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Abstract

By means of structural VARs we investigate the long-run nexus between inflation and output in the Eurozone under different identification schemes and model specifications. The Eurozone is an interesting case study due to its very low inflation rate and to the official adherence of its monetary authority to the classical dichotomy. We find a strong positive long-run connection between inflation and output, supporting recent theoretical models arguing that this might exist at low long-run inflation rates.

Keywords: long-run, non-vertical Phillips curve, empirical evidence

JEL Codes: E31, E40, E50, J64

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Introduction

Many economists and economic policy makers believe in the classical dichotomy (Mishkin, 2007). Yet, recent theoretical models imply nonlinearities in the long-run output-inflation nexus. Output and inflation are positively connected at low inflation rates, but negatively at high ones (Deveraux and Yetman, 2002; Vaona and Snower, 2008; Graham and Snower, 2008; Ahrens and Snower, 2014).

Low inflation rates – nonetheless subject to permanent shifts – are seldom observed for long periods of time (Dickens, 2001). Hence, high inflation observations might drive the results of cross-country studies (Ericsson et al., 2001). Nonetheless, Bullard and Keating (1995) find positive long-run output-inflation nexuses in low inflation countries.

Under these respects, the Eurozone experienced very low inflation rates for about two decades. The purpose of the present note is, therefore, to shed further light on the above issues by focusing on the Euro area.

Next, we introduce our data and methods. Baseline results and robustness checks follow. Finally, we conclude.

Data and Methods

We consider OECD quarterly series concerning the GDP deflator and the GDP in 2005 prices from 1996Q1 to 2014Q4. Inflation is computed with reference to the same quarter of the previous year. Data are in logs. Robustness checks also consider data regarding the harmonized consumer price index (CPI) and the short-term interest rate. Figures 1 and 2 show the series. The beginning and the end of the sample are characterized by some instability: a pattern to keep into account in the following of the analysis.

Figure 1 – Inflation in the Eurozone, 1996Q1-2014Q4

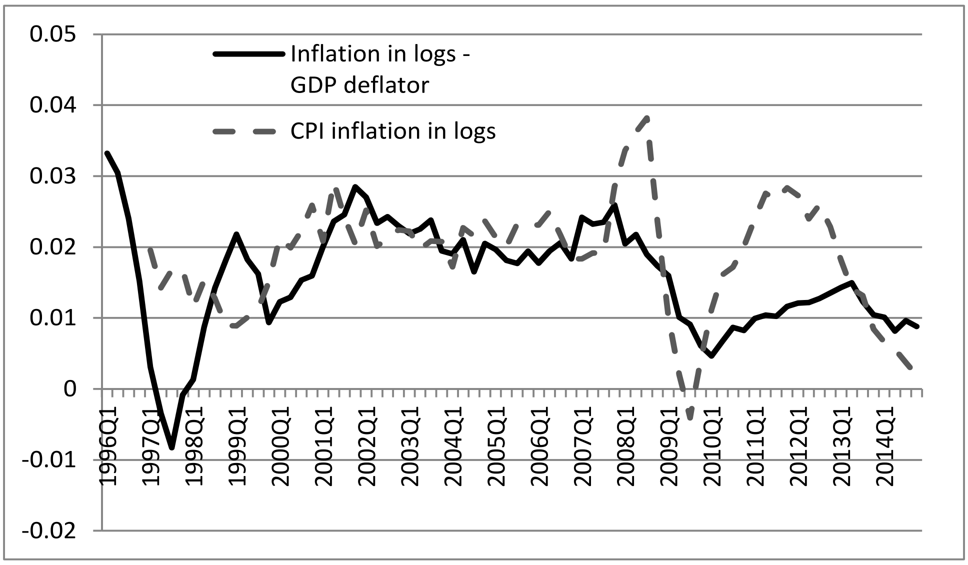
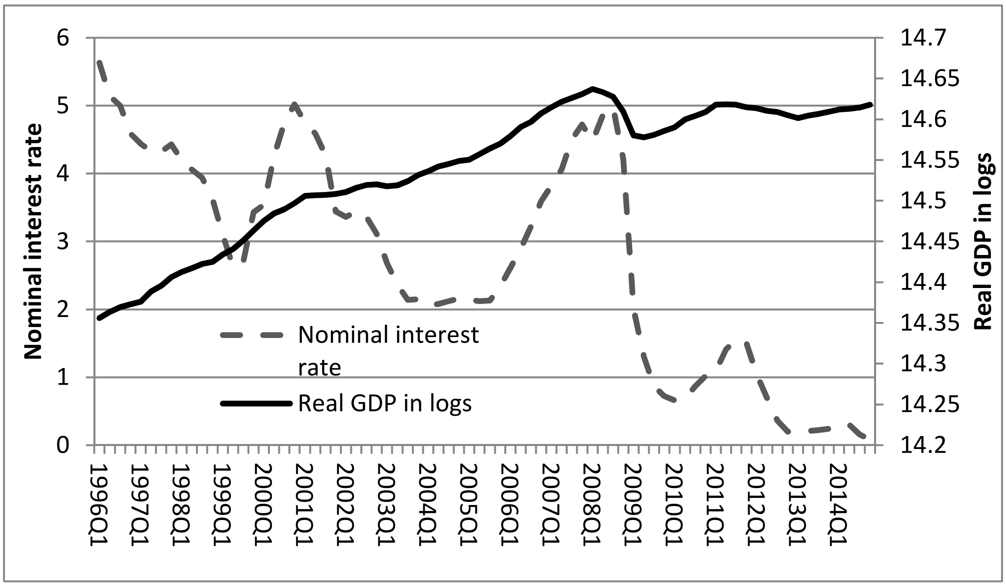


Figure 2 – Real GDP and the nominal interest rate in the Eurozone, 1996Q1-2014Q4



Regarding our methods, we start with unit root and (single equation) cointegration testing. We use the Schwarz information criterion (SIC) to choose the lag length of all tests. For brevity sake, we here only report the Augmented Dickey-Fuller (ADF) and the Phillips and Perron (PP) tests, the latter based on a spectral OLS autoregressive approach. More unit root tests are available upon request.

If tests detect cointegration, we will resort to a VECM. If all variables turn out to be I(1) but not cointegrated, we will resort to VARs in first differences after Davidson et al. (1978). We choose the lag length computing five criteria: the sequential modified likelihood ratio test statistic (LR), the final prediction error (FPE), the Akaike information criterion (AIC), the SIC, and the Hannan-Quinn information criterion (HQ). Next we follow the majority of the criteria. Furthermore, we use AIC to impose zero restrictions on the parameters of the included lags in baseline results, while in robustness checks we rely on HQ.

Estimation of bivariate structural VARS is widespread in the literature (as surveyed in Vaona, 2015). More specifically, we mainly rely on Blanchard and Quah (1989) decompositions (hereafter BQ), adopting a monetarist view, namely that, in the long-run, inflation is a purely monetary phenomenon (Roberts, 1993; Bullard and Keating, 1995; Rapach, 2003). Baseline results also include the identification approach by Cover et al. (2006) and Bashar (2011). Suffice here to say that this identification strategy assumes a vertical long-run aggregate supply curve, that can be shifted by movements of the demand curve, as demand shocks may induce more innovation and higher productivity. More technically, the approach by Bashar (2011) entails estimating an AB SVAR in output growth and inflation changes where the A matrix is $\begin{bmatrix} 1 & -\alpha \\ 1 & 1 \end{bmatrix}$ and the B matrix is $\begin{bmatrix} \cdot & \cdot \\ 0 & \cdot \end{bmatrix}$. Parameters to be estimated are denoted by dots. The value of α is derived from the identification assumption that demand shocks do not have any long-run real effect unless when shifting the supply curve.[1]

[1] Bashar (2003) diffusely compares BQ and Cover et al. (2006).

In robustness checks, we introduce an interest rate measure to move to a trivariate SVAR and we adopt the identification strategy by Rapach (2003), encompassing a monetarist view of long-run inflation and the assumption that, in the long-run, technological shocks do not influence the interest rate.

In baseline results we make use of accumulated structural impulse response functions (SIRFs) and forecast error variance decompositions (FEVD). While illustrating our robustness checks, for sake of brevity, we will focus on long term derivatives after, for instance, Rapach (2003). The long-run derivative of GDP with respect to inflation can be defined as

$$LRD_{GDP,INF} = \lim_{k\to\infty}\left(\partial GDP_{t+k}/\partial \varepsilon_{INF,t}\right)/\left(\partial INF_{t+k}/\partial \varepsilon_{INF,t}\right) \quad (1)$$

where *INF* denotes the inflation rate and $\varepsilon_{INF,t}$ the identified inflation shock. Further note that, in a trivariate setting, as in Rapach (2003) the infinite horizon response of structural disturbances is

$$\lim_{s\to\infty}\begin{pmatrix} INF_{t+s} \\ R_{t+s} \\ GDP_{t+s} \end{pmatrix} = \begin{pmatrix} d_{11} & 0 & 0 \\ d_{21} & d_{22} & 0 \\ d_{31} & d_{32} & d_{33} \end{pmatrix}\begin{pmatrix} \varepsilon_{INF,t} \\ \varepsilon_{R,t} \\ \varepsilon_{GDP,t} \end{pmatrix} \quad (2)$$

Therefore $LRD_{GDP,INF} = \frac{d_{31}}{d_{11}}$. The application of this equality to the bivariate case is straightforward. For notational purposes, the infinite horizon response of structural disturbances of a bivariate inflation-output SVAR with a monetarist identification assumption is

$$\lim_{s\to\infty}\begin{pmatrix} INF_{t+s} \\ GDP_{t+s} \end{pmatrix} = \begin{pmatrix} c_{11} & 0 \\ c_{21} & c_{22} \end{pmatrix}\begin{pmatrix} \varepsilon_{INF,t} \\ \varepsilon_{GDP,t} \end{pmatrix} \quad (3)$$

For most of our estimates we used JMulti after Lütkepohl and Krätzig (2004).

Baseline results

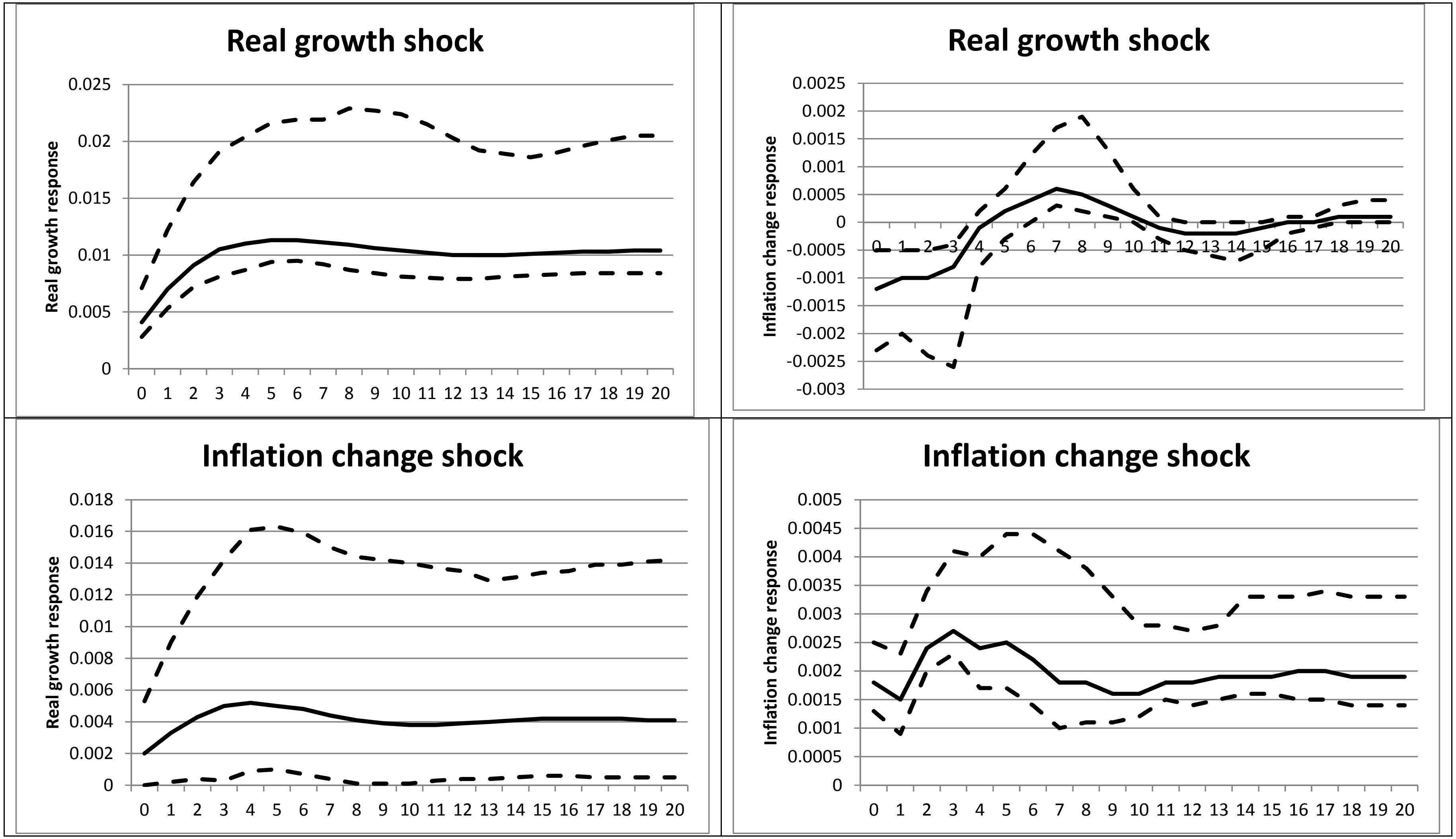
We start by running unit root and cointegration tests. Table 1 shows that inflation and real output are I(1), but they are not cointegrated.

Table 1 – Unit root and cointegration tests (p-values)

Unit root tests				
	ADF		**PP**	
	Levels	**First differences**	**Levels**	**First differences**
Inflation	0.10	0.00	0.10	0.00
Real Output	0.22	0.00	0.20	0.00
Single equation cointegration tests (null of no cointegration)				
Inflation equation	0.35			
Real output equation	0.87			

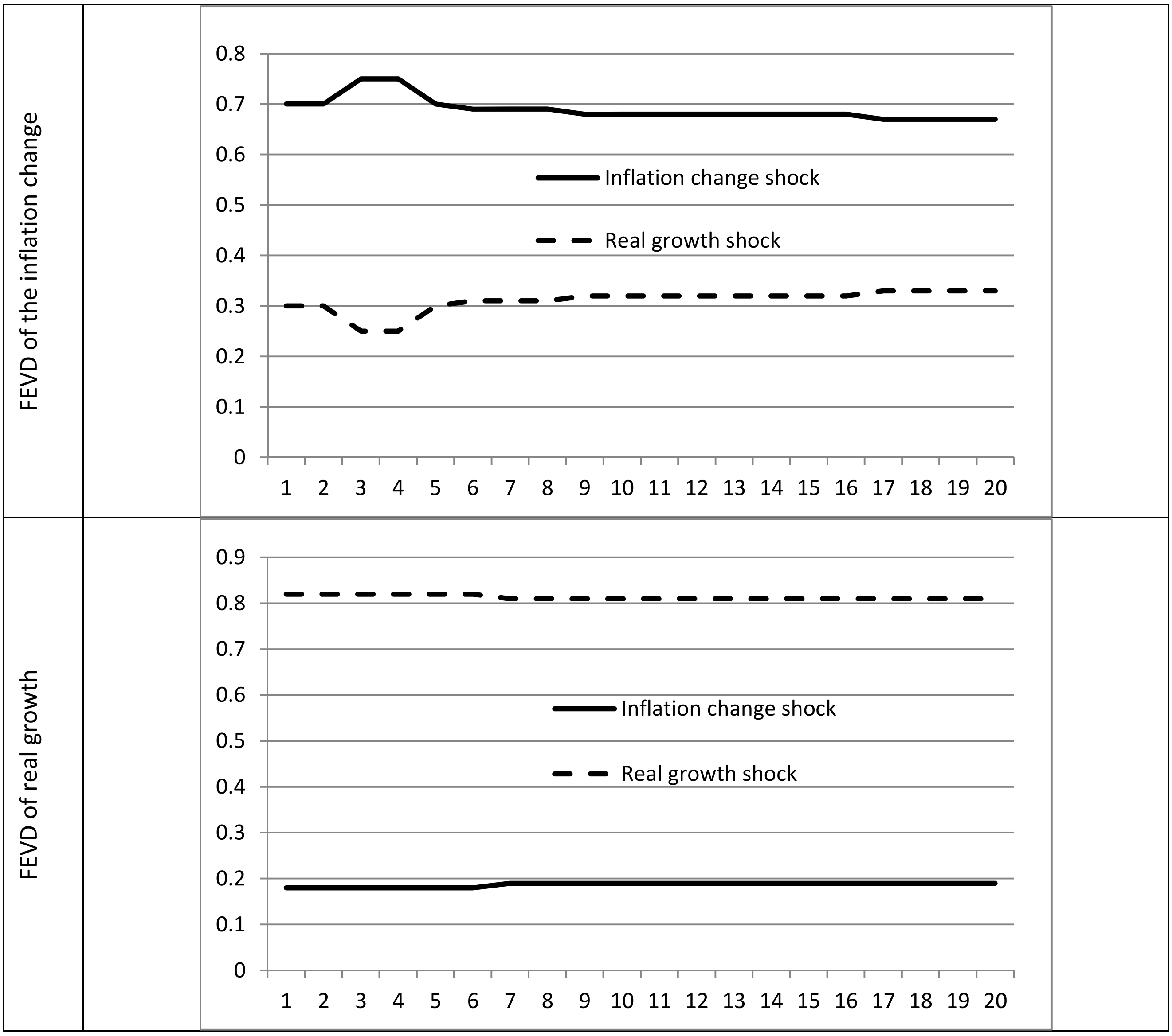
Hence, we estimate a VAR in first differences for output and inflation. Three lag length criteria (FPE, LR and AIC) point to 5 as the most suitable choice, the other two would point to a shorter lag structure. We stick to the majority of the criteria and we compute accumulated SIRFs (Figure 1). We find permanent effects of inflation on output. c_{11} is estimated to be 0.002 – with a bootstrapped t-statistic of 5.71 - while the estimated c_{21} is 0.004 – with a bootstrapped t-statistic of 2.08 - implying a value of $LRD_{GDP,INF}$ of 2. Bootstrapping should make our results robust to departures from standard assumptions regarding error processes.

Figure 1 – Accumulated impulse-response functions to one standard deviation structural shock (BQ identification)



Notes. 95% Studentized Hall Confidence Bootstrapped Intervals based on 200 repetitions.

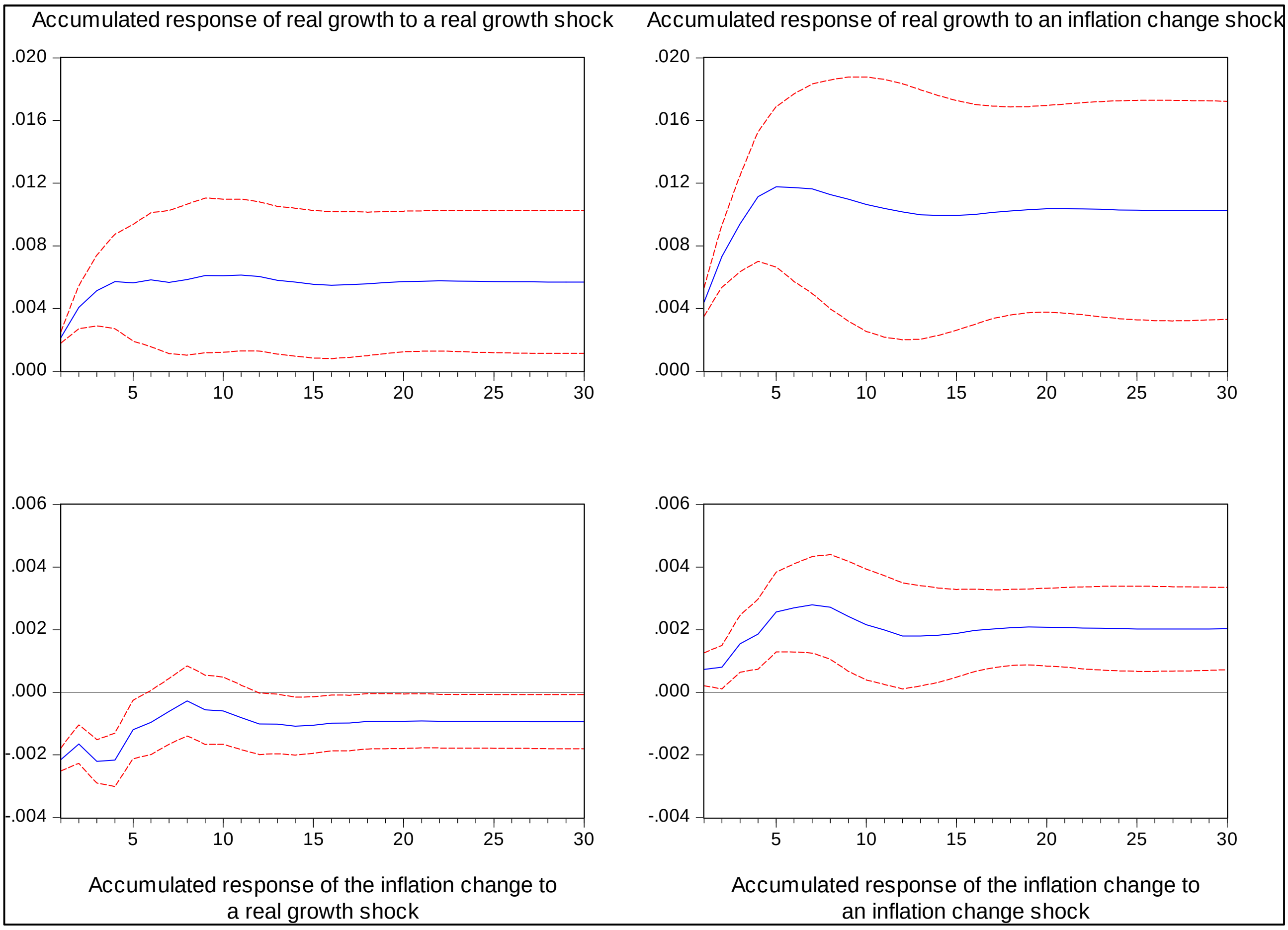
Figure 2 – Forecast error variance decompositions (BQ identification)



The effect of output shocks can be interpreted as the result of technological developments that raise output and reduce costs and inflation.

Figure 2 shows FEVDs: inflation shocks mainly drive inflation, while output shocks mainly output. Figure 3 shows SIRFs upon adopting the identification strategy à la Cover et al. (2006). Results are qualitatively similar those in Figure 1. Quantitatively they imply a larger $LRD_{GDP,INF}$ of 4.98. Finally note that after about two years SIRFs hit their long-run value making a medium run identification approach, as in Lastrapes (1998), superfluous.

Figure 3 - – Accumulated impulse-response functions to one standard deviation structural shock (identification à la Cover et al., 2006)



Note. Analytic response standard errors.

Robustness checks

Building on Figures 1 and 2, we start our robustness checks by focusing on subsample stability. We first drop observations before the introduction of Euro coins and banknotes and, then, we drop observations after the collapse of Lehman Brothers. In addition, we change our measure of inflation shifting from the GDP deflator to the CPI. Finally, we run a trivariate SVAR.

Table 2 – Unit root and cointegration tests (p-values)

Unit root tests				
	ADF		**PP**	
	Levels	**First differences**	**Levels**	**First differences**
CPI Inflation	0.23	0.00	0.07	0.00
Nominal interest rate	0.12	0.00	0.23	0.00
Single equation cointegration tests (null of no cointegration)				
Inflation equation	0.42			
Real output equation	0.34			
Nominal interest rate equation	0.12			

Inspecting Table 2, it is possible to conclude that both CPI inflation and the nominal interest rate are I(1). In a trivariate setting no cointegration shows up. Therefore, we can proceed applying the BQ decomposition. Table 3 shows the results concerning lag-length criteria, the estimated values of the relevant parameters of the long-run impact matrix and the implied long-run derivatives. Results are broadly similar to those contained in the above section. It is worth noting that $LRD_{GDP,INF}$ is larger in the more recent subsample, when inflation was lower. Upon inserting the nominal interest rate, $LRD_{GDP,INF}$ halves but it is still positive and the significance of underlying parameter is not affected to a great extent.

Table 3 - Results of robustness checks

Robustness check	**Lag length criteria**	**c_{11}**	**c_{21}**	**d_{11}**	**d_{31}**	**$LRD_{GDP,INF}$**
Sample 2002Q1-2014Q4	5[i]	0.0018 [3.4378]	0.0081 [1.9612]	-	-	4.5
Sample 1996Q1-2008Q3	5[i]	0.0025 [3.6170]	0.006 [2.1162]	-	-	2.4
CPI instead of GDP deflator	4[i]	0.0043 [4.1094]	0.0112 [2.9078]	-	-	2.6
Trivariate VAR	1[ii]	-	-	0.0052 [4.7001]	0.0053 [1.9583]	1.01

Notes. Bootstrapped t-statistics in brackets. i: chosen on the basis of LR, FPE and AIC. ii: chosen on the basis of FPE, AIC, SIC and HQ.

Conclusions

To conclude, we compare our results to those available in the literature and briefly infer some policy implications.

Our estimates of $LRD_{GDP,INF}$ are larger than the significant ones available, for instance, in Bullard and Keating (1995), namely those for Austria, Germany, Finland and the UK. However, it is also true that from the early sixties to 1992 - their observation period - inflation yearly rates ranged from 4% in Germany to 8% in the UK. In our sample, the average inflation rate is 1.5%. Our results are likely to derive from the nonlinearities in the output-inflation nexus highlighted by recent theoretical studies. We cannot detect, though, the threshold after which the effect of inflation on output either disappears or turns negative, exactly because of low inflation rates throughout our sample.

Under a policy perspective, the ECB officially adheres to the classical dichotomy (ECB, 2011, 55). There could be advantages in fully recognizing that, at low inflation rates, this might not hold. Firstly, monetary policy making might turn less conflictual, gaining credibility. Secondly, more consciousness regarding the long-run effects of monetary policy might avoid either unnecessary delays in interventions or too restrictive stances.

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Appendix to Positive long-run inflation non-superneutrality in the Euro area (not for publication)

Unit root tests

Log of inflation rate (LOGINFLA)

DF-GLS

Levels

Null Hypothesis: LOGINFLA has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on SIC, maxlag=11)

		t-Statistic
Elliott-Rothenberg-Stock DF-GLS test statistic		-0.972486
Test critical values:	1% level	-2.596160
	5% level	-1.945199
	10% level	-1.613948

*MacKinnon (1996)

DF-GLS Test Equation on GLS Detrended Residuals
Dependent Variable: D(GLSRESID)
Method: Least Squares
Date: 03/30/15 Time: 08:19
Sample (adjusted): 1996Q2 2014Q4
Included observations: 75 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
GLSRESID(-1)	-0.032362	0.033277	-0.972486	0.3340

R-squared	0.003847	Mean dependent var	-0.000325
Adjusted R-squared	0.003847	S.D. dependent var	0.003473
S.E. of regression	0.003466	Akaike info criterion	-8.478395
Sum squared resid	0.000889	Schwarz criterion	-8.447495
Log likelihood	318.9398	Hannan-Quinn criter.	-8.466057
Durbin-Watson stat	1.241582		

First differences

Null Hypothesis: D(LOGINFLA) has a unit root
Exogenous: Constant
Lag Length: 3 (Automatic - based on SIC, maxlag=11)

		t-Statistic
Elliott-Rothenberg-Stock DF-GLS test statistic		-4.963189
Test critical values:	1% level	-2.597939
	5% level	-1.945456
	10% level	-1.613799

*MacKinnon (1996)

DF-GLS Test Equation on GLS Detrended Residuals
Dependent Variable: D(GLSRESID)
Method: Least Squares

Date: 03/30/15 Time: 08:20
Sample (adjusted): 1997Q2 2014Q4
Included observations: 71 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
GLSRESID(-1)	-0.596373	0.120159	-4.963189	0.0000
D(GLSRESID(-1))	-0.195164	0.128756	-1.515769	0.1343
D(GLSRESID(-2))	0.264152	0.128387	2.057475	0.0435
D(GLSRESID(-3))	0.364709	0.105631	3.452671	0.0010

R-squared	0.513673	Mean dependent var	0.000158
Adjusted R-squared	0.491897	S.D. dependent var	0.003979
S.E. of regression	0.002836	Akaike info criterion	-8.838018
Sum squared resid	0.000539	Schwarz criterion	-8.710544
Log likelihood	317.7497	Hannan-Quinn criter.	-8.787326
Durbin-Watson stat	2.000573		

ERS Point Optimal

Levels

Null Hypothesis: LOGINFLA has a unit root
Exogenous: Constant
Lag length: 0 (Spectral OLS AR based on SIC, maxlag=11)
Sample: 1996Q1 2014Q4
Included observations: 76

		P-Statistic
Elliott-Rothenberg-Stock test statistic		16.17853
Test critical values:	1% level	1.911600
	5% level	3.042800
	10% level	4.045200

*Elliott-Rothenberg-Stock (1996, Table 1)

HAC corrected variance (Spectral OLS autoregression)	1.09E-05

First differences

Null Hypothesis: D(LOGINFLA) has a unit root
Exogenous: Constant
Lag length: 3 (Spectral OLS AR based on SIC, maxlag=11)
Sample (adjusted): 1996Q2 2014Q4
Included observations: 75 after adjustments

		P-Statistic
Elliott-Rothenberg-Stock test statistic		0.078111
Test critical values:	1% level	1.910000
	5% level	3.040000
	10% level	4.040000

*Elliott-Rothenberg-Stock (1996, Table 1)

HAC corrected variance (Spectral OLS autoregression)	0.000129

Ng_perron

Levels

Null Hypothesis: LOGINFLA has a unit root
Exogenous: Constant
Lag length: 0 (Spectral GLS-detrended AR based on SIC, maxlag=11)
Sample: 1996Q1 2014Q4
Included observations: 76

		MZa	MZt	MSB	MPT
Ng-Perron test statistics		-2.15947	-0.87107	0.40337	10.0263
Asymptotic critical values*:	1%	-13.8000	-2.58000	0.17400	1.78000
	5%	-8.10000	-1.98000	0.23300	3.17000
	10%	-5.70000	-1.62000	0.27500	4.45000

*Ng-Perron (2001, Table 1)

HAC corrected variance (Spectral GLS-detrended AR)	1.19E-05

First differences

Null Hypothesis: D(LOGINFLA) has a unit root
Exogenous: Constant
Lag length: 3 (Spectral GLS-detrended AR based on SIC, maxlag=11)
Sample (adjusted): 1996Q2 2014Q4
Included observations: 75 after adjustments

		MZa	MZt	MSB	MPT
Ng-Perron test statistics		-62.8337	-5.60392	0.08919	0.39260
Asymptotic critical values*:	1%	-13.8000	-2.58000	0.17400	1.78000
	5%	-8.10000	-1.98000	0.23300	3.17000
	10%	-5.70000	-1.62000	0.27500	4.45000

*Ng-Perron (2001, Table 1)

HAC corrected variance (Spectral GLS-detrended AR)	2.37E-05

Log of real GDP (LogPIL)

DF-GLS

Levels

Null Hypothesis: LOGPIL has a unit root
Exogenous: Constant
Lag Length: 1 (Automatic - based on SIC, maxlag=11)

		t-Statistic
Elliott-Rothenberg-Stock DF-GLS test statistic		0.155078
Test critical values:	1% level	-2.595745
	5% level	-1.945139
	10% level	-1.613983

*MacKinnon (1996)

DF-GLS Test Equation on GLS Detrended Residuals
Dependent Variable: D(GLSRESID)
Method: Least Squares
Date: 03/30/15 Time: 08:27
Sample: 1996Q1 2014Q4
Included observations: 76

Variable	Coefficient	Std. Error	t-Statistic	Prob.
GLSRESID(-1)	0.000682	0.004398	0.155078	0.8772
D(GLSRESID(-1))	0.734251	0.080266	9.147737	0.0000

R-squared	0.401517	Mean dependent var	0.003449
Adjusted R-squared	0.393429	S.D. dependent var	0.006233
S.E. of regression	0.004855	Akaike info criterion	-7.791789
Sum squared resid	0.001744	Schwarz criterion	-7.730454
Log likelihood	298.0880	Hannan-Quinn criter.	-7.767277
Durbin-Watson stat	2.004054		

First differences

Null Hypothesis: D(LOGPIL) has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on SIC, maxlag=11)

		t-Statistic
Elliott-Rothenberg-Stock DF-GLS test statistic		-3.951352
Test critical values:	1% level	-2.595745
	5% level	-1.945139
	10% level	-1.613983

*MacKinnon (1996)

DF-GLS Test Equation on GLS Detrended Residuals
Dependent Variable: D(GLSRESID)
Method: Least Squares
Date: 03/30/15 Time: 08:28
Sample: 1996Q1 2014Q4
Included observations: 76

Variable	Coefficient	Std. Error	t-Statistic	Prob.
GLSRESID(-1)	-0.344624	0.087217	-3.951352	0.0002

R-squared	0.172306	Mean dependent var	-2.66E-06
Adjusted R-squared	0.172306	S.D. dependent var	0.005176
S.E. of regression	0.004709	Akaike info criterion	-7.865691
Sum squared resid	0.001663	Schwarz criterion	-7.835024
Log likelihood	299.8963	Hannan-Quinn criter.	-7.853435
Durbin-Watson stat	1.941458		

ERS Point Optimal

Levels

Null Hypothesis: LOGPIL has a unit root
Exogenous: Constant
Lag length: 1 (Spectral OLS AR based on SIC, maxlag=11)
Sample: 1996Q1 2014Q4
Included observations: 76

	P-Statistic
Elliott-Rothenberg-Stock test statistic	155.0435

Test critical values:	1% level	1.911600
	5% level	3.042800
	10% level	4.045200

*Elliott-Rothenberg-Stock (1996, Table 1)

HAC corrected variance (Spectral OLS autoregression)	0.000126

First differences

Null Hypothesis: D(LOGPIL) has a unit root
Exogenous: Constant
Lag length: 0 (Spectral OLS AR based on SIC, maxlag=11)
Sample: 1996Q1 2014Q4
Included observations: 76

		P-Statistic
Elliott-Rothenberg-Stock test statistic		1.092787
Test critical values:	1% level	1.911600
	5% level	3.042800
	10% level	4.045200

*Elliott-Rothenberg-Stock (1996, Table 1)

HAC corrected variance (Spectral OLS autoregression)	2.20E-05

Ng_Perron

Levels

Null Hypothesis: LOGPIL has a unit root
Exogenous: Constant
Lag length: 1 (Spectral GLS-detrended AR based on SIC, maxlag=11)
Sample: 1996Q1 2014Q4
Included observations: 76

		MZa	MZt	MSB	MPT
Ng-Perron test statistics		0.21171	0.17033	0.80457	40.5210
Asymptotic critical values*:	1%	-13.8000	-2.58000	0.17400	1.78000
	5%	-8.10000	-1.98000	0.23300	3.17000
	10%	-5.70000	-1.62000	0.27500	4.45000

*Ng-Perron (2001, Table 1)

HAC corrected variance (Spectral GLS-detrended AR)	0.000326

First differences

Null Hypothesis: D(LOGPIL) has a unit root
Exogenous: Constant
Lag length: 0 (Spectral GLS-detrended AR based on SIC, maxlag=11)
Sample: 1996Q1 2014Q4
Included observations: 76

		MZa	MZt	MSB	MPT
Ng-Perron test statistics		-21.6303	-3.28861	0.15204	1.13278
Asymptotic critical values*:	1%	-13.8000	-2.58000	0.17400	1.78000
	5%	-8.10000	-1.98000	0.23300	3.17000
	10%	-5.70000	-1.62000	0.27500	4.45000

*Ng-Perron (2001, Table 1)

HAC corrected variance (Spectral GLS-detrended AR)	2.24E-05