ARGUMENTA OECONOMICA
No 1 (32) 2014
PL ISSN 1233-5835

II. ARTICLES

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DIVERGENT OPTIMAL INFLATION RATES IN EURO AREA COUNTRIES OR 'DOES ONE SIZE FIT ALL'?

The aim of this paper is to derive the optimal inflation rate for the euro area (EA) countries from the relationship between the aggregate inflation and the Relative Price Variability (RPV). In order to achieve this goal, we have utilized monthly data for the Harmonized Index of Consumer Prices between January 1997 and June 2013 for the first twelve EA countries and for the EA aggregate. In the first stage, parametric and semiparametric estimations allow us to find that the inflation-RPV relationship shows a U-shaped functional profile for the majority of the countries. In the second stage, within this benchmark and using both kinds of estimations, we obtain the optimal inflation rate defined as the one that minimizes the RPV. Moreover, we test the sensitivity of our results to the time period and, for semiparametric estimation, to the bandwidth selected.

For EA individual countries and for the EA aggregate, it is formally shown that although the European Central Bank's "below but close to 2%" inflation target is (almost) optimal for the EA average, it is not close to the optimum inflation rate for most of the individual EA countries.

Keywords: euro area, monetary policy, relative price variability, optimal inflation
JEL classification: E31, C23

1. INTRODUCTION

Since the idea of a common currency for Europe was first introduced, the issue of homogeneity (or lack of) member country inflation rates has been constantly revisited in the academic literature. In particular, an issue that is often examined is whether there is a common optimal inflation rate across the euro area (EA) countries (for a review of the literature on this issue, see Beck et al., 2009). If the answer is negative, then complications arise for the conduct of a common monetary policy, to the extent of questioning the rationale of the existence of a monetary union for the group of countries being examined.

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There are many criteria for the determination of the optimal rate of inflation, such as the one that maximizes growth or minimises unemployment. For example, Khan and Senhadli (2001) obtain the threshold level of inflation above which the relationship between inflation and growth is negative and Leigh (2010) analyses how the inflation rate impacted on Japan's growth rates. Moreover, Blanchard et al. (2010) examined the relationship between growth and inflation, and argued that central banks should target a 4% inflation rate during periods of positive economic growth to allow for nominal rate decreases during recessions.

The inflation target proposed by the European Central Bank (ECB) is chosen to maintain price stability – considered to be a key pre-requisite for increasing welfare and the economic growth potential. To guarantee price stability, the ECB aims to maintain inflation rates below, but close to, 2% over the medium term[1]. Through this policy, the ECB aims to prevent the risk of deflation by taking into account the possible overestimation of the true inflation rate. This overestimation is a consequence of using the HICP when measuring price level changes and provides a sufficient margin to face the implications of inflation differentials in the euro area.

Following a particular strand of the literature, in this paper we focus solely on the optimal rate of inflation as the one that minimizes costs for consumers. The usual approach in this literature is to determine whether a link exists between the Relative Price Variability (RPV) and the aggregate inflation (IN). We shall denote this relationship by IN-RPV. If an increase in inflation leads to a dispersion of prices (RPV), then search costs increase, as it is more difficult for firms and consumers to distinguish absolute and relative price changes and there is thus a welfare loss. In this context, one may characterise the optimal inflation rate as the one that minimizes the RPV.

The theoretical literature usually finds (or it is *ad-hoc* assumed) that there is a monotonic positive IN-RPV relationship, e.g., Graham (1930), Hercowitz (1981) and Rotemberg (1983). In this case, the optimal rate of inflation would be zero. However, not all empirical evidence confirms these

[1]As is established in the article 105.1 of the Maastricht Treaty (1992), "The primary objective of the ESCB shall be to maintain price stability". Later, at its meeting on 13 October 1998, the ECB's Governing Council defined price stability "as a year-on-year increase in the Harmonised Index of Consumer Prices (HICP) for the euro area of below 2%." And, more precisely, on 8 May 2003 the ECB's Governing Council "agreed that in the pursuit of price stability it will aim to maintain inflation rates close to 2% over the medium term".

findings. While the seminal works of Vining and Elwertowski (1976) and Parks (1978) concluded that there is a positive linear IN-RPV relationship, other authors find evidence of a negative or even a non-linear relationship.

Although most of the literature has focused on the USA experience, there are an important number of studies focusing on the European countries which lead to mixed conclusions. On the one hand, Pagano (1985) for Italy, Assarsson (1986) for Sweden, Domberger (1987) for the United Kingdom and Lehner (1999) for Switzerland have found a positive IN-RPV relationship. On the other hand, Fielding and Mizen (2000) and Silver and Ioannidis (2001) find this relationship negative for several European countries. Moreover, Caraballo et al. (2006) and Nautz and Scharff (2012) show that the nexus between the IN and the RPV depends on the inflationary context. That is, high and low inflation periods have different impacts on the RPV.

Recently, the non-linearity of the IN-RPV relationship has attracted increased attention, as the exact functional profile of the IN-RPV relationship has important implications for the design of monetary policy, especially as it can differ among countries. More precisely, a U-shaped IN-RPV relation could imply that the optimal inflation rate (i.e., the inflation rate that minimizes RPV) is non-zero and, thus, reducing the inflation rate beyond the minimum of the U-shaped function will result in welfare losses for consumers. For the USA, Fielding and Mizen (2008) use non-parametric regression techniques for a long series of USA expenditure data and obtain an optimal inflation rate of around 5%, while Bick and Nautz (2008) argue that the rate of inflation that minimizes the RPV in the USA has a U-shaped IN-RPV profile and is in the range of 1.8%-2.8%. Choi (2010) also finds a U-shaped IN-RPV profile for the USA and Japan, while Caraballo and Dabús (2013) find this profile for Spain.

To investigate the IN-RPV relationship for the first twelve EA countries and the EA as a whole, we consider a data set for the period 1997-2013. Parametric and semiparametric methods are used to obtain the functional form and optimal inflation. Robustness studies are also conducted. More precisely, we focus on the sensitivity of results to the selected time period and to the choice of the bandwidth for the semiparametric method and show that the qualitative results remain valid.

We find that for nine countries and for the EA the IN-RPV relationship is U-shaped, for Italy it is W-shaped, for Portugal it is monotonically decreasing, while a "bell-shaped" relation arises for the Netherlands. For the nine countries where it is U-shaped, we calculate the optimal inflation rate and find three categories of countries: low, medium and high optimal inflation countries. In particular, (some) countries can be placed in one of these categories regardless of the method used. Thus, the inflation rate that minimizes the RPV differs across the EA countries. This creates challenges for the conduction of a (common) monetary policy.

The remainder of the paper is organized as follows. Section 2 describes the data and the variables. In Section 3 the optimal inflation rate for each country is obtained through the estimation of the IN-RPV relationship shape.Section 4 discusses if the results are sensitive to the time period selected. Section 5 concludes.

2. DATA AND VARIABLES

To find the optimal inflation rate, we utilize monthly Harmonized Indices of Consumer Prices (HICP), as they have been constructed specifically to reflect pure inflation as they control for differences (or changes in) cross-country consumer behaviours. In the context of this paper, HICPs are preferred to Consumer Price Indices (CPI), as the former are specifically designed for comparisons between EA countries. Furthermore, as the ECB conducts a common monetary policy for the whole monetary union, it uses (targets) the EA HICP to assess price stability.

All data are from Eurostat and cover the EA as a whole (changing composition), and the first twelve individual EA countries: Austria (AT), Belgium (BE), Finland (FI), France (FR), Germany (DE), Greece (GR), Ireland (IE), Italy (IT), Luxembourg (LU), the Netherlands (NL), Portugal (PT), and Spain (ES), for the period from January 1997 to June 2013 (although Eurostat provides HICP data from 1995, there were observations missing for many countries and this is why our sample starts from 1997).

The analysis is carried out on a 3 digit level disaggregation, i.e.,37 subcategories (See Appendix A for the subcategories of the HICP).The inflation rate is calculated as the annual log-difference of the HICP. The RPV is a measure of the non-uniformity of the variations of individual prices, relative to the average inflation rate. We employ the traditional formula for the RPV used in this strand of the literature. Then, at time*t*, the RPV can be defined as follows:

$$RPV_t = \left(\sum_i w_{it} \left(IN_{it} - IN_t \right)^2 \right)^{1/2} \tag{1}$$

Where w_{it} is the weight of price i in the price index, IN_{it} the inflation rate of group i, and IN_t the overall inflation rate at time t.

Another formulation for the RPV in the literature is the coefficients of variation (CV). The traditional formula of the CV would not be appropriate for this paper as it implies that when the inflation is near zero, the RPV tends to infinity. Such a case is important as the sample used in this paper includes countries with low rates of inflation, such as Germany or Austria. This technical detail regarding the CV formula may drive the negative IN-RPV relationship found in some studies (e.g., Reinsdorf, 1994 and Silver and Ioannidis, 2001). Therefore, we have chosen expression (1) instead of the CV not only because it is the one most used in the literature concerning the IN-RPV relationship, but mainly because the CV can lead to confusing results when the inflation is close to zero or even negative, as it was for some months for the countries of the euro area.

Table 1 provides summary statistics on average inflation and RPV for each country. As can be seen, the inflation rate for all countries goes from negative to positive values, and, on average, is below 3% for all countries (except Greece). It is worth noting that the data exhibits a common pattern for inflation. In fact, all countries reached the maximum between 2008.06 and 2008.09, (except PT (2001), GR (1997), IE (2000), NL (2001)) when oil prices dramatically increased, and all countries reached their minimum in 2009.07-2009.10 (except Greece, 2013.06), when the impact of the economic crises was hit harder. This common pattern is not observed for the RPV, for which the minimum and maximum are reached at different moments. Furthermore, countries with a higher average inflation do not necessarily have a higher average RPV, as we can see comparing GR with NL, or ES with FI, BE or NL.

Table 1
Summary statistics

IN				RPV			
Mean	Std. Dev.	Min.	Max.	Mean	Std. Dev.	Min.	Max.
0.01934	0.00749	-0.00647	0.03968	0.00074	0.00023	0.00041	0.00136
0.01818	0.00910	-0.00428	0.03966	0.00082	0.00037	0.00000	0.00229
0.02017	0.01154	-0.01756	0.05733	0.00101	0.00045	0.00000	0.00263
0.01549	0.00771	-0.00743	0.03483	0.00085	0.00033	0.00031	0.00208
0.02642	0.01118	-0.01333	0.05186	0.00092	0.00030	0.00000	0.00194
0.01881	0.01031	-0.00443	0.04612	0.00104	0.00032	0.00000	0.00187
0.01670	0.00816	-0.00794	0.03947	0.00084	0.00025	0.00000	0.00143
0.03148	0.01389	-0.00978	0.06446	0.00113	0.00048	0.00000	0.00364
0.02198	0.01910	-0.03052	0.05874	0.00125	0.00046	0.00063	0.00294
0.02223	0.00717	-0.00092	0.04148	0.00075	0.00021	0.00035	0.00140
0.02454	0.01308	-0.01503	0.05637	0.00095	0.00044	0.00000	0.00240
0.02175	0.01083	-0.00142	0.05313	0.00388	0.00244	0.00000	0.00666
0.02385	0.01278	-0.01813	0.05007	0.00087	0.00029	0.00000	0.00179

Source: authors' calculations from Eurostat data

Note: IN is expressed on a per unit basis and RPV is obtained using the inflation rate expressed on a per unit basis.

3. ESTIMATING OPTIMAL INFLATION

Prior to obtaining the optimal inflation rate, we investigate the form of the IN-RPV relationship. If we do not make any a priori assumptions about the functional form of the IN-RPV relation, we can define this relation by an unknown function *g*. Moreover, as we aim to isolate the effect of the IN on the RPV, we introduce the lags of both variables in order to remove their possible effects on the RPV. Therefore, the IN-RPV relationship can be defined as follows:

$$RPV_t = g(IN_t) + \sum_{k=1}^{K} \lambda_k IN_{t-k} + \sum_{j=1}^{J} \delta_j RPV_{t-j} + u_t \qquad (2)$$

where $g(IN_t)$ captures the effect of inflation on the RPV and thus determines the functional form of the IN-RPV relationship and u_t is the regression residual. The main goal of this paper is to estimate $g(IN_t)$ for all the EA-12 countries and the EA aggregate. More precisely, due to the implications in identifying the optimal inflation rate, we test if such a function is linear or if it presents a U-shape. This task is approached using various econometric techniques. At first, we use a parametric model where the $g(IN_t)$ function is a quadratic function. This allows us to have first evidence proof about the possibility of a U-shape for function *g*. Afterwards, following Fielding and Mizen (2008), we proceed to complement the standard parametric estimation of the RPV function with a semiparametric model. This is done so as to eliminate any bias that would occur from (necessary) *ad-hoc* assumptions as to the functional form of the IN-RPV relationship.

3.1. Parametric regression analysis

In this section, $g(IN_t)$ in equation (2) is defined as a quadratic function in order to test if it exhibits a U-shape, therefore our basic regression equation takes the following form:

$$RPV_t = \alpha + \beta_1 IN_t + \beta_2 IN_t^2 + \sum_{k=1}^{K} \lambda_k IN_{t-k} + \sum_{j=1}^{J} \delta_j RPV_{t-j} + u_t \,. \qquad (3)$$

Equation (3) is estimated using OLS and therefore the errors are assumed to be normally distributed, homoskedastic and serially uncorrelated.The stationarity of each series was examined using the Augmented Dickey-Fuller test[2]. These tests were conducted selecting the number of lags with the Akaike criteria for each country and including a constant or not wherever appropriate, based on the results of multiple trials for each individual series (the results are available upon request). We have not included a trend because it would be not consistent with a long-run term positive but non-accelerating inflation in the EMU framework.

Based on the results of the Akaike criteria, the optimal lag lengths (K,J) in equation (3) for the EA as a whole are selected. These optimal K and J for the EA are used for all countries in order to make results comparable, i.e., the lags K and J are the same for all countries. Equation (3) is important to determine whether the functional form for each country is linear or quadratic. In particular, if we find that β_2 is not significant, then the IN-RPV relationship is

[2]Our results seem to contradict those obtained by Christopoulos and Tsionas (2005). These authors used the ADF test to examine the stationarity of the inflation series of 15 European countries, including those analysed in this paper, and they conclude that the inflation series has a unit root for all of them. However, such a difference in the results may be due to the periods analysed: Christopoulos and Tsionas (2005) focus on 1961-1999, while this work is based on 1997-2013. Moreover, Lopez (2009) and Zhou (2013), applying alternative tests, find evidence of inflation stationarity for the member countries of the euro area.

linear with a slope given by β_1. However, if β_2 is significant and positive and β_1 is significant but negative, then the IN-RPV relationship exhibits a U-shape. In this case, the optimal rate of inflation (IN*) is the minimum point of the U-shaped function (the minimum rate for the RPV). As Choi *et al.* (2011) point out, the minimum point[3] can be estimated as $IN^* = -\beta_1/(2\,\beta_2)$. The results from the OLS regression for each country are provided in Table 2.

Table 2

Results of OLS regressions

	β_1	β_2	R^2	JB	BG
EA	-3.91 (-1.39)	135.36* (1.77)	0.88	19.82***	1.32
AT	-1.00 (-0.12)	159.38 (0.62)	0.34	234.21***	3.72***
BE	-23.82*** (-3.37)	652.14*** (3.90)	0.52	1195.59***	6.69***
DE	-5.48** (-2.05)	222.65** (2.50)	0.87	26.03***	1.40
ES	-20.12** (-1.97)	401.04** (2.00)	0.52	1668.28***	1.09
FI	-19.65** (-2.57)	467.72** (2.71)	0.70	3564.95***	0.80
FR	-8.99* (-1.78)	378.24** (2.43)	0.55	1595.87***	3.55***
GR	-77.60*** (-3.36)	1198.77*** (3.41)	0.43	1281.11***	1.23
IE	-2.23 (-1.33)	35.93 (0.86)	0.79	7222.31***	2.48***
IT	-6.32 (-1.22)	131.26 (1.07)	0.67	1165.47***	2.63***
LU	-14.82** (-2.09)	371.38** (2.62)	0.56	3270.92***	1.43
NL	0.63 (0.01)	-92.90 (-0.13)	0.88	1784.11***	1.44
PT	-6.09*** (-3.45)	100.89** (2.36)	0.63	658.43***	1.03

Source: authors' calculations from Eurostat data

[3]See Appendix B for details on obtaining the optimal inflation.

Note: t-statistics in parentheses. They are based on standard errors computed according to the Newey-West procedure to allow for residuals that exhibit both autocorrelation and heteroskedasticity of unknown form.

Asterisks ***, **, * denote that the coefficients are significant or the null hypothesis can be rejected at 1%, 5% and 10% levels, respectively.

JB: Jarque-Bera statistics for normality.

BG: F-statistics for the Breusch-Godfrey Serial Correlation LM Test.

From Table 2 we can conclude that for the majority of countries the signs of the $\beta_1$and $\beta_2$are consistent with a U-shaped IN-RPV functional form at a 5% (or even 1%) significance level. However, for AT, IE and IT we have weak evidence for a U-shaped IN-RPV functional form as, although coefficients have the proper signs, β_2 is not significant at the 5% level. Furthermore, the signs of the coefficients for NL suggest that the IN-RPV relationship is 'bell-shaped', but they are clearly not significant.

For all countries, except NL, we will calculate the optimal inflation using the expression $IN^* = -\beta_1/(2\ \beta_2)$. Figure 1 displays the results. From this figure, we can separate the results into three categories: a) countries with low optimal inflation rates which are EA (0.014), AT (0.003), DE (0.012) and FR (0.011), b) countries with an optimal inflation rate around 2% which are BE (0.018), FI (0.021) and LU (0.019), and finally c) countries with relatively high optimal inflation rates which are ES (0.025), GR (0.024), IE (0.031), IT (0.024) and PT (0.030)[4].

Finally, we have to take into account the problems of endogeneity suggested by Scharff and Schreiber (2012) with respect to the general level of inflation. If this is the case, the appropriate estimation technique should be different. In order to test the presence of this problem, we have obtained the Durbin-Wu-Hausman test (see Appendix C). Only for DE and FI at a 10% level of significance can we reject the hypothesis that inflation can be treated as exogenous[5].

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[4]However, these results should be interpreted cautiously, because of the problems of autocorrelation exhibited by the residuals in five countries.

[5] We have used GMM techniques to estimate equation (3) using one and two instruments for IN. For all countries (including NL) β_1 and β_2 show the expected signs, but they are not significant for AT, BE, IE, IT and NL. Therefore, except for BE, we obtain the same results with both techniques (OLS and GMM) –results for GMM estimations are available from the authors upon request.

3.2. Semiparametric regression analysis

We proceed to estimate $g(IN_t)$ through a semiparametric approach which combines the features of both parametric and nonparametric models. In particular, using a similar methodology to that of Fielding and Mizen (2008), Choi (2010) and Caraballo and Dabús (2013), we estimate the following model[6]:

$$RPV_t = \theta_1 RPV_{t-1} + \theta_2 IN_{t-1} + g(IN_t) + \varepsilon_t \tag{4}$$

where $g(IN_t)$ is an unknown smooth differential function that attempts to capture the non-linear impact of inflation on RPV at time *t*. Therefore, the goal is to estimate $g(IN_t)$ in (4). The $g(IN_t)$ function is estimated semiparametrically in two stages[7]. In the first stage, the parameters λ_k are estimated from the regression equation:

$$RPV_t = \lambda_1 \overline{RPV}_{t-1} + \lambda_2 \overline{IN}_{t-1} + \eta_t \tag{5}$$

where $\overline{RPV}_{t-1}$ and $\overline{IN}_{t-1}$ are the residual series from a non-parametric regression of RPV_{t-1} and IN_{t-1} on IN_t respectively. In the second stage, the $g(IN_t)$ function is estimated non-parametrically from the regression:

$$\hat{\eta}_t = g(IN_t) + v_t \tag{6}$$

where $\hat{\eta} = RPV_t - \lambda_1 \overline{RPV}_{t-1} - \lambda_2 \overline{IN}_{t-1}$.

In both stages, the non-parametric regressions of RPV_{t-1} and IN_{t-1} on IN_t and regression (6) are estimated using kernel regressions which are non-parametric techniques that aim to find non-linear relationships between two random variables. In particular, the conditional expectation of random variables is estimated. For the purposes of this paper, the Nadaraya-Watson kernel regression estimator is implemented. As the results of non-parametric regression are very sensitive to the set value of the bandwidth parameter (b) – which behaves as a smoothing parameter – this parameter is selected using a Mean Squared Forecast Error (MSFE) criterion. We have used an outlier-robust Epanechnikov kernel, which is the most common kernel function used in the relevant literature. Moreover, a number of authors note that it is not the choice of the kernel function that is important, but rather the choice of the bandwidth parameter. As a robustness check we have examined the sensitivity of the results to the bandwidth parameter. The results are

[6] For equations (4), (5) and (6), we assume that the conditional expectations of the errors terms are equal to zero.

[7] See Appendix D for details concerning the semiparametric estimation.

presented in the next section. The above methodology is applied for all countries except NL, given the results for this country obtained in the previous section.

We estimate $g(IN_t)$ for all countries. For Portugal this relationship seems to be decreasing, while Italy exhibits a W-shape function ($g(IN_t)$). The results are presented in Appendix E.

Therefore we have excluded both countries, and we continue our paper with nine countries and the EA. Having estimated $g(IN_t)$, the next step is to calculate the derivative of the $g(IN_t)$function, as it captures the sensitivity of the RPV to marginal increases in inflation. If the derivative $g'(IN_t)>0$ ($g'(IN_t)<0$), then the RPV is increasing (decreasing) with inflation, while the optimal inflation rate, i.e., the one that minimizes the RPV, is given by $g'(IN_t)=0$. For our sample, we calculate the optimal inflation rates corresponding to the optimal bandwidth for the EA and to the optimal bandwidth for each country (Table 3).

Table 3
Results from the semiparametric model

	IN-EA	**IN***	**b***
EA	0.0129		0.0015
AT	0.002	0.0019	0.0009
BE	0.0144	0.0145	0.0009
DE	0.0054	0.0054	0.001
ES	0.0308	0.0308	0.0012
FI	0.0284	0.0282	0.0009
FR	0.0058	0.0049	0.0013
GR	0.0320	0.0328	0.0009
IE	0.0191	0.0170	0.0018
LU	0.0214	0.0214	0.0012

Source: authors' calculations from Eurostat data
Note: IN is expressed on a per unit basis.
IN-EA: inflation rate that minimizes RPV using the optimal bandwidth obtained for the EA.
IN*: inflation rate that minimizes RPV using the optimal bandwidth for each country.
b*: optimal bandwidth for each country.

Regarding the optimal inflation rate as reported in Table 3, there is a discrepancy among the countries. The results show that the ECB's "below, but close to 2%" target is appropriate for the EA, Belgium, Ireland and Luxemburg. However, this target is too low for Finland, Greece and Spain and too high for Austria, France and Germany. Therefore, although the ECB's target is indeed optimal for the EA as a whole, it may be harmful for some countries[8]. However, it is interesting to note that the actual average inflation rates for the countries with lower than 2% optimal inflation rates (Austria, Germany and France) were actually closer to the 2% target set by the ECB.

In Figure 1, we compare the results obtained with OLS and semiparametric estimations.

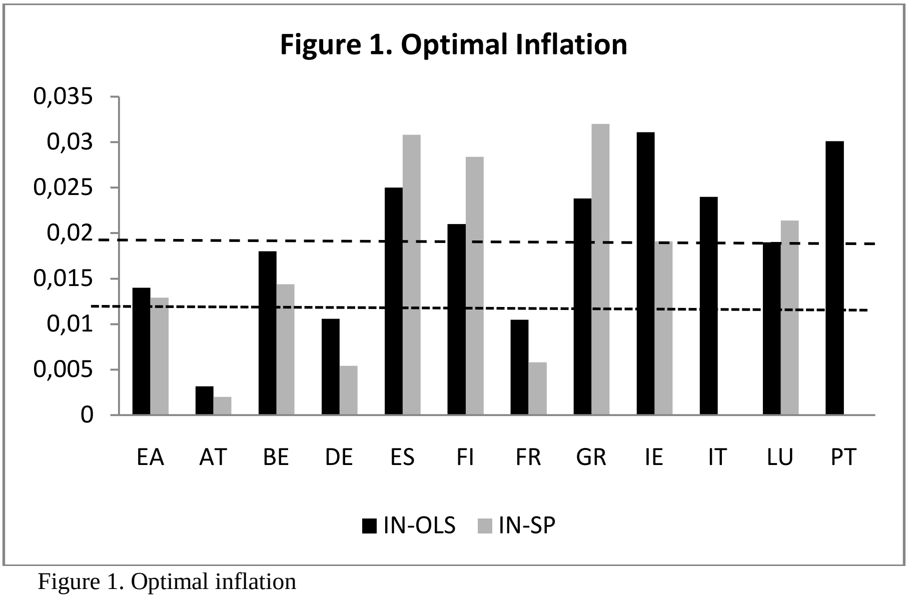

Figure 1. Optimal inflation

Source: authors' calculations from Eurostat data

Note: IN is expressed on a per unit basis. IN-OLS and IN-SP denote the optimal inflation rates derived from OLS and semiparametric estimations respectively.

Figure 1 indicates that there are significant differences between the two estimation methods. In particular, we find that in the low inflation countries (AT, DE and FR) the optimal inflation estimated using OLS are is quite higher. This is consistent with the known problems that OLS estimation runs

[8]If the optimal inflation rate that minimizes the RPV for a country is different (whether it is higher or lower) than the goal proposed by the ECB, this means that the country is going to reach a higher RPV if it fulfills the goal of the ECB instead of fulfilling its own objective. Therefore, the cost of inflation for such a country is higher with the goal of the ECB than with its own goal.

into when dealing with outliers. This thesis is reinforced by the result for IE, another outlier. Thus, one would expect the semiparametric estimation to yield more accurate results.

As mentioned earlier, optimal inflation could be sensitive both to the selected bandwidth parameter and the time period under investigation. As a robustness test, in Figure 2, we examine the sensitivity of optimal inflation to the selection of the bandwidth parameter in the semiparametric estimation. As can be seen, excluding the very low bandwidth, the optimal inflation rates are very stable. Thus, our results are robust to the bandwidth parameter selected.

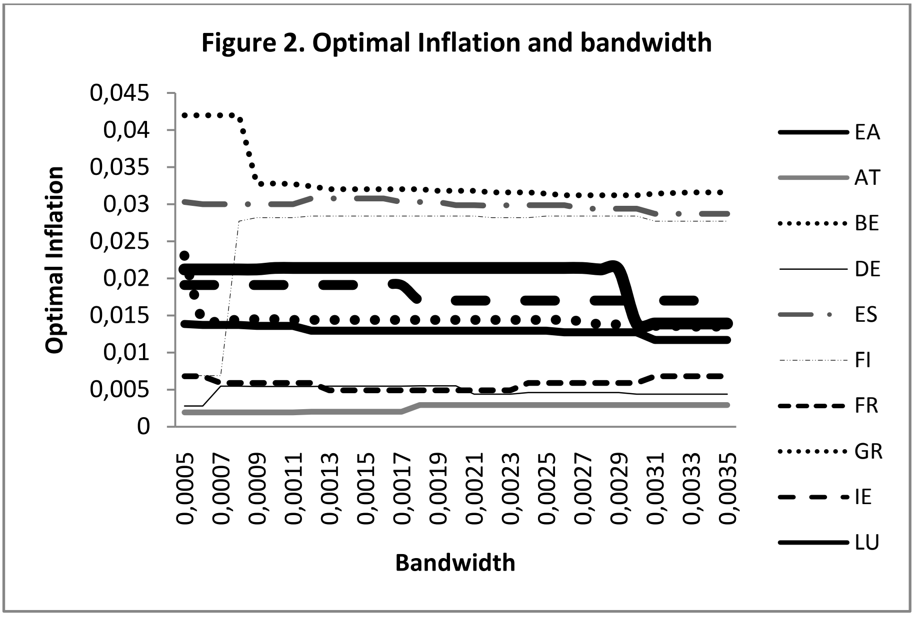

Figure 2. Optimal inflation and bandwidth
Source: authors' calculations from Eurostat data
Note: IN is expressed ona per unit basis.

Finally, we compare the parametric and semiparametric models (Table 4) and find that the significant parametric components of our semiparametric model are very similar to those in the quadratic model. In fact, the Wald test cannot reject the hypothesis that the two coefficients are equal.

Table 4

Comparison of the parametric and semiparametric models

	EA	AT	BE	DE	ES
RPV_{t-1}	0.91*** (31.66)	0.66*** (6.04)	0.44** (2.52)	0.93*** (27.55)	0.51*** (2.70)
$\overline{RPV}_{t-1}$	0.91*** (3.19)	0.65* (3.70)	0.54** (2.24)	0.96*** (4.94)	0.62** (2.08)
Wald test H_0: $\delta_1 = \lambda_1$	0.00	0.00	0.14	0.02	0.12
	FI	**FR**	**GR**	**IE**	**LU**
RPV_{t-1}	0.73*** (7.08)	0.64*** (4.96)	0.51*** (3.38)	0.85*** (13.94)	0.62*** (5.74)
$\overline{RPV}_{t-1}$	0.69*** (2.31)	0.64** (2.14)	0.58*** (2.72)	0.87** (3.29)	0.62*** (3.04)
Wald test H_0: $\delta_1 = \lambda_1$	0.01	0.00	0.09	0.00	0.00

Source: authors' calculations from Eurostat data

Note: t-statistics in parentheses. Asterisks ***, **, * denote that the coefficients are significant at 1%, 5% and 10% levels, respectively. The Wald test statistics is distributed as a $\chi 2(1)$.

4. SENSITIVITY OF OPTIMAL INFLATION TO TIME PERIOD

Having previously shown that for the semiparametric estimation the qualitative results are robust to the changes in the bandwidth parameter, we conduct a further robustness check to test the sensitivity of optimal inflation to the time period for both parametric and semiparametric estimations.

4.1. Parametric estimation

Regarding the parametric estimation, we estimate equation (3) for rolling samples for windows of six, seven, eight and nine years and derive the corresponding optimal inflation. Furthermore, we estimate recursive coefficients, starting with the sample 1997:01–2002:12 and adding a month each time, and again, we calculate the changes in the optimal inflation.

Our robustness test relies on the $\beta_2$coefficient. In particular, if $\beta_2$is not significant, then using Choi's expression for the calculation of the optimal inflation rate would not yield meaningful results. Therefore, in Table 5 we summarize the results for the β_2 coefficient for the various time periods in question. In particular, the numbers in Table 5 represent the ending year of each sample, for example for the six-year window 2005:12 means that the

$\beta_2$coefficient is significant for the subsample 2000:01–2005:12. For a nine-year window, if in the Table we have 08:01–08:05, this means that β_2 is significant for the following samples: 1999:02 to 2008:01, 1999:03 to 2008:02, 1999:04 to 2008:03, 1999:05 to 2008:04, 1999:06 to 2008:05.

It is evident from Table 5 that there is not a common pattern for all countries. Nor do we see structural breaks. Apparently, for most cases (excluding the first two or three years of the sample) the IN-RPV relationship is U-shaped.

Table 5

Sensitivity of the optimal inflation to the time period

	SIX	SEVEN	EIGHT	NINE	RECURSIVE
EA	From 09:03	From 09:01	From 09:01	From 08:03	From 08:01
AT	07-07-07:10 09:06-09:10 10:06-11:03	09:06-11:03	09:06-11:03	08:01-08:05 09:06-11:03	08:01-08:07
BE	From 04:01	Always	Always	Always	From 03:12
DE	07:06-08:06 From 09:07	07:09-08:07 From 09:07	08:03-08:07 From 09:03	07:11-08:07 From 09:07	From 07:10
ES	From 06:01	From 06:05	From 07:07	From 08:02	From 08:01
FI	04:03-10:11 From 12:09	04:03-11:08 12:05 12:11	04:12-12:06 13:01 13:05-13:06	always	From 04:03
FR	05:09-07:12 From 09:03	06:09-08:01 From 09:03	07:06-08:01 From 09:02	06:01-06:02 From 09:01	06:01-08:01 From 09:01
GR	02:12-04:02 08:02-10:08 11:03-12:04	03:12-05:02 06:06-07:05 08:10-12:10	04:12-05:05 06:06-07:05 08:12-12:11	05:12-10:03 10:11 11:01 11:03-13:02	Always
IE	03:03-03:07 06:11-08:11	07:11-08:11 09:04-09:06	08:11-08:12	09:04-09:09	09:04-09:10
IT	07:02-07:12 From 09:06	Only 08:03 Only 08:10 09:06-13:03	08:07-08:12 09:06-09:10 09:12-11:08 12:09-13:03	07:10-07:12 08:07-11:06	08:07-08:08 09:05-11:06
LU	02:12-06:09 09:01-12:01	03:12-06:09 07:03, 07:04 09:01-12:09	All except 07:08-08:11	All except 08:07-08:11	Always
PT	03:10-04:02 05:06-09:02 13:05,13:06	03:12-04:03 04:10-04:12 05:07-05:12 06:12-09:07 13:01 13:04-13:06	05:06-06:01 07:08-09:03 11:10-12:05 From 12:08	05:12-07:01 08:12-09:09 From 12:06	03:10-04:09 05:06-08:06 From 08:11

Source: authors' calculations from Eurostat data

Figure 3. Optimal inflation. Rolling and recursive estimations

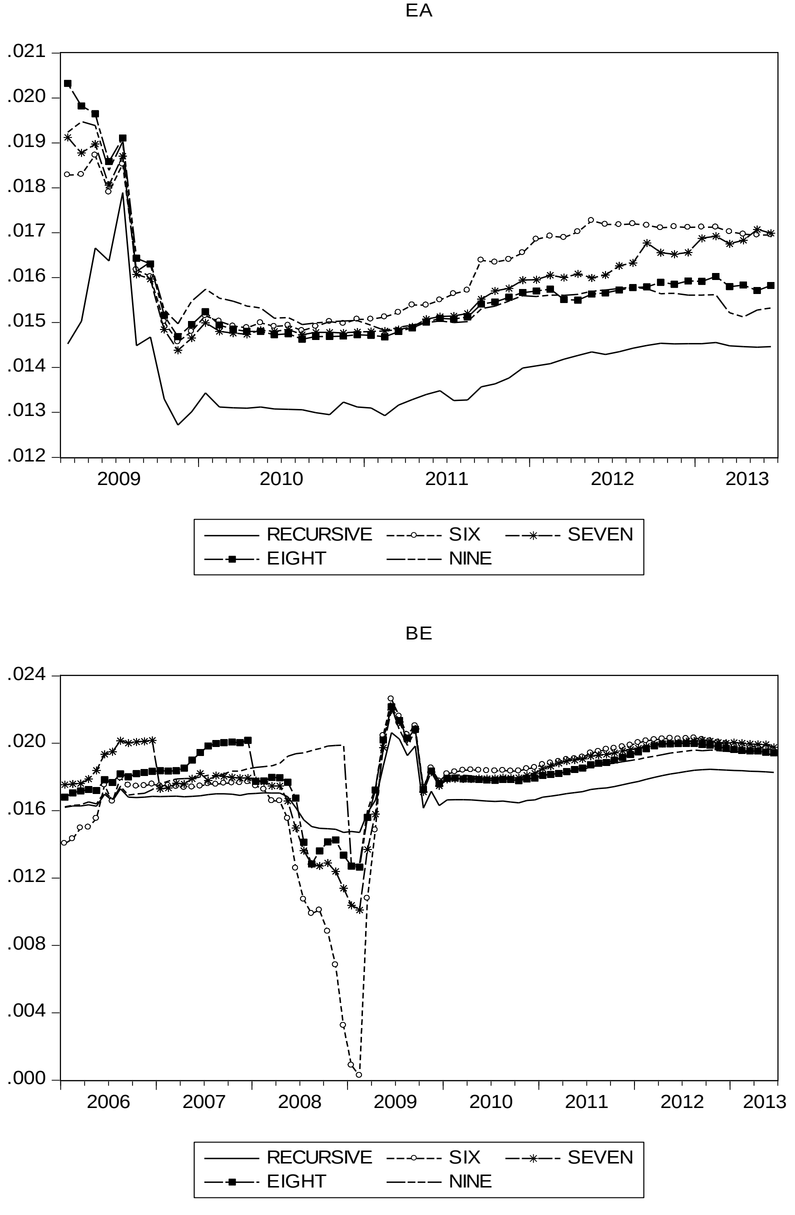

Figure 3. Optimal inflation. Rolling and recursive estimations
Source: authors' calculations from Eurostat data

In Figure 3 we show how the optimal inflation rate varies over different time periods. In particular, the results for the whole period and the recursive methodology for the EA (from 09:03) and BE (from 06:01) are presented as the $\beta_2$coefficient is significant for these countries for the relative time periods. For example, in Figure 3 optimal inflation in 2009:01 implies the optimal inflation calculated for the following samples: 2003:02–2009:01 (six year window), 2002:02–2009:01 (seven year window), 2001:02–2009:01 (eight year window), 2000:02–2009:01 (nine year window) and 1997:01–2009:01 for the recursive method.

Figure 4 displays the results for the optimal rate of inflation using recursive estimations for the EA, BE, DE, ES, FI, GR, LU from 2008:01 (i.e., the first result for optimal inflation has been calculated for the sample 1997:01–2008:01).

Figure 4. Optimal inflation. Recursive regressions

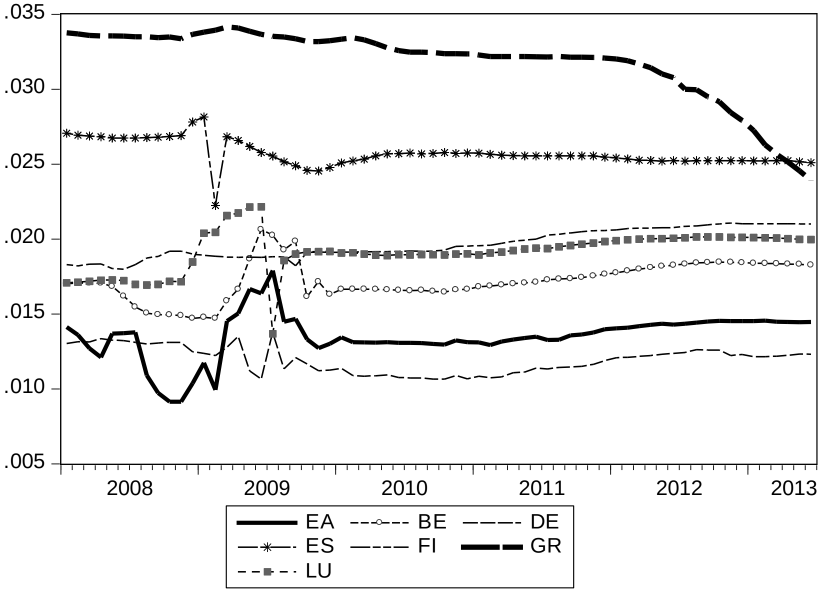

Figure 4. Optimal inflation. Rolling and recursive regressions
Source: authors' calculations from Eurostat data

As before, we have high optimal inflation countries (ES and GR), and medium ones (LU, FI and BE), while DE has a relatively low optimal inflation rate. The optimal inflation rate for the EA is relatively low.

Moreover, Figures 3 and 4 show the effects of the economic crisis on the level of optimal inflation for some countries. Both months of higher inflation in 2008 and lower inflation in 2009 (even negatives rates) exacerbated RPV[9], and such outliers affect optimal inflation, leading in some cases to lower (higher) optimal inflation when inflation increases (decreases). These results further support the need for semiparametric regression analysis, rather than relying on simple parametric regression analysis.

4.2. Semiparametric approach

This section analyses the sensitivity of the derived optimal inflation rate when calculated using semiparametric methods. As before, we use rolling regressions for windows of different sizes and recursive regressions. The results are depicted in Figure 5 in which the nine countries have been grouped into three categories according to their (relative) inflation levels: low (AT, DE and FR), medium (BE, IE and LU) and high (ES, FI and GR). In fact, the estimations start from 2005:12. That is, the data for 2005:12 corresponds to the period 1997:01–2005:12. The graphs in the left column refer to the results from the recursive estimation, while the graphs in the right column provide the results from rolling regressions for eight year windows, i.e., the first data corresponds to the estimation for the period 1998:01–2005:12. To make comparisons easier we have included the results for the EA in all graphs. From Figure 5 we can conclude that the optimal inflation rate is more sensitive to time periods[10] than to bandwidth parameters, especially for fixed size windows, but the results differ across the three country groups.

[9] This fact can be explained by the different behaviour between tradable and non-tradable inflation.

[10] As shown in the theoretical literature, the existence of price rigidities in an economy explains how changes in inflation may affect the RPV. If mechanisms underlying price rigidity change over time, there may be changes in the IN-RPV relationship. And, therefore, the optimal inflation defined as the one that minimizes RPV, could change too.

Figure 5. Optimal inflation. Recursive and rolling semiparametric estimations

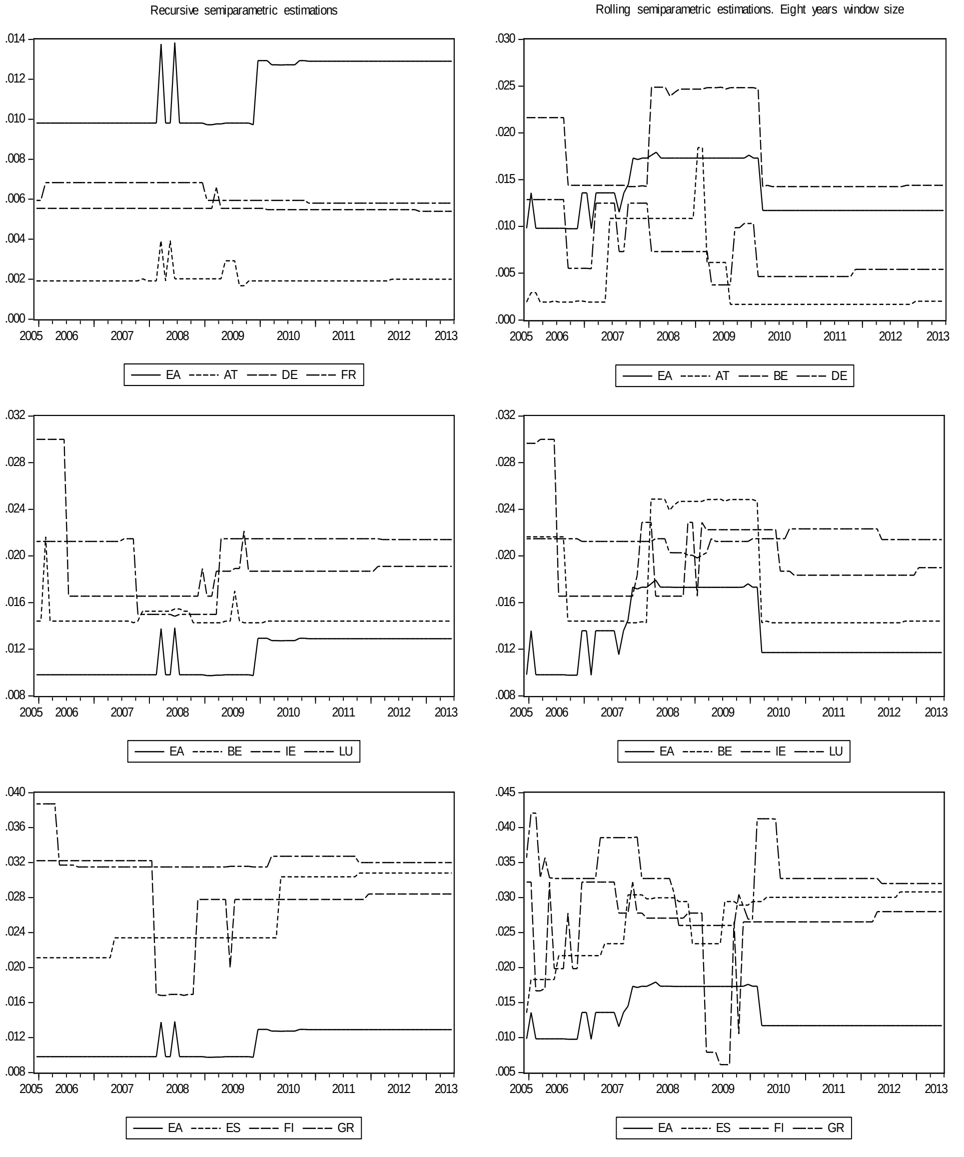

Figure 5. Optimal inflation. Recursive and rolling semiparametric estimations

Source: authors' calculations from Eurostat data

Note: IN is expressed on a per unit basis.

5. CONCLUSIONS

In this paper, we examined the optimal rate of inflation for the EA as a whole and for each individual member country. The optimal inflation refers to the rate of inflation that minimizes costs for consumers. In the context of this paper, the optimal inflation rate is the one that minimizes the RPV.

The IN-RPV relationship was examined using both parametric and semiparametric methods of the EA as a whole and for each individual member country. For the majority of countries, we find that this relationship exhibits a U-shape and thus we can calculate the optimal inflation rate as the one that minimizes RPV. However, there are three outliers: NL, where the IN-RPV relationship exhibits a “bell-shape”; PT, where the relation is always decreasing and IT, where it shows a W-shape.

Based on the results, the countries in question can be split into three categories based on the optimal inflation rate: low (lower than 1.4%, AT, DE and FR), medium (1.4%–2.1%, BE, and LU) and high (over 2.1%, ES and GR). However, the derived optimal inflation rate for IE and FI depends on the method selected and they can be considered as countries with either a medium or high optimal inflation rate. Robustness analysis show that the qualitative results are not dependent on the bandwidth parameter selection for the semiparametric or the time period selected.

For the EA as a whole, the optimal inflation rate is near 2% which would imply that the ECB’s (official) target is indeed optimal. However, as previously shown, this inflation rate is not optimal for the majority of the EA member countries. In this sense, our results indicate a possible need to revise the EA-wide common inflation target goal.Non-optimal inflation targeting in the EA could have dire consequences for certain member countries. In particular, they can lead to systematic price differentials resulting in real exchange rate appreciations, a reduction of competitiveness, increases of real (short term) interest rates and/or longer economic cycles (e.g.,Angeloni and Ehrmann, 2007; Fendel and Frenkel, 2009).

A possible extension of the analysis developed in this paper is the choice of a method to select the appropriate length of the time period for calculating the optimal inflation rate.

Appendix A. Categories of the HCPI

Table A. COICOP 3 digit subcategories

CP011	Food
CP012	Non-alcoholic beverages
CP021	Alcoholic beverages
CP022	Tobacco
CP031	Clothing
CP032	Footwear including repair
CP041	Actual rentals for housing
CP043	Maintenance and repair of the dwelling
CP044	Water supply and miscellaneous services relating to the dwelling
CP045	Electricity, gas and other fuels
CP051	Furniture and furnishings, carpets and other floor coverings
CP052	Household textiles
CP053	Household appliances
CP054	Glassware, tableware and household utensils
CP055	Tools and equipment for house and garden
CP056	Goods and services for routine household maintenance
CP061	Medical products, appliances and equipment
CP062	Out-patient services
CP063	Hospital services
CP071	Purchase of vehicles
CP072	Operation of personal transport equipment
CP073	Transport services
CP081	Postal services
CP082	Telephone and telefax equipment
CP083	Telephone and telefax services
CP091	Audio-visual, photographic and information processing equipment
CP092	Other major durables for recreation and culture
CP093	Other recreational items and equipment, gardens and pets
CP094	Recreational and cultural services
CP095	Newspapers, books and stationery
CP096	Package holidays
CP121	Personal care
CP123	Personal effects n.e.c.
CP124	Social protection
CP125	Insurance
CP126	Financial services n.e.c.
CP127	Other services n.e.c.

Source: Eurostat

Note: COICOP = United Nations Classification of individual consumption by purpose

Appendix B. Calculus for optimal inflation

In order to calculate the optimal inflation from equation (3) as the one that minimises RPV, we obtain the first derivative with respect to IN and equate to zero, and check if the second derivative is greater than zero. If this is the case, we can obtain the optimal inflation from expression (a):

$$\frac{\partial RPV_t}{\partial IN_t} = \beta_1 + 2\beta_2 IN_t = 0 \text{ (a)}$$

$\dfrac{\partial^2 RPV_t}{\partial IN_t^2} = 2\beta_2 > 0$ if β_2 is positive, as we have obtained for all countries except NL. Therefore, the optimal inflation can be calculated from expression (a) as:

$IN^* = -\beta_1/(2\,\beta_2)$.

Appendix C. Test for endogeneity

The Durbin-Wu-Hausman Test is used to test the endogeneity of some, or all, of the equation regressors. Under the null, the variable is considered as exogenous. In this case we are going to test if IN_t is endogenous. In estimation 1 and 2 we have used one and two instruments respectively for IN_t. The instruments chosen are the lags of IN_t. The test statistic is distributed as a $\chi^2(1)$.

Table C. Endogeneity test

	Estimation 1	**Estimation 2**
EA	1.04	0.20
AT	0.11	0.19
BE	1.13	2.43
DE	3.53*	0.83
ES	0.23	1.84
FI	2.10	2.90*
FR	0.11	1.44
GR	0.18	0.17
IE	0.15	2.09
LU	1.55	1.09

Source: authors' calculations from Eurostat data

Note: Asterisks ***, **, * denote that the null hypothesis is rejected at 1%, 5% and 10% levels, respectively.

Appendix D. Semiparametric estimation

A semiparametric regression is of the form:

$y(i) = b \cdot x(i) + f(z(i)) + u(i)$,

where b is a fixed parameter (the parametric bit), $f(\cdot)$ is the non-parametric bit and $u(i)$ is a residual. To estimate b, we can use the regression:

$y(i) = b \cdot x\sim(i) + v(i)$,

where $x\sim(i)$ is the residual from a non-parametric regression of $x(i)$ on $z(i)$, and $v(i)$ is a new residual. In this way b is consistently estimated, because $x\sim(i)$ is orthogonal to $z(i)$. We then do a non-parametric regression of the form

$v(i) = f(z(i)) + u(i)$,

which gives us a consistent estimate of $f(\cdot)$.

Appendix E

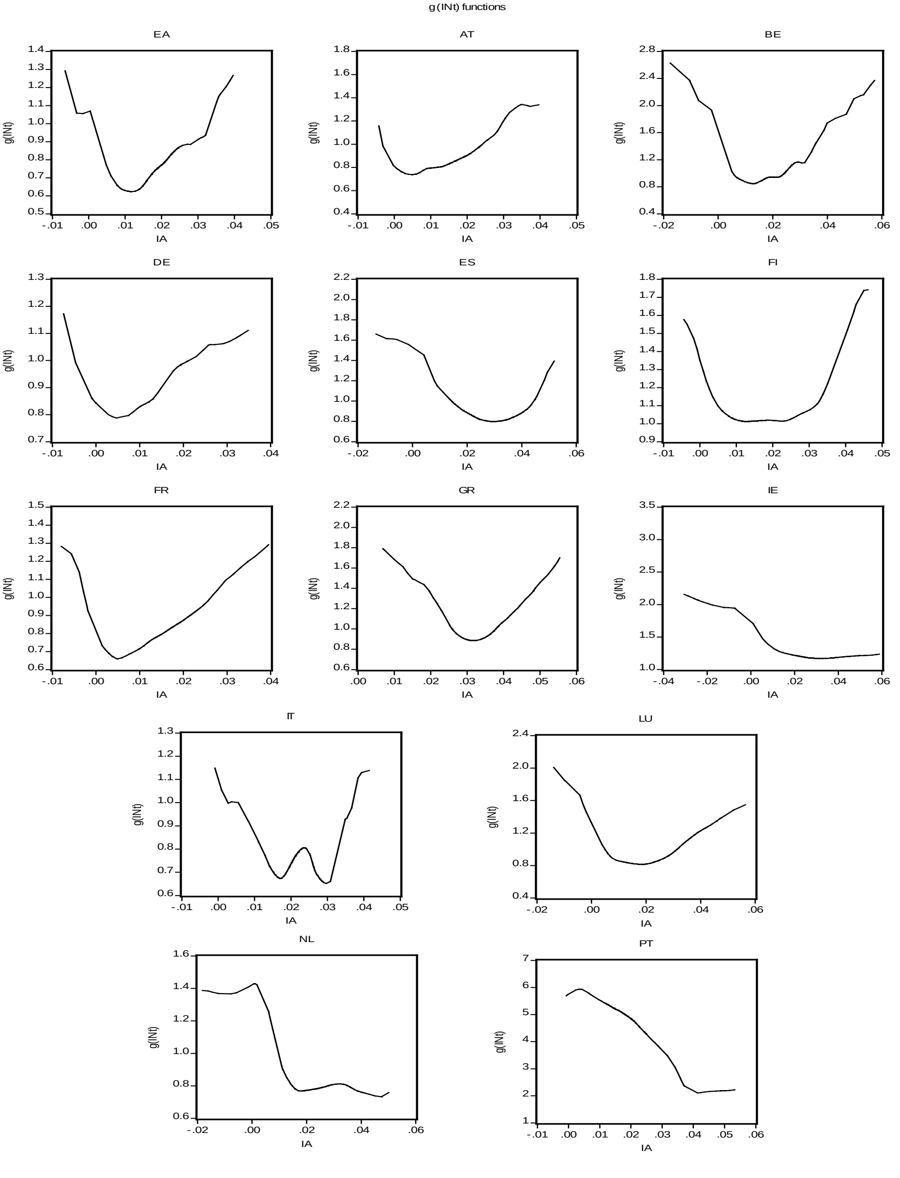

Figure E. $g(IN_t)$ functions
Source: authors' calculations from Eurostat data
Note: the inflation rates are in percentages.

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Received: April 2012, revised: November 2013

Acknowledgments: *M. Ángeles Caraballo acknowledges financial support from the Junta de Andalucía (CICE, Proyecto de Excelencia SEJ-4546).*