Introduction of the Euro

Within the Euro-area group, the introduction of the Euro might have influenced market integration. In monetary search models search costs are certainly more affected by all price quotes given in a common currency instead of a currency in non-physical form where price comparisons come at the cost of using fixed exchange rates. Therefore, we split the sample period into the pre-Euro part (05/1997-12/2001) and the post-Euro part (01/2002-08/2008).

Table 3 summarizes the results for the Euro-area. While the effects of expected and unexpected product specific inflation are significant different from zero, overall expected inflation has no impact on price dispersion. This holds for both, the pre- and post-Euro samples. Furthermore, the shift of the V-shaped inflation-RPV nexus is not statistically different from zero in both sub-samples. The introduction of the Euro in 2002 had no impact on the relationship between inflation and RPV. Even before the Euro was introduced no significant impact of overall expected inflation on RPV can

be found. These results are in line with Engel and Rogers (2004) and Parsley and Wei (2008) who find no evidence for a significant change in the integration of Eurozone consumer markets after the introduction of the Euro. They conclude that market integration in Europe occurred already throughout the decade of the 1990s.

Table 3: Inflation and Relative Price Variability:  
The Introduction of the Euro

	$RPV_{it} = \alpha_i + \lambda_t + \beta_1  \pi_{it}^e  + \beta_2  (\pi_{it} - \pi_{it}^e) $ $+ \beta_3  \Pi_t^e - a  + \beta_4 D_t  \Pi_t^e - a  + \epsilon_{it}$	
	05/1997-12/2001	01/2002-08/2008
$\hat{\beta}_1$	0.175** (0.040)	0.382** (0.029)
$\hat{\beta}_2$	0.139** (0.028)	0.280** (0.051)
$\hat{\beta}_3$	0.155 (0.127)	0.066 (0.058)
$\hat{\beta}_4$	-0.531 (0.900)	0.193 (0.161)
$a^*$	0.0015	0.001
$H_0 : a = 0$	1.691 [0.24]	1.425 [0.31]
Obs	672	960
Product Groups	12	12
Countries	12	12

Notes: Euro-area panel used. See Table 1 for further explanations.

## 6 Conclusion

In contrast to classical menu-cost or misperception models, the monetary search model recently established by Head and Kumar (2005) predicts that the relationship between inflation and the variability of relative prices is non-linear. In this model, the impact of inflation on price dispersion and welfare crucially depends on the level of search costs.

If search costs are sufficiently high, the relationship between inflation and both, price dispersion and welfare is predicted to be asymmetrically V-shaped with a positive vertex indicating the optimal rate of inflation. In case of very low search costs, however, the model implies that the relationship between inflation and price dispersion breaks down.

In this paper, we use monthly CPI-data of a panel of 27 EU countries to test the empirical content of both predictions. Assuming that search costs should be negatively related to the level of market integration, we estimate the inflation-RPV nexus for two subgroups of EU countries, i.e. the highly integrated Euro-area and the less integrated EU 27 economy.

Our empirical results confirm both theoretical predictions for the role of inflation regarding different levels of market integration. On the one hand, the relation between RPV and HICP inflation is V-shaped for the less integrated EU27 countries, where the vertex occurs at positive values of inflation. On the other hand, we found no impact of inflation on RPV for the highly integrated markets of the Euro-area. These results proved to be robust with respect to alternative splits of the sample, accounting for a particular role of acceding countries in the EU enlargement of 2004 and the introduction of the Euro.

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# Appendix

## A1 The Monetary Search Model

### A1.1 Basic Model Setup

The Head and Kumar (2005) monetary search economy consists of  $H \geq 3$  different types of households, with a continuum of identical sellers and buyers in each household and a continuum of identical households in each type. A type  $h$  household produces good  $h$  and derives utility only from consumption of good  $h + 1$ , modulo  $H$ . Exchange is facilitated by the existence of fiat money. At the beginning of each period households receive a lump-sum transfer of new units of fiat money from the government that has no other purpose than to increase the stock of money at gross rate  $\gamma$ . Members of a representative type  $h$  who are sellers produce good  $h$  at marginal costs  $\phi$ . In contrast, buyers of this representative household observe random number of price quotes and may purchase good  $h + 1$  at the lowest price observed. Let  $q_{kt}$  denote the measure of the household's buyers who observe  $k \in \{1, 2, \dots, K\}$  price quotes in period  $t$ . For each price quote observed, the household pays a search cost of  $\mu$  units. Thus, household's total disutility of search in period  $t$  is equal to  $\mu \sum_{k=1}^K k q_{kt}$ .<sup>11</sup> Overall, a representative household maximizes the expected discounted sum of utility from consumption minus total production and search costs over an infinite horizon:

$$U = E_0 \left\{ \sum_{t=0}^{\infty} \beta^t [(u(c_t) - \phi y_t - \mu(2 - q_t))] \right\}, \quad (3)$$

where  $\beta$  is a discount factor,  $c_t$  is consumption of the preferred good in time period  $t$  and  $y_t$  is total production in period  $t$ .

Restricting the analysis to symmetric and stationary monetary equilibria (SME's), buyers' reservation levels are endogenous and depend on the marginal value of fiat money.

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<sup>11</sup> Without loss of generality, we will assume in the following that  $K = 2$  (see also Head and Kumar, 2005, Corollary 2). This causes buyers to observe either one price quote with probability  $q_t$  or two prices with probability  $1 - q_t$ . Hence, total search costs in period  $t$  are equal to  $\mu(2 - q_t)$ .

Furthermore, all households choose the same probability for their buyers to observe different numbers of price quotes, the same distribution of posted prices, and all have the same consumption, money holdings, and valuation of money. It is also important to note that if the SME is characterized by some buyers observing one price while others observe two, then the distribution of prices will exhibit price dispersion necessarily (Head and Kumar, 2005, p. 542). Moreover, in this model the relationship between inflation and RPV is determined by two opposing effects resulting in an asymmetrically V-shaped inflation-RPV nexus (see Section 2).

### A1.2 The Importance of Search Costs

According to Head and Kumar (2005) the household's optimal choice of  $q$  is given by

$$q^* = \begin{cases} 0 & \text{if } \mu < \mu_L \equiv u'(c_2)[c_2 - c_1] \\ \frac{[u'^{-1}(\frac{\mu}{c_2 - c_1}) - c_2]}{c_1 - c_2} & \text{if } \mu_L \leq \mu \leq \mu_H \\ 1 & \text{if } \mu > \mu_H \equiv u'(c_1)[c_2 - c_1] \end{cases} \quad (4)$$

where  $c_1$  and  $c_2$  are the expected purchases of buyers observing one and two price quotes, respectively, and  $\mu_L$  and  $\mu_H$  are state contingent cut-off levels for search costs. Equation (4) illustrates the importance of search costs for the household's search strategy and ultimately for the existence of an equilibrium with price dispersion. More specifically, an SME with price dispersion only exists if search costs lie in a certain interval ( $\mu_L \leq \mu \leq \mu_H$ ). In a low search cost market ( $\mu < \mu_L$ ) the household behaves optimally by setting the probability of observing only one price quote equal to zero. In this scenario, sellers' market power erodes, the price distribution is concentrated around the marginal cost price and the real effects of inflation vanish. With very high search costs ( $\mu > \mu_H$ ) the household has no incentive to have any of its buyers observe a second price quote,  $q^* = 1$ . Here, the sellers' act as monopolists and the price is equal to the buyer's reservation level.

### A1.3 Results from a Simulation Study

In our model simulation, we use a CRRA utility function with the coefficient of relative risk aversion equal to 1.5 and set the discount factor,  $\beta$ , equal to 0.95. To achieve an average mark-up of prices over marginal costs of 10%, we set  $\phi = 0.1$  and  $\mu = 0.028$ . This mark-up value is consistent with plausible estimates from the literature (see e.g. Gali, Gertler, and Lopez-Salido, 2001). Furthermore, we allow  $\gamma$ , the growth rate of the money stock (the inflation rate), to range between 1 and 1.4. The solid line in Figure 1, as well as, the upper graph of Figure 2 depict the V-shaped relationship between inflation and price dispersion for this benchmark scenario.

The middle graph in Figure 2 demonstrates how lower search costs affect the inflation-RPV nexus. Compared to the benchmark simulation search costs are set equal to 0.021 (mark-up = 7.4%) which causes the inflation-RPV relationship to shift downwards. Decreasing the level of search costs even further ( $\mu = 0.0093$ ) results in a breakdown of the non-linear inflation-RPV linkage (see lower graph in Figure 2). In this case price dispersion equals zero for any level of inflation.

Overall, for a high search cost market RPV is V-shaped in expected overall inflation with the vertex occurring at positive levels of the inflation measure. But, if search cost fall below a certain threshold value, the real effects of inflation on RPV vanish and the classical dichotomy holds.

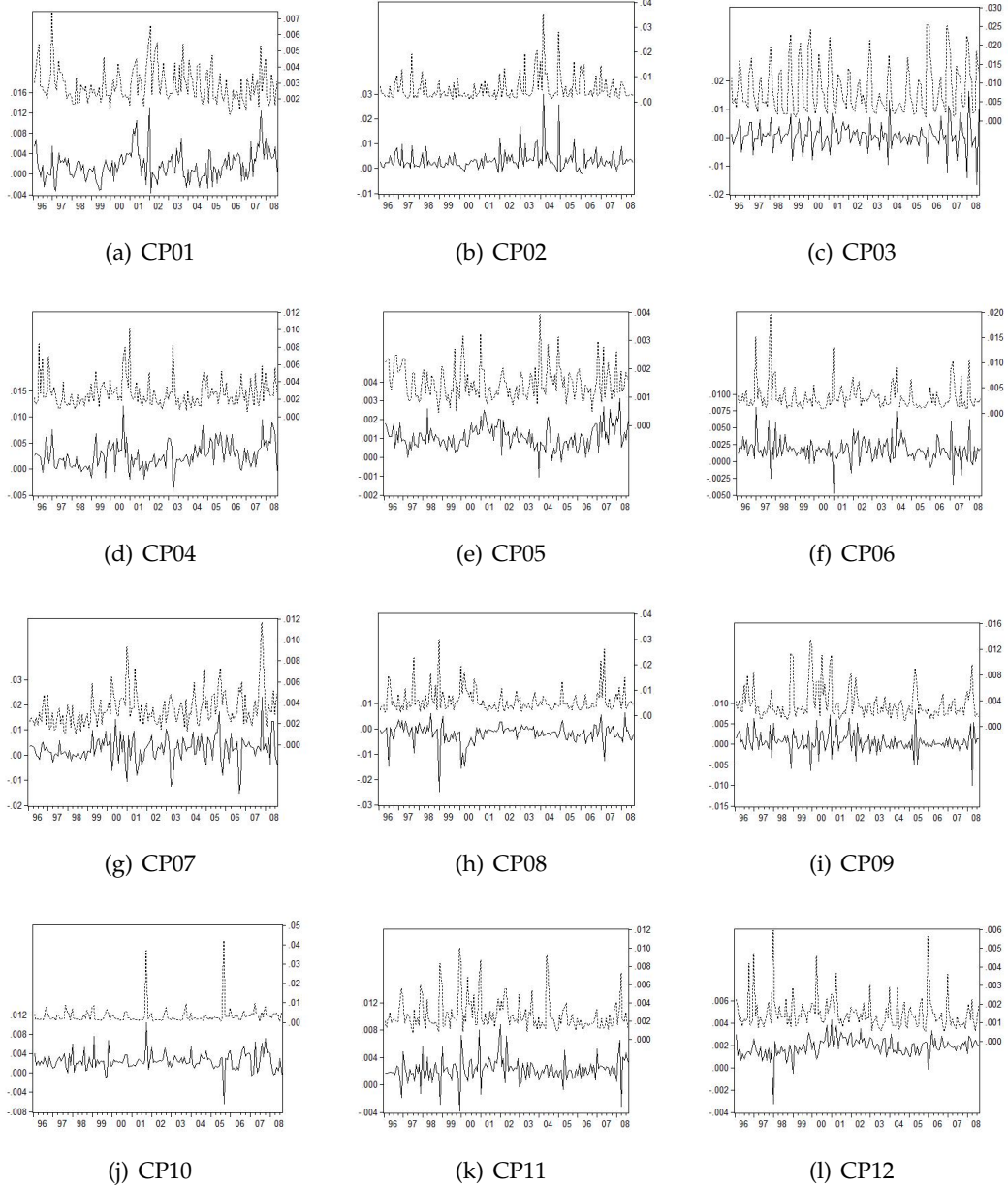
Table 4: Summary Statistics

	Mean	Standard Deviation	Minimum	Maximum	Countries	Product Groups	Obs
<b>Euro-area</b>							
$\Pi_t$	0.001723	0.002573	-0.005985	0.009748	12	12	151
$RPV_{it}$	0.003763	0.004623	0.000460	0.097040	12	12	1812
<b>EU-27</b>							
$\Pi_t$	0.002703	0.003162	-0.004868	0.025044	27	12	151
$RPV_{it}$	0.006790	0.008490	0.000845	0.182809	27	12	1812

Notes: Monthly overall HICP inflation is denoted by  $\Pi_t$  and  $RPV_{it}$  measures monthly product specific relative price variability (see Section 3.1 for further explanations). Sample: 1996.02-2008.08.

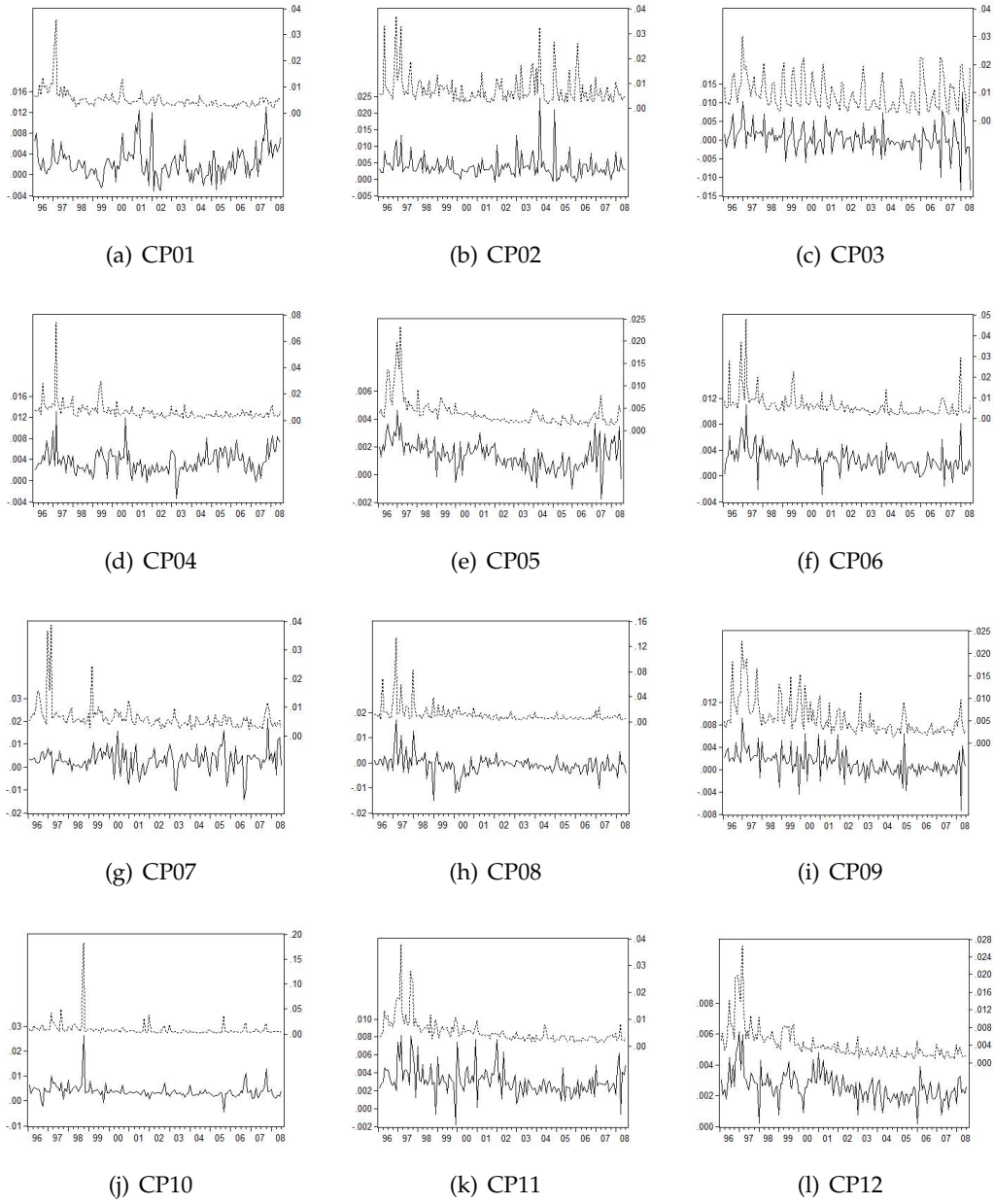


Figure 3: Product specific inflation and RPV (Euro-area)



Notes: Monthly HICP product specific inflation rates (left scale). Monthly product specific RPV (right scale). 1996.02-2008.08.

Figure 4: Product specific inflation and RPV (EU-27)



Notes: Monthly HICP product specific inflation rates (left scale). Monthly product specific RPV (right scale). 1996.02-2008.08.

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