Deflation in the Euro Zone: Overview and Empirical Analysis

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Abstract

Two main issues, closely related to each other, have occupied the European Central Bank in recent years: the sovereign debt crisis and the possibility of deflation in the Euro Zone. In this paper we discuss the causes, the consequences and the policy options regarding deflation. In addition, we assess the magnitude of the risk of deflation in the Euro Zone. For this purpose, we will employ the methodology of Kilian and Manganelli (2007). Our results suggest that the threat of deflation in the Euro Zone is related to the international financial crisis and to the sovereign debt crisis in Europe. Thus, the probability of deflation in the Euro zone increased in recent years. Nevertheless, it appears to have subsided in 2017, justifying the view taken by the ECB's Governing Council, according to which deflation is no longer a problem for the Euro zone.

JEL Classification: E31, F45, F47.

Key Words: deflation, debt crisis, Eurozone, GARCH model.

1. Introduction

The stagflation of the 1970s made inflation the number one enemy of central banks in advanced economies. However, the Japanese experience since the late 1990s and the international financial crisis initiated in the United States of America in 2007 have made deflation emerge as the main concern of monetary policymakers. Consequently, an interest in measuring the risk of deflation has developed (see, e.g., Fleckenstein et al., 2013).

The phenomenon of deflation occurs when general price levels fall for a prolonged period of time, with goods and services becoming cheaper in money terms. This may be the outcome of higher efficiency in production or improvements in supply. However, it may also be the result of demand deficiency or a symptom of an increased risk of 'secular stagnation' (see, e.g., Pagano and Sbracia, 2014). More disturbingly, it could pave the way for a deflationary spiral in the Euro Zone, leading it into a new Great Depression.

The aim of this paper is to provide an overview of deflation and to present an empirical analysis of deflation in the Euro Zone. Our preliminary results suggest that the risk of deflation in the Euro Zone is related to the international financial crisis and to the sovereign debt crisis in Europe. However, the uncertainty concerning the appropriate model for forecasting inflation/deflation is large. To measure the risk of deflation in the Euro Zone we employ the methodology of Kilian and Manganelli (2007). This methodology has the advantage of requiring macroeconomic data that can be easily obtained. Important alternative methodologies exist (well represented by Fleckenstein et al., 2013), but require financial data which is much harder to obtain, and assumptions allowing the extraction of inflation expectations from that data.

The remainder of the paper is organised as follows. Section 2 presents an overview of issues raised by the possibility of deflation in the Euro Zone, giving particular emphasis to the main causes and consequences of deflation, and to the policy measures that may be used to combat deflation. Section 3 describes the methodology and data used in the empirical analysis. In Section 4 we discuss the results produced by the empirical model. The paper concludes in Section 5.

2. The Threat of Deflation

One of the consequences of the international financial crisis that began in 2007 in the USA was the heightened concern about deflation in other regions of the world. These concerns were especially acute in the Euro Zone after the beginning of the sovereign debt crisis. In 2009, Ireland's consumer price inflation was negative 4.5 per cent recorded; in 2010 it was negative 1 per cent. In 2011, inflation rebounded (2.6 per cent) but it then went on a declining, turning negative again in 2015 (0.3 per cent) and 2016 (0.2 per cent).

The possibility of deflation in the Euro Zone has been presented as an impending menace to the well-being of Europeans. However, the basic macroeconomic models do not describe deflation as something different from inflation. In fact, a well-known model in monetary economics, due to Milton Friedman, predicts that the optimal rate of inflation is actually negative (Friedman, 1969). Maintaining a certain rate of deflation is the optimal course of monetary policy according to that model. Nevertheless, in ordinary media reports, avoiding deflation appears to be a more pressing concern than avoiding inflation.

When discussing deflation, typically reference is made to the ongoing – since the early 1990s – crisis in Japan, deflation being a key characteristic of that crisis since the late 1990s (see, e.g., Williams, 2009). Despite the efforts of successive governments to revive the economy, Japan appears have been trapped in a low-growth/low-inflation equilibrium. On the other hand, it should be noted that the fear of a deflationary spiral of the sort described by Fisher (1933) did not materialize.

The debt-deflation spiral by Irving Fisher is more likely to occur in countries where the private sector is highly indebted and attempts to deleverage quickly, to that end cutting consumption and investment aggressively – the result may be an overall slump caused by lack of demand. This was the scenario most feared in Europe, given the extraordinary accumulation of debt in the years leading to the crisis. In such an environment, policy options would be limited by the high debt levels of both the public and private sectors, and by the "zero lower bound" on interest rates. Namely, it was feared that fiscal policy would be severely restricted by the need to reduce public debt at the same time that a "liquidity trap" would come into operation and render monetary policy ineffective – unable to stimulate the economy by lowering the interest rate and encouraging lending and spending.

In this case, the prospects would be dire not just for the countries most affected by the sovereign debt crisis but also for the rest of the Euro zone and of the European Union, given the disruption and increase in uncertainty that a large-scale crisis in several members, albeit small, of the Euro zone would surely cause. Therefore, the perspective of a deflationary crisis in the whole of the Euro zone was viewed as a worrisome possibility by policy-makers and business leaders.

2.1. Causes and Consequences

As we mentioned above, it is common to think of deflation as an event that is closely related with poorer economic performance. However, a decline in prices does not always have to be associated with inferior economic performance. For example, as noted by Bordo et al. (2004), in the late 19th century, new technological and policy innovations allowed a vast expansion in the exploitation of America’s abundant natural resources, leading to both falling prices and rapid economic growth. In this case, we are in presence of what is usually known in the economic literature by ‘good deflation’, brought about by a positive supply shock in the economy. In contrast, when prices decline for a long period of time as the result of a negative demand shock, countries are facing a ‘bad deflation’ (Saxonhouse, 2005; Hicks and Wani, 2014).

Although many other factors have been discussed in the economic literature (e.g., Brooks and Quising, 2002; Rogoff, 2003; Hicks and Wani, 2014; Horwitz, 2014; IAGS, 2014; Tasos and Stamatiou, 2014; Micossi, 2015 and Ciccarelli and Osbat, 2017), the main cause of deflation in the Euro Zone is probably weak demand coupled with reduced effectiveness of monetary policy (see, e.g., Eijffinger, 2009, and Claeys, 2014). A major contributor to the weakness of demand is the set of fiscal austerity measures implemented in the wake of the sovereign debt crisis. Public spending cuts propagate throughout the economy, leading to spending cuts by the private sector, aggravating the lack of the demand and creating the possibility of a recessionary spiral.

Besides internal factors to the Euro Zone, there are also several outside risks, such as monetary policy tightening in the United States, geopolitical shocks (e.g. Ukraine), and the growth slowdown in emerging and developing countries (Atradius, 2014).

These potential negative effects of a deflationary environment in the Euro Zone are of particular concern in the case of the peripheral countries – Portugal, Greece, Spain and Ireland – that are currently working to recover their economies from the international financial crisis. The combination of low inflation and high sovereign debt levels will make economic recovery in those countries more difficult and vulnerable to negative demand shocks, possibly leading to continued instability in the Euro Zone.

2.2. Policy Measures

Policy measures to avoid deflation must venture into unconventional areas, for conventional monetary policy transmission may cease to work in a low-inflation, liquidity-trap environment. As argued by Rogoff (2003), it is better to prevent deflation than to try to cure it, and monetary policy must take the lead. Expansionary fiscal policies can also play an important complementary role. The case for expansionary fiscal policies to combat deflation is strengthened by the larger multipliers that operate at the zero lower bound (Christiano et al., 2011). Structural reforms, particularly those improving credit intermediation, could similarly be useful (Rogoff, 2003), especially given that many countries lack the 'fiscal space' necessary to be able to expand government spending. This was the case of the countries most affected by the Eurozone crisis, namely Portugal and Greece. The implementation of structural reforms is a lengthy process with an uncertain outcome; expansionary fiscal policy coordination at the Eurozone level might have been helpful to reduce the impact of the crisis while implementing structural reforms, but the public opinion in the surplus countries appeared to be clearly against that sort of action.

The specter of a deflationary environment represents, consequently, an important menace to financial stability since debt problems, financial crises, and low inflation may deepen the economic problems in the countries most affected by the sovereign debt crisis. Traditionally, a central bank counteracts inflationary pressures by raising interest rates and deflationary developments by cutting interest rates. However, if the central bank has lowered its interest rates to almost zero, it can no longer use it to stop the price decline. A central bank will then only have unconventional measures at its disposal to raise prices and/or to create inflation expectations in the economy (Bernoth et al., 2014).

Under these circumstances, and coinciding with a period in which the European Central Bank (ECB) reduced its base interest rates without restoring confidence to the markets, the ECB started buying sovereign and private sector bonds in very large amounts, pushing cash into the markets – the strategy known as Quantitative Easing (QE). In theory, QE increases the supply of money in the economy, increasing spending and potentially inflating prices. The main objective of these QE programs was to improve credit conditions, with the added benefit (possibly, the main benefit) of supporting the market for bonds issued by the countries hit by the sovereign debt crisis (see Bernoth et al., 2014 and Illing, 2014).

However, despite the United States having gone through three big QE programmes, the inflation rate did not rise above the 3%. The Japanese economy has also stagnated for more than a decade, while interest rates went to zero and the Bank of Japan implemented a QE programme. Thus, it is unclear how successful QE programs have been, namely in the Euro zone – see Driffill (2016). Nevertheless, the Governing Council of the ECB declared in March 2017 that deflation had ceased to be a concern. In the remainder of the paper we analyze the evolution of the probability of deflation in the Euro zone.

3. Econometric Model and Data

3.1. The General Econometric Approach

Our empirical approach to the measurement of deflation risk in the Eurozone follows Kilian and Manganelli (2007). Kilian and Manganelli use a GARCH(1,1) model for the conditional variance of inflation shocks. The general model can thus be written as:

$$\pi_t = \mu_t + u_t \quad (1)$$

$$u_t = \varepsilon_t \sqrt{h_t}, \quad \varepsilon_t | I_t \sim N(0,1) \quad (2)$$

$$h_t = \alpha_0 + \alpha_1 u_{t-1}^2 + \beta_1 h_{t-1} \quad (3)$$

where I_t is the information set (containing the series μ up to time *t* and the lags of $u$andε), π_t is inflation, μ_t is the conditional mean of inflation and u_t is the inflation shock, which is written as the product of its conditional variance, given by h_t, and a Gaussian innovation, ε_t.

The conditional mean of inflation is determined by a forecast model. Kilian and Manganelli consider three alternative specifications of this forecast model for inflation. The first forecast model uses only inflation lags. The second forecast model includes lagged percent changes of the oil price besides inflation lags. The third forecast model replaces the oil price changes with money supply growth rates. Besides the oil price and the money supply, we will also consider nominal unit labour costs, real GDP, the output gap and the nominal effective exchange rate. These variables are commonly used in the literature on inflation forecasting (see, e.g., the surveys in IMF, 2015, and Moccero et al. 2011). Additionally, we will also consider models in which lags of the above mentioned variables (in combinations of two) are used alongside inflation lags.

The basic idea underlying the framework described above is illustrated in Figure 1.

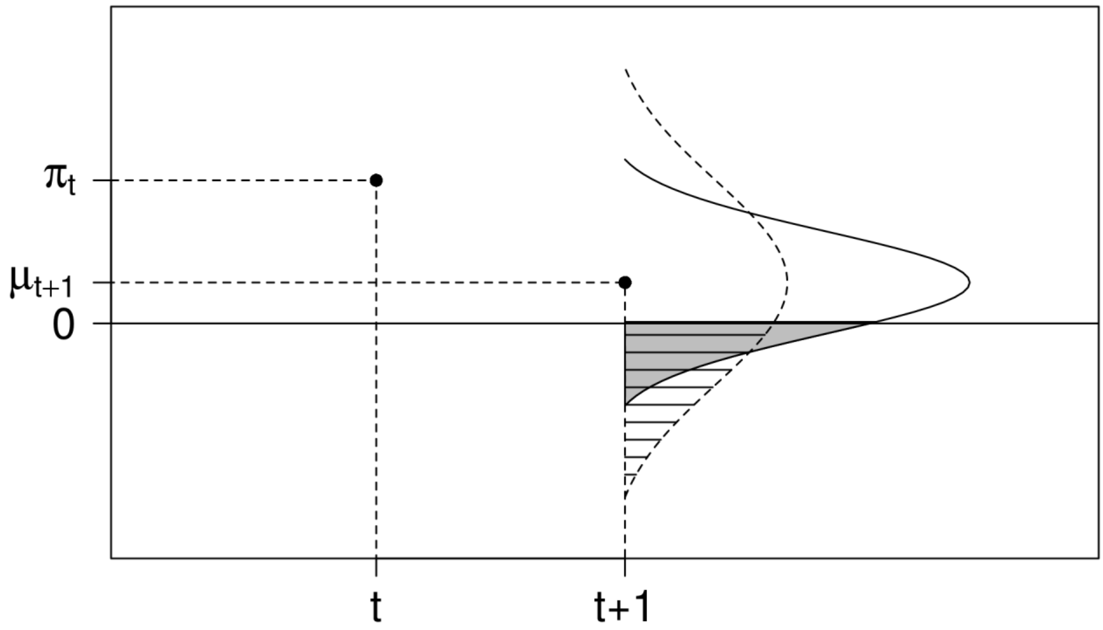


Figure 1: Illustrating deflation probabilities.

In Figure 1, it is assumed that at time *t* inflation was positive ($\pi_t > 0$). At time *t+1*, the conditional mean of inflation is still positive ($\mu_{t+1} > 0$). However, inflation at time *t+1* will equal its conditional mean plus a shock (u_{t+1}). The shock may be such that inflation at time *t+1* is actually negative (i.e., there is deflation). For deflation to occur, the shock will have to be sufficiently negative, the threshold being the symmetric of the conditional mean of inflation ($-\mu_{t+1}$). The focus of our empirical analysis is therefore on the computation of the probability that the shock to inflation is

$$u_{t+1} < -\mu_{t+1} \tag{4}$$

which is equivalent to

$$\varepsilon_{t+1} < -\frac{\mu_{t+1}}{\sqrt{h_{t+1}}} \quad (5)$$

The GARCH specification for the inflation shock allows its variance to change over time. Therefore, the same conditional mean may be associated with different deflation probabilities, since the shape of the density of the shock is evolving. In Figure 1, two inflation (shock) densities are plotted to the right of *t+1*, with both densities centred at μ_{t+1}. Thus, Figure 1 shows an example where the increase of the conditional variance of the inflation shock (giving rise to the dashed density depicted) implies a larger deflation probability (the shaded area is smaller than the area with horizontal stripes).

The procedure employed for estimating the GARCH model[1] assumes that the innovations (ε_t) are normally distributed. Nevertheless, one should test that assumption and attempt to adjust the estimate of the probability if the normality assumption is rejected. To do so we employ the following procedure. We first estimate the density of epsilon. This gives us the points identified by a cross in the example represented in Figure 2. The x-coordinates of the points are equally spaced, i.e., $x_2 - x_1 = x_3 - x_2 = \cdots$, where $x_1 < x_2 < x_3 < \cdots$ We then assume that the y-coordinate of point (x_i, y_i) represents the probability that the innovation takes a value between the mid-points of $[x_{i-1}, x_i]$ and $[x_i, x_{i+1}]$ – this corresponds to the rectangles shown in Figure 2. In Figure 2, the probability of deflation is thus given by the area of the shaded rectangles to the left of the threshold $(-\mu_{t+1}/\sqrt{h_{t+1}})$.

[1] All computations were performed using Gretl 2016d.

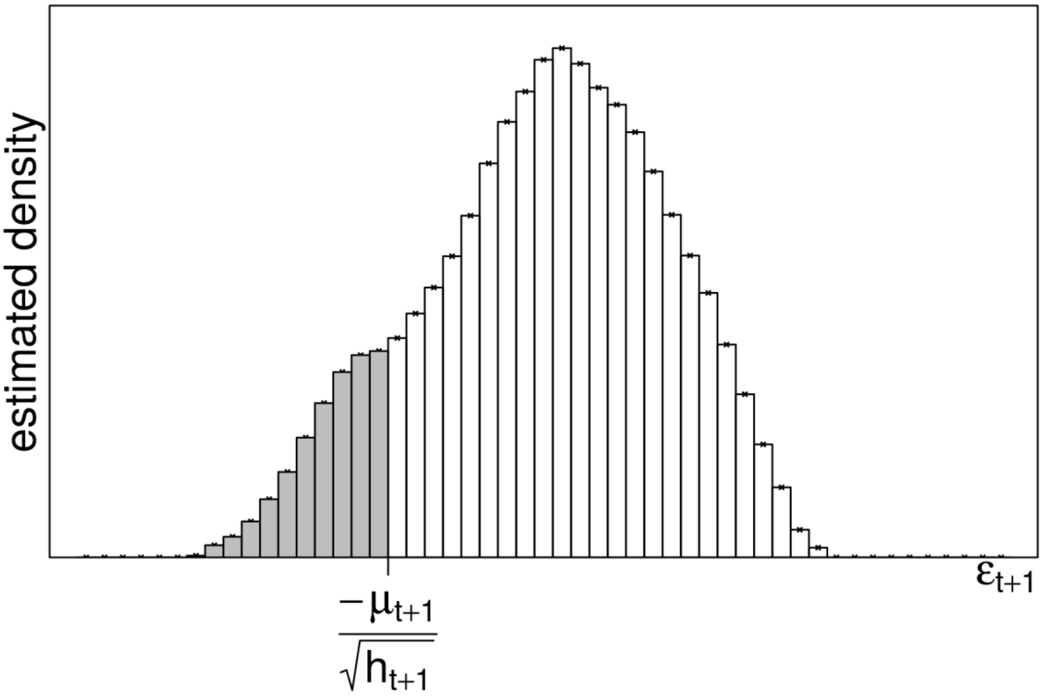


Figure 2: Estimating deflation probabilities under non-normality.

The models to be estimated are of the form:

$$\pi_t = \beta_0 + \sum_{i=1}^{l} \beta_i \pi_{t-i} + u_t \quad (6)$$

$$\pi_t = \beta_0 + \sum_{i=1}^{l} (\beta_i \pi_{t-i} + \theta_i x_{t-i}) + u_t \quad (7)$$

$$\pi_t = \beta_0 + \sum_{i=1}^{l} (\beta_i \pi_{t-i} + \theta_i x_{t-i} + \varphi_i y_{t-i}) + u_t \quad (8)$$

In the first form, the forecast model (conditional mean of inflation) includes only *l* lags of inflation. In the second form, there are also *l* lags of another variable (one of those mentioned above). In the third form, the conditional mean depends on *l* lags of inflation and of two other variables. The combination of lagged inflation and seven other variables gives a total of 29 alternative formulations of the forecast model. As in Killian and Manganelli (2007), the number of lags (l) is chosen (among $l = 1,2,3$) so as to optimise the value of the Bayesian Information Criterion.

3.2. Data

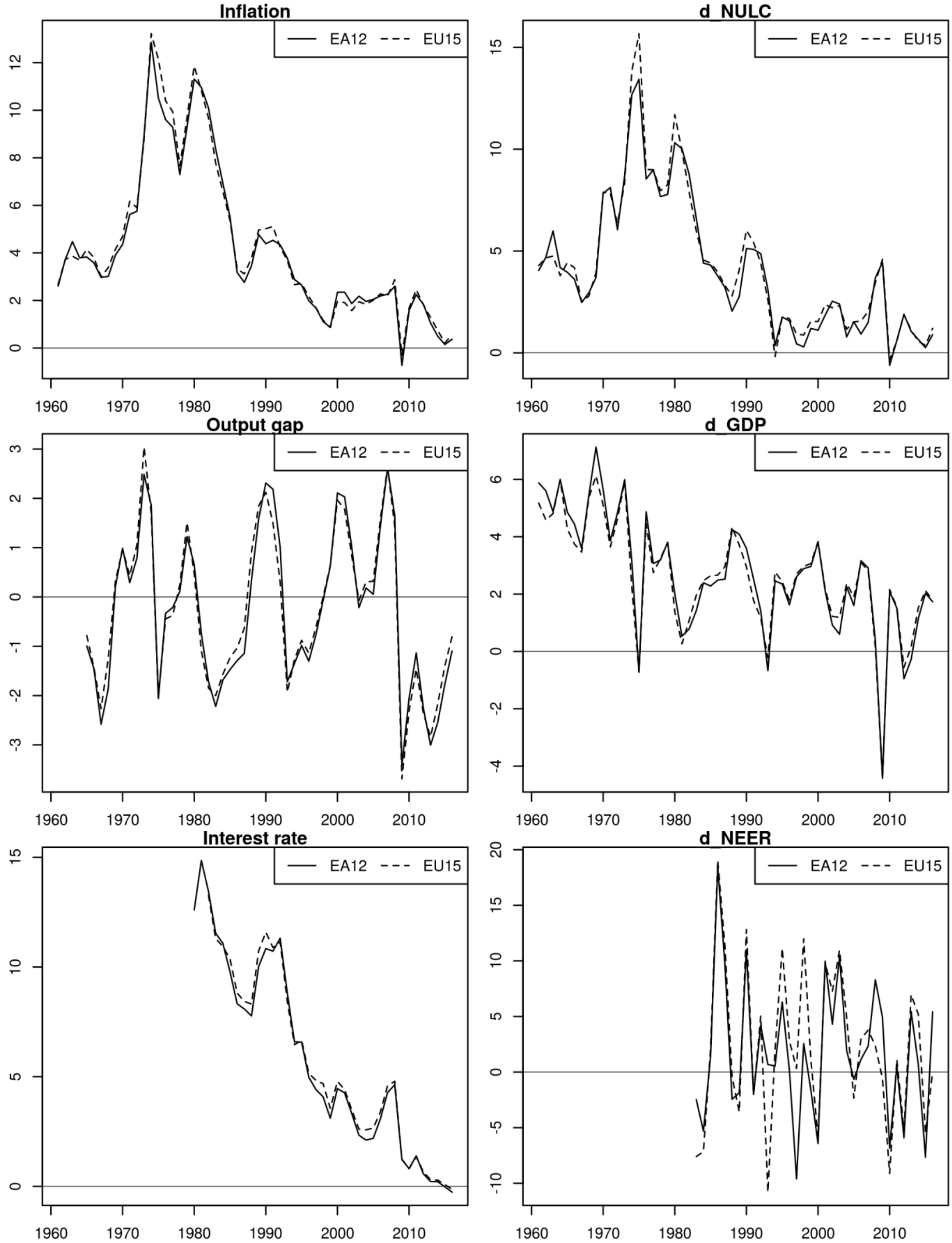
We use the following data from AMECO for the Euro Area (12 countries – EA12) and for the European Union (15 countries – EU15):

- Price deflator of private final consumption expenditure;
- Gross domestic product at constant market prices;
- Gap between actual and potential gross domestic product at constant market prices;
- Nominal unit labour costs (total economy);
- Nominal effective exchange rates (performance relative to the rest of 35 industrial countries; double export weights);
- Nominal short-term interest rates (weighted average, using GDP for the weights).

When needed, we linked series that include only West Germany until 1991, to series beginning in 1991 that include reunited Germany. Namely, this procedure was required for GDP, the output gap and the interest rate.

We constructed an oil price series with series provided by FRED (Federal Reserve Bank of St. Louis economic data) for the West Texas Intermediate oil price. To convert the oil price series from US dollars to euro we used the USD-EUR exchange rate data from AMECO. For the money supply, we used Germany's M1 aggregate (from the IMF's International Financial Statistics) and the OECD's broad money (M3) indicator for the Euro Area (19 countries). The two series were linked in 1970, which is the earliest date for which data is available for the OECD's indicator.

Most of the series span the period 1960-2016. The exceptions are the output gap (which begins in 1967), the nominal effective exchange rate (which begins in 1982) and the interest rate (which begins in 1980 for EA12 and in 1982 for EU15). Growth rates (including inflation) were computed as the first difference of the logarithm of the levels. Figure 3 shows the behaviour of the series for which we have data for both EA12 and EU15. The differences appear to be very small. For completeness, Figure 4 shows the (log) growth rate of the oil price and of money supply in Europe.



Note: “d_x” represents the (log) growth rate of variable *x* in percentage. Inflation and the output gap are also in percentage. NULC: nominal unit labour costs. NEER: Nominal effective exchange rate.

Figure 3: Time series for the Euro Area (12 countries) and the European Union (15 countries).

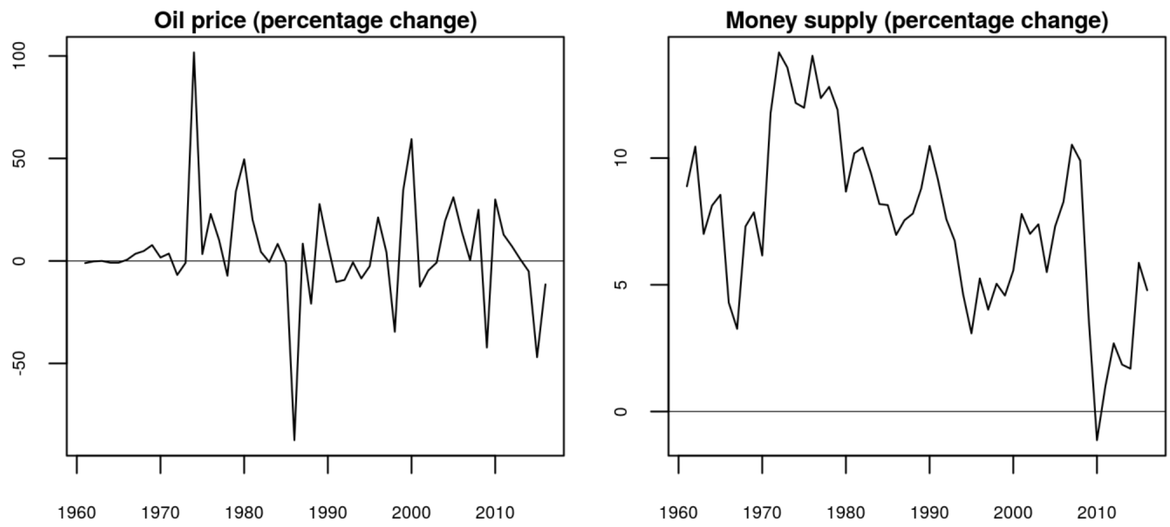


Figure 4: Oil price and money supply growth.

The time series plots reveal that deflation has only once been recorded in our sample: in 2009, the year in which the international financial crisis was at its height, as the behaviour of GDP in that year confirms.

4. Results

As mentioned above, we combine lagged inflation and six other variables in 29 different models. The list of the models is given in Table 1.

Tables 2, 3, 4 and 5 present a selection of the results obtained from estimating those models, both for EA12 and for EU15, in the sample 1984-2016, where all models can be estimated, and in a longer sample (1969-2016 in the case of EA12; 1968-2016 in the case of EU15), where we lack data to estimate 13 of the models. For comparison, Table 6 shows the result of applying our procedure to the dataset used by Kilian and Manganelli (2007).

Several results stand out. First, the preferred number of lags is almost always one, according to BIC, especially when we use the most recent sample. A small number of lags appears to be enough to account for the dynamics of inflation: only a few models show signs of autocorrelation in the residuals. Second, the root mean squared error (RMSE) is smaller in the most recent sample. This is not surprising, since this sample covers the period known as "the great moderation" – see, e.g., McConnell and Perez-Quiros (2000) and Stock and Watson (2003). Third, at the 10% significance level, almost all models fail to pass the Quandt likelihood ratio (QLR) test, i.e., almost no model appears to be have constant parameters over the sample period. Conspicuous exceptions are the models estimated with Kilian and Manganelli's data for Germany. This should be related to the fact that inflation in Germany has been much more stable than in other countries, namely in the period of the oil shocks. Fourth, ARCH effects are largely absent from the more recent sample. Evidence of conditional heteroskedasticity becomes clearly visible only when one extends the sample to include the oil-shocks period. Kilian and Manganelli associate the existence of heteroskedasticity with the failure of the models to pass the structural stability tests. Fifth, the assumption of normality is almost always rejected, except in the Kilian and Manganelli dataset. Therefore, one may want to place higher weight on the probability of deflation computed using an estimated density (recall section 3.1) rather than the probability obtained with the normal distribution (probabilities reported in the final two columns of the tables).

Besides the results just discussed, the interest of analysing the estimation output lies in being able to say something about deflation in Europe in 2017. The results make it difficult to choose one model. In fact, if we use BIC as the criterion for choosing the best model, we would choose – for both EA12 and EU15 – model 1 (purely autoregressive model) in the shorter sample and model 11 (which includes also GDP growth and labour costs) in the longer sample. However, model 1 fails the QLR test in both samples, whereas model 11 fails the QLR test in the shorter sample and passes (at the 5% significance level) in the longer sample. Restricting the choice in the shorter sample to models that pass the QLR test at the 5% significance level would lead to choosing model 29 (which includes the interest rate and the nominal effective exchange rate) for EA12 and model 8 (which features the interest rate) for EU15. We will thus focus our discussion on models 1, 8, 11 and 29.

These models produce forecasts for inflation in 2017 between 0.28% and 0.61% for EA12 and between 0.51% and 0.87% in for EU15. The dispersion of the forecasts is not large. The dispersion concerning the probability that inflation will be negative in 2017 is also relatively small: for EA12, the probability varies between 13% and 20% (using the estimated density); for EU15, the range is not very different, going from 7% to 18% (again using the estimated density). Thus, our models put the probability of deflation occurring in Europe in 2017 at less than 20%. However, the estimates obtained on the larger sample lead to bigger probabilities. This increase derives from the fact that the MSE is bigger in the larger sample. Note that the models (in general, not just the ones selected above) seem unable to anticipate changes in the trend of inflation, which were especially pronounced in the earlier part of the larger sample – see Figures 5 and 6. This inability to anticipate trend changes is not surprising for the purely autoregressive models, but it has the implication that the other variables bring no useful information in that regard.

However, how do the deflation probabilities produced by our models look like? Until 2009, they were always very low, rarely exceeding 10%. After 2009, they became much larger – see Figure 7. However, in our sample, 2009 is the only year in which there was deflation. The models completely failed to anticipate deflation in 2009, but then produced high (in some cases above 60% or even 80%) deflation probabilities for 2010, a year in which the inflation rate returned to the normal (according to the stated monetary policy goal) 1.5%-2% range. Nevertheless, inflation probabilities have been increasing in recent years (a period of declining inflation), approaching or even surpassing 20%. The current year of 2017 appears to mark a change in that trend.

Table 1: Models to be estimated.

Model	The conditional mean depends on *l* lags of:
1	Inflation
2	Inflation and money growth
3	Inflation and oil price growth
4	Inflation and the change in nominal unit labour costs
5	Inflation and GDP growth
6	Inflation and the output gap
7	Inflation and the change in the nominal effective exchange rate
8	Inflation and the interest rate
9	Inflation, money growth and GDP growth
10	Inflation, oil price growth and GDP growth
11	Inflation, the change in nominal unit labour costs and GDP growth
12	Inflation, the output gap and GDP growth
13	Inflation, the change in the nominal effective exchange rate and GDP growth
14	Inflation, the interest rate and GDP growth
15	Inflation, oil price growth and money growth
16	Inflation, the change in nominal unit labour costs and money growth
17	Inflation, the output gap and money growth
18	Inflation, the change in the nominal effective exchange rate and money growth
19	Inflation, the interest rate and money growth
20	Inflation, the change in nominal unit labour costs and oil price growth
21	Inflation, the output gap and oil price growth
22	Inflation, the change in the nominal effective exchange rate and oil price growth
23	Inflation, the interest rate and oil price growth
24	Inflation, the output gap and the change in nominal unit labour costs
25	Inflation, the change in the nominal effective exchange rate and unit labour costs
26	Inflation, the interest rate and the change in nominal unit labour costs
27	Inflation, the change in the nominal effective exchange rate and the interest rate
28	Inflation, the interest rate and the output gap
29	Inflation, the change in the nominal effective exchange rate and the interest rate

Table 2: Statistics from the estimated models using the sample 1969-2016 for EA12.

Model	BIC	Lags	RMSE	BG	QLR	ARCH	DH	$\hat{\mu}_{2017}$	$P_N(\pi_{2017} < 0)$	$P_E(\pi_{2017} < 0)$
1	170.2	1	1.315	1.65	25.9***	6.82***	18.4***	0.19	41	28
2	169.9	1	1.258	1.23	20***	2.57	23.4***	0.51	31	20
3	172.9	1	1.299	5.34**	27.4***	5.04**	14.4***	0.39	35	28
4	171.4	2	1.179	1.21	24.1***	6.15**	5.2*	0.53	19	15
5	166.6	1	1.215	0	16.6**	8.33***	16.8***	0.35	34	30
6	171.9	1	1.285	0.47	26.3***	7.94***	31.5***	0.31	39	30
9	168.6	1	1.193	0.09	18.5**	9.04***	6.2**	0.67	18	22
10	168.2	1	1.188	1.07	20.5***	6.91***	13.4***	0.4	32	28
11	164.0	1	1.136	0.18	14.3*	8.98***	16.8***	0.49	27	17
12	170.4	1	1.215	0	19.9**	8.57***	15.4***	0.36	34	29
15	173.3	1	1.252	3.17*	22***	1.98	20.9***	0.54	29	20
16	172.6	1	1.243	1.32	19.4**	1.4	20.9***	0.49	31	22
17	173.5	1	1.255	1.46	31.1***	3.6*	3.4	0.65	19	22
20	174.1	2	1.119	1.12	22.4**	4.63**	5*	0.51	21	16
21	173.1	1	1.25	2.17	38.4***	5.55**	20.5***	0.64	26	26
24	171.2	2	1.086	0.71	22**	6.49**	8.4**	0.9	9	8

Notes: BIC: Bayesian Information Criterion. Lags: the number of lags chosen for each model by BIC. RMSE: square root of the mean of the squared residuals. BG: Breusch-Godfrey test statistic (null hypothesis: no autocorrelation of order one). QLR: Quandt likelihood ratio test statistic (null hypothesis: no structural break). ARCH: LM-ARCH test statistic (null hypothesis: no ARCH effect of order one). DH: Doornik-Hansen normality test statistic (null hypothesis: normal distribution).$\hat{\mu}_{2017}$: the estimated conditional mean of inflation in 2017. $P_N(\pi_{2017} < 0)$: the estimated probability of deflation in 2017 using the normal distribution in the computation.$P_E(\pi_{2017} < 0)$: the estimated probability of deflation in 2017 using an estimated density in the computation. ***: significant at the 1% significance level. **: significant at the 5% significance level. *: significant at the 10% significance level.

Table 3: Statistics from the estimated models using the sample 1984-2016 for EA12.

Model	BIC	Lags	RMSE	BG	QLR	ARCH	DH	$\hat{\mu}_{2017}$	$P_N(\pi_{2017} < 0)$	$P_E(\pi_{2017} < 0)$
1	90.9	1	0.863	0.03	14.8**	0.62	13.3***	0.61	22	13
2	94.4	1	0.862	0.04	34.1***	0.53	10.2***	0.55	23	14
3	94.2	1	0.86	0	15.8**	0.46	5.5*	0.8	15	15
4	93.9	1	0.857	0	16.2**	0.08	13.6***	0.63	22	12
5	93.4	1	0.85	0.65	16.9**	2.85*	12.7***	0.61	19	10
6	94.3	1	0.861	0.19	26.3***	0.84	16.4***	0.64	21	10
7	94.2	1	0.86	0.01	16.8**	0.77	11.8***	0.56	24	15
8	91.6	1	0.827	0.05	14.1**	0.23	8.5**	0.35	26	17
9	96.9	1	0.849	0.71	39.2***	2.72*	10.5***	0.56	21	12
10	96.4	1	0.843	0.45	17.4**	2.91*	11.6***	0.66	18	11
11	93.9	1	0.813	1.04	29.6***	0.97	15.2***	0.72	16	7
12	96.9	1	0.849	0.55	26***	2.96*	11.3***	0.62	19	10
13	96.8	1	0.848	0.59	22.1***	2.93*	12.3***	0.59	20	11
14	94.5	1	0.82	0.54	18**	1.45	12.4***	0.52	23	13
15	97.7	1	0.86	0	33.2***	0.41	13.1***	0.8	20	10
16	97.4	1	0.857	0	32.9***	0.08	14.5***	0.78	21	10
17	97.8	1	0.861	0.3	33.3***	0.82	16.4***	0.75	22	11
18	97.5	1	0.857	0.03	32.4***	0.67	11.7***	0.53	25	16
19	95	1	0.826	0.03	30.8***	0.27	4.3	0.36	24	18
20	97.4	1	0.856	0.01	17.4**	0.08	10.6***	0.41	27	13
21	97.4	1	0.856	0.09	24***	0.68	6.1**	0.77	14	16
22	97.2	1	0.854	0.1	18.2**	0.52	9**	0.74	22	15
23	95.1	1	0.827	0.1	15.6*	0.24	8.1**	0.45	11	10
24	97.2	1	0.854	0.13	24.3***	0.14	16.2***	0.57	24	11
25	96.5	1	0.845	0.06	16.2*	0.01	12.3***	0.59	23	15
26	95.1	1	0.827	0.07	13.7	0.18	8.2**	0.37	22	14
27	97.4	1	0.857	0.21	25.5***	1.12	15.4***	0.54	24	13
28	95.1	1	0.827	0.07	21.6***	0.21	9.8***	0.33	27	17
29	93.8	1	0.811	0.01	12.3	0.34	6.8**	0.28	30	20

Notes: BIC: Bayesian Information Criterion. Lags: the number of lags chosen for each model by BIC. RMSE: square root of the mean of the squared residuals. BG: Breusch-Godfrey test statistic (null hypothesis: no autocorrelation of order one). QLR: Quandt likelihood ratio test statistic (null hypothesis: no structural break). ARCH: LM-ARCH test statistic (null hypothesis: no ARCH effect of order one). DH: Doornik-Hansen normality test statistic (null hypothesis: normal distribution). $\hat{\mu}_{2017}$: the estimated conditional mean of inflation in 2017. $P_N(\pi_{2017} < 0)$: the estimated probability of deflation in 2017 using the normal distribution in the computation. $P_E(\pi_{2016} < 0)$: the estimated probability of deflation in 2017 using an estimated density in the computation. ***: significant at the 1% significance level. **: significant at the 5% significance level. *: significant at the 10% significance level.

Table 4: Statistics from the estimated models using the sample 1968-2016 for EU15.

Model	BIC	Lags	RMSE	BG	QLR	ARCH	DH	$\hat{\mu}_{2017}$	$P_N(\pi_{2017} < 0)$	$P_E(\pi_{2017} < 0)$
1	173	1	1.305	2.18	27.2***	2.86*	9**	0.5	25	15
2	172.9	1	1.254	1.78	21.5***	0.61	14.4***	0.5	23	12
3	175.6	2	1.191	0.32	31.1***	7.77***	6.5**	1.49	2	2
4	175.3	1	1.285	1.72	26.1***	1.94	11.7***	0.54	24	14
5	166	1	1.168	0.13	21.9***	3.9**	1.3	0.31	33	34
6	171.5	1	1.236	0.51	38.5***	4.87**	24.2***	0.51	31	21
9	168.4	1	1.151	0.3	23.7***	5.01**	7.8**	0.41	27	26
10	168.6	1	1.154	1.26	20.6***	3.74*	4.7*	0.44	24	25
11	162.5	1	1.084	0.6	14.1	4.48**	8.1**	0.87	21	18
12	169.2	1	1.16	0.02	28.9***	5.28**	3	0.47	23	25
15	176.7	1	1.253	3.3*	24.2***	0.52	14.4***	0.79	25	24
16	176.1	1	1.245	1.68	21.4***	0.26	19.1***	0.7	22	13
17	174.8	1	1.229	1.41	39.4***	2.94*	6.7**	0.78	11	13
20	179	1	1.282	3.43*	27.9***	1.62	11.8***	0.5	27	16
21	173.2	1	1.209	1.79	43.3***	3.82*	19.6***	0.58	28	19
24	171.8	2	1.058	0.89	28.7***	4.18**	0.2	1.19	5	6

Notes: BIC: Bayesian Information Criterion. Lags: the number of lags chosen for each model by BIC. RMSE: square root of the mean of the squared residuals. BG: Breusch-Godfrey test statistic (null hypothesis: no autocorrelation of order one). QLR: Quandt likelihood ratio test statistic (null hypothesis: no structural break). ARCH: LM-ARCH test statistic (null hypothesis: no ARCH effect of order one). DH: Doornik-Hansen normality test statistic (null hypothesis: normal distribution). $\hat{\mu}_{2017}$: the estimated conditional mean of inflation in 2017. $P_N(\pi_{2017} < 0)$: the estimated probability of deflation in 2017 using the normal distribution in the computation. $P_E(\pi_{2017} < 0)$: the estimated probability of deflation in 2017 using an estimated density in the computation. ***: significant at the 1% significance level. **: significant at the 5% significance level. *: significant at the 10% significance level.

Table 5: Statistics from the estimated models using the sample 1984-2016 for EU15.

Model	BIC	Lags	RMSE	BG	QLR	ARCH	DH	$\hat{\mu}_{2017}$	$P_N(\pi_{2017} < 0)$	$P_E(\pi_{2017} < 0)$
1	87.8	1	0.823	0.09	14.7**	1.23	6.1**	0.72	9	7
2	91.2	1	0.822	0.12	32***	1	5.2*	0.73	8	6
3	90.9	1	0.819	0.01	16.2**	0.95	6.6**	0.64	14	9
4	90.1	1	0.809	0.03	14.1**	0.09	5.4*	0.67	12	6
5	90.2	1	0.809	0.74	18.7***	4.42**	6.5**	0.59	14	8
6	91.1	1	0.82	0.37	33.9***	1.46	11.6***	0.6	14	6
7	91.3	1	0.823	0.08	19.7***	1.18	3.6	0.89	3	3
8	88.8	1	0.793	0.05	14*	0.73	3.5	0.51	16	12
9	93.6	1	0.809	0.78	44.3***	4.13**	4.2	0.77	9	9
10	92.9	1	0.8	0.43	19.8**	4.73**	4.7*	0.52	18	15
11	89.5	1	0.76	0.59	29.8***	1.34	11.3***	0.84	9	6
12	93.7	1	0.809	0.66	35.6***	4.56**	2.6	0.55	11	12
13	93.5	1	0.807	0.86	25.1***	4.37**	15.6***	0.95	15	6
14	91.7	1	0.786	0.4	21.5***	3*	4.8*	0.61	10	9
15	94.4	1	0.818	0.02	30***	0.79	5.7*	0.61	15	12
16	93.6	1	0.808	0.01	30.2***	0.1	4.8*	0.77	8	6
17	94.6	1	0.82	0.73	33.9***	1.51	7.5**	0.55	20	14
18	94.6	1	0.821	0.1	36.5***	0.87	5.7*	0.7	11	7
19	92.2	1	0.792	0.03	29.2***	0.92	3.1	0.56	10	8
20	93.6	1	0.808	0	15.4*	0.09	6.6**	0.72	11	6
21	93.9	1	0.813	0.22	30.4***	1.15	11.3***	0.66	19	9
22	94.2	1	0.816	0	20.9***	0.72	3.8	0.77	5	4
23	92.3	1	0.793	0.03	14.8*	0.67	2.5	0.46	19	16
24	93.5	1	0.807	0.22	29.9***	0.13	6.8**	0.71	11	8
25	93.4	1	0.806	0.01	17.7**	0.04	6.5**	0.73	10	7
26	92	1	0.79	0.03	13.9	0.17	2.2	0.55	11	9
27	94.5	1	0.819	0.42	42.6***	1.38	9.1**	0.66	9	5
28	92.3	1	0.793	0.06	28.1***	0.7	13***	0.66	13	6
29	91.5	1	0.783	0.01	16.6**	0.37	1.6	0.59	6	6

Notes: BIC: Bayesian Information Criterion. Lags: the number of lags chosen for each model by BIC. RMSE: square root of the mean of the squared residuals. BG: Breusch-Godfrey test statistic (null hypothesis: no autocorrelation of order one). QLR: Quandt likelihood ratio test statistic (null hypothesis: no structural break). ARCH: LM-ARCH test statistic (null hypothesis: no ARCH effect of order one). DH: Doornik-Hansen normality test statistic (null hypothesis: normal distribution). $\hat{\mu}_{2017}$: the estimated conditional mean of inflation in 2017. $P_N(\pi_{2017} < 0)$: the estimated probability of deflation in 2017 using the normal distribution in the computation. $P_E(\pi_{2017} < 0)$: the estimated probability of deflation in 2017 using an estimated density in the computation. ***: significant at the 1% significance level. **: significant at the 5% significance level. *: significant at the 10% significance level.

Table 6: Statistics from the estimated models using the dataset of Kilian and Manganelli (2007).

Model	BIC	Lags	RMSE	BG	QLR	ARCH	DH	$\hat{\mu}_{2003}$	$P_N(\pi_{2003} < 0)$	$P_E(\pi_{2003} < 0)$
USA										
1	164.1	3	1.644	0.02	18.5**	0.62	2.5	2.06	5	3
2	166.9	1	1.786	3.67*	32.4***	3.13*	4.5	2.23	12	11
3	168.0	1	1.811	4.77**	15.6**	3.27*	5.2*	2.50	7	5
15	170.5	1	1.784	4.09*	30.4***	3.41*	3.8	2.22	11	11
Germany										
1	138.1	1	1.190	1.14	5.9	2.44	0.5	1.44	12	14
2	139.9	1	1.163	0.89	5.3	2.02	1.5	1.28	12	20
3	141.3	1	1.184	1.05	6.9	2.11	1.0	1.52	11	12
15	143.0	1	1.155	0.68	6.4	1.87	2.0	1.20	13	20
Japan										
1	203.8	1	2.819	1.41	17.1***	12.16***	13.9***	-0.44	64	72
2	191.0	2	2.093	0.86	17.9*	1.78	2.4	-0.67	73	77
3	207.5	1	2.819	1.40	31.8***	12.31***	13.8***	-0.43	64	72
15	197.3	1	2.368	3.96*	24.3***	1.33	1.5	-0.40	63	67

Notes: BIC: Bayesian Information Criterion. Lags: the number of lags chosen for each model by BIC. RMSE: square root of the mean of the squared residuals. BG: Breusch-Godfrey test statistic (null hypothesis: no autocorrelation of order one). QLR: Quandt likelihood ratio test statistic (null hypothesis: no structural break). ARCH: LM-ARCH test statistic (null hypothesis: no ARCH effect of order one). DH: Doornik-Hansen normality test statistic (null hypothesis: normal distribution). $\hat{\mu}_{2003}$: the estimated conditional mean of inflation in 2003. $P_N(\pi_{2003} < 0)$: the estimated probability of deflation in 2003 using the normal distribution in the computation. $P_E(\pi_{2003} < 0)$: the estimated probability of deflation in 2003 using an estimated density in the computation. ***: significant at the 1% significance level. **: significant at the 5% significance level. *: significant at the 10% significance level.

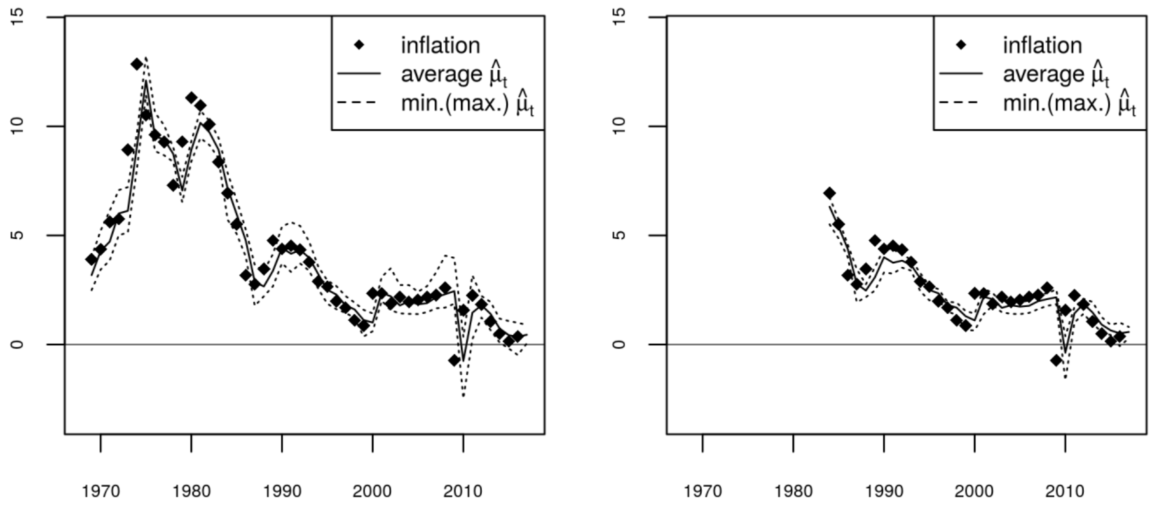


Figure 5: Maximum, minimum and average estimated conditional mean of inflation in EA12 using (when available) the sample 1969-2016 (left) or just 1984-2016 (right).

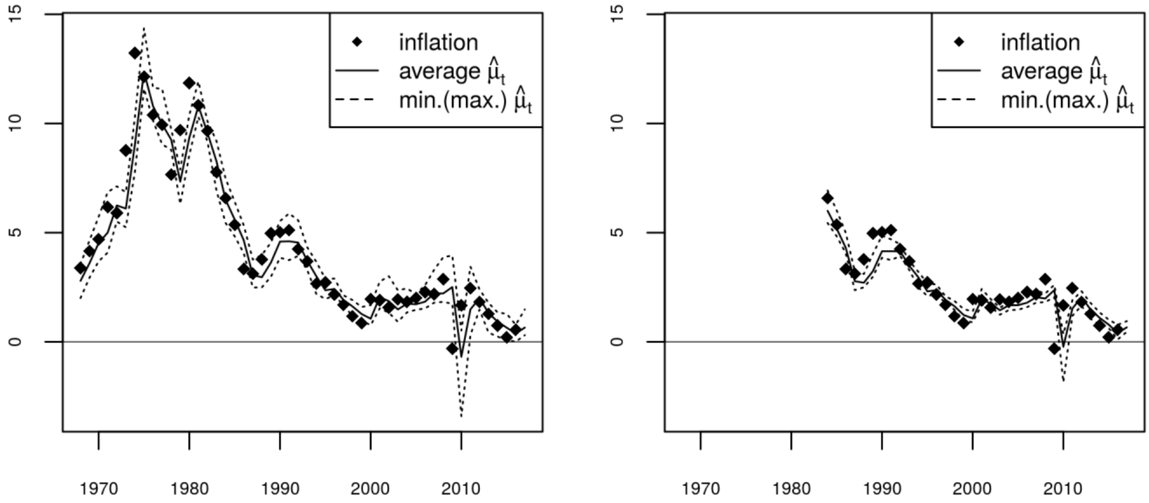


Figure 6: Maximum, minimum and average estimated conditional mean of inflation in EU15 using (when available) the sample 1968-2016 (left) or just 1984-2016 (right).

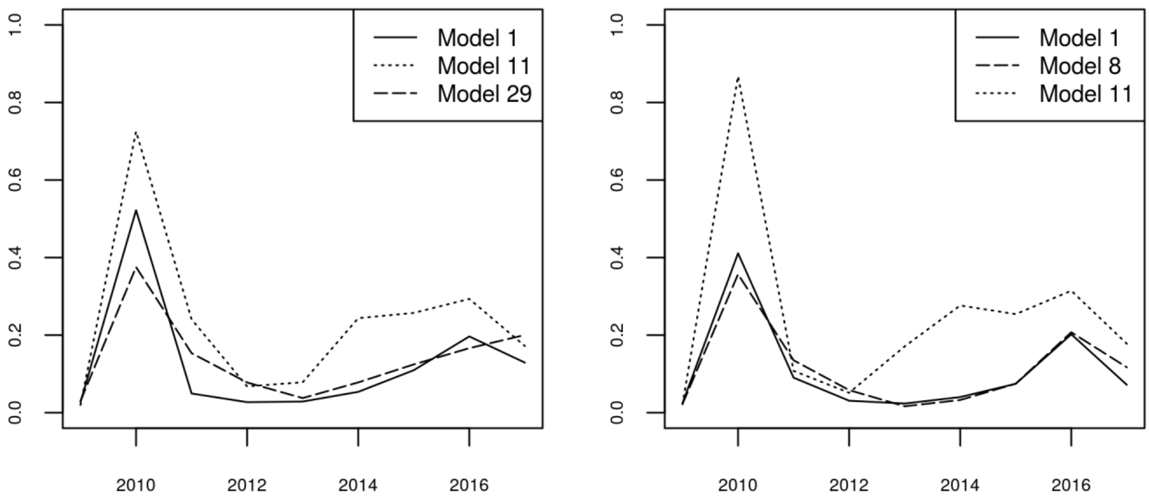


Figure 7: Probability of deflation in EA12 (left) and EU15 (right).

5. Conclusion

The main objective of this paper was to estimate the probability of deflation occurring in the Euro Area (12 countries – EA12) and in the European Union (15 countries – EU15). For this purpose, we applied the methodology developed by Kilian and Manganelli (2007). The results show an increase in deflation probabilities after 2009, when the international financial crisis was giving way to the sovereign debt crisis in the Euro area. Deflation probabilities were approaching 20%, but in 2017 that trend seems to have been reversed. This corroborates the ECB's Governing Council's view. The models analyzed in the paper put the probability of deflation occurring in Europe in 2017 between 7% and 20%. However, the uncertainty concerning the appropriate model for forecasting inflation in the Euro zone is large, thus these conclusions should be taken with some caution.

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