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ASSESSING THE SENSITIVITY OF INFLATION TO ECONOMIC ACTIVITY

by Konstantins Benkovskis, Michele Caivano, Antonello D'Agostino, Alistair Dieppe, Samuel Hurtado, Tohmas Karlsson, Eva Ortega and Tímea Várnai

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In 2011 all ECB publications feature a motif taken from the €100 banknote.

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Abstract

A number of academic studies suggest that from the mid-1990s onwards there were changes in the link between inflation and economic activity. However, it remains unclear the extent to which this phenomenon can be ascribed to a change in the structural relationship between inflation and output, as opposed to a change in the size and nature of the shocks hitting the economy. This paper uses a suite of models, such as time-varying VAR techniques, traditional macro models, as well as DSGE models, to investigate, for various European countries as well as for the euro area, the evolution of the link between inflation and resource utilization and its dependence on the nature and size of the shocks. Our analysis suggests that the relationship between inflation and activity has indeed been changing over time, while remaining positive, with the correlation peaking during recessions. Quantitatively, the link between output and inflation is found to be highly dependent on which type of shocks hit the economy: while, in general, all demand shocks to output imply a reaction of inflation of the same sign, the latter will be less pronounced when output fluctuations are driven by supply shocks. In addition, a sharp deceleration of activity, as opposed to a subdued but protracted slowdown, results in a swifter decline in inflation. Inflation exhibits a rather strong persistence, with a negative impact still visible three years after the initial shock.

Keywords: Demand shock, inflation response, macro model, output growth, Phillips curve.

JEL: E31, E32, E37.

Non-technical summary

This paper investigates the links between output and inflation and the impact of an economic slowdown on prices. Modern macroeconomic theory would suggest that, in addition to demand conditions, supply shocks and expectations play an important role in the determination of inflation. We have mainly focused on the link between inflation and resource utilization, but also touched upon the effects of supply shocks.

We start by surveying the academic literature. A key theme emerging is uncertainty around the extent of the output - inflation linkages; with a number of studies suggesting that from the mid-1990s onwards there were changes in the link between inflation and economic activity. However, it remains unclear whether these changes are due to a shift in the structural relationship between inflation and output or to a change in the size and nature of the shocks affecting the economy.

Our approach has been to employ a suite of models, such as time-varying VAR techniques, traditional macro models, as well as DSGE models, for individual countries as well as for the euro area, to assess (i) whether the inflation process has indeed been changing over the last twenty years and (ii) the extent to which the response of inflation to output fluctuations depends on the nature and duration of the shocks hitting the economy. Our main results can be summarized as follows:

- Using time-varying VAR techniques, our analysis suggests that the relationship between inflation and activity has indeed been changing over time, with the correlation peaking during recessions.
- Depending on which type of shock hits the economy, inflation would be lower by up to 0.7 percentage points and prices by up to 1.5% after three years in response to a decline to GDP of 1%, excluding Hungary's PUSKAS model which suggests declines of up to 3.3%.
- To the extent that the decrease in output growth is driven by supply shocks, thus lowering potential output growth, the negative effect on inflation will be mitigated.
- A sharp deceleration of activity, as opposed to a subdued but protracted slowdown, results in a swifter decline in inflation rates over a three year horizon.
- Inflation exhibits a rather strong persistence, with a negative impact still visible three years after the initial shock.

1. Introduction

In the biennium 2008-2009 the world has been hit by a severe economic and financial downturn, the deepest since the beginning of the Great Depression in 1929. Moreover, in line with the substantial weakening of global demand and economic activity, inflationary pressures have been diminishing. However, it remains to be determined to what extent the moderation in consumer price inflation has been the result of reduced demand pressures rather than of favourable developments on the supply side. Modern macroeconomic theory would suggest that, in addition to demand conditions, supply shocks and expectations play an important role in the determination of inflation.

In this exercise we want to investigate the sensitivity of inflation to developments in economic activity in the euro area by assessing (i) whether the link between inflation and output displays significant changes over time; (ii) to what extent the nature and duration of the shocks affect that link. The analysis is carried out using time-varying VAR techniques, traditional macro models and DSGE models, for individual countries as well as for the euro area as a whole.

In the academic literature there were a number of studies suggesting that from the mid-1990s onwards, the properties of the inflation process have changed substantially in most advanced economies. Our own analysis using a time-varying VAR, allowing for stochastic volatility, seems to confirm this but does not give indications about the source of such a change. To assess the dependence of the inflation response to output fluctuations on the nature of the shocks hitting the economy, we have resorted to more structural models and assessed the impact on consumer inflation of alternative shocks to growth, such as a decline in: (a) foreign demand; (b) domestic demand; and (c) investment spending. In addition, we analyzed different time profiles for each shock. The main results show that, as expected, demand-driven fluctuations induce larger price responses to restore the equilibrium; instead, when most of the shocks originate on the supply side of the economy, and thus affect its long-run growth properties, the impact on inflation is more moderate.

The outline of the rest of the paper is as follows. In section two we present a literature review in order to provide a context for the current exercise. Section three discusses the time-varying VAR approach, with special emphasis on inflation development in the recent period. In section four, we briefly present the macro-econometric models used in this analysis, and the shocks and scenarios used in the macro-econometric models followed by the simulation results. Finally, in section five we summarize the results. In an appendix we provide additional tables and charts relating to the results, and describe the macro-econometric models used in this analysis.

2. The inflation-output trade-off: a literature review

The relation between inflation and economic activity has been a long standing building block of most business cycle theories; the main tool economists and policy-makers rely upon to understand this relation is the Phillips curve. Since its introduction, more than 50 years ago, the curve has been at the centre of an intense debate about its reliability as a tool for policy-making.

The failure of old-style Phillips curves at tracking and predicting the inflation dynamics of the 1970's and a growing literature on the fallacy of the curve as a structural relation, triggered by the Lucas' critique, prompted, at the end of the 1970s, a number of attempts to resuscitate the inflation-unemployment trade-off, that found a major success in Gordon's triangle model. According to this model, the change in inflation depends on three factors: inflation expectations, demand pull (represented by the deviation of an activity variable from its long-run level) and supply shocks. The typical specification of an inflation process based on the triangle model (usually referred to as the *accelerationist Phillips curve*) is given by:

$$\pi_t = \sum a_j \pi_{t-j} + \sum b_i \left(u_{t-i} - u^*\right) + c z_{t-1}, \qquad (1)$$

where π is the inflation rate, the term $\sum a_j \pi_{t-j}$ is a proxy for inflation expectations, the term $(u\text{-}u^*)$ represents deviations of the unemployment rate (or another demand variable) from its long run level, and z collects other control variables (like e.g. oil prices). For (1) being such that the price level accelerates when unemployment is below its long run level the restriction $\sum a_j = 1$ has to be imposed. Specifications of the Phillips curve based on (1) performed well both in terms of in-sample fit and as forecasting models of inflation up to the early 1990s. Fuhrer (1995) performed various tests in order to assess the stability of the curve for the US, finding no evidence of structural changes in the Phillips curve coefficients and in particular in the trade-off between inflation and unemployment, represented by the sum of coefficients b_i.

From around the mid-1990s, most advanced economies were characterized by a period of low inflation, coupled with steady growth and diminishing unemployment. This combination of factors challenged once again the link between inflation and economic activity. A variety of studies documented striking changes in the properties of the inflation process in most industrialised countries: Cogley and Sargent (2002), using a Bayesian VAR with time-varying coefficients, find the U.S. inflation process to be characterized by a lower persistence in the 1990s compared with the two previous decades; Levin and Piger (2003) analyze the inflation process of twelve major industrialised countries, finding that they exhibit a shift in the mean and, once the latter has been taken into account, relatively low persistence since the 1980s[1]. Altissimo et al. (2006) summary of the Eurosystem's Inflation Persistence Network documents a drop in inflation persistence in the euro area.

Supported by growing evidence, the hypothesis that the inflation process had changed in most countries has become a fairly well established stylized fact; it remains controversial whether, among the factors underlying the reduction in inflation variability, there is a change in the structural relationship between inflation and output as argued in Brayton, Roberts and Williams (1999), Williams (2006), Roberts (2006) or Kuttner and Robinson (2008) for the US. The latter possibility has been recently challenged by Smets and Wouters (2007), who show, by means of counterfactual exercises conducted through an estimated DSGE model, that most of the decline in inflation volatility seems to be due to a reduced volatility in the shocks underlying the inflation process rather than to structural changes in the Phillips curve parameters.

Empirical evidence, supporting a weakening of the link between inflation and economic activity, motivated a number of authors to assess whether the Phillips curve remained a useful tool for inflation forecasting and policy guidance. Among others, Atkeson and Ohanian (2001) found that inflation forecasts delivered by Phillips curve models were less reliable than those of simple univariate competitors, signalling a clear instability in the economic relationships embedded in Phillips curves. Clark and McCracken (2003) conduct a number of simulations showing that the relatively poor predictive performance of Phillips curves is mainly attributable to shifts in the coefficients linking inflation to the output gap. The results of Atkeson and Ohanian (2001) have been recently revisited by Stock and Watson (2008), who, beside confirming the unreliability of Phillips curve inflation forecasts in normal times, suggest that the curve may still be a useful forecasting tool when the economy is far from its long-run path (typically, at a turning point).

A number of interpretations have been proposed to explain the observed changes in the inflation-output trade-off. A stream of literature focuses on the occurrence of changes in the structure of the labor market that can be responsible for the apparent flattening of the Phillips curve, implying that the link between inflation and economic activity would be essentially intact, once those changes are taken into account. Gordon (1997) finds that a smoothly

[1] The change in the inflation process remains however a controversial issue; recently, Pivetta and Reis (2007) found no evidence of a significant change in the inflation behaviour.

changing NAIRU improves the inflation forecasts obtained through a Phillips curve, thus reinforcing the view of a structural link between inflation and unemployment. This conclusion has been recently corroborated by Dickens (2008).

A recent stream of literature, including Borio and Filardo (2007), Razin and Binyamini (2007) and the IMF's World Economic Outlook (2006), suggests that globalization may have changed the slope of the Phillips curve. Among the sceptics, Ball (2006) and Gaiotti (2008), show that the evidence is not robust.

Contrary to advocates of structural changes, a number of authors argue the flattening of the curve to be an achievement of good policies, which essentially affects the estimates from reduced form models, while not implying changes in the underlying pricing behaviour of firms. As such, this line of research implicitly supports the Lucas' view of the Phillips curve as a non-structural relationship, not suitable for policy advice. Williams' (2006) conclusions go in this direction when suggesting that the change in the slope of the Phillips curve may be rationalized with an improved anchoring of inflation expectations by more credible policy-makers. Roberts (2006) makes this claim more explicitly, showing that the observed changes in Phillips curves are almost completely due to changes in the monetary policy reaction functions. Sargent, Williams and Zha (2006) argue that the key factor underlying the evolution of U.S. inflation in the post-70s period is a change in the monetary authority's beliefs as to the slope of the Phillips curve. As those beliefs became consistent with an almost vertical Phillips curve the monetary authority pursued disinflationary policies, leading to an observed, though not truly structural, weakening of the link between inflation and unemployment. Smets and Wouters (2007) find that monetary policy may have contributed to the flattening of the Phillips curves, although to a modest extent.

2.1 Evidence for the euro area

The literature for the euro area has mainly focused on the so-called *New Keynesian Phillips Curve* (NKPC), while that on traditional accelerationist specifications is still relatively sparse. In the New Keynesian version of the curve, the lagged inflation terms are replaced by a future expectation, to give:

$$\pi_t = aE(\pi_{t+1}) + bx_t + \varepsilon_t, \qquad (2)$$

where the term x_t represents the output gap and is directly linked to the real marginal cost of production of the economy[2]. This formulation has been found to be often inadequate for capturing dynamics and has been augmented with a lagged inflation term, to give the so-called *hybrid Phillips curve*:

$$\pi_t = a_1 E(\pi_{t+1}) + a_2 \pi_{t-1} + bx_t + \varepsilon_t, \qquad (3)$$

Empirical estimates of the slope of the Phillips curve in the euro area, both for traditional and for New Keynesian versions of the curve are surveyed in Table 1. The estimates do not differ wildly and for samples covering the last 30 years lie approximately in the range [0.1 0.4] (annualised) when the excess demand variable used in the Phillips curve is the output gap, and in the range [–0.2 –0.5] when the unemployment gap is used; the latter estimates are broadly consistent with those obtained using the output gap for values of the Okun's law coefficient around -0.4/-0.5, as estimated by e.g. Fabiani and Mestre (2004) and, more recently, Perman and Tavera (2007). Slope coefficients in specifications using real marginal costs, while displaying a larger variability (estimates range between 0.04 and 0.56), confirm the relevance of the Phillips curve (in its hybrid specification) as a model for describing inflation dynamics in the euro area.

There have been relatively few attempts aimed at formally testing whether the inflation-output trade-off has changed over time in the euro area, and, while there seems to be a general consensus over the apparent flattening of the Phillips curve in the last 15 years, the issue of the overall stability of the curve remains open. Among the studies that explicitly address this issue, one of the most comprehensive analysis for the euro area as a whole is that of Musso et al. (2007), who find evidence of shifts both in the mean of inflation and in the slope of the Phillips curve over the 1970-2005 period. In particular, the estimate of the output gap coefficient drops from around 0.5 in the 1970-1979 period to slightly more than 0.1 in the 1980-2005 period.

Recently, Paloviita (2008) documented a further reduction of the output gap coefficient from values between 0.1 and 0.2, depending on the Phillips curve specification, in the 1981-1993 period, to values between 0 and 0.1 in the 1994-2006 period. Groen and Mumtaz (2008) reach opposite conclusions by allowing shifts in trend inflation when analyzing the performance of new Keynesian Phillips curves for the euro area, the U.S. and the United Kingdom. Bajo-Rubio et al. (2007) evaluate the stability of the Phillips curve for Spain and, in spite of

[2] In many empirical specifications of the NKPC, proxies of real marginal costs have been preferred to output gaps, due to the uncertainty surrounding the estimates of the latter variable, which often gives rise to counter-intuitive results.

structural breaks in the inflation process, do not find evidence of instability of the coefficients of the curve.

Table 1. Estimates of the slope of the Phillips curve for the euro area

Paper	model	estimation method	data frequency	Excess demand variable	Sample	Estimated slope
Cuñado and de Gracia (2003)	PC	OLS	A	unemployment gap	1960-2001	-0.52
Fabiani and Mestre (2004)	PC	ML	Q	unemployment gap	1970-1999	-0.06
Logeay and Tober (2006)	PC	ML	Q	unemployment gap	1973-2002	-0.11
Schumacher (2008)	PC	ML	Q	unemployment gap	1979-2003	-0.086
Coenen and Wieland (2002)	NKPC	VAR	Q	output gap	1975-2000	0.02
Angeloni and Ehrmann (2004)	HPC	PIV	Q	output gap	1998-2003	0.09
Djoudad and Gauthier (2003)	HPC	GMM	Q (A)	output gap	1983-2000	0.17
Domenech et al. (2001)	HPC	GMM	Q	output gap	1986-2000	0.06
Smets (2003)	HPC	GMM	A	output gap	1977-1997	0.18
Moons et al. (2007)	HPC	Bayesian	Q	output gap	1980-2005	0.09
Musso et al. (2007)	PC	OLS	Q (A)	output gap	1970-2005	0.28
	TVPC	NLLS			1970-1979	0.47
	TVPC	NLLS			1980-2005	0.13
Paloviita (2008)	HPC	GMM	A	output gap	1981-2006	0.16
					1981-1993	[0.19 - 0.24][(2)]
					1994-2006	[0 - 0.12][(2)]
Gali et al. (2001, 2003)	PC	OLS	Q	output gap	1970-1998	0.05
	NKPC	GMM		real marginal costs		[0.05 - 0.1][(1)]
	HPC	GMM		real marginal costs		[0.02 - 0.09][(1)]
Gagnon and Khan (2005)	HPC	GMM	Q	real marginal costs	1970-1998	0.01
Hondroyiannis et al. (2008)	HPC	OLS	Q	real marginal costs	1970-2005	0.07
Jondeau and Le Bihan (2005)	HPC	GMM	Q (A)	real marginal costs	1970-1999	0.56
		ML				0.32
Sahuc (2002)	HPC	GMM	A	real marginal costs	1970-1998	0.06

Notes:
PC: traditional Phillips curve; NKPC: New Keynesian Phillips curve; HPC: hybrid Phillips curve; TVPC: time varying coefficients Phillips curve.
Q: quarterly; Q (A): quarterly annualised; A: annual.
PIV: Panel data; instrumental variables estimation; VAR: vector autoregression; OLS: ordinary least squares; NLLS: non-linear least squares; ML: maximum likelihood; GMM: generalized method of moments.
(1) The range of estimates depends on different sets of identifying assumptions.
(2) The range of estimates depends on slight modifications of the empirical specification of the Phillips curve.

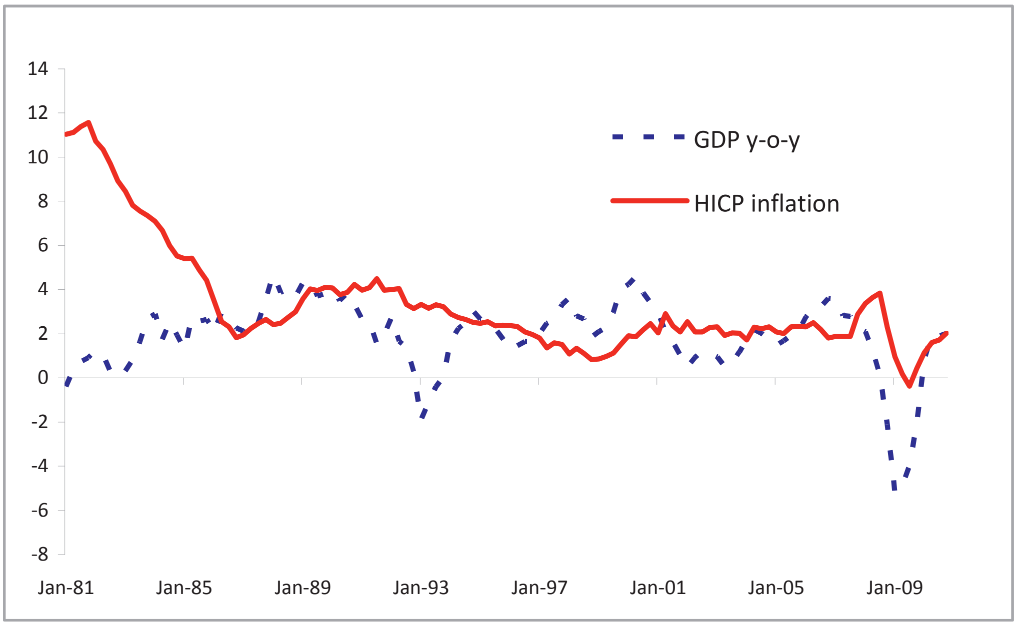
Evidence of nonlinearities for the euro area Phillips curve is at best mixed. Microeconomic evidence provided in Fabiani et al. (2006) suggests that demand variables have a larger effect on prices set by firms when demand falls than when it rises, implying a possible asymmetry in the Phillips curve at the aggregate level. On the other hand, another piece of the evidence presented by those authors suggests that positive cost shocks impact on prices more than negative shocks, a finding which is consistent with a different form of asymmetry in the Phillips curve. Analysis at the aggregate level does not help to settle the issue: Aguiar and Martins (2005) test for nonlinear Phillips curve specifications in the euro area, finding that, while the curve turns out to be linear, some nonlinearity can be estimated for the Okun's law. Musso et al. (2007) do not find sufficient evidence in favour of nonlinear specification either. On the other hand, Dolado et al. (2005) investigate how nonlinear Phillips curve may affect the reaction function of the monetary authority and their findings are compatible with a convex Phillips curve for most European countries. Cuñado and de Gracia (2003) also find evidence of some nonlinearity in the curve, with an estimate of the slope that turns out to be no longer significant in periods of very low inflation. Baghli et al. (2007) estimate a nonparametric model to assess the degree of nonlinearity in the output-inflation trade off, finding that, for the euro area as a whole and for its major member economies, the Phillips curve is highly nonlinear, with the output costs of disinflations rapidly growing when the economy overheats.

In the remainder of this paper we assess the sensitivity of inflation to economic activity with respect to both time-varying aspects and to possible nonlinearities associated to the nature, the size and the time path of the shocks hitting the economy. In the next section we will address some of these issues by estimating a bivariate model for the output and inflation of the euro area with time-varying parameters.

3. Time-varying relationship between inflation and output in the euro area

Figure 1 below shows the year-on-year HICP changes and the year-on-year GDP growth in the euro area over the sample 1981:Q1- 2010:Q3. A number of features emerge from this figure. We observe a fairly quick decline of inflation during the 1980's until 1987. After that date, inflation declines more steadily from around 4% in the early 1990s to below 2% in the late 1990s. Subsequently, inflation was fairly stable in the euro area, until the recent period, which saw an increase to almost 4% in the middle of 2008 and then a subsequent drop in inflation due to base effects and following the collapse in demand, resulting in a negative inflation rate in 2009Q3. When the economy starts to recover at the beginning of 2010 there is also a rise in inflation which increases to above 2% by the third quarter of 2010, partly due to higher oil prices over this period.

Figure 1
Comparison of GDP growth and inflation in the Euro area



Source: Eurostat / AWM database.

In this section we analyse the relationship between HICP inflation and GDP growth until the beginning of the most recent recovery by means of a Time Varying Coefficient Vector Autoregression (TV-VAR) model with stochastic volatility. This model allows both the autoregressive coefficients and the elements of the innovation covariance matrix to drift over time. That is, denoting the vector of endogenous variables as $z_t = [\pi_t, y_t]$ where π_t is the annual inflation rate and y_t year-on-year GDP growth, we assume that z_t has the following VAR representation:

$$z_t = A_{0,t} + A_{1,t} z_{t-1} + ... + A_{p,t} z_{t-p} + \varepsilon_t \qquad (4)$$

where $A_{0,t}$ is a vector of time-varying intercepts, $A_{i,t}$ are matrices of time-varying coefficients, $i = 1,2...p$ and ε_t is a Gaussian white noise with zero mean and time varying covariance matrix Σ_t. Let $A_t \equiv [A_{0t}, A_{1t}, ..., A_{pt}]$ and $\theta_t \equiv vec(A_t)$, where $vec(A_t)$ is the column stacking operator. The TV-VAR parameters, collected in the vector θ_t, are postulated to evolve according to:

$$p(\theta_t | \theta_{t-1}, Q) = I(\theta_t) f(\theta_t | \theta_{t-1}, Q)$$

where $I(\theta_t)$ is an indicator function that takes a value of 0 when the roots of the associated VAR polynomial are inside the unit circle and is equal to 1 otherwise. $f(\theta_t | \theta_{t-1}, Q)$ is given by:

$$\theta_t = \theta_{t-1} + \omega_t$$

where ω_t is a Gaussian white noise with zero mean and covariance Ω. Q is the covariance matrix of θ_t.

The VAR reduced-form innovations in (4) are postulated to be zero-mean normally distributed, with time-varying covariance matrix Σ_t that is factorized as:

$$\sum_t = F_t D_t F_t^{'}$$

where F_t is lower triangular, with ones on the main diagonal, and D_t a diagonal matrix. Let σ_t be the vector of the diagonal elements of $D_t^{(1/2)}$ and ϕ_t the off-diagonal element of the matrix F_t^{-1}. We postulate that the standard deviations, σ_t, evolve as geometric random walks, belonging to the class of models known as stochastic volatility. The contemporaneous relationship ϕ_t among the two variables of the VAR is assumed to evolve as an independent random walk, leading to the following specifications:

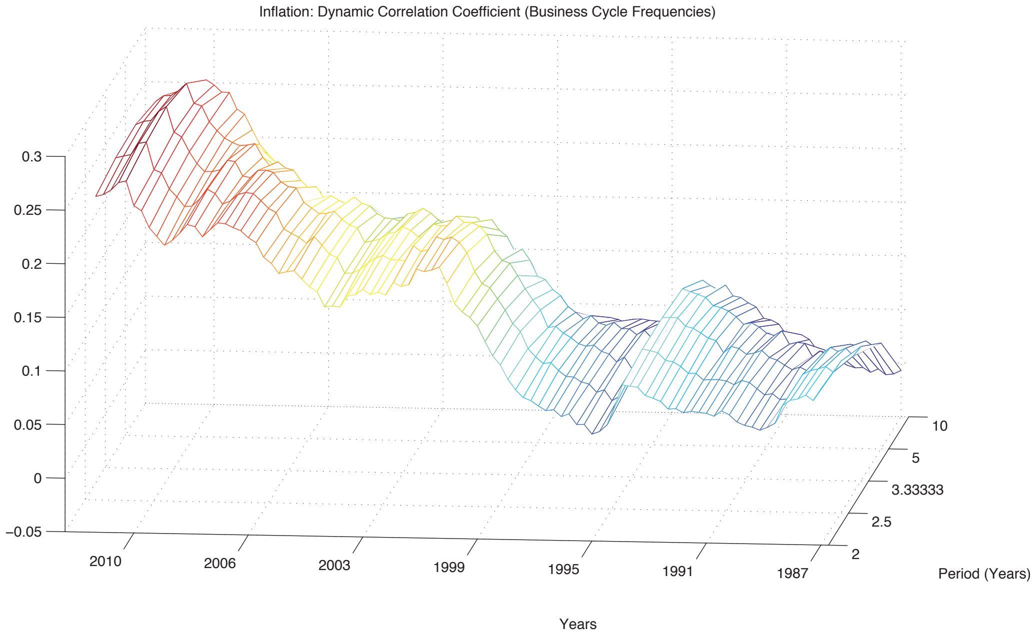
$$\log(\sigma_t) = \log(\sigma_{t-1}) + \xi_t$$

$$\phi_t = \phi_{t-1} + \psi_t$$

Where ξ_t and ψ_t are Gaussian white noises with zero mean and covariance matrix Ξ and Ψ. We postulate that ξ_t ψ_t, ω_t and ε_t, are mutually uncorrelated at all leads and lags. The parameters of the model are estimated by Bayesian techniques. A detailed description of the algorithm can be found in D'Agostino, Gambetti and Giannone (2009). We can use this statistical model to understand whether the link between inflation and output has been changing over time.

From the estimated time-varying VAR model we compute the evolutionary cross-spectrum between inflation and GDP. Figure 2 plots these dynamic correlation coefficients derived as in Croux, Forni and Reichlin (2001), between inflation and GDP year-on-year growth over the period 1988:Q2 – 2010:Q4. The vertical axis represents the correlation at business cycle frequencies. The correlation, in general, is quite low over time and over the frequency band, however, the picture also shows that the relationship between the two variables has been changing over time. In particular, the correlation peaks during the recessions (1992-1993 and the ongoing recession) and during the slowing down period (2001). Furthermore, the link between inflation and output is stronger in the second half of the sample from 2001.

Figure 2



This behaviour of the correlation coefficient over time seems to suggest that the inflation response to economic activity is stronger in recessions, thus corroborating the microeconomic evidence showing that the output/inflation link may be asymmetric, with demand variables affecting prices more when demand falls (see e.g. Fabiani et al., 2006). Also, the very low correlation during economic expansions is additional evidence of the increase in sacrifice ratios when the economy overheats, pointed out recently by Baghli et al. (2007), among others. The increase in the correlation coefficient over the most recent years of the sample seems to be in stark contrast with the literature documenting a decrease in the slope of the Phillips curve (e.g. Paloviita ,2008, and Musso et al., 2007). However, this increased correlation could well reflect the impact of higher oil prices observed during 2008, which disappeared in 2009 to come back in 2010, especially in its latter part, and reaching close to 2008 levels in 2010Q4. As the economy and oil prices started to pick-up during 2010, there are signs that the correlation starts to decrease, but this change is small, suggesting perhaps that a higher correlation since 1999, could be more permanent.

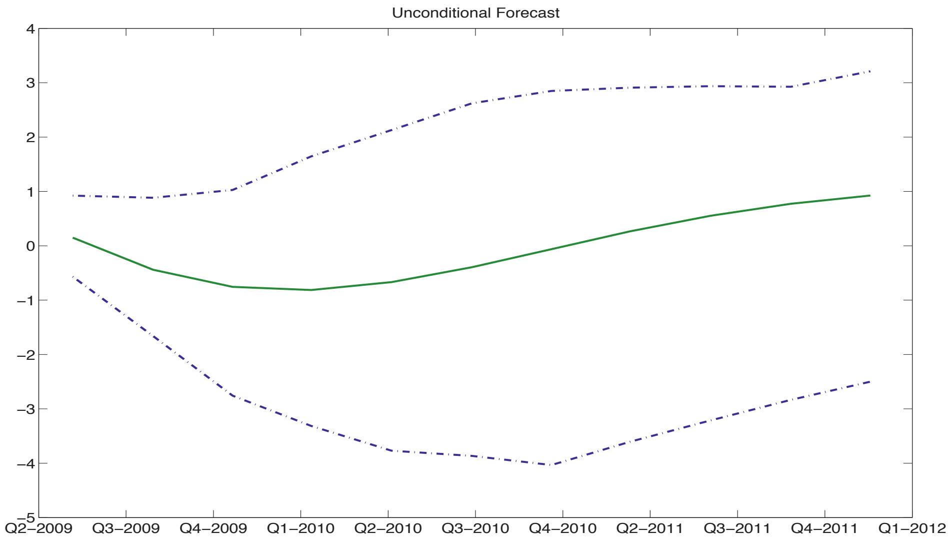
Existing evidence can be reconciled with the results of our TV-VAR model in at least two ways. First, existing literature documents a weaker causal link from output to inflation, while the unconditional correlation just shows the co-movement of the two variables. A weaker causality from output to inflation increases the output cost of disinflations and, therefore, induces stronger output responses to policy-induced shocks to inflation, which would result in higher unconditional correlation between output and inflation. Second, the existing literature focuses on the demand pressures on prices, documenting that this channel of price pressure seems to be less important in recent years than in the past. By contrast, the evidence displayed by the unconditional correlation is basically agnostic about the structural links between output and inflation, and it is not in contrast with the possibility that the joint behaviour of output and inflation over the period under review may have been determined by a combination of shocks that were, on the one hand, different for output and inflation and, on the other, inducing a moderation in consumer price dynamics during recession and a synchronization between output and inflation higher in the past decade than in the previous one. This possibility seems to be able to explain the surge in output-inflation correlation during recessions, according to Smets and Wouters (2004). These authors document that, during the 1992-1993 recession, both output and inflation in the euro area were mainly driven by negative investment shocks inducing a drop both in economic activity and in inflation. During the subsequent recovery the sources of output and price dynamics were instead different and, above all, implying opposite effects on the two variables: while output growth was primarily driven by a positive shock to the labour supply, the main driving force underlying consumer inflation were negative shocks to the inflation objective; the latter seems to be consistent with a convergence path of the European countries towards the EMU. The slowdown experienced in 2001 was again the result of different shocks, inducing however a similar response in output and inflation: output growth was damped by negative productivity shocks, whose positive effect on inflation was more than offset by the counteracting effect of a combination of lower inflation objective and, to a major extent, negative price mark-up shocks. The latter are consistent with the increased frequency of price decreases, documented at the microeconomic level by Angeloni *et al* (2006), occurring in coincidence with the euro cash changeover and various VAT measures at the beginning of the 2000s.

Figure 3 shows the unconditional inflation forecast implied by the model. In the absence of exogenous shocks such as an oil price shock, inflation should be stable and low (green line) for all of 2009; from the beginning of 2010 inflation should gradually increase to almost 1% by the end of 2011. The dotted blue lines around the forecasts are the confidence bands; they are quite wide, signalling high uncertainty around the predictions.

All in all, this suggests that the assessment of the effects of output fluctuations on inflation has to be conducted by properly identifying whether there are demand pressures acting on consumer prices, and whether other factors may offset these pressures. An example would be the development of oil prices, which could be positively related to demand, and would also reinforce upward pressures on inflation.

For this reason, in the rest of the paper we will analyse in more detail the behaviour of inflation in response to shocks to the economy of different types, sizes and time profiles.

Figure 3



4. Simulations to show the inflation sensitivity to economic activity

Economic textbook reasoning suggests that the size and sign of the impact of an economic slowdown on inflation depends on the nature of the shocks underlying the slowdown with supply and demand shocks affecting inflation differently. Compared with the time-varying VAR approach from the previous section, using large-scale macro models will enable to assess the impact of a slowdown of economic activity on inflation due to different sources of shocks.

In this section, we start by giving a summary of the various models (both DSGE and traditional macroeconomic models) used in this exercise, before going into more detail regarding the price formation mechanisms in these models, namely the Phillips curve specifications. Then, results are presented of several model-based simulations aimed at assessing the impact of a slowdown of economic activity on inflation.

4.1 Summary of macro models

Appendix A summarizes the various open economy macro models used for the simulation analysis and highlights their similarities as well as their different features. The eight models vary in numerous features, however, they can be broadly divided into two main groups based on their type – 4 traditional and 3 DSGE models – with the ECB's New Multi-country Model (NMCM, see Dieppe et al., 2011a and 2011b) being somewhere in the middle. The four traditional models are the Spain's MTBE model (Ortega et al., 2007), Latvia's Macroeconomic Model (LMM, see Benkovskis, and Stikuts, 2006), Bank of Italy Quarterly Model (BIQM, Banca d'Italia, 1986), and Hungary's Quarterly Projection Model (NEM, see Benk et al., 2006). The three DSGE models, estimated with Bayesian methods, are the ECB's New Area Wide Model (NAWM, see Christoffel et al., 2008), Spain's BEMOD model (see Andrés, et al., 2009), and Hungary's PUSKAS model (see Jakab and Világi, 2008).

Three of these models explicitly include the euro area (NAWM, and BEMOD), or at least a large part of a monetary union (NMCM, which models the five largest euro area economies). Although the main goal of the exercise is the sensitivity of inflation in the euro area, the results for some individual countries can give us useful information about the effect of a slowdown. Therefore, the analyses also covered five other, individual country models (Spain, Italy, Latvia, and two models for Hungary), results of which can provide useful consideration.

In all these models, the inflation process is modelled by some variant of the Phillips curve. In Table A2 in Appendix A, we report the key parameters of the general hybrid new Keynesian Phillips curve form (see equation 3), which consists of the Calvo parameter, the backward indexation term, and a marginal costs/output gap term. This should be considered for some cases only illustrative, as for some models, the specification doesn't directly translate into this framework[3], nonetheless it should give us an idea of the different persistence of inflation. We follow Altissimio et al. (2006), summary of the Eurosystem's Inflation Persistence Network by considering the three main factors affecting price response to shocks under a hybrid new Keynesian Phillips curve framework:

(i) Extrinsic persistence, which is due to shocks to marginal costs or output gap. We see that for all models, the slope of the Phillips curve is small, suggesting significant price stickiness.

[3] Notably in the case of the NMCM, the specification contains a time-varying discount factor, therefore the parameters in the table are normalised around a constant discount factor. Whilst the Phillips curve specification in the MTBE, NEM and LMM models are backward looking, they are nonetheless richer in terms of driving fundamentals.

(ii) Intrinsic persistence, which is the extent of dependence of inflation on its own past. We can see that BEMOD-Spain is the most forward-looking model, followed by the other DSGEs (BEMOD-Rest of the euro area, NAWM and PUSKAS), suggesting a decrease in the degree of inflation persistence. Whilst the NMCM is estimated to have a strong forward-looking component, this is nonetheless less than the DSGE models. The more traditional macro models have strong intrinsic persistence. As we will see, this partly explains the differences across models. For Italy's BIQM model, the main Phillips curve is on the wage equation, which is fully forward-looking. However, expectations are formed by learning, which effectively adds intrinsic persistence.

(iii) Expectation formation, and how it affects inflation formation is also crucial. In the DSGE models, expectations are model-consistent. Rational expectations wouldn't add any additional persistence to inflation, but imperfect information[4], or expectations based on learning would. In the NMCM, PUSKAS and BIQM, learning plays a crucial role, adding further persistence to price settings.

In the large-scale macro models considered, the Phillips curve is only one aspect of the economy. Wage formation may add further stickiness to inflation and the interaction of driving fundamentals is also clearly important. Given the large-scale models used in the Central Banks, doing full model simulations would give us a better idea of how the economy and prices respond to shocks.

4.2. Shocks and scenarios

This section presents the results of several model-based simulations aimed at assessing the impact of a slowdown of economic activity on inflation. Compared with the time-varying VAR approach from section three, such an exercise will give a possibility to look on the inflation sensitivity from a different angle. While previously the focus was on the changes in inflation sensitivity over time, in this section we can discuss the reaction of inflation to different types of demand and supply shocks. The three shocks considered are:

(i) **A decline in foreign demand**, where the decline in GDP growth is driven by a sequence of negative shocks to foreign demand.

(ii) **A decline in domestic demand**, primarily affecting consumption.

(iii) **A decline in investment spending.** Here we introduce a supply shock, which has a direct impact on the supply side of the economy.

[4] A number of the DSGE models are simulated as a series of unanticipated shocks.

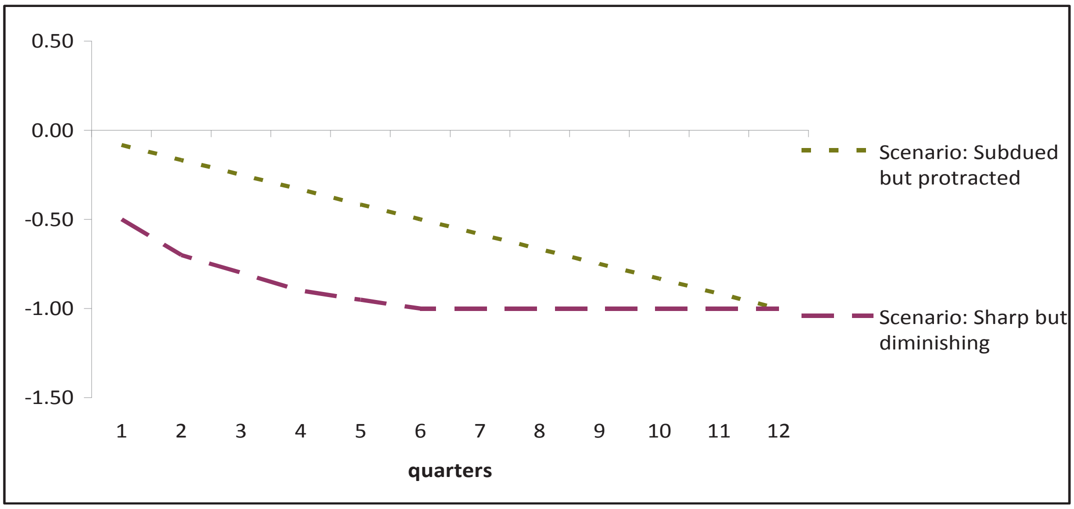
Not only the source, but also the profile of a slowdown is known to influence the strength of the disinflationary effects. For the different countries in the euro area, the recent recession has taken different profiles, some of them entering aggressively into the recession but recovering faster while others witnessing a softer start of the recession but a longer downturn period. Therefore, for each type of shock, two alternative profiles have been considered:

(i) a **subdued, but protracted** slowdown in economic activity, corresponding to a uniform downward shift in quarter-on-quarter real GDP growth (by 1/12 ppts) over a three-year period; and

(ii) a **sharp, but diminishing** slowdown ("V-shape"), in which quarter-on-quarter real GDP growth drops by 0.5 ppts in the first quarter and then by 0.2, 0.1, 0.1, 0.05 and 0.05 ppts in the subsequent five quarters.

Both profiles are calibrated to have the same effect on GDP growth, giving rise to a cumulated decline in real GDP growth of one percentage point, see Figure 4.

Figure 4
Comparison of subdued but protracted vs. sharp but diminishing shocks
Shock to GDP



All variables in percentage deviations from their level in baseline scenario

Combining the different shocks and the different time profiles for the shocks, we arrive at the six different scenarios.[5] We employ the usual assumptions that nominal interest rates, exchange rates and most fiscal variables are treated as exogenous, with the exception of BEMOD, where these are endogenous and with the NAWM and PUSKAS model we report scenarios with either policy rules endogenous or exogenous, so we can compare the impact.

[5] In the case of MTBE, we have only conducted simulations for the "subdued but protracted" scenario.

In the next three subsections we report the simulation results for the three types of shocks and the two different time profiles. In section 4.2.1, we discuss the foreign demand shocks under the subdued slowdown scenarios. In section 4.2.2, we analyze the shocks to domestic demands, and the investment shocks are discussed in section 4.2.3. Then, in section 4.3 and section 4.4 we compare across the different time path and sources of shocks. In the summary tables and charts, variables are reported as percentage deviation from baseline levels.

4.2.1. Foreign shocks

At the origin of the 2008-2010 recession, all economies in the eurozone were hit by a substantive negative shock from the rest of the world. All models identify this negative foreign demand shock among the main ones behind the fall in activity. Here we simulate a decline in growth driven by a sequence of negative shocks to foreign demand. In this scenario all models assume that only foreign demand is changing, whereas all other foreign variables are unchanged[6]. In general, other changes in the international environment would also affect the domestic economy (e.g. changes in foreign prices will give rise to wealth effects through changes to the terms of trade; a financial channel will impact the domestic economy via changes in foreign interest rates and exchange rates). However, in our scenario we assume, that only foreign demand is changing, whereas all other foreign variables are unchanged.

The foreign demand shock would impact the domestic economy through various channels. First, lower foreign demand would directly affect exports and growth. Second, the reaction from exporter firms would affect the rest of the economy and the effects of the shock would be hence more broadly propagated.

The price of domestic exports is slow to adjust to the decrease in world demand. This fuels a short-run decrease in export demand and, given slow adjustment of other demand components, output immediately undershoots its long-run level. Factor utilisation decreases as supply capacity is relatively slow to adjust. Firms decrease their demand for labour, increasing unemployment. Though prices are sticky, they are not fixed and inflation falls below the baseline as firms react to lower demand and lower marginal costs or more negative output gap: the net effect is for inflation to decrease below its baseline value.

[6] This is, admittedly, not very realistic, but it serves the purpose of highlighting the foreign demand channel, and makes it easier to interpret the results. In the NMCM, each country is shocked individually, and the countries are not linked. Since BEMOD includes both Spain and the rest of the Euro area as endogenous blocks, two sets of simulations with this model: in the first one shocks are calibrated so that the Spanish GDP follows the target paths, in the other the same is done for euro area GDP

The impulse responses of prices to a subdued but protracted shock across models and countries are presented in Table 2 and Figure 5.

Following a gradual decline in world demand, the different models give a broadly similar response with the initial impact on price being small but becoming larger over time. After three years the range of price responses in the models without monetary policy reaction is fairly large: prices are between 0.1% and 0.9% lower compared to the baseline, with most models yielding falls between 0.3% and 0.8%, in response to a decline to GDP of 1%. This translates into a reduction in annual inflation of between 0.1 to 0.4 percentage points.

The largest inflation responses are for forward-looking models with learning (NMCM and BIQM) which have forward-looking Phillips curves but expectations follow a learning approach that adds persistence to the inflation process, but also the more traditional models of Spain's MTBE and Hungary's NEM, where prices are purely backward looking also show relatively large price responses to a foreign demand shock. The price responses after 3 years are less for DSGE models like NAWM and Hungary's PUSKAS where prices are both more forward looking, and rational, and the Phillips curve has a smaller response to the mark-up than the NMCM. In the Latvian LMM model the price responses are very limited, being not more than 0.15% lower compared to baseline at the end of the three year horizon. For the NMCM, the estimated Phillips curves are still more backward looking than those for the three DSGE models considered, NAWM, BEMOD and PUSKAS, which correspondingly have smaller price effect for this scenario.

The results using DSGE models with endogenous monetary policy and exchange rate reactions are also reported. In particular we report results for the BEMOD from the Bank of Spain, which covers both Spain and the euro area. We also compare simulations from the NAWM and PUSKAS with endogenous policy to those with exogenous policy to enable us to isolate the impact of monetary policy.

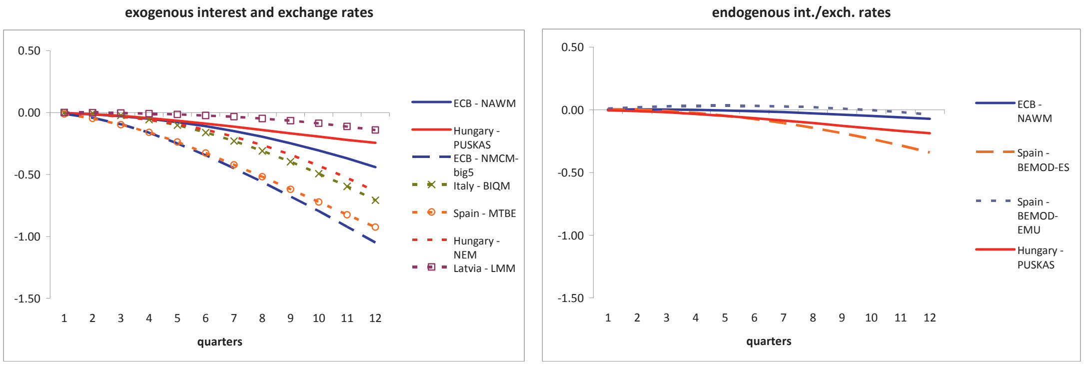
When including endogenous monetary policy reactions, inflation will be affected by the response of interest rates to shocks and also by the effect of the corresponding exchange rate changes in imported inflation, and agents will take this into account when forming their expectations and will change their actions accordingly. Compared to the model results with exogenous monetary policy, price responses are now smaller because interest rates decrease offsetting to some extent the downward price pressures coming from weaker demand.

Table 2: Negative shock to world demand of size equivalent to 1% GDP fall in 3 years.
Subdued but protracted - Impact on Prices

	GDP	Prices										
		exogenous interest and exchange rates							endogenous int./exch. rates			
country		ECB	Hungary	ECB	Italy	Spain	Hungary	Latvia	ECB	Spain	Spain	Hungary
model		NAWM	PUSKAS	NMCM-big5	BIQM	MTBE	NEM	LMM	NAWM	BEMOD-ES	BEMOD-EMU	PUSKAS
type		DSGE	DSGE	Learning	Traditional	Traditional	Traditional	Traditional	DSGE	DSGE	DSGE	DSGE
year												
1	-0.21	-0.03	-0.02	-0.08	-0.02	-0.08	-0.03	0.00	0.00	-0.01	0.02	-0.02
2	-0.54	-0.13	-0.10	-0.40	-0.20	-0.38	-0.17	-0.03	-0.02	-0.09	0.03	-0.08
3	-0.88	-0.34	-0.21	-0.86	-0.55	-0.77	-0.48	-0.10	-0.05	-0.26	-0.01	-0.16

All variables in percentage deviations from their level in baseline scenario

Figure 5: Negative shock to world demand of size equivalent to 1% GDP fall in 3 years.
Subdued but protracted - Impact on Prices



All variables in percentage deviations from their level in baseline scenario

4.2.2. Domestic demand shocks

In most countries across Europe, private demand was severely hit. This negative shock to demand could take a variety of forms, from a shock to confidence to a wealth shock. Here we report the response of prices to a shock to domestic demand. Given the different modelling approaches it was impossible to harmonise the shocks across models, so this shock has been implemented in different ways across different models (e.g. a shock to: risk premium, consumption preference, financial wealth, cost of capital, interest rate spreads)[7]. Therefore, one should be careful when comparing results. However in all models, the effect on private spending is a fall in consumption and some (secondary) downward impact on investment (e.g. from higher cost of capital). This reduction in demand and output puts downward pressure on prices. Furthermore, through the decline in inflation, domestic producers are becoming more competitive, so exports tend to increase and imports decline leading to an improved trade balance.

[7] Within the NAWM, the decline in domestic demand has been implemented by a sequence of domestic risk premium shocks, while in the NMCM the shock is to interest rate spreads. In the Bank of Italy's BIQM model the shock is implemented as a shock to the risk premium, assuming that it hits the rate relevant for consumption decisions only; in Bank of Hungary's traditional NEM model the shock was implemented through shocks to the risk premium and to household income; in Bank of Hungary DSGE model this scenario is represented by a series of shocks to consumption preferences and the cost of capital. In the Bank of Spain's DSGE model, BEMOD, the impact comes via shocks to consumption preferences, while in the Bank of Spain's traditional macro model, MTBE, it is implemented through a reduction in the financial wealth of households. Finally, in the Bank of Latvia's model,LMM, the domestic demand shock was produced by direct shock to the residual of consumption equation.

The impulse responses of prices to the subdued but protracted slowdown in domestic demand are presented in Table 3 and Figure 6. Generally, the responses are not very different compared to the foreign demand shock, with prices lower in the exogenous policy scenario by 0.1% to 0.9% after 3 years compared to the baseline (or equivalently annual inflation lower by 0.1 to 0.4 percentage points). The exception is in the Hungarian PUSKAS model where the responses are much larger, as without offsetting monetary policy domestic prices are very sensitive to the decline in consumption.

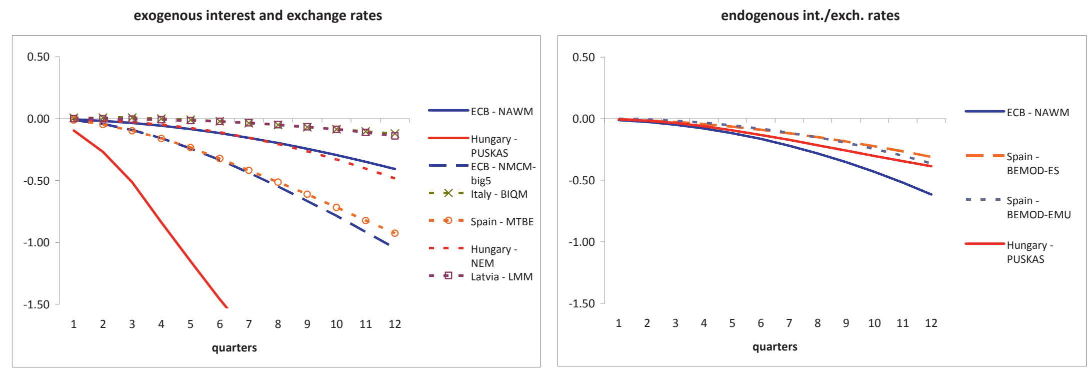
We also report results from the DSGE models with endogenous interest rates and exchange rates. Price responses for the for Hungarian PUSKAS model are smaller than with exogenous policy and broadly in line with BEMOD. However, price responses are not smaller with endogenous policy reaction in the case of the NAWM, where the shock was implemented by a sequence of domestic risk premium shocks, since the reaction of exchange rates lead to an appreciation of the domestic currency and hence further additional downward pressure on prices.

Table 3: Negative shock to domestic demand equivalent to a 1% GDP fall in 3 years.
Subdued but protracted - Impact on Prices

	GDP	Prices										
		exogenous interest and exchange rates							endogenous int./exch. rates			
country model type		ECB NAWM DSGE	Hungary PUSKAS DSGE	ECB NMCM-big5 Learning	Italy BIQM Traditional	Spain MTBE Traditional	Hungary NEM Traditional	Latvia LMM Traditional	ECB NAWM DSGE	Spain BEMOD-ES DSGE	Spain BEMOD-EMU DSGE	Hungary PUSKAS DSGE
year												
1	-0.21	-0.03	-0.43	-0.08	0.01	-0.08	-0.02	0.00	-0.04	-0.02	-0.01	-0.03
2	-0.54	-0.14	-1.58	-0.39	-0.03	-0.37	-0.14	-0.03	-0.20	-0.11	-0.10	-0.15
3	-0.88	-0.32	-2.46	-0.85	-0.09	-0.77	-0.37	-0.10	-0.48	-0.25	-0.28	-0.32

All variables in percentage deviations from their level in baseline scenario

Figure 6: Negative shock to domestic demand equivalent to a 1% GDP fall in 3 years.
Subdued but protracted - Impact on Prices



All variables in percentage deviations from their level in baseline scenario

4.2.3. Investment-specific shocks

Firms have been widely affected in the recent recession through not only the fall in foreign and domestic demand, but also by other factors like financial difficulties or other supply factors. In this section, we introduce a shock which has a direct impact on the supply side of the economy. It has been implemented in slightly different ways across models, but in each case can be considered as a direct shock to investment[8]. Compared to the previous foreign and domestic demand shocks, this supply-side shock affects inflation through an additional channel: an investment-specific shock leads to a more pronounced decline in the capital stock, thereby becoming a scarce factor of production and affecting the supply side of the economy in such a way that prices could go up. This then mitigates some of the disinflationary pressures coming from a fall in investment demand. However, the supply-side effects are different in magnitude and nature across models.

Table 4 and Figure 7 show the inflation responses across countries and models to the subdued but protracted scenario for GDP. Obviously, the fall in investment is more pronounced, while that of consumption is less severe, as the same reduction in GDP is driven by the exogenous increase in the cost of capital, thus impacting directly investment. Overall, prices fall by between 0.1% and 0.8% at the end of the horizon for models with exogenous monetary policy, and annual inflation rates are between zero and 0.3 percentage points lower. With endogenous monetary policy, interest rates fall according to the Taylor rule in order to help undo the fall in output caused by this shock[9]; negative pressures on prices are thus partly compensated. Together with the effect of more powerful supply channels, this makes the NAWM, PUSKAS and BEMOD models show smaller drops in inflation.

The reason behind the rise in prices in the BEMOD-Spain simulations lies in the intensity of the supply-side effects of this shock due to the different parameter estimates for Spain than for the rest of EMU. In particular, two parameters are making the most of the difference. On the one hand, estimated investment adjustment costs are much lower for Spain, which exacerbates the fall in capital in that economy, lowering more the marginal product of labor and hence increasing further the marginal cost of the economy, which translates into higher prices. On the other hand, wage indexation to past CPI inflation is estimated to be much larger in Spain than in the rest of EMU. Wages are very sticky in Spain, which prevents them from adjusting downwards fast when marginal product of labor is falling as is the case in this shock. As a result real marginal costs increase more in Spain (BEMOD-Spain simulation) than if the shock occurred in the rest of the EMU economy (BEMOD-EMU).

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[8] This has been implemented via a set of investment-specific technology shocks in the NAWM and through shocks to the capital stock in the NMCM. In the BIQM, the shock has been modelled as a business confidence shock. In BEMOD, the investment-specific productivity shock is used, while in the traditional macro model this shock is represented by an increase in firms' financing costs. In the NEM the shock is implemented through positive shocks to the risk premium that increases the cost of capital and lowers the demand for investment, while in the DSGE model this scenario is represented by a series of shocks to the cost of capital. Finally, in the LMM model, the implementation was via a direct shock to the residual of the investment equation..

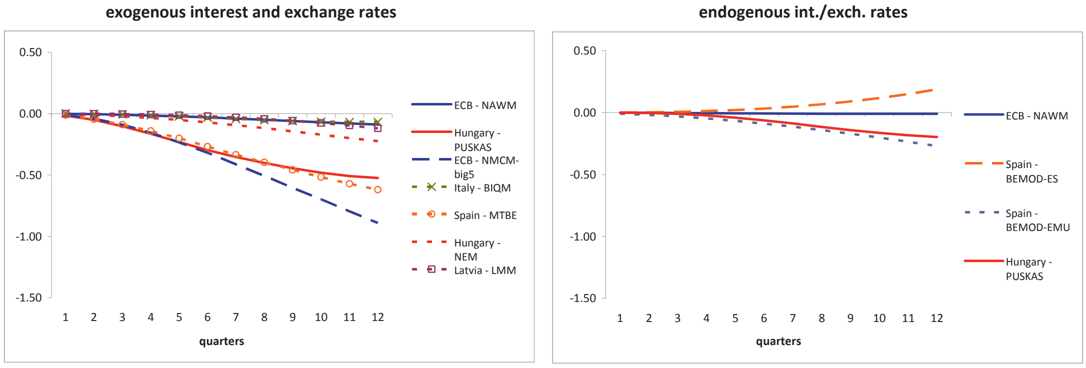
[9] In the case of BEMOD-Spain, the weight of Spain in the monetary policy decisions is very small (as opposed to the rest of the euro area in the BEMOD-EMU simulations) and this effect is operating at a much lower intensity.

Table 4: Negative supply shock to investment equivalent to a 1% GDP fall in 3 years.
Subdued but protracted - Impact on Prices

	GDP	Prices										
		exogenous interest and exchange rates							endogenous int./exch. rates			
country		ECB	Hungary	ECB	Italy	Spain	Hungary	Latvia	ECB	Spain	Spain	Hungary
model		NAWM	PUSKAS	NMCM-big5	BIQM	MTBE	NEM	LMM	NAWM	BEMOD-ES	BEMOD-EMU	PUSKAS
type		DSGE	DSGE	Learning	Traditional	Traditional	Traditional	Traditional	DSGE	DSGE	DSGE	DSGE
year												
1	-0.21	-0.01	-0.08	-0.08	0.00	-0.07	-0.02	0.00	0.00	0.00	-0.03	-0.01
2	-0.54	-0.04	-0.32	-0.37	-0.04	-0.30	-0.08	-0.03	-0.01	0.04	-0.10	-0.08
3	-0.88	-0.08	-0.49	-0.75	-0.07	-0.54	-0.18	-0.09	-0.01	0.14	-0.22	-0.17

All variables in percentage deviations from their level in baseline scenario

Figure 7: Negative supply shock to investment equivalent to a 1% GDP fall in 3 years.
Subdued but protracted - Impact on Prices



All variables in percentage deviations from their level in baseline scenario

4.3. Sharp but diminishing versus subdued but protracted shock

We now turn to the case of the sharp but diminishing slowdown where the drop in GDP is more severe, but short-lived, see Figure 8. Since the mechanisms involved are the same as before and the observed responses are relatively similar to the subdued but protracted shock, we can be quite brief. The price effects are transmitted slowly in both subdued and sharp scenarios with very little impact on prices at the end of the first year. The exception being the Hungarian PUSKAS model, where there are already significant effects in the first year for the domestic demand and investment shocks. However, by the end of the third year, differences between the 'subdued, but protracted' and 'sharp but diminishing' scenarios emerge, with the sharp but diminishing slowdown in real GDP growth generally implying a swifter and more sizeable deceleration of inflation over the projected horizon. Indeed, the impact on prices can be up to double compared to the subdued slowdown. The one exception is for BEMOD Spain with endogenous policy where inflation is positive (see explanation above).

In the sharp but diminishing slowdown, firms and unions react to the quicker slowdown by reducing prices and wages. This reduces the cost side pressure on inflation, further strengthening the decrease in inflation. This partly reflects the speed of adjustment of wages and employment, where the rapidity of adjustment depends on the sharpness of GDP slowdown, and to some degree the persistence of wages and employment, and the degree of forward-lookingness of firms and households. Indeed, the stronger response could be partly because, with the sharp shock, the corporate sector is forced into a quicker adjustments in wages and employment, whereas in the subdued shock it is a gradual process, so wages and prices are only reduced gradually.

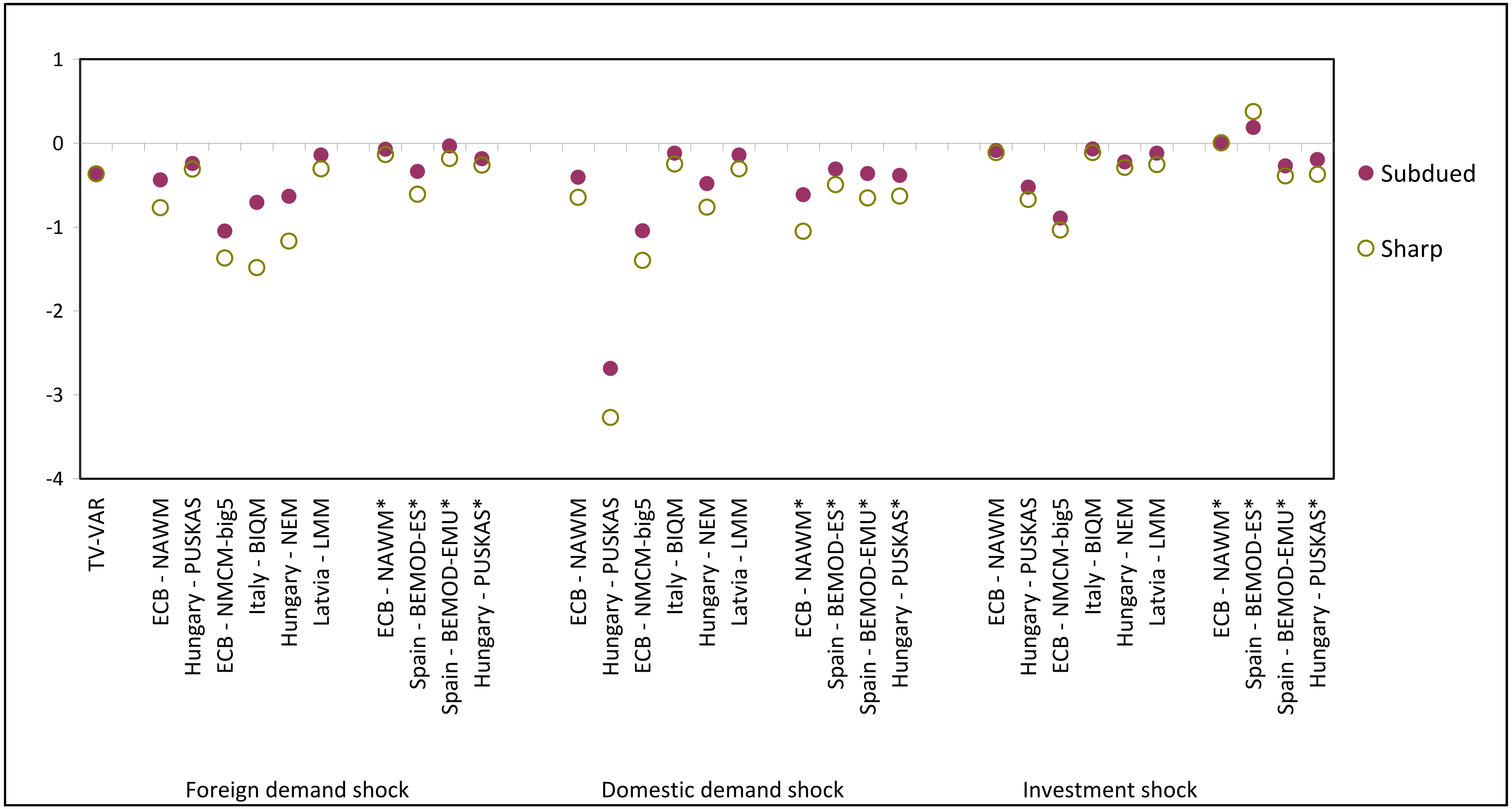
We also performed the exercise with the time-varying VAR from section 3, see Figure B4 in the Appendix.. The sharp and protracted scenarios imply quite similar paths (in deviation from the unconditional forecast) for future inflation. A sharper fall of GDP translates into lower inflation until the sixth quarter of the shock, while after this date inflation rates, implied by the sharp scenario, are slightly higher than those implied by the protracted one. Both tend to converge back to the inflation rate of the baseline forecasts after 11 quarters. Overall, the TV-VAR suggests that after 3 years prices would be lower by 0.4% and average annual inflation lower by 0.2 percentage points. However, there is large uncertainty around these results, but it is important to note that they are within the range of model estimates.

Overall, the results provide a wide range of estimates of the impact of a cumulative decline in GDP of 1%, suggesting prices would be lower by between 0.1% and 1.5% after 3 years, with Hungary's PUSKAS model showing declines of up to 3.3%. Without allowing for the corresponding reaction of the monetary policy (through a Taylor rule), average annual inflation would be lower by up to 0.7 percentage points in these 3 years. An alternative way of reporting these results is in terms of sacrifice ratios. This would suggest a 1ppt decline in inflation would mean GDP is lower by between 1.5% and 10%. This compares with Durand et al. (2008) average estimate of 2% for the euro area for the period 1994 to 2003 under short-run identification restrictions.

4.4. Comparing foreign, domestic and investment specific shocks

As could be expected, the results vary quantitatively and qualitatively depending on the source of the shock, even if the effect on output is the same in all simulations. In particular, shocks to prices and to productivity that would cause a slowdown would also cause an increase in prices, while GDP-equivalent demand shocks would cause a decline in prices. Figure 9 compares the effects of world versus domestic versus investment shocks after three years.

Figure 8
Comparison of Subdued but protracted vs. Sharp but diminishing shocks
Cumulated percentage deviation of prices from baseline at the end of the third year

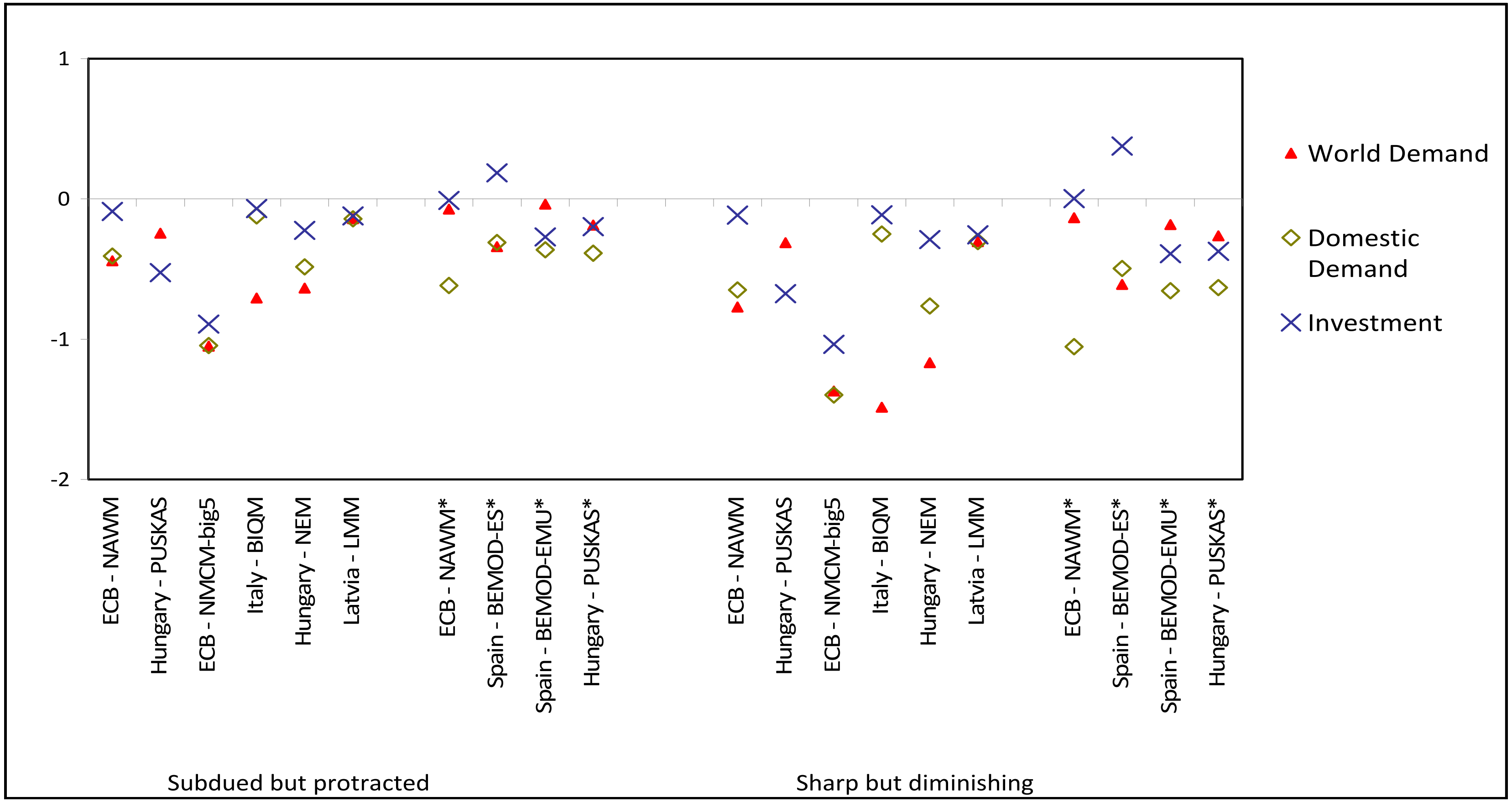


* Endogenous interest rates and exchange rates

Figure 9

Comparison of World demand vs. Domestic demand vs. Investment shocks

Cumulated percentage deviation of prices from baseline at the end of the third year



* Endogenous interest rates and exchange rates

Overall the results seem to suggest that after three years with exogenous monetary policy and exogenous exchange rates, the largest impact on prices occurs after a foreign demand shock, (the exception is Hungarian PUSKAS model due to having separate domestic and export sectors), and the smallest price responses come from the investment shock as this shock has stronger supply-side effects, partially offsetting the downward inflationary pressures.

However, there are some differences across models. In particular, it matters whether the simulations were with exogenous or with endogenous policy reactions. Furthermore, the treatment of expectations is crucial (backward-looking, rational forward-looking, learning), as well as price and wage stickiness (frequency of changes, degree of indexation), and in general the extent of labour market flexibility.

Some of these differences in results could be due to different country structures (e.g. different import content of different demand categories), but could also just reflect differing model choices. In Appendix C, we briefly consider the propagation mechanisms in each model.

5. Conclusions

The aim of this study has been to investigate the impact of business cycle fluctuations on HICP inflation in the euro area and across euro area countries, taking into account different shocks and assumptions regarding the path of real output growth.

Modern macroeconomic theory would suggest that, in addition to demand conditions, supply shocks and expectations play an important role in the determination of inflation. In this exercise we have mainly focused on the link between inflation and resource utilization, but also touched upon the effects of supply shocks.

A large number of studies tend to suggest that the inflation process has changed in most countries, since the mid-1990s. However, it remains unclear whether, among the factors underlying the reduction in inflation variability, there is a change in the structural relationship between inflation and output, a decreased volatility of shocks or if better monetary policy is the main determinant. Using time-varying VAR techniques, our analysis suggests that this relationship has indeed been changing over time, with the correlation peaking during recessions, and thus demand has a stronger impact on inflation during downturns. The extent to which the latter result is due to different structural properties of the Phillips curve during economic slowdowns (a possibility raised by Baghli et al., 2007, among others), rather than to the occurrence of a particular combination of shocks hitting the economy in the period under review, as suggested by Smets and Wouters (2004), remains to be analyzed in more depth, although the analysis conducted with the macro-econometric models suggests the latter is a potentially relevant factor.

Our approach has been to employ a suite of models, such as time-varying VAR techniques, traditional macro models, as well as DSGE models, for individual countries as well as for the euro area. In addition, we have investigated the effect of different types of shocks, alternative paths for real output growth, and different assumptions about the response of monetary policy. This methodology gives rise to a rather wide range of inflation responses. We tend to regard this as an advantage, compared to restricting the analysis to a single model or country.

The last recession was caused by a variety of shocks, to external as well as internal demand and also to supply, and the slowdown in activity has shown different profiles in different European economies. In this paper we use a range of macroeconomic models, built at various central banks for the analysis of their individual economies as well as for the euro area as a whole, to illustrate the mechanisms through which inflation responds to the main shocks behind a recession like the recent one, and we quantify the responses for different profiles of a downturn.

Depending on which type of shocks hits the economy, we found that in response to a decline to GDP of 1%, inflation would be lower by up to 0.7 percentage points in the euro area. Inflation exhibits a rather strong persistence, with a negative impact still visible three years after the initial shock. Equivalently, prices would be lower by up to 1.5% after 3 years, excluding Hungary's PUSKAS model which suggests declines of up to 3.3%. For the euro area as a whole, the NAWM estimate of the impact on prices is up to 1%. To the extent that the decrease in output growth is driven by supply shocks, thus lowering potential output growth, the negative effect on inflation and prices will be mitigated.

An alternative way of reporting these results is in terms of sacrifice ratios. This would suggest that a one percentage point decline in inflation would mean that GDP is lower by between 1.5% and 10%. This compares with Durand et al. (2008) average estimate of 2% for the euro area for the period 1994 to 2003. We also find that a sharp deceleration of activity, as opposed to a subdued but protracted slowdown, results in a swifter decline in inflation rates over a 3 year horizon.

6. Appendix A: Macro models summary and their Phillips curve estimates

The three DSGE models, estimated with Bayesian methods, are the ECB's NAWM, Spain's BEMOD model, and Hungary's PUSKAS model. The NAWM and the BEMOD include explicitly the euro area which is divided into Spain and rest of the euro area in BEMOD, while PUSKAS includes only one country (Hungary) facing the rest of the world. The rest of the world is exogenous in BEMOD and PUSKAS, while in the NAWM it arises as a pre-recursive block of foreign variables.

All of the three DSGE models are used in policy simulations, and forecast decomposition, further BEMOD and the NAWM in counterfactual analyses, and only the NAWM in providing projections. In addition, all of the three models contain model-consistent expectations, besides PUSKAS also features learning in the inflation process. Furthermore, the agent structure of the three models consists of utility maximizing households, government conducting fiscal as well as monetary policy, and firms although the firms' types differ to some extent in each model. In the NAWM and BEMOD there are firms producing tradable and non-tradable goods while in BEMOD additionally those producing durable goods. In the PUSKAS model, firms are divided into domestic and exporting firms respectively.

The ECB's NMCM contains 5 endogenous country blocks and with the rest of the world being exogenous, and is used in projections, counterfactual analysis and policy simulations. The model is based on optimizing agents (households, firms, unions, and governments). It has explicit treatment of expectations, with one version having rational model-consistent expectations. However, for this exercise, expectations are formed via learning. It is estimated with advanced classical techniques.

Finally, the four traditional models are the Spain's MTBE model, Latvia's LMM model, Bank of Italy Quarterly Model (BIQM), and Hungary's NEM model. Each of the traditional models represents a one-country model which faces an exogenous foreign economy. The MTBE, the LMM and the NEM are similar in some features. All three of them are used in projections and simulation analyses for scenarios, do not have forward-looking expectations, and have similarly simple agent structure (households, firms and government), though in the NEM there is no fiscal policy rule. The BIQM is used in policy simulations, and has both learning and ad-hoc expectations. Furthermore, considering the actors, the BIQM contains also banks.

Table A1: Overview of models

	Type	Coverage	Sectors/agents	Estimation	Expectations	Openness	Use
ECB's NAWM	DSGE	Euro area (open economy)	Households Firms (intermediate/final) Government (monetary and fiscal policy)	Estimated (Bayesian) Sample: 1985– 2006	Model-consistent	pre-recursive block of foreign variables	in projections forecast decomposition, counterfactual analyses and policy simulations
Spain's BEMOD	DSGE	Spain, euro area (open economy)	Households Firms (tradable / non-tradable / durables) Government (monetary and fiscal policy)	Estimated (Bayesian) Sample: 1997q1-2007q4	Model-consistent	2-country monetary union, ROW exogenous	counterfactual analyses, policy simulations and forecast decomposition
Hungary's PUSKAS	DSGE	Hungary (open economy)	Households Firms (domestic / export) Government (monetary and fiscal policy)	Estimated (Bayesian) Sample: 1995q2– 2008q3	Model-consistent Learning in inflation	exogenous	policy simulations and forecast decomposition
ECB's NMCM	Learning	5 countries (Germany, France, Italy, Spain, Netherlands)	Households Firms Unions Government (monetary and fiscal policy)	Classical: Non-linear SUR/GMM/Kalman filter Sample: 1980q1 – 2007q2	Learning	5-country monetary union, ROW exogenous	in projections, counterfactual analyses and policy simulations
Italy's BIQM	Traditional	Italy (open economy)	Private Sector Banks Government	Classical Sample: 1971q1 – 2008q4	Learning Ad-hoc	exogenous	in projections, counterfactual analyses and policy simulations
Spain's MTBE	Traditional	Spain (open economy)	Households Firms Government (fiscal policy)	FIML with Error correction mechanisms Sample: 1986q1 – 2007q4	Not forward-looking	exogenous	in projections and simulation analyses for scenarios
Hungary's NEM	Traditional	Hungary (open economy)	Households Firms Government	Classical Sample: 1998q1 – 2008q4	Not forward-looking	exogenous	in projections and simulation analyses for scenarios
Latvia's LMM	Traditional	Latvia (open economy)	Households Firms Government (fiscal policy)	Classical Sample: 1995q1 – 2008q3	Not forward-looking	exogenous	in projections and simulation analyses for scenarios

Table A2: Phillips curve estimates of the models

		Prices[1]			Wages	
		Calvo parameter	Indexation	Marginal Costs / Output gap	Calvo parameter	Indexation
NAWM	**Euro area**	0.92	0.41	0.005	0.77	0.63
BEMOD[2]	**Spain**	0.90	0.27	0.010	0.61	0.77
BEMOD[2]	**Rest of Euro area**	0.93	0.35	0.004	0.69	0.16
PUSKAS	**Hungary**	0.92	0.43	0.005	0.66	0.19
NMCM	**France**	0.75	0.35	0.013	0.74	0.34
NMCM	**Germany**	0.76	0.38	0.012	0.80	0.44
NMCM	**Italy**	0.73	0.32	0.008	0.73	0.33
NMCM	**Spain**	0.67	0.25	0.050	0.75	0.36
NMCM	**Netherlands**	0.69	0.28	0.027	0.71	0.30
BIQM[3]	**Italy**	-	-	-0.012 / 0.180	-	-
MTBE[4]	**Spain**	-	-	0.400	-	-
NEM[5]	**Hungary**	-	-	0.080	-	-
LMM[6]	**Latvia**	-	-	0.100	-	-

1 - For NAWM and BEMOD, only parameters for prices in the non-traded sector are reported, while for PUSKAS, only those for prices in the domestic sector.

2 - Parameters for prices in the traded sector show lower price stickiness than those for non-traded sector.

3 - Phillips curve on wages; coefficient on expected inflation is restricted to 1; represented coefficients on unemployment rate and capacity utilisation as a measure of economic slack

4 - Parameter gives the response of GDP deflator to 1% demand shock at the end of the first year

5 - Phillips curve on core inflation

6 - Phillips curve on GDP deflator

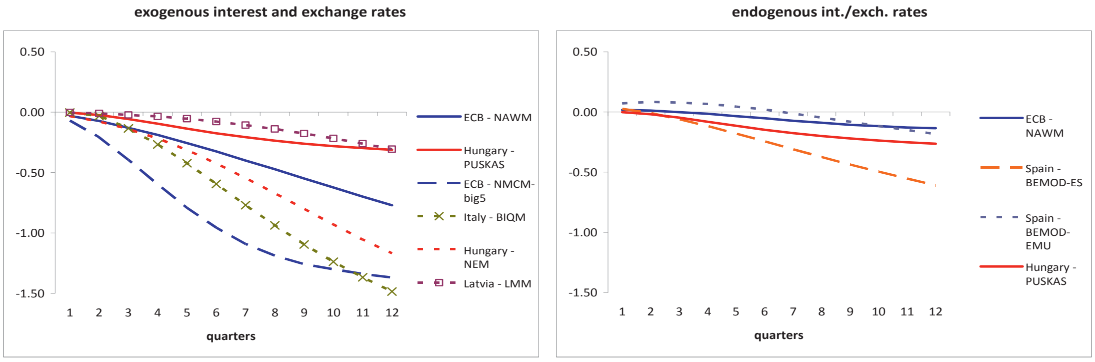
7. Appendix B: Additional simulation results

Table B1: Negative shock to world demand of size equivalent to 1% GDP fall in 3 years.
Sharp but diminishing - Impact on Prices

	GDP	Prices									
		exogenous interest and exchange rates						endogenous int./exch. rates			
country		ECB	Hungary	ECB	Italy	Hungary	Latvia	ECB	Spain	Spain	Hungary
model		NAWM	PUSKAS	NMCM-big5	BIQM	NEM	LMM	NAWM	BEMOD-ES	BEMOD-EMU	PUSKAS
type		DSGE	DSGE	Learning	Traditional	Traditional	Traditional	DSGE	DSGE	DSGE	DSGE
year											
1	-0.73	-0.11	-0.04	-0.32	-0.11	-0.12	-0.02	0.00	-0.04	0.08	-0.04
2	-0.99	-0.36	-0.19	-1.01	-0.68	-0.49	-0.09	-0.06	-0.28	0.00	-0.16
3	-1.00	-0.66	-0.29	-1.32	-1.30	-0.99	-0.24	-0.12	-0.52	-0.13	-0.24

All variables in percentage deviations from their level in baseline scenario

Figure B1: Negative shock to world demand of size equivalent to 1% GDP fall in 3 years.
Sharp but diminishing - Impact on Prices



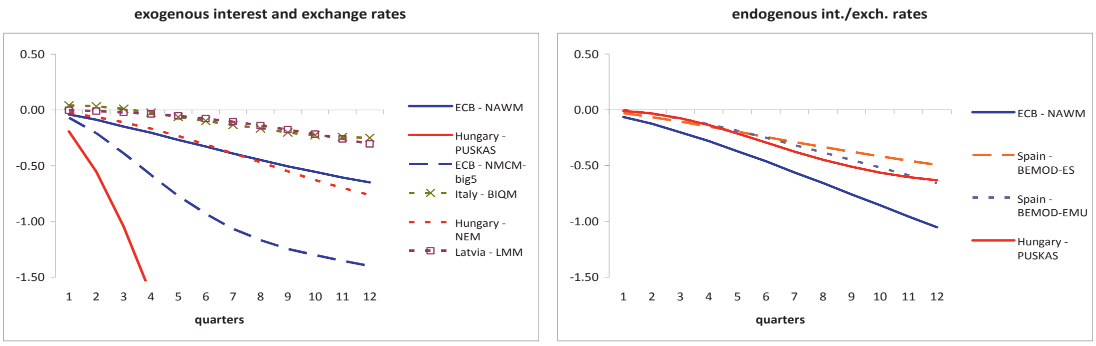
All variables in percentage deviations from their level in baseline scenario

Table B2: Negative shock to domestic demand equivalent to a 1% GDP fall in 3 years.
Sharp but diminishing - Impact on Prices

	GDP	Prices									
		exogenous interest and exchange rates						endogenous int./exch. rates			
country		ECB	Hungary	ECB	Italy	Hungary	Latvia	ECB	Spain	Spain	Hungary
model		NAWM	PUSKAS	NMCM-big5	BIQM	NEM	LMM	NAWM	BEMOD-ES	BEMOD-EMU	PUSKAS
type		DSGE	DSGE	Learning	Traditional	Traditional	Traditional	DSGE	DSGE	DSGE	DSGE
year											
1	-0.73	-0.12	-0.86	-0.31	0.02	-0.09	-0.02	-0.17	-0.09	-0.06	-0.06
2	-0.99	-0.36	-2.81	-0.98	-0.11	-0.35	-0.09	-0.51	-0.27	-0.28	-0.33
3	-1.00	-0.58	-3.35	-1.33	-0.23	-0.66	-0.24	-0.91	-0.44	-0.55	-0.58

All variables in percentage deviations from their level in baseline scenario

Figure B2: Negative shock to domestic demand equivalent to a 1% GDP fall in 3 years.
Sharp but diminishing - Impact on Prices



All variables in percentage deviations from their level in baseline scenario

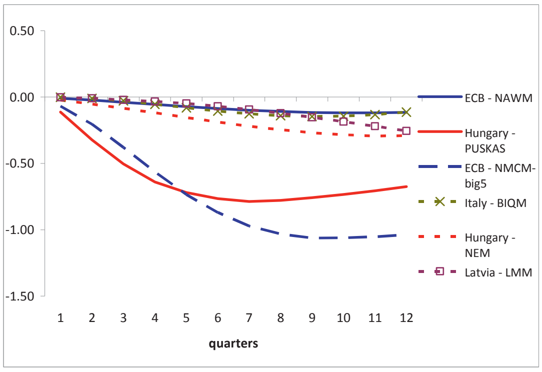
Table B3: Negative supply shock to investment equivalent to a 1% GDP fall in 3 years.
Sharp but diminishing - Impact on Prices

	GDP	Prices									
		exogenous interest and exchange rates						endogenous int./exch. rates			
country		ECB	Hungary	ECB	Italy	Hungary	Latvia	ECB	Spain	Spain	Hungary
model		NAWM	PUSKAS	NMCM-big5	BIQM	NEM	LMM	NAWM	BEMOD-ES	BEMOD-EMU	PUSKAS
type		DSGE	DSGE	Learning	Traditional	Traditional	Traditional	DSGE	DSGE	DSGE	DSGE
year											
1	-0.73	-0.03	-0.39	-0.30	-0.02	-0.07	-0.02	-0.01	0.02	-0.10	-0.05
2	-0.99	-0.09	-0.76	-0.90	-0.11	-0.20	-0.08	-0.02	0.12	-0.24	-0.24
3	-1.00	-0.12	-0.72	-1.05	-0.13	-0.28	-0.20	0.00	0.30	-0.36	-0.36

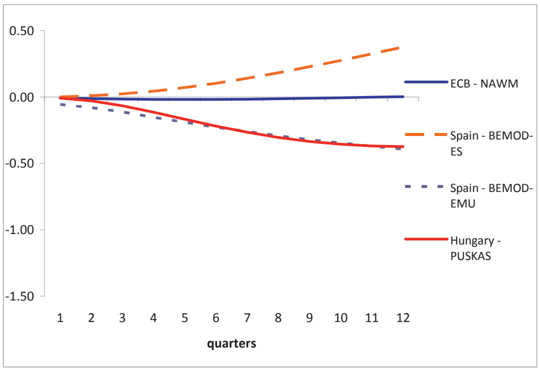
All variables in percentage deviations from their level in baseline scenario

Figure B3: Negative supply shock to investment equivalent to a 1% GDP fall in 3 years.
Sharp but diminishing - Impact on Prices

exogenous interest and exchange rates

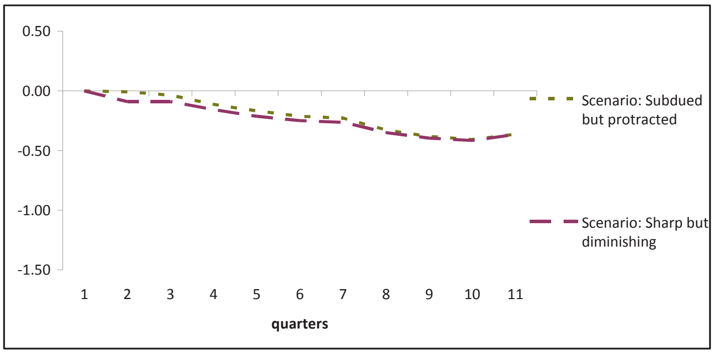


endogenous int./exch. rates



All variables in percentage deviations from their level in baseline scenario

Figure B4
TV-VAR shocks
Subdued but protracted vs. sharp but diminishing shocks - Impact on Prices



Percentage deviations from their level in unconditional forecast

8. Appendix C: Propagation mechanisms in the models

Here we report how the shocks propagate in the different macro-models, highlighting key channels. We start with the DSGE models and then go onto the NMCM before moving to the more traditional models.

In the NAWM DSGE model the impact on prices is significant and broadly similar for the foreign or domestic demand shock whereas the disinflationary effects are virtually negligible in case the slowdown is driven by a reduction in investment spending. The discrepancy in the disinflationary effects is explained by the fact that the investment specific-technology shock underlying the assumed reduction in investment spending has substantial supply-side effects which mitigate the downward pressures on domestic prices resulting from the implied fall in demand. Specifically within the NAWM, both capital, and labour-input related cost of production decline in response to shocks to foreign demand and to domestic risk premium, giving rise to downward pressures on prices. In contrast, negative investment-specific technology shocks lead to a more pronounced decline in the capital stock. As a result, capital becomes the relatively scare factor of production and, with wages being sticky, the cost of capital falls by relatively little, containing the fall in overall production cost, and hence the decline in prices.

In the **BEMOD DSGE model for both Spain and the euro area**, the effect of the economic downturn on inflation differs across shocks. Foreign demand shock causes very small price changes in the case of aggregate EMU inflation. This shock causes price drops for non-tradable consumption goods and tradable consumption goods produced both in Spain and in the rest of the euro area, but prices of imported consumption goods (oil-derived and otherwise) are growing. The prices of these imported goods are constant in dollars, but when EMU growth slows down euro interest rates fall, and the euro depreciates. This offsetting effect of the monetary policy and exchange rate reaction is smaller in other shocks, either because the Spanish economy has a smaller influence on the common monetary policy or because of the smaller role played by the exchange rate. The investment-specific shock is especially interesting in BEMOD since it helps notice supply side differences across EMU. In particular, a negative investment shock leads to higher supply-side inflationary pressures in Spain than in the rest of the EMU, as investment drops faster in Spain and wages adjust more sluggishly. The results for Spain and the rest of the EMU are not identical, but clearly the most important factor is the source of the shock.

In the **Hungarian DSGE model (PUSKAS)** the domestic price response to a foreign demand shock is limited. There are two sectors producing to the domestic and the export market, respectively. So there are two Phillips curves, one for the domestic HICP inflation, and one for the export price inflation. Consequently, slowdown in domestic demand affects only domestic firms and thus domestic inflation directly, while slowdown in external demand hits the exporting firms, and has only indirect effect on domestic inflation. This results in a significantly smaller effect on HICP in the latter case.

Meanwhile, in the other two scenarios the mechanism is very similar, there are only quantitative differences. Obviously, for the latter scenario, the fall in investment is more pronounced, while that of consumption is less severe, as the reduction in GDP is driven by the exogenous increase in the cost of capital, thus a fall in investment. As the production in the domestic sector is less capital-intensive, the domestic prices are less sensitive to a fall in investment than to that in consumption. Therefore the reaction of HICP to the fall in investment is smaller than to the slowdown in domestic demand (i.e. consumption). Moreover, when the monetary policy (i.e. interest rate path) is exogenous, it does not mitigate the effect on inflation, especially in the case of the second scenario (fall in domestic demand).

In the **NMCM** the main transmission from a negative demand shocks to prices is via marginal costs directly affecting the hybrid new Keynesian price and wages Phillips curve so firms respond by decreasing prices, and unions respond to rising unemployment by reducing their wage demands. As the shock is significant (either by being sharp, or by being protracted) agents (firms, households and unions) are surprised and adjust their behaviour accordingly. The adjustment of behaviour is quicker in the sharp response leading to a larger decrease in prices. However the composition of the shocks is less important as prices are affected by overall level of demand rather than the composition. The investment demand shock has less effect, as optimal output is lower in this scenario. However there are not significant supply side effects in the short run, particularly since technical progress is broadly unchanged. As a result, the response of consumer prices to this shock is fairly similar to that of a domestic demand shock. The main differences across countries comes from different estimated speeds of adjustment of wages and prices as well as estimated adjustment paths of firms, unions and households to factor demands. According to the NMCM, France and Netherlands show the largest price effects.

In the **Bank of Italy Quarterly Model** the drop in exports induced by the fall in world imports and the resulting reduction in output translates in a widening of output gaps, which impacts on prices and wages, with some lags. For the investment-specific shock, there are no substantial supply-side effects in the short run. As a result, the response of consumer prices to this shock is very similar to that generated by a risk premium shock affecting consumption, the main difference being a less pronounced disinflation in the sharp but diminishing scenario. The latter difference is driven by a stronger effect of the investment-specific shock on the desired addition to capacity output, which decreases with respect to the baseline more than in the case of a shock affecting consumption. With the overall reduction in real GDP fixed, this implies that at the end of the projection horizon there is less excess capacity than with a shock to other demand components, implying more moderate downward pressures on prices.

For the **Spanish MTBE**, the model is mainly demand-driven, so prices are pushed down directly by the fall in output. There is also another important channel: in response to the lower demand, firms reduce investment and employment; with higher unemployment, wages fall, which pushes prices down; and with lower prices, lower wages are bargained, which further decreases prices and wages, due to the strong indexation effect in the Spanish economy. The size of this effect on prices is different depending on the source of the shock, but the differences are much smaller than for example they are with the Spanish BEMOD.

In the **Hungarian NEM model** the sensitivity of inflation to the three different GDP slowdown scenarios is qualitatively similar due to the fact that the Phillips curve depends on output gap representing the inflationary pressure from the demand side. That is, the GDP components do not have separated effect on inflation. Slowdown in both foreign and domestic demand enforces the private sector to adjust the prices downward compared to the baseline, through whether less positive or more negative output gap. However, there are quantitative differences mainly due to the supply-side effects. Investment cuts counteract the previous effect through the output gap, as it is accompanied by the decrease in capital stock, and therefore in potential output. Therefore inflation is more sensitive to the slowdown in foreign demand than that in domestic demand, while being less sensitive in case of investment shocks. In addition to the former impacts, the lower output temporarily raises unit labour cost, which counteracts the decline in inflation, though this impact is less pronounced.

In **Latvia's LMM** model, consumer deflator and HICP are defined as a weighted average of domestic prices (GDP deflator) and import prices (which are exogenous). The GDP deflator, in turn, is determined by import prices, unit labour costs and the output gap. Therefore, changes in inflation are driven by changes in output gap and are almost unaffected by changes in GDP composition. The only exception is the case of a decline in investment spending, as changes in investments affect the capital stock and, therefore, potential GDP and the output gap. However, in the case of LMM this effect is negligible.

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