European Economic Review 56 (2012) 624–634

Contents lists available at SciVerse ScienceDirect

European Economic Review

journal homepage: www.elsevier.com/locate/eer

# Inflation, price dispersion and market integration through the lens of a monetary search model ☆

Sascha S. Becker *, Dieter Nautz

*Department of Economics, Freie Universität Berlin, Germany*

ARTICLE INFO

*Article history:*
Received 22 April 2010
Accepted 16 January 2012
Available online 28 January 2012

*JEL classification:*
C23
D40
E31
F40

*Keywords:*
Inflation
Relative price variability
Monetary search
Market integration

ABSTRACT

Monetary search theory implies 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 results in an optimal inflation rate above zero. For highly integrated markets with low search costs, however, the impact of inflation on price dispersion should only be small. Using price data of the European Union member states, this paper tests and confirms these predictions of monetary search theory.



## 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 (Rotemberg, 1983) 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 monotonic inflation–RPV relationship in which inflation always lowers welfare. As a consequence, the early empirical evidence is typically based on the linear regressions of RPV on the rate of inflation (see e.g. Debelle and Lamont, 1997; Jaramillo, 1999).

Recent monetary search models predict that the impact of inflation on price dispersion and welfare is more complex. In particular, Head and Kumar (2005) show that both the inflation–RPV and the inflation–welfare nexus are V-shaped implying that the optimal rate of inflation is above zero. This paper uses the Head and Kumar (2005) framework to shed more light on the functional relationship between inflation and RPV. Solving the monetary search model numerically reveals two further implications. Firstly, RPV should react stronger to inflation when inflation is low. Secondly, when search costs decrease, the curvature of the asymmetrically V-shaped inflation–RPV relationship flattens and price dispersion responds less to inflation. Assuming that search costs decrease when markets become more integrated, the

☆ This research was supported by the Deutsche Forschungsgemeinschaft through the CRC 649 "Economic Risk". Financial support by the Monetary Stability Foundation is also gratefully acknowledged.

* Corresponding author. Tel.: +49 3083852989.
*E-mail addresses:* sascha.becker@fu-berlin.de (S.S. Becker), dieter.nautz@fu-berlin.de (D. Nautz).

0014-2921/$ - see front matter © 2012 Elsevier B.V. All rights reserved.
doi:10.1016/j.euroecorev.2012.01.004

empirical part of the paper estimates the relationship between inflation and RPV for sub-groups of European countries with different degrees of goods market integration.

Adopting the monetary exchange framework proposed by Shi (1999), Head and Kumar (2005) extend the non-sequential price setting model of Burdett and Judd (1983) in order to link inflation and the optimal search strategy. The model of Head and Kumar (2005) is able to generate a V-shaped relationship between inflation and price dispersion because it combines the effect of search intensity on sellers' market power with welfare costs of inflation. Both of these features are present in other models, but typically not together. While sticky price models restrict the attention to the welfare costs of inflation-induced increases of price dispersion, search models, including Benabou (1988, 1992), generally abstract from the inflation tax. These models imply a monotonic increasing relationship between inflation and search intensity which stimulates competition and, thus, lowers the welfare costs of inflation.[1]

Contradicting the predictions of standard menu-cost or misperception models, recent empirical evidence suggests that the relationship between inflation and RPV is non-monotonic, see e.g. Fielding and Mizen (2008), Bick and Nautz (2008), and Choi (2010). A first attempt to explicitly test the implications of the Head and Kumar model is given by Caglayan et al. (2008). Using price observations from bazaars, convenience stores, and supermarkets in Turkey, they find a symmetric V-shaped relationship between inflation and RPV, but do not explore the role of market integration.

Although European integration has made considerably progress on average, notable differences in goods market integration across Europe have remained. Since the European Union (EU) contains countries with different degrees of integration, it is a natural candidate for an empirical test of the Head and Kumar model predictions. 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 heterogenous 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).[2]

Our empirical results show that the impact of inflation on price dispersion is non-monotonic 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. On the other hand, the impact of inflation on price dispersion is only small and insignificant for the highly integrated Euro-area markets where search costs are low.

The paper is organized as follows: Section 2 briefly reviews the Head and Kumar (2005) monetary search model and introduces 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 EU-27 and the Euro-area countries. Section 5 investigates the inflation–RPV nexus accounting for important policy events that may have increased European market integration over time. Specifically, we consider the effects of the introduction of the Euro as a physical currency in 2002 and the role of the EU enlargement in 2004 for the empirical inflation–RPV relationship. Section 6 offers some concluding remarks.

## 2. The model

### 2.1. Inflation, price dispersion and welfare

Head and Kumar (2005) emphasize 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. 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 depends on the level of inflation.

In the following, we consider two further implications on the functional relationship between inflation and price dispersion by solving the monetary search model numerically for a plausible set of parameter values typically used in calibrated macroeconomic models, see Head and Kumar (2005) and Head et al. (2010a). It is worth emphasizing that both results hold for a very broad range of parameter values, see Appendix A for a more detailed presentation of the model and the simulation exercise.

[1] Molico (2006) simulates a model assuming a pricing environment with bilateral bargaining. In accordance with Head and Kumar (2005), he finds that increasing the rate of monetary expansion tends to decrease price dispersion and to improve welfare provided that the rate of inflation is low. Moreover and similar to the implications derived from the Head and Kumar model, the distribution of prices tend to become less disperse as search frictions become small (see also Camera and Corbae, 1999)

[2] The literature on search models of multiple currencies and price dispersion is scant and does not focus on inflation, compare Camera et al. (2004) and Craig and Waller (2004). Using the single-currency model of Head and Kumar (2005) to study price dispersion in countries with different currencies should, therefore, be seen as a first approximation and a starting point of a multiple-currency analysis.

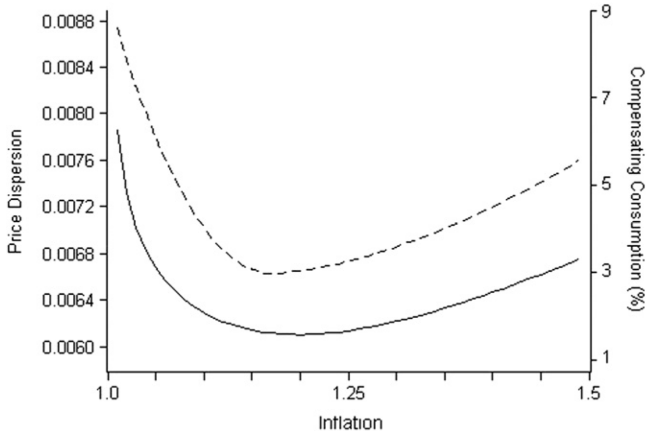


**Fig. 1.** Inflation, price dispersion and welfare. *Notes*: The figure shows the impact of expected inflation on price dispersion and welfare as predicted by the Head and Kumar (2005) monetary search model. Price dispersion (solid line, left scale); compensating consumption (%) (dashed fine, right scale). For more details, see Appendix A.

Fig. 1 displays the benchmark simulation for inflation's impact on welfare and price dispersion. 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. 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). However, when inflation exceeds a critical value, the welfare distorting effect of inflation eventually dominates.

As a result, the relationship between expected inflation and price dispersion can be captured by a 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 positive and located below but very close to the vertex of the inflation–RPV nexus. Accordingly, this vertex may serve as a proxy for $\Pi^*$.

Fig. 1 further shows that the relationship between inflation and price dispersion is asymmetric. The economics behind this asymmetry can be explained as follows. At low levels of inflation, a relatively large fraction of buyers observe only a single price. In this situation, an increase in inflation induces strong increases in buyers' search intensity in order to avoid inflation-induced increases of sellers' market power. Accordingly, changes in inflation have relatively large effects on search intensity and, thereby, on price dispersion. As the rate of inflation rises, the share of buyers observing only one price decreases. Therefore, any further increase in inflation has a smaller effect on search intensity and price dispersion.

In the appendix, we show that asymmetrically V-shaped effects of inflation require that search costs are 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, i.e. search costs are sufficiently high, 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, search costs have been calibrated to achieve an average mark-up of prices over marginal costs of 10%, compare Gali et al. (2001) and Head et al. (2010a). However, due to the ongoing market integration in Europe, 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 Fig. 2 displays the asymmetric V-shaped relationship between inflation and RPV for the benchmark simulation where search costs are high. The two remaining graphs present simulation results for moderate and low search costs, respectively. Compared to the benchmark, decreasing search costs shift the inflation–RPV nexus downwards. More importantly, the curvature of the relationship gets progressively flatter: with lower search costs the proportion of buyers observing only one price quote decreases. Therefore, an increase in inflation has a smaller impact on search intensity and price dispersion responds less to inflation.

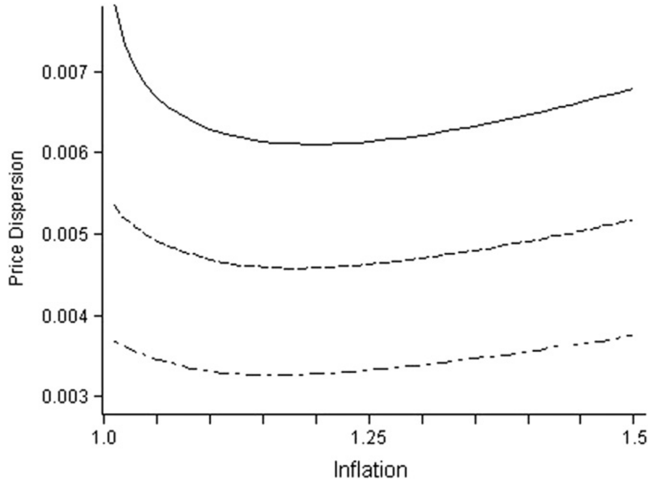


**Fig. 2.** The inflation–RPV nexus and the role of search costs. *Notes*: Figure plots price dispersion versus inflation for varying levels of search costs: (i) high search costs (upper graph), (ii) moderate search costs (middle graph), and (iii) low search costs (lower graph). See Appendix A and Fig. 1 for more details.

We summarize this implication of the Head and Kumar (2005) monetary search model as follows:

**Hypothesis 2.** With increasing market integration, i.e. decreasing search costs, the V-shaped relationship between expected inflation and RPV gets progressively flatter and the impact of inflation on the dispersion of prices declines.

In the limiting case, when search costs are zero, inflation has no impact on price dispersion.[3]

### 2.3. *Market integration in the European Union*

Over the past two decades, markets within the European Union have become progressively more integrated as internal barriers to trade have been dismantled. Two crucial steps in this process were the completion of the Single Market Program (SMP) in 1992 and the start of the Economic and Monetary Union (EMU) in 1999. The first removed important physical, administrative, and technical barriers to integration. The second increased price transparency through a common currency and eliminated exchange rate variations between the 11 (later 17) members of the Euro-area.

The European Commission (1996, p. 74) expected that "increased price transparency will enhance competition and whet consumer appetites for foreign goods; price discrimination between different national markets will be reduced". In accordance with these policy intentions, several contributions provided direct evidence on the impact of European market integration on mark-ups and price dispersion. Allen et al. (1998) and Sauner-Leroy (2003) analyze firms' pricing behavior in different product sectors across European countries and find that mark-ups have significantly declined during the implementation period of the SMP. Similar effects of European integration on mark-ups are reported by Badinger (2007), Christopoulou and Vermeulen (2008), and Holland (2009).

A large and growing literature analyzes the empirical consequences of market integration on price dispersion in Europe. While Crucini et al. (2005) find a large degree of price dispersion prior to 1990, there is a clear consensus that price dispersion significantly declined during the last two decades. The significance of the introduction of the Euro is, however, less clear. Several studies including Lutz (2003), Engel and Rogers (2004), and Rogers (2007) find a significant decrease of price dispersion throughout the 1990s, while the adoption of a common currency seems to have only weak additional effects on price dispersion. A significant Euro-effect on price dispersion is found by Allington et al. (2005) who analyze highly disaggregated price data across European countries. Parsley and Wei (2008) show that price dispersion among the countries in the Eurozone is uniformly lower compared to non-Euro countries.

Irrespective of an additional Euro-effect for market integration, there is a broad consensus that the Euro-area represents a highly integrated market where search costs are low. Compared with the Euro-area, the EU-27 economy consists of a very heterogeneous group of countries and clearly exhibits a lower degree of market integration.[4] According to the

[3] When search costs fall below a critical threshold value, all buyers optimally observe more than one price quote. The only possible price distribution is then concentrated at the marginal cost price and price dispersion equals zero. Accordingly, if search costs are extremely low, the distorting effect of inflation on price dispersion vanishes and the classical dichotomy holds.

[4] 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.

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 subgroups of EU member states characterized by different levels of market integration.

## 3. Data and measurement

Many empirical contributions analyze the impact of inflation on inter-market relative price variability (RPV), see e.g. Debelle and Lamont (1997), Jaramillo (1999), and Becker and Nautz (2009). Inter-market 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 intra-market side (deviations of individual product specific inflation rates with respect to the product average inflation rate across cities or countries) seems to be underresearched.[5] In the following empirical study, the focus shall be on price variability in Europe within the intra-market 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 12 major HICP subcategories for all 27 EU member states.[6] Following the empirical literature, intra-market relative price variability is defined as:

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

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 B presents some summary statistics on the RPV and inflation measures. Panel Unit root tests indicate that all inflation and RPV measures are stationary.

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, we estimate an AR(12) model for $\pi_{it}$ and $\Pi_t$.[7] 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. Inflation, price dispersion and the role of market integration

### 4.1. The empirical model

This section empirically tests the implications of market integration on the inflation–RPV nexus derived from 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 ($\Pi^e$). To control for the predictions of menu-cost and signal extraction models, we follow the empirical literature on the intra-market 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 regression model. The panel equation contains a product fixed effect ($\alpha_i$) and monthly time dummies ($\lambda_t$):[8]

$$\mathrm{RPV}_{it} = \alpha_i+\lambda_t+\beta_1|\pi_{it}^e|+\beta_2|(\pi_{it}-\pi_{it}^e)|+\beta_3|\Pi_t^e-a|+\beta_4 D_t|\Pi_t^e-a|+\epsilon_{it}. \tag{2}$$

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. The equation is estimated by means of minimizing the sum of squared residuals using a grid search procedure for $a$.[9]

[5] Exceptions include Lach and Tsiddon (1992), Reinsdorf (1994), Parsley (1996), Fielding and Mizen (2000), and Caglayan et al. (2008).

[6] 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); and miscellaneous goods and services (CP12). Data series are seasonally adjusted using the Census X11 procedure.

[7] Additionally to the autoregressive parts, the $\pi_{it}$ forecast model also contains past values of overall HICP inflation (up to 3 lags).

[8] Including lagged price dispersion or a measure of overall unexpected inflation ($\Pi-\Pi^e$) to Eq. (2) does not affect our results.

[9] 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.

| | $\text{RPV}_{it}=\alpha_i+\lambda_t+\beta_1\lvert\pi^e_{it}\rvert+\beta_2\lvert(\pi_{it}-\pi^e_{it})\rvert+\beta_3\lvert\Pi^e_t-a\rvert+\beta_4 D_t\lvert\Pi^e_t-a\rvert+\epsilon_{it}$ | |
|---|---|---|
| | EU-27 | Euro-area |
| $\widehat{\beta}_1$ | 1.616** (0.183) | 0.333** (0.022) |
| $\widehat{\beta}_2$ | 0.560** (0.041) | 0.283** (0.004) |
| $\widehat{\beta}_3$ | 0.343** (0.082) | 0.023 (0.029) |
| $\widehat{\beta}_4$ | 0.543** (0.251) | 0.132 (0.131) |
| $\widehat{a}$ | 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). Heteroskedasticity-consistent standard errors in parentheses, $p$-values in brackets. $D_t$ is a dummy variable equal to 1 when $\Pi^e_t<a$ 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.

Hypothesis 1, furthermore, states that the impact of expected inflation on RPV is asymmetric. The asymmetry is captured by the term $D_t\lvert\Pi^e_t-a\rvert$ where $D_t$ is a dummy variable which equals one when $\Pi_t<a$ and zero otherwise. 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 $\beta_3$. Since theory predicts that the response of RPV to expected inflation is stronger for the values of inflation below the vertex, we would expect $\beta_4$ to be greater than zero.

According to Hypothesis 2, higher market integration flattens the V-shaped relationship between inflation and RPV. We, therefore, expect that the size and significance of the estimated coefficients for $\beta_3$ and $\beta_4$ should decrease with the degree of market integration. Whereas both coefficients should be close to zero for highly integrated markets like the Euro-area, they should be positively signed and significant for less integrated markets like the EU-27 economy.

### 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. In line with menu-cost and misperception models, we find a significant positive effect of expected and unexpected product specific inflation on price dispersion, i.e. $\widehat{\beta}_1$, $\widehat{\beta}_2>0$. More interestingly, however, for the huge, and probably less integrated EU-27 market both coefficients on overall inflation, $\widehat{\beta}_3$ and $\widehat{\beta}_4$, are highly significant and plausibly signed. 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. The null hypothesis $a=0$ is rejected at the 1% significance level. Thus, in line with Hypothesis 1, the estimated relationship between inflation and price dispersion is asymmetrically V-shaped around a positive vertex. The estimated vertex, $\widehat{a}=0.0025$, implies that the optimal annual inflation rate for the EU-27 economy should be about 3%.[10]

### 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. According to Hypothesis 2, a flatter, almost negligible, inflation–RPV relationship for the highly integrated Euro-area market is predicted by monetary search theory. In fact, compared to the results obtained for the EU-27 panel, the estimated coefficients of overall inflation , $\widehat{\beta}_3=0.023$ and $\widehat{\beta}_4=0.132$, are substantially smaller and far from being significant. In the same vein, the estimated $a$ that determines the vertex of the V-shaped inflation–RPV relationship equals zero in the Euro-area.

## 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 might have been changes in the level

[10] Note that this estimate for the optimal inflation rate should be viewed with caution. As a referee pointed out, there are probably too many aspects of the welfare cost of inflation that are left out in the model of Head and Kumar (2005). In particular, welfare effects of inflation are typically small in models with representative agents and no idiosyncratic risk.

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 10 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 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. Since the accession of those countries into the EU Single Market should have significantly fostered market integration, the effect of inflation on price dispersion should have decreased accordingly.

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 striking differences with respect to overall expected inflation. In line with Hypothesis 1, we find evidence of a significant asymmetric V-shaped relation between overall expected inflation and RPV in the pre-2004 regression.

In line with expectations, the results indicate that the effect of inflation on price dispersion has actually decreased during the post-2004 period. The estimated slope coefficients are both smaller $\widehat{\beta}_3 = 0.154 < 0.341$ and $\widehat{\beta}_4 = 0.226 < 0.308$ than their pre-2004 counterparts and insignificant. Moreover the null hypothesis $a = 0$ cannot be rejected for the post-2004 period. Therefore, the V-shaped inflation–RPV relationship got flatter as markets of the EU acceding countries have been more integrated in the post-2004 period. Put differently, the results reflect that the EU-enlargement did improve market integration in the acceding countries in a significant way.

### 5.2. The introduction of the euro

Within the Euro-area group, the introduction of the Euro might have influenced market integration and, thus, the real effects of inflation. In this section, we will analyze if the common currency had a significant impact on the relationship between inflation and price dispersion. 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 indicates that the introduction of the Euro in 2002 had no impact on the relationship between inflation and RPV. While the effects of expected and unexpected product specific inflation are significant different from zero, overall expected inflation has no impact on price dispersion. In accordance with Table 1, this holds for both, the pre- and post-Euro samples. Similarly, the shift of the V-shaped inflation–RPV nexus is not statistically different from zero in both sub-samples. Even before the Euro was introduced no significant V-shaped relationship 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 2**
Inflation and relative price variability: the EU enlargement in 2004.

| | $\mathrm{RPV}_{it} = \alpha_i + \lambda_t + \beta_1 \lvert \pi^e_{it} \rvert + \beta_2 \lvert (\pi_{it} - \pi^e_{it}) \rvert + \beta_3 \lvert \Pi^e_t - a \rvert + \beta_4 D_t \lvert \Pi^e_t - a \rvert + \epsilon_{it}$ | |
|---|---|---|
| | 05/1997–04/2004 | 05/2004–08/2008 |
| $\widehat{\beta}_1$ | 1.104** (0.146) | 0.327* (0.148) |
| $\widehat{\beta}_2$ | 0.458** (0.157) | 0.262** (0.016) |
| $\widehat{\beta}_3$ | 0.341** (0.102) | 0.154 (0.116) |
| $\widehat{\beta}_4$ | 0.308** (0.078) | 0.226 (0.334) |
| $\widehat{a}$ | 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*: Estimation results are based on acceding countries only. See Table 1 for further explanations.

**Table 3**
Inflation and relative price variability: the introduction of the Euro.

| | $\text{RPV}_{it} = \alpha_i + \lambda_t + \beta_1 \lvert \pi^e_{it} \rvert + \beta_2 \lvert (\pi_{it} - \pi^e_{it}) \rvert + \beta_3 \lvert \Pi^e_t - a \rvert + \beta_4 D_t \lvert \Pi^e_t - a \rvert + \epsilon_{it}$ | |
|---|---|---|
| | 05/1997–12/2001 | 01/2002–08/2008 |
| $\widehat{\beta}_1$ | 0.175** (0.040) | 0.382** (0.029) |
| $\widehat{\beta}_2$ | 0.139** (0.028) | 0.280** (0.051) |
| $\widehat{\beta}_3$ | 0.155 (0.127) | 0.066 (0.058) |
| $\widehat{\beta}_4$ | −0.531 (0.900) | 0.193 (0.161) |
| $\widehat{a}$ | 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*: Estimation results are based on Euro-area countries only. See Table 1 for further explanations.

## 6. Concluding remarks

In contrast to classical menu-cost or misperception models, the recent literature predicts that the relationship between inflation and the variability of relative prices is V-shaped. Advancing on Head and Kumar (2005), we show that the impact of inflation on price dispersion and welfare crucially depends on the level of search costs. In particular, we consider two testable implications of the model: First, the relationship between inflation and price dispersion is predicted to be asymmetrically V-shaped. Second, for decreasing search costs the V-shaped relationship gets progressively flatter. We use monthly HICP-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, the inflation–RPV nexus is estimated 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 EU-27 market, where the vertex occurs at positive values of inflation. On the other hand, we find that the impact of inflation on RPV gets negligible 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 as a physical currency.

The relationship between inflation and relative price variability has important implications for the welfare cost of inflation. While the earlier literature typically predicts a monotonic increasing effect of inflation on price dispersion, recent evidence suggests that the relationship is actually V-shaped implying e.g. a positive optimal rate of inflation. Yet, the economics behind the non-monotonicity are still unclear. Choi (2010) for example shows that a V-shaped relationship between inflation and relative price variability can be generated in a Calvo model of sticky prices with heterogenous sectors. The current paper shows that similar results can be obtained from monetary search theory. However, as Head et al. (2010b) recently emphasized, different models of price dynamics can have very different implications for policy. Therefore, exploring to what extent the empirical relationship between market integration and price dispersion could help to shed more light on the relevant price dynamics would be an interesting avenue for future research.


## Acknowledgments

We thank Aleksander Berentsen, Jörg Breitung, participants at the annual Congress of the Verein für Socialpolitik, the INFINITI Conference on International Finance, the annual Congress of the European Economic Association, the Macroeconometric Workshop of the German Institute of Economic Research and two anonymous referees for helpful comments and suggestions.


## Appendix A. The monetary search model

### A.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 the 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 $k \in \{1,2,\ldots,K\}$ 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 $\mu\sum_{k=1}^{K} kq_{kt}$.[11] Overall, a representative household maximizes the expected discounted sum of utility from consumption minus total production and search costs over an infinite horizon:

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

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

Restricting the analysis to symmetric and stationary monetary equilibria (SMEs), buyers' reservation levels are endogenous and depend on the marginal value of fiat money. 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).[12]

### A.2. The importance of search costs

According to Head and Kumar (2005) and Head et al. (2010a) the household's optimal choice of $q$ is given by

$$q^* = \begin{cases} 0 & \text{if } \mu < \mu_L \equiv u'(c_2)[c_2-c_1], \\ \dfrac{\left[u'^{-1}\left(\dfrac{\mu}{c_2-c_1}\right)-c_2\right]}{c_1-c_2} & \text{if } \mu_L \le \mu \le \mu_H, \\ 1 & \text{if } \mu > \mu_H \equiv u'(c_1)[c_2-c_1], \end{cases} \tag{4}$$

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.

Eq. (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 ($\mu_L \le \mu \le \mu_H$). When search costs fall below a critical threshold value ($\mu < \mu_L$), 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. Furthermore, 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.

### A.3. Results from a simulation study

Following Gali et al. (2001) and Head and Kumar (2005), we use a log utility function and set the discount factor, $\beta$, equal to 0.9. To achieve an average mark-up of prices over marginal costs of 10%, we set $\phi = 0.1$ and $\mu = 0.029$. Furthermore, we allow $\gamma$, which determines the growth rate of the money stock and the rate of inflation to range between 1 and 1.5. The solid line in Fig. 1 and the upper graph of Fig. 2 depict the V-shaped relationship between inflation and price dispersion for this benchmark scenario.

The middle and lower graphs in Fig. 2 demonstrate how lower search costs affect the inflation–RPV nexus. Compared to the benchmark simulation search costs are set equal to 0.024 (mark-up=5.2%) and 0.019 (mark-up=3.1%), respectively, which causes the inflation–RPV relationship to get progressively flatter. Decreasing the level of search cots even further ($\mu \le 0.011$) results in a breakdown of the non-linear inflation–RPV linkage. In this case, price dispersion equals zero for any level of inflation.

In line with Head and Kumar (2005), 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. The level of search costs determines the curvature of the

[11] 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 $\mu(2-q_t)$.

[12] Head et al. (2010a) study the extend to which real and nominal prices adjust to fluctuations in productivity and the money growth rate in a similar but stochastic environment.

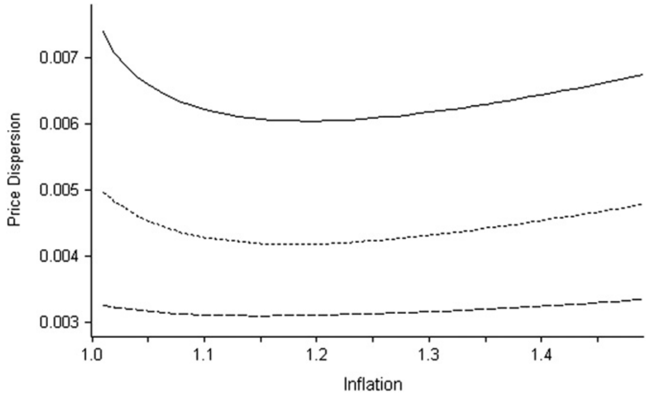


**Fig. 3.** The inflation–RPV nexus and the role of search costs under increased risk aversion. *Notes*: Figure plots price dispersion versus inflation for varying levels of search costs: (i) high search costs (upper graph), (ii) moderate search costs (middle graph), and (iii) low search costs (lower graph). In contrast to the simulation framework presented in Appendix A.3, the CRRA parameter, *a*, equals 1.5.

inflation–RPV nexus. With lower search costs, price dispersion responds less to inflation. In the limiting case, if search cost fall below a certain threshold value, the real effects of inflation on RPV vanish and the classical dichotomy holds.

### *A.4. Robustness analysis*

In accordance with Head and Kumar (2005), the benchmark simulation of the model assumed log utility. However, the role of search costs for the functional relationship between inflation and price dispersion may depend on the curvature of the utility function. In the following, we, therefore, investigate the robustness of the model implications by considering a whole range of values for the coefficient of relative risk aversion. In order to focus on the impact of the utility function, we maintained an average mark-up of 10% and adjusted the cost of search accordingly. Starting with the benchmark case of log utility, i.e. $\alpha = 1$, we closely followed Head et al. (2010a) and simulated the model for coefficients of relative risk aversion up to $\alpha = 1.5$.

For all values of $\alpha$, the simulation results confirm the predictions of the benchmark scenario derived with log utility. Fig. 3 shows exemplarily the relationship between inflation and relative price variability for $\alpha = 1.5$. In line with Hypotheses 1 and 2, the relationship is asymmetrically V-shaped and gets progressively flatter with decreasing search costs. Further robustness checks, e.g. varying the discount factor or the marginal costs of production, lead to very similar results. This indicates that the qualitative implications of the Head and Kumar (2005) monetary search model hold for a broad range of parameter constellations.

## Appendix B. Tables

Table 4.

**Table 4**
Summary statistics.

| | Mean | Standard deviation | Minimum | Maximum | Countries | Product groups | Obs |
|---|---|---|---|---|---|---|---|
| **Euro-area** | | | | | | | |
| $\Pi_t$ | 0.001723 | 0.002573 | −0.005985 | 0.009748 | 12 | 12 | 151 |
| $RPV_{it}$ | 0.003763 | 0.004623 | 0.000460 | 0.097040 | 12 | 12 | 1812 |
| **EU-27** | | | | | | | |
| $\Pi_t$ | 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 for further explanations). Sample: 1996/02–2008/08.

## References

Allen, C., Gasiorek, M., Smith, A., 1998. The competition effects of the Single Market in Europe. Economic Policy 13, 441–486.
Allington, N.F.B., Kattuman, P.A., Waldmannc, F.A., 2005. One market, one money, one price? International Journal of Central Banking 1, 73–115.

Badinger, H., 2007. Has the EU's Single Market Programme fostered competition? Testing for a decrease in mark-up ratios in EU industries. Oxford Bulletin of Economics and Statistics 69, 497–519.
Barro, R.J., 1976. Rational expectations and the role of monetary policy. Journal of Monetary Economics 2, 1–32.
Benabou, R.J., 1988. Search, price setting, and inflation. Review of Economic Studies 55, 353–376.
Benabou, R.J., 1992. Inflation and efficiency in search markets. Review of Economic Studies 59, 299–329.
Becker, S.S., Nautz, D., 2009. Inflation and relative price variability: new evidence for the United States. Southern Economic Journal 76, 146–164.
Bick, A., Nautz, D., 2008. Inflation thresholds and relative price variability: evidence from U.S. cities. International Journal of Central Banking 4, 61–76.
Burdett, K., Judd, K.L., 1983. Equilibrium price dispersion. Econometrica 51, 955–969.
Caglayan, M., Filiztekin, A., Rauh, M.T., 2008. Inflation, price dispersion, and market structure. European Economic Review 52, 1187–1208.
Camera, G., Corbae, D., 1999. Money and price dispersion. International Economic Review 40, 985–1008.
Camera, G., Craig, B., Waller, C.J., 2004. Currency competition in a fundamental model of money. Journal of International Economics 64, 521–544.
Choi, C.-Y., 2010. Reconsidering the relationship between inflation and relative price variability. Journal of Money, Credit and Banking 42, 769–798.
Christopoulou, R., Vermeulen, P., 2008. Markups in the Euro-area and the US over the period 1981–2004, a comparison of 50 sectors. ECB Working Paper No. 856.
Craig, B., Waller, C.J., 2004. Dollarization and currency exchange. Journal of Monetary Economics 51, 671–689.
Crucini, M.J., Telmer, C.I., Zachariadis, M., 2005. Understanding European real exchange rates. American Economic Review 95, 724–738.
Debelle, G., Lamont, O., 1997. Relative price variability and inflation: evidence from US cities. Journal of Political Economy 105, 132–152.
Elliott, G., Timmermann, A., 2008. Economic forecasting. Journal of Economic Literature 46, 3–56.
Engel, C., Rogers, J.H., 2004. European market integration after the Euro. Economic Policy 19, 347–384.
European Commission, 1996. The 1996 Single Market review—background information for the report to the Council and European Parliament. Commission Staff Working Paper, SEC (96) 2378, Brussels, Belgium, December 16.
Fielding, D., Mizen, P., 2000. Relative price variability and inflation in Europe. Economica 67, 57–78.
Fielding, D., Mizen, P., 2008. Evidence on the functional relationship between relative price variability and inflation with implications for monetary policy. Economica 75, 683–699.
Gali, J., Gertler, M., Lopez-Salido, J.D., 2001. European inflation dynamics. European Economic Review 45, 1237–1270.
Hansen, B.E., 1999. Threshold effects in non-dynamic panels: estimation, testing, and inference. Journal of Econometrics 93, 345–368.
Head, A., Kumar, A., 2005. Price dispersion, inflation, and welfare. International Economic Review 46, 533–572.
Head, A., Kumar, A., Lapham, B., 2010a. Market power, price adjustment, and inflation. International Economic Review 51, 73–98.
Head, A., Liu, L.Q., Menzio, G., Wright, R., 2010b. Equilibrium price dispersion and rigidity: a new Monetarist approach. Working Paper No. 10-034, Penn Institute of Economic Research.
Holland, D., 2009. The impact of European and global integration on the mark-up of prices over costs. National Institute Economic Review 208, 118–128.
Jaramillo, C.F., 1999. Inflation and relative price variability: reinstating parks' results. Journal of Money, Credit and Banking 31, 375–385.
Lach, S., Tsiddon, D., 1992. The behavior of prices and inflation: an empirical analysis of disaggregated price data. Journal of Political Economy 100, 349–389.
Lutz, M., 2003. Price convergence under EMU? First estimates. Working Paper No. 2003-08, Institute of Economics, University of St Gallen.
Molico, M., 2006. The distribution of money and prices in search equilibrium. International Economic Review 47, 701–722.
Parsley, D.C., 1996. Inflation and relative price variability in the short and long run: new evidence from the United States. Journal of Money, Credit and Banking 28, 323–341.
Parsley, D., Wei, S.-J., 2008. In search of a Euro effect: big lessons from a Big Mac meal? Journal of International Money and Finance 27, 260–276
Reinsdorf, M., 1994. New evidence on the relation between inflation and price dispersion. American Economic Review 84, 720–931.
Rogers, J.H., 2007. Monetary union, price level convergence, and inflation: how close is Europe to the USA? Journal of Monetary Economics 54, 785–796
Rotemberg, J., 1983. Aggregate consequences of fixed costs of price adjustment. American Economic Review 73, 433–463.
Sauner-Leroy, J.-B., 2003. The impact of the implementation of the Single Market Programme on productive efficiency and on mark-ups in the European Union manufacturing industry. European Economy, Economic Papers, No. 192.
Shi, S., 1999. Search, inflation and capital accumulation. Journal of Monetary Economics 44, 81–103.