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What caused the euro area post-pandemic inflation?

An application of Bernanke and Blanchard (2023)

No 343

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Abstract

This paper applies the semi-structural model proposed by Bernanke and Blanchard (2023) to analyse wage growth, price inflation and inflation expectations in the euro area. It is part of a broader project coordinated by Bernanke and Blanchard to provide a unified framework for analysing and comparing global inflation dynamics across the major world economic areas, including US, euro area, Canada, UK, and Japan. The paper makes four main contributions. First, it estimates the model using quarterly data from the euro area covering the period from the first quarter of 1999 to the second quarter of 2023. Second, it conducts an empirical assessment of how euro area price inflation responds to various exogenous shocks. This includes evaluating how shock transmission evolved during the pandemic and comparing it with experience in the United States. Third, the model decomposes the drivers of wage growth and price inflation in the post-pandemic period. It emphasises the transmission channels and the respective roles of supply and demand forces that have contributed to the recent inflationary surge. Notably, it identifies the impact of labour market tightness, productivity, global supply chain disruptions and energy and food price shocks. Finally, the model generates conditional projections based on these exogenous shocks, enabling a more robust cross-check of inflation forecasts during times of significant global economic disturbances.

JEL codes: C5, E47, E52, E58, F4.

Keywords: econometric modelling, forecasting and simulation, monetary policy, central banking.

Non-technical summary

- Amid the current high inflation and the disruptions created by the coronavirus (COVID-19) pandemic, Bernanke and Blanchard (2023) have proposed an estimated semi-structural model for wage growth, price inflation and inflation expectations to understand the recent drivers of inflation in the United States. The straightforward design of the model makes it easy to replicate for other economies, providing a unified framework for analysing and comparing inflation dynamics globally. Various central banks in advanced economies, including the Bank of Canada, the Bank of England, the Bank of Japan and the European Central Bank (as well as several national central banks in the Eurosystem), have done so. This paper presents a replication that adapts and estimates the Bernanke and Blanchard model for the euro area economy.

- According to the estimated model, euro area inflation since 2021 has been driven by both supply and demand factors, with the former playing a primary role. Supply-side shocks were mostly related to energy and food price shocks, partly due to the invasion of Ukraine. At the same time the euro area was hit by an inflationary shock stemming from the combination of pent-up demand for goods and services that accumulated due to subdued spending and excess saving during pandemic lockdowns, and shortages of these goods due to supply chain disruptions. According to the model these shocks exhibit a large degree of persistence; other supply-side shocks, like energy and food, generally have a more temporary impact on price inflation, as those cost-push shocks also reduce income and, hence, aggregate demand.

- A combination of real wage catch-up and wage bargaining amid elevated inflation expectations has resulted in higher nominal wage growth, but there is no strong evidence so far that labour market overheating, as measured by the job vacancies to unemployment ratio, has significantly impacted wage growth and price inflation in the euro area (although there has been a small but positive contribution recently). However, caution is needed when interpreting the consequences of high labour market tightness on wages, as the model may fail to recognise that real wages might not have been able to catch up with past inflation if the labour market had not tightened.

- Finally, the estimation shows that the pandemic period may have affected some of the estimated parameters of the model. If these revert to their pre-pandemic values there is a risk of larger second-round effects from wages to prices, as the data in the pandemic imply a flatter Philips curve and weaker pass-through of wages to prices.

1 Introduction

Inflation has risen sharply since 2021 in many advanced economies, including the euro area. However, understanding the drivers of this surge is not a trivial task, as several factors may have contributed: an increase in demand after pandemic lockdowns, supply constraints, pandemic fiscal and monetary stimuli and the Russian invasion of Ukraine. For the United States, Bernanke and Blanchard (2023) introduce a semi-structural model of aggregate wage-price determination to investigate factors that may have been driving the increase in inflation.[1] The model contains four equations, which jointly determine nominal wages, prices and short- and long-run inflation expectations. The estimation strategy follows a hybrid approach that approximates a structural vector autoregression (SVAR) with added exogenous variables. The empirical model incorporates a flexible lag structure, to allow for richer dynamics and include measures of key shocks to product and labour markets, such as shortages or energy and food prices, to account more explicitly for the forces affecting inflation.

In this paper we estimate the Bernanke and Blanchard (henceforth "BB") model using euro area quarterly data over the period from the first quarter of 1999 to the second quarter of 2023. It is important to bear in mind that the pandemic period saw high macroeconomic volatility and the relationship between economic variables may have changed, temporarily or permanently. Therefore, while it is too early to say whether there has been a structural break after the pandemic or whether the volatility of the different shocks has simply increased, we compare the model parameters estimated on the full sample to the coefficients estimated on a shorter sample ending in the fourth quarter of 2019, as a way of assessing how the most recent data since the pandemic period affect the model's estimation and simulation.

In the United States, the estimated model suggests that price inflation was driven by shocks to prices given wages, owing to the spike in commodity prices and sectoral shortages in 2021 and 2022. Tight labour markets were not the primary driver of price inflation but explained the surge in nominal wage growth well. The effects of tight labour markets on nominal wage growth and inflation in the US are estimated to be more persistent than those of product-market shocks. Therefore, there is a risk that inflation becomes entrenched if the labour market remains tight. Under the assumption that monetary and fiscal policy transmit directly via labour market tightness, as maintained in the original BB paper, conditional projections with the US model show that achieving 2% inflation warrants a forceful and decisive tightening of monetary policy to rebalance labour demand and labour supply and offset the inflationary effects of past labour market shocks.

Compared to the US results, we find that the response of inflation to a shock to the vacancy-to-unemployment ratio is smaller in the euro area, owing to a flatter wage Phillips curve and weaker wage-to-price pass-through. This suggests weaker

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[1] Blanchard, O. J. and Bernanke, B. S. (2023), "What Caused the US Pandemic-Era Inflation?", Working Paper 31417, National Bureau of Economic Research, Cambridge MA.

transmission of labour market tightness shocks to euro area inflation. The impact of a global supply chain pressure shock in the euro area is also smaller than in the US, but is more persistent, and has long-term effects on inflation. With respect to energy prices, we find very similar transmission patterns, and it seems that there has been no structural break once we allow for the pandemic data in the estimation. Last, the response to a temporary shock to food inflation is stronger on impact in the euro area but reverts more quickly, even turning negative after one year.

Labour market shocks explained only part of nominal wage growth in the euro area between the first quarter of 2022 and the second quarter of 2023. In fact, as in the United States, price shocks (commodity prices and shortages) contributed to higher wage growth owing to higher short-term inflation expectations and stronger real wage growth catch-up with past inflation. Measures introduced during the pandemic in the euro area to protect workers and wages, such as job retention schemes, partly offset the contributions from subdued productivity growth.

Price inflation in the euro area was mainly driven by large positive contributions from energy prices shocks between the second quarter of 2021 and the first quarter of 2023. Higher food price inflation has added to inflationary pressures since the first quarter of 2022. The euro area was also hit by an inflationary shock stemming from the combination of pent-up demand for goods and services amid subdued spending and excess savings accumulated during lockdowns, and shortages of these goods due to supply chain disruptions. More recently, tight labour market conditions have been contributing to higher inflation through their effects on wage growth. Last, the model suggests that, absent the unexpected pandemic era shocks considered here, euro area inflation would have settled at a level slightly below 2%, in line with the ECB inflation target of "below, but close to, 2%" prior to the 2021 monetary policy strategy review.

Model-based conditional projections indicate that negotiated wage growth[2] stabilises at around 4.3% in the end of 2023 and remains elevated until at least the end of 2025 (4.0% in 2024 and 4.2% in 2025). Annual HICP inflation is expected to slow down faster than projected by ECB staff projections and reach the 2% inflation target as early as mid-2024, before rising back somewhat above it thereafter. However, the BB model does not capture several relevant factors incorporated into the staff projections which underpin the stickiness of inflation in the short term, such as the indirect effects of the removal of energy-related fiscal measures introduced in 2022 to shield households and firms from high energy prices.

The same model estimated on a shorter sample ending before the pandemic in the fourth quarter of 2019 predicts more persistent price inflation in the short term and annual HICP inflation stabilising above the target, owing to a steeper wage Phillips curve and stronger wage pass-through. This suggests that there may have been a structural break in the model, although it is too early to conclude whether this is

[2] Negotiated wage captures the outcome of collective bargaining processes and is a timely indicator of possible wage pressures (without the effect of wage drift, i.e., the difference between negotiated and actual wages). It differs from compensation of employees, which consists of wages and salaries in cash and kind plus employers' social contributions.

indeed the case. But if the parameters of the model revert to their pre-pandemic values, there is indeed a risk therefore of stronger second-round effects.

Overall, the model is particularly well-suited to explaining specific post-pandemic inflation dynamics and is therefore a useful benchmark for cross-checking inflation forecasts. For example, at the current juncture it is a handy tool for assessing the potential impact of tensions in the Middle East and the Red Sea on inflation through the effects on global supply chains. However, it may not be flexible enough to cope with future monetary policy challenges. The model specification could be improved by including for instance: (i) an explicit role for demand-side policies (and, consequently, monetary and fiscal policies), (ii) more forward-looking expectations, or (iii) modelling of labour market tightness and global supply chain pressures. These changes would help capture the general equilibrium and anticipated effects of policy shifts, in particular the role of the expectation channel for policy announcements.

After this introduction, the paper is divided into four sections. Section 2 illustrates the model; Section 3 deals with the estimation strategy; Section 4 reports the simulation results and different conditional scenarios using the model; Section 5 concludes. An Appendix provides additional information on the data used to estimate the model and various robustness checks.

2 The model

In their original paper Bernanke and Blanchard (2023) introduce a semi-structural model of aggregate wage-price determination. The model consists of four equations that jointly determine nominal wages (w_t), prices (p_t) and short- and long-run inflation expectations (p_t^e and π_t^*).

Nominal wages

The nominal wage depends on the expected price, an aspiration wage, and an indicator of the tightness of the labour market, x_t. Nominal wage growth is modelled as an expectations-augmented wage Phillips curve, with a role of for real wage catch-up if inflation turns out to be higher than expected ($\alpha \neq 0$) and a shock term that captures other factors affecting wage determination, z_w:

$$w_t - w_{t-1} = (p_t^e - p_{t-1}) + \alpha(p_{t-1} - p_{t-1}^e) + \beta(x_t - \alpha x_{t-1}) + z_w$$

Prices

The price level depends on the level of nominal wages and a shock term capturing the relative costs of non-labour inputs, markups and other factors affecting price setting, z_{pt}. Given this modelling assumption, price inflation then equals nominal wage growth plus the first difference in the exogenous factors, which include commodity price shocks and global supply chain pressures that affect prices given wages:

$$p_t - p_{t-1} = (w_t - w_{t-1}) + (z_{p_t} - z_{p_{t-1}})$$

Long-run inflation expectations

Long-run inflation expectations in turn evolve as a weighted average of the last period’s long-run inflation expectations and actual inflation, with γ determining the degree of anchoring:

$$\pi_t^* = \gamma\pi_{t-1}^* + (1-\gamma)(p_t - p_{t-1})$$

Short-run inflation expectations

Short-run inflation expectations are a weighted average of long-run inflation expectations and actual inflation, with δ being a parameter that determines the degree of anchoring:

$$p_t^e - p_{t-1}^e = \delta\pi_t^* + (1-\delta)(p_t - p_{t-1})$$

3 Estimating the model's parameters

3.1 Estimation strategy

The model is approximated with a hybrid approach that uses a structural vector autoregression (SVAR) with added exogenous variables. The empirical model incorporates a more flexible lag structure, to allow for richer dynamics than in the simpler model in Section 2 and includes measures of key shocks to product and labour markets to account more explicitly for the forces affecting inflation. Identification in the SVAR model is achieved by imposing the condition that wages are sticky and respond to the other endogenous variables in the model with a lag of one quarter. Wage inflation affects price inflation contemporaneously and, through its effects on it, inflation expectations too. We impose restrictions on the coefficients to ensure well-behaved long-run properties, such as different homogeneity constraints on the sum of coefficients which ensure that the Phillips curve is vertical in the long-run. The SVAR model is then estimated equation by equation; each equation incorporates different exogenous variables to account for the economic drivers of each endogenous variable. We present below a summary of the equations. A more thorough description can be found in Bernanke and Blanchard (2023).

Nominal wage growth equation

The nominal wage equation includes four of its own lags: lagged short-term inflation expectations, lagged long-term productivity growth (A_t^{LT}), lagged labour market tightness (vu_t) and lagged unexpected inflation ($\breve{\pi}_t$):

$$w_t = \sum_{i=1}^{4} \beta_{w_i} w_{t-i} + \sum_{i=1}^{4} \beta_{\pi_i^{e1}} \pi_{t-i}^{e1} + \beta_A A_{t-1}^{LT} + \sum_{i=1}^{4} \beta_{vu_i} vu_{t-i} + \sum_{i=1}^{4} \beta_{\breve{\pi}_i} \breve{\pi}_{t-i} + \epsilon_w$$

subject to $\sum_{i=1}^{4} \beta_{w_i} + \beta_{\pi_i^{e1}} = 1$ (vertical long-run wage Phillips curve)

Price inflation equation

Price inflation is regressed on lagged price inflation, current and lagged nominal wage growth, current long-term productivity growth, current and lagged relative energy (E_t) and food (F_t) price inflation, and current and lagged global supply chain pressures (S_t):

$$\pi_t = \sum_{i=1}^{4} \alpha_{\pi_i} \pi_{t-i} + \sum_{i=0}^{4} \alpha_{w_i} w_{t-i} + \alpha_A A_t^{LT} + \sum_{i=0}^{4} \alpha_{E_i} E_{t-i} + \sum_{i=0}^{4} \alpha_{F_i} F_{t-i} + \sum_{i=0}^{4} \alpha_{S_i} S_{t-i} + \epsilon_\pi$$

subject to $\sum_{i=1}^{4} \alpha_{\pi_i} + \sum_{i=0}^{4} \alpha_{w_i} = 1$ (homogeneity assumption)

Long-term inflation expectations

Long-term inflation expectations are regressed on lagged long-term inflation expectations and current and lagged price inflation:

$$\pi_t^{e10} = \sum_{i=1}^{4} \rho_{\pi_i^{e10}} \pi_{t-i}^{e10} + \sum_{i=0}^{4} \rho_{\pi_i} \pi_{t-i} + \epsilon_{\pi^{e10}}$$

subject to $\sum_{i=1}^{4} \rho_{\pi_i^{e10}} + \sum_{i=0}^{4} \rho_{\pi_i} = 1$ (in the long run, a sustained increase in inflation will raise inflation expectations by the same amount)

Short-term inflation expectations

Short-term inflation expectations are regressed on lagged short-term inflation expectations and current and lagged long-term inflation expectations and price inflation:

$$\pi_t^{e1} = \sum_{i=1}^{4} \gamma_{\pi_i^{e1}} \pi_{t-i}^{e1} + \sum_{i=0}^{4} \gamma_{\pi_i^{e10}} \pi_{t-i}^{e10} + \sum_{i=0}^{4} \gamma_{\pi_i} \pi_{t-i} + \epsilon_{\pi^{e1}}$$

subject to $\sum_{i=1}^{4} \gamma_{\pi_i^{e1}} + \sum_{i=0}^{4} \gamma_{\pi_i^{e10}} + \gamma_{\pi_i} = 1$ (in the long run, a sustained increase in inflation will raise inflation expectations by the same amount)

3.2 Euro area data

To estimate the empirical model, we use the following endogenous and exogenous variables for the euro area (see Appendix for more details about the different variables and mnemonics used to estimate the model) over the period from the first quarter of 1999 to the second quarter of 2023:

Endogenous variables

- HICP overall index, working day and seasonally adjusted
- Negotiated wages, seasonally adjusted using X13
  - Alternative indicators for assessing nominal wages in the euro area include compensation per employee and compensation per hour. We also estimated the model using compensation per employee and the conclusions were in line with the version with negotiated wage growth estimated on the pre-pandemic sample. Nevertheless, the results are not robust, and are counterintuitive when the sample period is extended beyond 2020, due to possible measurement issues with compensation per employee during the pandemic. Compensation per hour is a more suitable gauge of labour costs but faced limitations due to measurement errors as regards euro area hours worked, rendering the indicator impractical for the estimation.
- Consensus forecast for expected inflation one year ahead
- ECB Survey of Professional Forecasters for expected inflation five years and above ahead

Exogenous variables

- HICP energy, neither calendar not seasonally adjusted
- HICP food incl. alcohol and tobacco, working day and seasonally adjusted

- Job vacancies-to-unemployed (v/u) ratio
  - The v/u ratio is a key indicator in the wage equation but is only available for the euro area from the fourth quarter of 2006 and may be subject to structural breaks and measurement errors. To estimate the wage equation we fit the ratio for the period from the first quarter of 2006 to the second quarter of 2023 and then backcast it for the period from the first quarter of 1999 to the fourth quarter of 2005 by using the EU Commission survey on labour shortage as a factor limiting production in industry, which starts in the first quarter of 1995 and is highly correlated with the v/u ratio.
- NY Fed Global Supply Chain Pressure Index, lagged by one quarter.
- Labour productivity, measured as gross domestic value-added per worker, calendar and seasonally adjusted. The variable enters as an eight-quarter moving average to account for the long-term trend in productivity growth.

3.3 Estimation results

The euro area model is estimated equation by equation with quarterly data over the period from the first quarter of 1999 to the second quarter of 2023.[3] The summary regression tables below provide the sum of the coefficients associated with each explanatory variable, which include the overall contribution from the distributed lag structure, as well as the joint and overall statistical significance of estimated parameters. In addition, the R-squared of the constrained linear regressions are provided as a measure of the goodness of the fit of the simulated variables against sample data.

The wage equation is estimated by imposing the constraint that the sum of coefficients on lagged wage growth and short-run inflation expectations must be equal to one (homogeneity assumption). This ensures that the long-run wage Phillips curve is vertical. Dummy variables were introduced in the second and third quarters of 2020 to account for the job retention schemes introduced during the first lockdown and lifted thereafter. Table 1 shows the results of the estimation of the wage growth equation.

[3] See Appendix for the results of the estimation of the model on the pre-pandemic sample.

Table 1
Wage growth equation

Sample period: first quarter 1999 to second quarter 2023

(Sum of coefficients)

Independent variables	Wage growth	Labour market tightness	Unexpected inflation	Short-term inflation expectations	Long-term productivity	Lockdown (2020Q2 and 2020Q3)
Lags	-1 to -4	-1 to -4	-1 to -4	-1 to -4	-1	0
Sum of coeff.	0.309	0.064	0.066	0.691	0.075	2.340
p-stat (sum)	0.126	0.565	0.595	0.001	0.288	0.036
p-stat (joint)	0.285	0.147	0.003	0.000	0.288	0.056
R-squared	0.722					
N (obs)	89					

Notes: Sample period is from the first quarter of 1999 to the second quarter of 2023. p-value (sum) is the p-value for the null hypothesis that the sum of coefficients is zero, p-value (joint) is the p-value for the joint hypothesis that each of the lag coefficients separately equals zero.

According to the estimation, nominal wage growth is not very persistent: coefficients on lagged wage growth sum to 0.3 and are not significant. The sum of the coefficients on the degree of labour market tightness is positive, but the coefficients are not jointly significant (only the third and fourth lags are significant), suggesting that the slope of the euro area wage Phillips curve is rather flat and that the pass-through of labour market shocks to wage growth is slow. Coefficients associated with unexpected inflation are positive overall, which provides some evidence of wages catching up with past inflation. Short-term inflation expectations are also a significant driver of wage growth; the coefficients are jointly significant, although there is a delay before expectations pass through to wages, as the only significant coefficient is associated with the fourth lag. Finally, trend productivity growth is positively associated with nominal wage growth, as economic theory suggests too.

The price inflation equation reflects the imposed homogeneity assumption that the sum of the coefficients on past price and wage inflation sum to one. The estimated coefficients are jointly statistically significant for all variables except wage growth and long-term productivity growth (Table 2). Price inflation is quite persistent, as indicated by the positive coefficients associated with the distributed lags. There is weak but significant and rapid pass-through from wage growth to price inflation, the bulk of which occur within one quarter. The coefficients associated with relative energy price inflation and relative food inflation are also significant. The contemporaneous relationships between price inflation and relative commodity prices inflation are in line with energy and food weights in the HICP basket, while the sum of coefficients associated with the current and lagged observations are lower, which implies that in equilibrium the demand reaction moderates the initial inflationary effects of the price shock to some extent. The coefficients associated with supply chain pressures are also positive and significant, but the pass-through to price inflation is slower and more persistent than with other price shocks.

Table 2

Price inflation equation

Sample period: first quarter 1999 to the second quarter 2023

(Sum of coefficients)

Independent variables	Price inflation	Wage growth	Relative energy price inflation	Relative food price inflation	Supply chain pressure	Long-term productivity
Lags	-1 to -4	0 to -4	0 to -4	0 to -4	0 to -4	-1
Sum of coeff.	0.687	0.313	0.038	0.013	0.210	0.073
p-stat (sum)	0.000	0.060	0.039	0.872	0.034	0.213
p-stat (joint)	0.001	0.115	0.000	0.000	0.050	0.213
R-squared	0.974					
N (obs)	90					

Notes: Sample period is from the first quarter of 1999 to the second quarter of 2023. p-value (sum) is the p-value for the null hypothesis that the sum of coefficients is zero, p-value (joint) is the p-value for the joint hypothesis that each of the lag coefficients separately equals zero.

Long-run inflation expectations (Table 3) evolve as a weighted average of the previous level of long-run expectations and realised price inflation. Again, the sum of coefficients must be equal to one to ensure homogeneity. Long-term inflation expectations are estimated to be very well anchored around the nominal anchor, more so than short-run inflation expectations, indicating that the credibility of the ECB inflation target is high. However, long-term inflation expectations also react to realised and lagged price inflation with coefficients which are positive and statistically significant.

Table 3

Long-term inflation expectations equation

Sample period: first quarter 1999 to second quarter 2023

(Sum of coefficients)

Independent variables	Long-term inflation expectations	Price inflation
Lags	-1 to -4	0 to -4
Sum of coeff.	0.988	0.012
p-stat (sum)	0.000	0.005
p-stat (joint)	0.000	0.000
R-squared	0.830	
No. observations	93	

Notes: Sample period is from the first quarter of 1999 to the second quarter of 2023. p-value (sum) is the p-value for the null hypothesis that the sum of coefficients is zero, p-value (joint) is the p-value for the joint hypothesis that each of the lag coefficients separately equals zero.

Short-run inflation expectations (Table 4) are modelled as a weighted average of short- and long-run inflation expectations and realised price inflation. The coefficients of the three variables sum to one to ensure homogeneity: in the long run a sustained increase in inflation will raise inflation expectations by the same amount. The degree of anchoring of euro area short-term inflation expectations is fairly weak, as they co-move significantly with realised inflation. The estimation also points to some pass-through of long-term inflation expectations to short-term inflation expectations.

Table 4

Short-term inflation expectations equation

Sample period: first quarter 1999 to second quarter 2023

(Sum of coefficients)

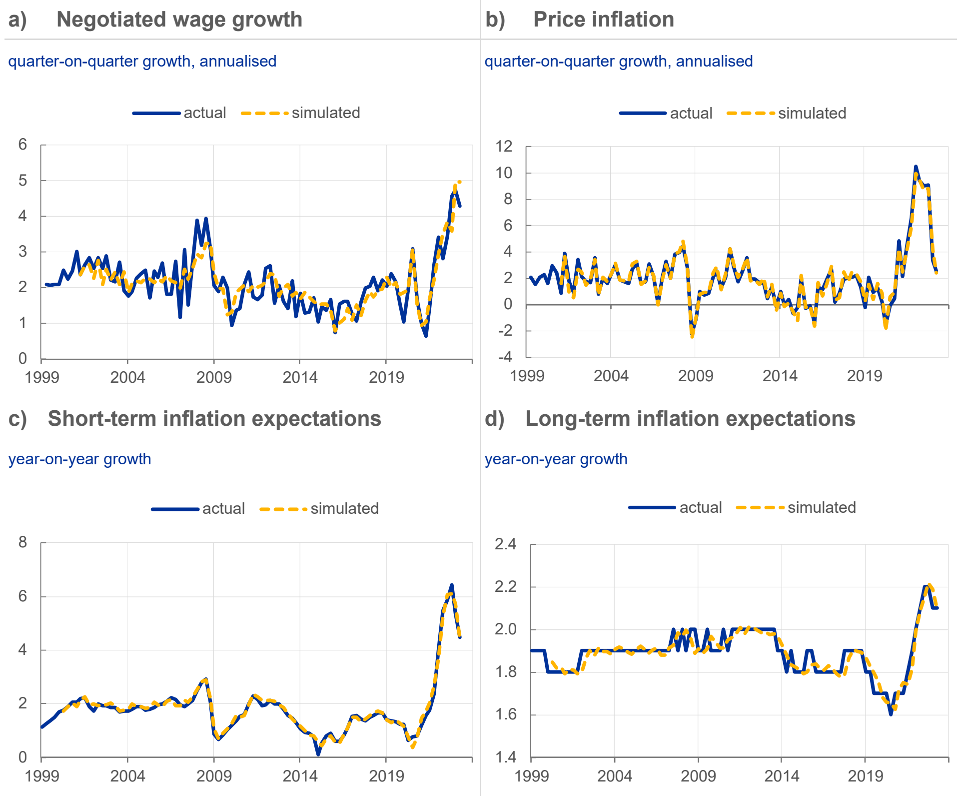
Independent variables	Short-term inflation expectations	Long-term inflation expectations	Price inflation
Lags	-1 to -4	0 to -4	0 to -4
Sum of coeff.	0.719	0.079	0.202
p-stat (sum)	0.000	0.025	0.000
p-stat (joint)	0.000	0.285	0.000
R-squared		0.984	
No. observations		93	

Notes: Sample period is from the first quarter of 1999 to the second quarter of 2023. p-value (sum) is the p-value for the null hypothesis that the sum of coefficients is zero, p-value (joint) is the p-value for the joint hypothesis that each of the lag coefficients separately equals zero.

The empirical fit of the model can be evaluated by comparing the actual and fitted values of the estimated model (Chart 1). The model can explain the price variables very accurately, while the wage equation requires some additional residuals to fit the data.

Chart 1

Actual and fitted values



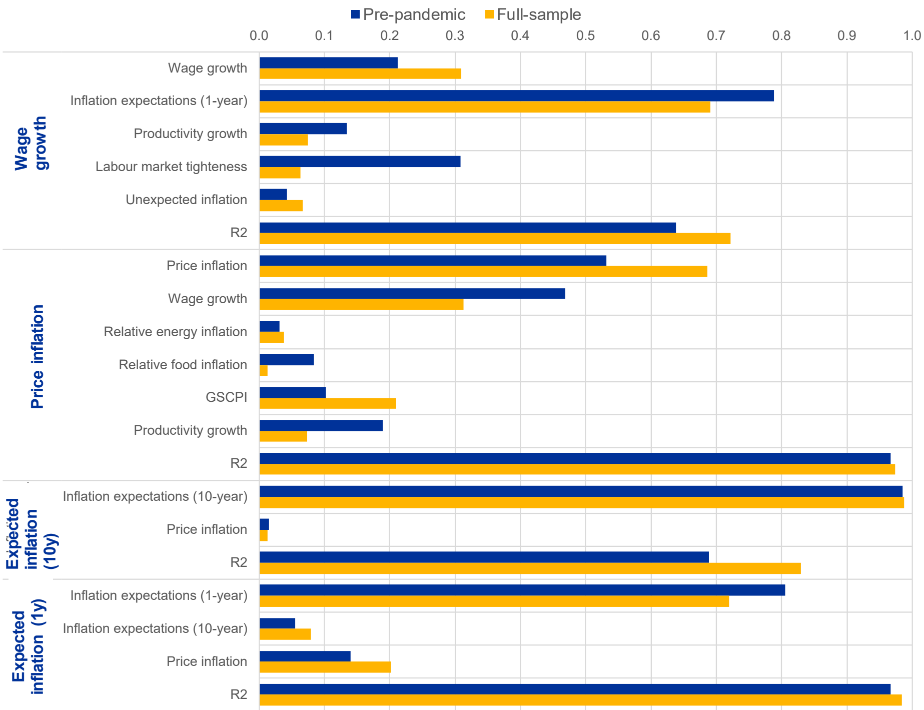
Note: Simulated data are based on in-sample predictions of the model estimated over the period from the first quarter of 1999 to the second quarter of 2023.

Sensitivity to the pandemic period

The pandemic period, which started in the first quarter of 2020, was marked by high macroeconomic volatility. The relationship between economic variables may have changed temporarily or permanently. It is too early to say whether there has been a structural break in the economy after the pandemic or whether volatility has simply increased, but we can compare the parameters of the model estimated on the full sample to those estimated on a shorter sample ending in the fourth quarter of 2019 to assess how the pandemic period affects the estimation (Chart 2).

Chart 2
Sensitivity to sample period

(Sum of coefficients)



Note: The sample period is from the first quarter of 1999 to the fourth quarter of 2019 for the pre-pandemic estimation, and from the first quarter of 1999 to the second quarter of 2023 for the full sample estimation.

Introducing data from the pandemic period appears to affect the coefficients significantly. Nominal wage growth is more persistent and less responsive to productivity and labour market shocks. Nevertheless, short-term inflation expectations and unexpected inflation continue to be key determinants of wage growth. Price inflation is estimated to be more persistent too, but also more responsive to energy shocks and supply chain disruptions than before the pandemic. However, the wage-to-price pass-through and the overall relationship to food inflation are weaker. The formation of long-term inflation expectations has until now been little affected in the post-pandemic period, but short-term inflation expectations are estimated to be less well anchored. However, as emphasised before, it is still too early to conclude that there has been a significant permanent structural break in the transmission of different shocks to macroeconomic variables in the last few years.

4 Model-based simulations

4.1 Impulse response analysis

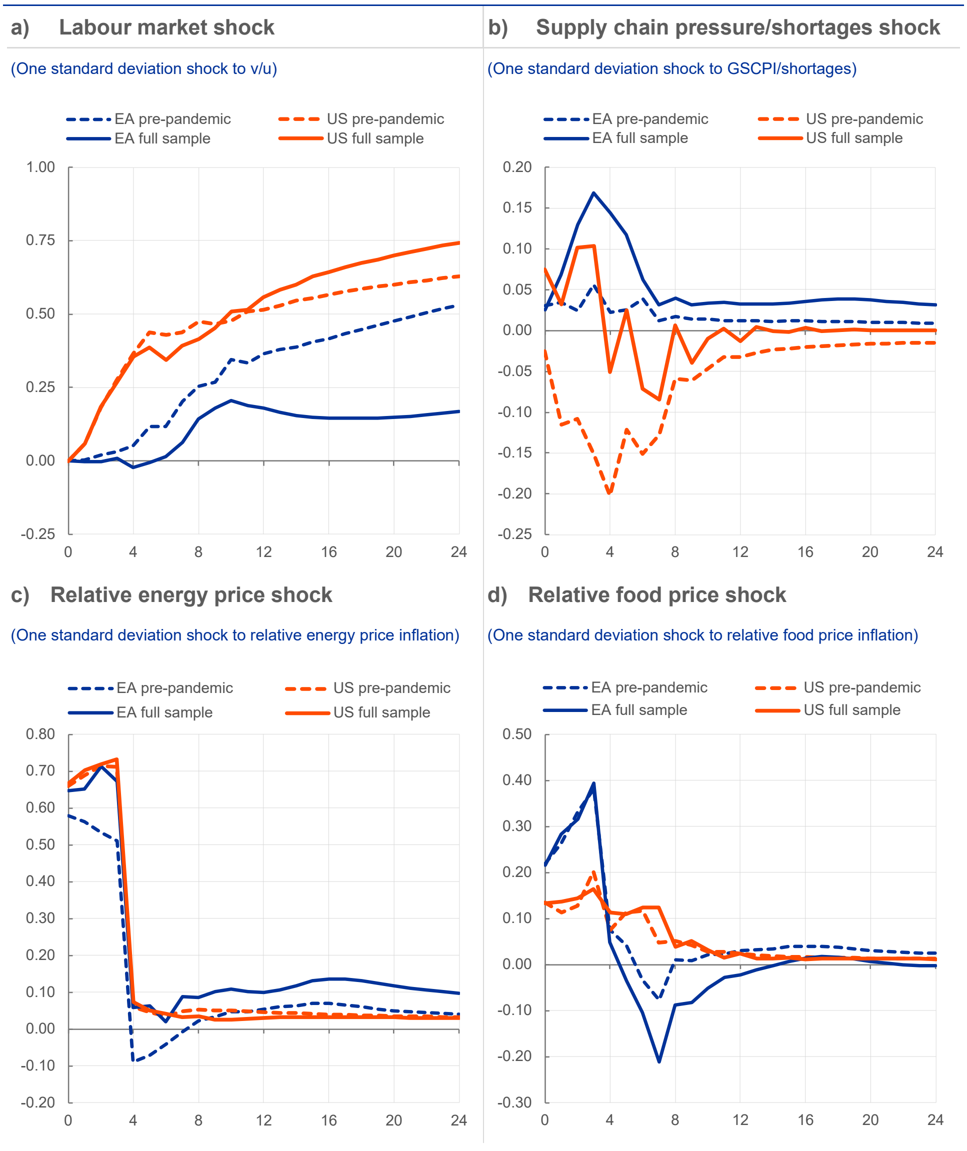
To compare the properties of the euro area model with the US model, we perform an impulse response analysis to shocks to the different added exogenous variables. This provides a better understanding of the internal propagation mechanisms of the models, going beyond the information the estimated parameters provide on the contemporaneous and lagged relationships between variables.

The estimated model can be used to compute impulse response functions (IRFs) that consider both simultaneous and lagged relationships between wages, prices, and inflation expectations. For example, we can estimate the dynamic effects of a shock to a particular equation or a change in any of the exogenous variables, taking a general equilibrium and dynamic perspective. Estimated impulse responses using the full model capture not only the direct effects of a given shock (e.g., as reflected in the estimated coefficients associated with the shocked variable in each of the equations) but also the knock-on effects in all subsequent periods. Impulse responses analysis therefore makes it possible to compare the dynamic properties of the models in response to selected shocks.

Chart 3 shows the estimated impulse responses of annual price inflation to shocks to the different exogenous variables for the euro area and the US models. The chart shows both the results of the models estimated using the full sample (the solid lines) and only with data prior to the pandemic (the dotted lines). The impulse responses of annual price inflation to a permanent one standard deviation shock to the vacancy-to-unemployment ratio are smaller in the euro area than in the US, owing to the flatter wage Phillips curve and weaker wage-to-price pass-through (Chart 3a). In the US, the significant wage-to-price pass-through and adaptive short-run inflation expectations imply more pronounced second-round effects than in the euro area. In this model, labour market shortages capture most of the demand channels that may impact inflation in the different economies. The implication is that, according to this model, a given fiscal impulse would contribute more to inflation in the US than in the euro area. Shocks to global supply chain pressures have a smaller contemporaneous impact in the euro area than in the US, but the response of inflation is more persistent in the former, due to the significance of the full distributed lag structure of the price equation. In the US model, the shock is initially larger but annual inflation quickly returns to baseline. The more persistent impact of supply chain disruptions may have also put more pressure on economic activity in the euro area than the US and could be one of the factors behind the faster recovery of the US economy after the pandemic; euro area firms are also more integrated into global value chains and the euro area economy is more open. Impulse responses of annual price inflation to a one standard deviation temporary shock to relative energy inflation (a permanent shock to relative prices) are closely aligned and fairly robust to the choice of the sample period. Annual price inflation returns close to the baseline within one year. In the euro area, the effects are more persistent if the sample includes the pandemic period. Finally, impulse responses of annual price inflation to a one standard deviation temporary shock to relative food inflation (a permanent shock to relative prices) are stronger on impact in the euro area but more persistent in the US. Considering the euro area full sample version, annual price inflation falls below baseline after one year before stabilising in the third year.

Chart 3

Impulse responses of annual price inflation to shocks to the exogenous variables



Notes: The figure shows the full model dynamic responses of inflation to a) a one standard deviation positive shock to the vacancy-to-unemployed ratio, b)) the global supply-chain pressure index (Google searches index for “shortages” for the US, c) the relative price of food, and d)) the relative energy price. The euro area model is estimated from the first quarter of 1999 onwards; the US model from the first quarter of 1990 onwards.

Overall, the impulse responses of the US model, which is estimated from the first quarter of 1990 onwards, are more robust to including the pandemic period in the estimation, apart from the IRFs to the shortages shock.

4.2 Dynamic decompositions

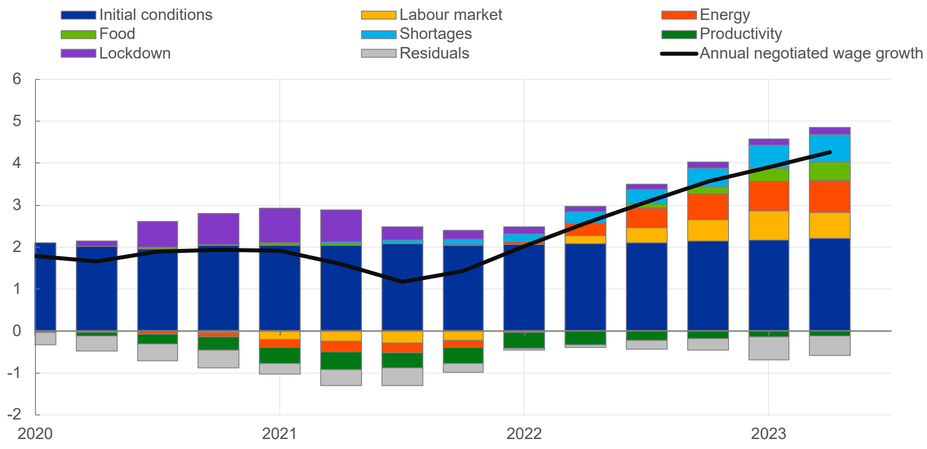
The estimated euro area model and the calculated IRFs for historical shocks can also be used to decompose the variation in any endogenous variable into its sources, taking dynamic and general equilibrium effects fully into account.

Chart 4 decomposes annual nominal wage growth into the contributions of initial conditions and exogenous shocks occurring during the pandemic. The initial conditions capture a counterfactual scenario in which there are no shocks to the euro area economy between the first quarter of 2020 and the second quarter of 2023 and show how nominal wage growth would look like absent those shocks. According to the model, their contribution is stable at around 2 percentage points per year. Labour market shocks explained only part of the above-trend nominal wage growth between the first quarter of 2022 and the second quarter of 2023 in the euro area. In fact, as in the United States, price shocks (commodity prices and shortages) contributed to higher wage growth by raising short-term inflation expectations and due to the real wage growth catch-up with unexpected inflation. Measures introduced during the pandemic to protect workers and wages such as job retention schemes captured by the lockdown shocks offset the negative contributions from lower productivity growth to some extent.

Chart 4

Sources of nominal wage growth in the euro area

(year-on-year growth rate, from the first quarter of 2020 to the second quarter of 2023)



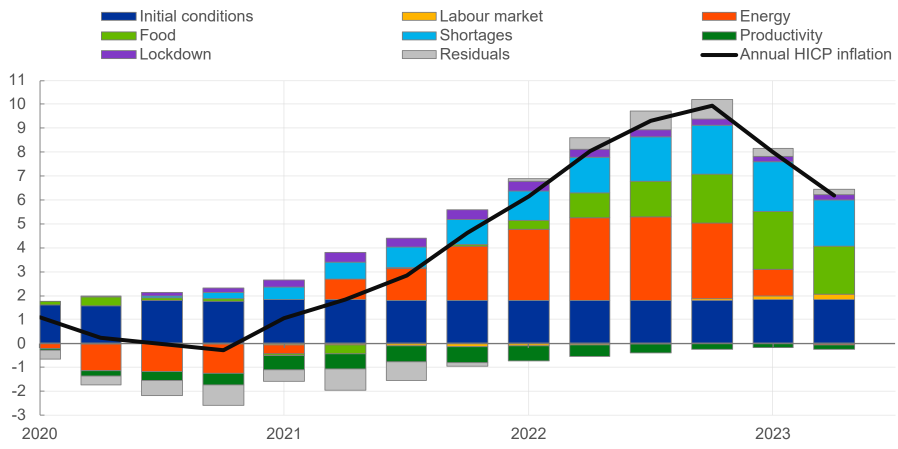
Notes: The figure shows a decomposition of the sources of annual negotiated wage growth between the first quarter of 2020 and the second quarter of 2023, based on the solution of the full model and the implied impulse response functions. The continuous line shows negotiated wage growth, and the total net heights of the bars are the model's forecast of inflation in each period, given initial conditions up to the fourth quarter of 2019. The contributions of the residuals are computed as the difference between actual and simulated data. The dark blue portion of each bar shows the contribution of pre-2020 data. The coloured segments of each bar show the general equilibrium, fully dynamic contribution of each exogenous variable to inflation in that period, as implied by the estimated model. Shocks to the rate of change of the relative price of energy and food are constructed as deviations of the values of those variables from zero. Shocks to the shortage variable are constructed as deviations of the values from the sample mean. Shocks to the vacancy-to-unemployment ratio variable are constructed as the actual value minus the value in the fourth quarter of 2019.

Chart 5 decomposes annual HICP inflation into the contributions of initial conditions and exogenous shocks occurring during the pandemic. According to the model, price inflation in the euro area was mainly driven by large positive contributions of energy prices shocks between the second quarter of 2021 and the first quarter of2023, initially due to strong energy demand with the re-opening of the economy, but later due to adverse supply-side effects, including supply chain bottlenecks and other distortions sparked by the Russian invasion of Ukraine. Since the first quarter of 2022, higher food price inflation has added to the inflationary pressures. Unlike in the US, energy contributions remained significant until the end of 2022, hence inflationary pressures were more persistent in the euro area. The euro area was also hit by an inflationary shock stemming from the combination of pent-up demand for goods and services amid subdued spending and excess savings accumulated during lockdowns and shortages for these goods due to supply chain disruptions. However, while the contribution of shortages to US price inflation was relatively short-lived, they are estimated to be affecting price inflation more persistently in the euro area, as shown by the impulse response function to a global supply chain pressure shock. More recently, tight labour market conditions have been contributing somewhat to higher inflation through their effects on wage growth. In the euro area, the small but increasing contributions from tight labour market conditions reflects the mild and delayed pass-through of the historically high vacancies-to-unemployed ratio to higher wages and prices. Last, the contributions of the initial conditions in the euro area are on average slightly below 2 percentage points, suggesting that, absent the pandemic era shocks considered here, inflation would have likely remained below 2%, in line with the ECB inflation target of "below, but close to, 2%" prior to the 2021 Strategy Review.

Chart 5

Sources of price inflation in the euro area

(year-on-year growth rate, from the first quarter of 2020 to the second quarter of 2023)



Notes: The figure shows a decomposition of the sources of annual HICP inflation between 2020Q1 and 2023Q2, based on the solution of the full model and the implied impulse response functions. The continuous line shows actual inflation, and the total net heights of the bars are the model's forecast of inflation in each period, given initial conditions up to the fourth quarter of 2019. The contributions of the residuals are computed as the difference between actual and simulated data. The dark blue portion of each bar shows the contribution of pre-2020 data. The coloured segments of each bar show the general equilibrium, fully dynamic contribution of each exogenous variable to inflation in that period, as implied by the estimated model. Shocks to the rate of change of the relative price of energy and food are constructed as deviations in the values of those variables from zero. Shocks to the shortage variable are constructed as deviations in the values from the sample mean. Shocks to the vacancy-to-unemployment ratio variable are constructed as the actual value minus the value in the fourth quarter of 2019.

4.3 Conditional projections

In the second quarter of 2023 wage growth and price inflation in the euro area were still above levels consistent with price stability. In this sub-section we perform four different exercises to understand how technical assumptions affect macroeconomic outcomes through the internal propagation mechanism of the BB model. First, we replicate the exercise of Bernanke and Blanchard (2023) with alternative scenarios for the labour market tightness assumption. Second, we explore parametric uncertainty by comparing forecasts when the model is estimated up to the fourth quarter of 2019 or the second quarter of 2023. Third, we quantify the implications of the uncertainty related to market-based energy assumptions using option-implied probability densities of oil and gas prices. Finally, we assess the differences between the model-based projections and the Eurosystem's macroeconomic projection exercise when forecasting in the third quarter of 2023 with the same information set.

4.3.1 Alternative scenarios for macroeconomic policy and labour market tightness

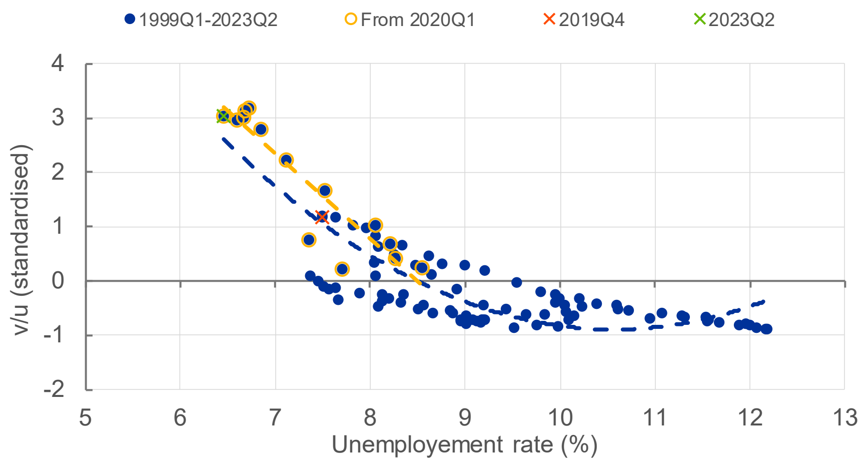
To assess the risk of a wage-price spiral and the stabilisation properties of macroeconomic policy as Bernanke and Blanchard (2023), we simulate the model from the third quarter of 2023, conditioning on assumptions about the expected paths of the added exogenous variables. In our baseline, energy and food prices are assumed to grow at 2%, supply chain pressures and productivity growth return to their historical mean, while the vacancy-to-unemployment ratio returns to its mean within eight quarters.[4] We can consider different scenarios using the model to understand how different demand conditions may impact expected price inflation and wage growth in the next few years. This includes the impact of monetary policy. For example, since 2022 the ECB has hiked short-term interest rates to achieve a restrictive monetary policy stance and slow demand pressures. This may bring down labour demand (reducing the number of job vacancies) and activity (raising the number of unemployed), eventually leading to a decline in the v/u ratio. Chart 6 describes the relationship between the v/u ratio and the unemployment rate for the euro area: using this curve, we can infer the impact of macroeconomic policy, which in the model operates through the v/u ratio, on the unemployment rate. For instance, in the second quarter of 2023 the v/u ratio was three standard deviations away from its sample mean and the unemployment rate stood at 6.4%. On a simple linear relationship, if v/u returns to its historical mean (0), the unemployment rate would increase to around 8.5%.

4 Relative energy and food inflation are endogenous to wage growth so if wage growth in the simulations is larger than 2%, the relative price of energy and food declines. The assumption of 2% energy inflation is below the pre-pandemic sample mean of 3.6%.

Chart 6

Labour market tightness and the unemployment rate in the euro area

(from the first quarter of 1999 to the second quarter of 2023)



Note: The linear fit is estimated on the period from the first quarter of 2020 to the second quarter of 2023; the non-linear fit on the period from the first quarter of 1999 to the second quarter of 2023.

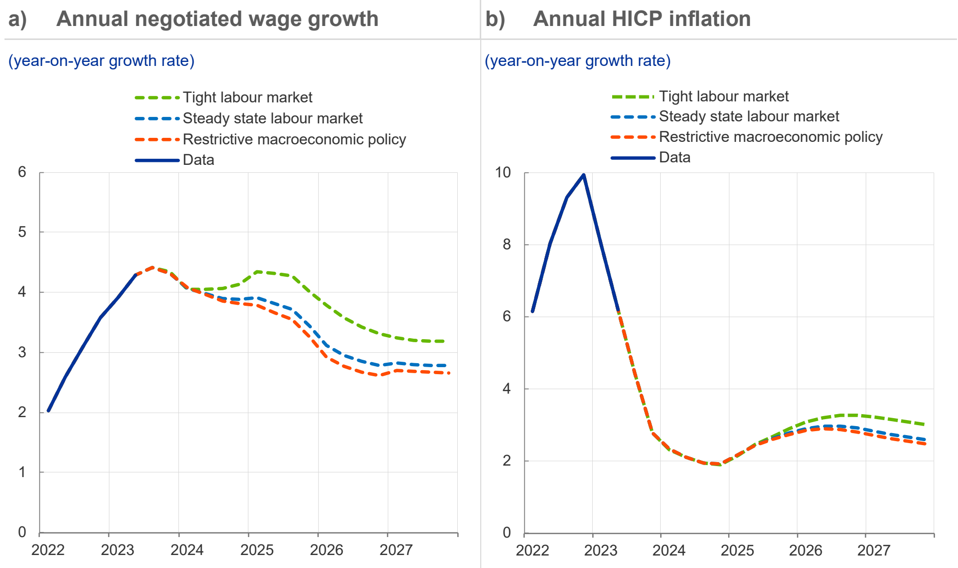
In addition to this central case, we consider two alternative scenarios based on different macroeconomic policy stances and therefore labour market trajectories. Specifically, we assume that macroeconomic policy leads v/u from its value in the second quarter of 2023 to one of the following terminal values over the course of eight quarters:

- the current value of v/u in the euro area (three standard deviations above the mean), i.e., a tight labour market contingency that would be consistent with an unemployment rate of 6.4%;
- the sample minimum of v/u for the euro area (0.9 standard deviations below the mean) achieved with a restrictive macroeconomic policy (fiscal and monetary) which would be consistent with an unemployment rate of between 9% and 10%.

Chart 7 shows the results of the conditional projections for euro area annual negotiated wage growth and annual HICP inflation, starting in the third quarter of 2023. According to these, wage growth is expected to stabilise towards the end of 2023 and moderate thereafter but remain high until at least the end of 2025. Annual HICP inflation is expected to slow down substantially and reach the 2% target in mid-2024 before rising back above 2%, even in a scenario with restrictive macroeconomic policy.

Chart 7

Conditional projections from the third quarter of 2023



Notes: The figure shows projected annual wage growth and annual price inflation in the model if v/u settles to three alternative terminal levels after eight quarters. In addition, relative energy and food inflation are endogenous to wages and energy and food inflation are assumed to be 2%, shortage to return to its historical mean and labour productivity growth to be 0.7% per year.

4.3.2 Sensitivity to the estimation sample: excluding observations from the pandemic period

We assess the robustness of the conditional projections presented above to the sample period used for the estimation of the parameters. Chart 8 shows conditional projections under the same set of assumptions and sensitivities as above, but with an additional sensitivity to the sample period used for estimation. In blue, the conditional projections are computed as above using parameters estimated on the full sample up to the second quarter of 2023. In red, the parameters are estimated on the sample ending in the fourth quarter of 2019, prior to the pandemic.

The projections using the model estimated on the pre-pandemic period point to more persistent price inflation in the short-term and the stabilisation of annual HICP inflation at around 3% until the end of 2026. The flatter wage Phillips curve and weaker wage-to-price pass-through in the full sample estimated version imply possibly softer second-round effects and a faster disinflation process, driven by substantial food disinflation. However, even with these factors explaining the short-term disinflation, inflation is still expected to settle at around 3% in the medium term. These sensitivities make it possible to gauge risks to the inflation outlook stemming from changes in the fundamental relationships between wages, prices and expectations. This suggests that stronger second-round effects could be a potential source of upside risks to euro area inflation if the model parameters revert to their pre-pandemic values, which could maintain price inflation significantly above target.

Chart 8

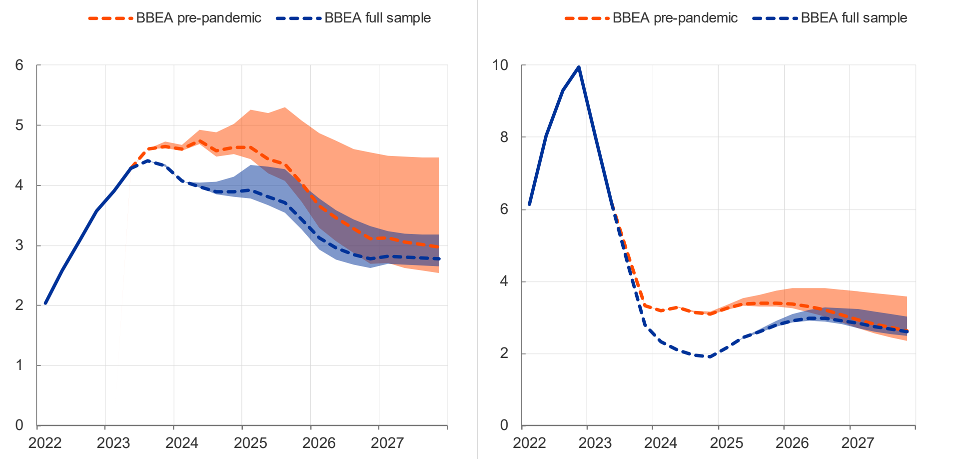
Conditional projections from the third quarter of 2023: sensitivity to estimation period

a) **Annual negotiated wage growth**

(year-on-year growth rate)

b) **Annual HICP inflation**

(year-on-year growth rate)



Notes: The figure shows projected annual wage growth and annual price inflation in the model if v/u settles to three alternative terminal levels after eight quarters. In addition, relative energy and food inflation are endogenous to wages and energy and food inflation are assumed to be 2%, shortage to return to its historical mean and labour productivity growth to be 0.7% per year. The bands depict the conditional projections for the endogenous variables with the alternative paths for v/u.

4.3.3 Sensitivity to technical assumptions

We also assess the risks associated with the uncertainty surrounding the technical assumptions, particularly energy price inflation. In our previous simulations we assumed that energy inflation would remain stable at 2% throughout the projection horizon. To account for the uncertainty associated with this assumption we have employed options-implied probability densities of oil and gas prices to derive the probability densities of HICP energy inflation (Chart 9). Information about expected energy price inflation quantiles serves as the basis for a model-based analysis that allows us to evaluate the balance of risks for annual wage growth and price inflation.

Chart 9

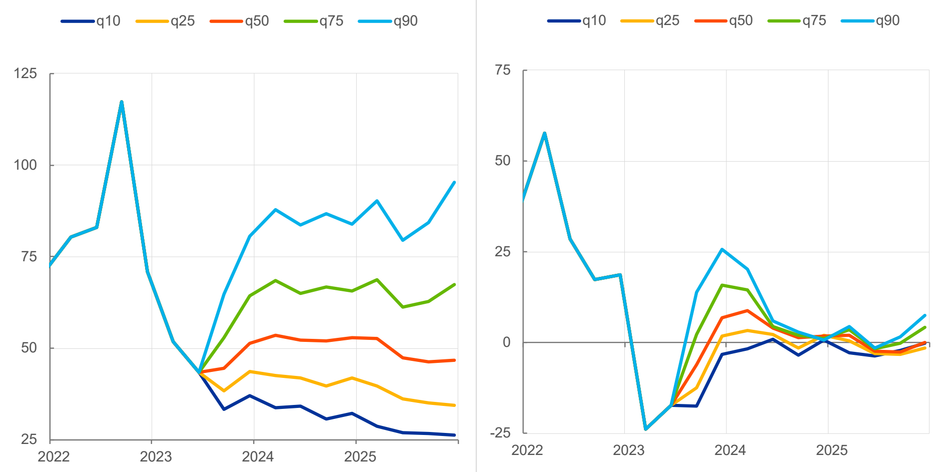
Energy price assumption percentiles based on market expectations

a) **Synthetic energy price index**

(USD per MWh, level)

b) **HICP energy inflation**

(quarter-on-quarter growth rate, annualised)



Notes: Chart a) shows the quantiles of the distribution of the expected synthetic energy price index, extracted from 22 August 2023 market quotes of options on ICE Brent Crude Oil and Dutch TTF natural gas futures with fixed quarterly expiry dates. Chart b) shows the estimated impact of those quantiles on the distribution of quarter-on-quarter growth rates of HICP energy inflation in the euro area.

Chart 10 indicates that the balance of risks for annual price inflation is tilted to the upside in the short term, amid risks that energy inflation picks up in the first quarter of 2024 before unwinding.

Chart 10

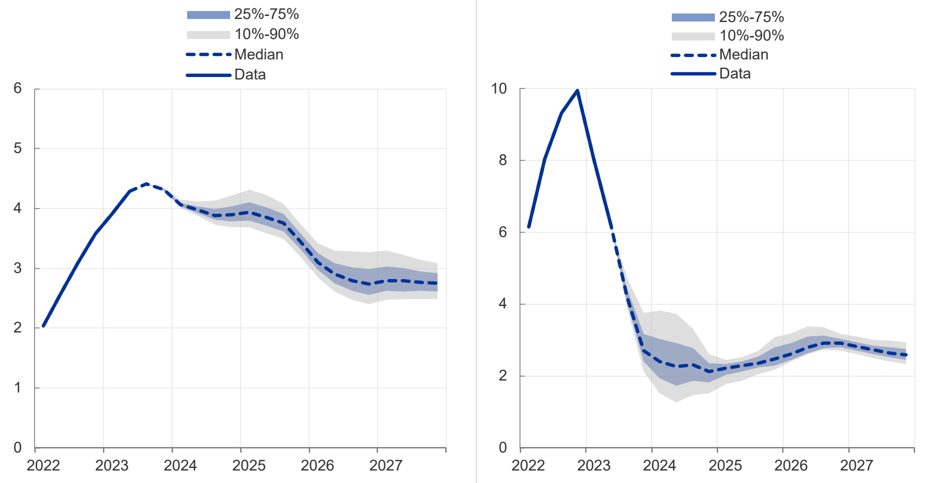
Conditional projections using options-implied probability densities

a) **Annual negotiated wage growth**

(year-on-year growth rate)

b) **Annual HICP inflation**

(year-on-year growth rate)



Notes: The figure shows projected annual wage growth and annual price inflation in the model if v/u settles at three alternative terminal levels after eight quarters. The bands are computed using the 10%, 25%, 50%, 75% and 90% range of options-implied densities of gas and oil prices extracted from 22 August 2023 market quotes of options on ICE Brent Crude Oil and Dutch TTF natural gas futures with fixed quarterly expiry dates.

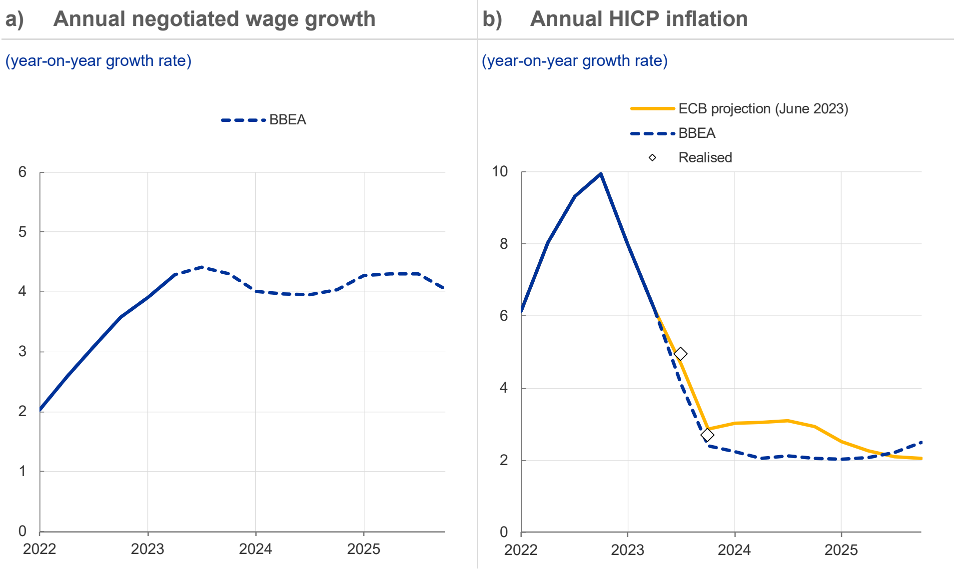
4.3.4 Forecasting with assumptions consistent with the Eurosystem’s macroeconomic projections exercise of June 2023

Last, we design a realistic scenario to benchmark the model’s conditional projections with the Broad Macroeconomic Projection Exercise (BMPE) of June 2023, performed jointly by ECB and Eurosystem staff. To do this we align our information set, namely the initial conditions (as at the second quarter of 2023) and the technical assumptions underpinning the conditional projections (about energy prices, food prices, productivity growth, shortages and labour market tightness) with that used in the June 2023 BMPE.

Chart 11 depicts the projections of annual wage growth and annual HICP inflation in the June 2023 BMPE and the conditional projections using the Bernanke and Blanchard model with the common set of assumptions. The model predicts above-trend wage growth until the end of 2025. Meanwhile, annual inflation eases significantly and settles around the ECB inflation target around mid-2024, a year earlier than in the June 2023 BMPE due to the swifter disinflation process driven by substantial food disinflation. In 2023 and 2024 annual HICP inflation is lower than in the June 2023 BMPE, even though wage growth is projected to be higher. This mainly reflects the weak wage-to-price pass-through in the model. At the same time, the model does not incorporate the indirect inflationary effects projected by the ECB and Eurosystem staff for 2024 from the removal of energy-related fiscal measures introduced in 2022. The white diamonds depict annual HICP inflation outturns for the third quarter and fourth quarters of 2023.

Chart 11

Conditional projections using Eurosystem technical assumptions



Note: The figure shows projected annual wage growth and HICP inflation using the June 2023 BMPE technical assumptions.

We can perform decompositions of the projected variables to understand the drivers behind the conditional scenarios. Charts 12 and 13 depict the decomposition of annual wage growth and annual HICP inflation for a conditional projection consistent with the June 2023 BMPE.

Chart 12

Decomposition of annual negotiated wage growth

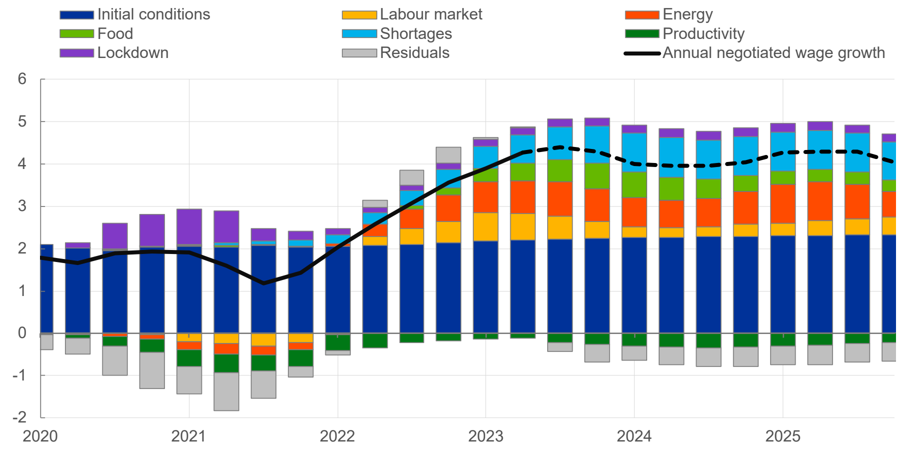
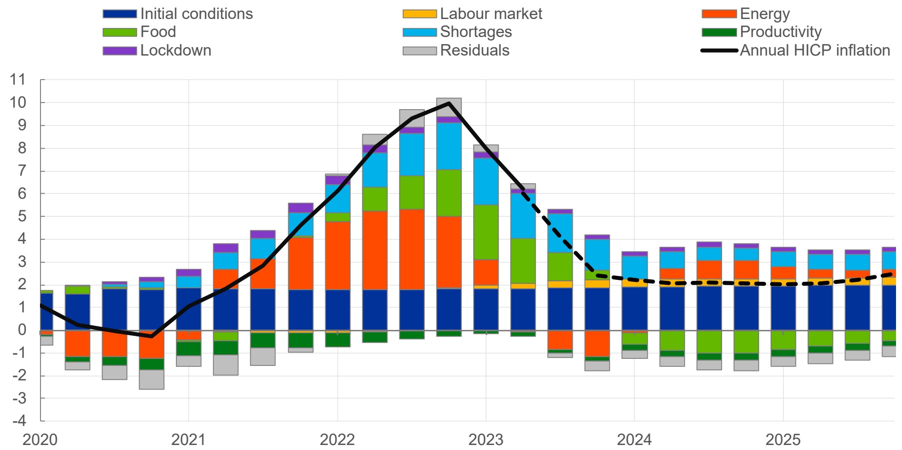


Chart 13

Decomposition of annual HICP inflation



Under this contingency, labour market conditions would still put upward pressure on wage growth and price inflation until the end of 2025. Higher wage growth since mid-2024 is explained by the significant positive contributions of prices shocks, which reflect the delayed real wage growth catch-up effect and the pass-through of supply bottlenecks and higher energy and food prices to wages through their effect on inflation expectations. In 2024 and 2025 food prices and productivity growth are expected to contribute to the disinflation, while energy, shortages and the labour market would still put upward pressure on HICP inflation, and wage growth. As shown in Chart 3, food price shocks imply negative inflation one year after they materialise. Thus, according to the model, the food price shocks that occurred in 2022 and 2023 may push down inflation in 2024 and 2025 and support the overall disinflation process. At the same time, global supply chain pressures and energy prices are expected to drive inflation persistently above target over the projection horizon.

5 Conclusions

Based on a recent model by Bernanke and Blanchard, this paper identifies the drivers of post-pandemic inflation and provides a model-based assessment of medium-term wage and price dynamics in the euro area.

The model shows that the main drivers of inflation in the euro area have been supply-side shocks, with a more limited role for demand shocks as captured by labour market tightness, notwithstanding the supply-demand imbalances due to pent-up demand and supply chain disruptions. These pandemic-era shortages may have had a more persistent impact on euro area inflation than initially anticipated. Also, the role of supply shocks in the euro area is larger than in the US, mostly due to its greater exposure to the idiosyncratic effects of the Russian invasion of Ukraine.

Conditional projections using the model show that wage growth may remain high over the coming years, as real wages catch up with the price level after the recent high inflation episode. According to the model, HICP inflation may decline faster than anticipated in ECB staff projections in June 2023 and reach target as early as mid-2024 when conditioning on a comparable set of technical assumptions. However, inflation risks are still tilted to the upside given market-based expectations for future energy prices. Stronger second-round effects may also materialise if the historical relationships between different macroeconomic variables become more similar to those in the pre-pandemic period.

Finally, this paper explores the implications of integrating the pandemic period in the estimation sample for the model properties (IRFs) and conditional projections, shedding light on potential structural breaks and non-linearities during the pandemic period that could be relevant when re-estimating the main macroeconometric models of the euro area.

Overall, the model is particularly well-suited to explaining the specific post-pandemic inflation dynamics and therefore provides a useful benchmark for cross-checking inflation forecasts. For example, at the current juncture, the model is a useful tool for assessing the potential impact of tensions in the Middle East and the Red Sea on inflation via its effect on global supply chains. However, the model may not be flexible enough to cope with future monetary policy challenges. The model specification could be improved for instance by adding (i) an explicit role for demand-side policies (and hence monetary and fiscal policies), (ii) more forward-looking expectations, and (iii) modelling of labour market tightness and global supply chain pressures. These changes would help capture the general equilibrium and anticipated effects of policy shifts, in particular the role of the expectation channel for policy announcements.

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7 Appendix

7.1 Data

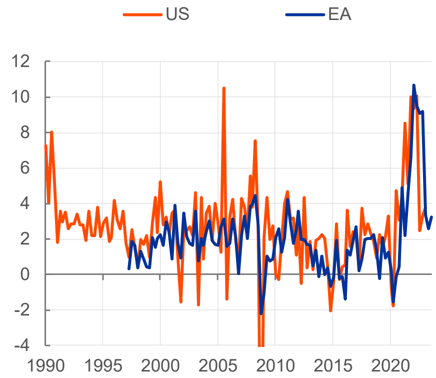
	United States	Euro area
Endogenous variables		
π_t	Price inflation, as measured by quarterly annualised rates of change in the Consumer Price Index (CPI), Bureau of Labor Statistics (BLS)	Price inflation, as measured by the quarterly annualised rates of change in the quarterly average of euro area (changing composition) - HICP Overall index, European Central Bank (ECB)
w_t	Rate of growth of nominal wages, quarterly and annualised, as measured by the rate of change in the Employment Cost Index (ECI), BLS	Rate of growth of nominal wages, quarterly and annualised, as measured by the rate of change in euro area (changing composition) negotiated wage growth (seasonally adjusted)
π_t^{e1}	Short-term inflation expectations, measured by one-year inflation expectations as constructed by the Federal Reserve Bank of Cleveland	Short-term inflation expectations, measured by the quarterly average of one-year ahead inflation expectations from the monthly consensus survey
π_t^{e10}	Long-term inflation expectations, measured by the Cleveland Fed’s ten-year inflation expectations series	Long-term inflation expectations, measured by the longer-term (five years ahead) annual HICP inflation forecast of the ECB Survey of Professional Forecasters (SPF)
$\breve{\pi}_t$	Losses to workers’ purchasing power due to inflation, measured by the four-quarter average of CPI inflation minus the one-year inflation expectation four quarters earlier. Catch-up is a linear combination of past gp and cf1.	Losses to workers’ purchasing power due to inflation, measured by the four-quarter average of HICP inflation minus the one-year inflation expectation four quarters earlier. Catch-up is a linear combination of past gp and cf1.
Exogenous variables		
E_t	Rate of growth of the relative price of energy, quarterly and annualised, measured as the rate of change of the ratio of CPI energy prices to the ECI	Rate of growth of the relative price of energy, quarterly and annualised, measured as the rate of change of the ratio of HICP energy prices to compensation per employees
F_t	Rate of growth of the relative price of food, quarterly and annualised, measured as the rate of change of the ratio of CPI food prices to the ECI	Rate of growth of the relative price of food, quarterly and annualised, measured as the rate of change of the ratio of HICP food prices to compensation per employees
vu_t	Ratio of job vacancies to unemployment, from the BLS Job Openings and Labor Turnover Survey (JOLTS) and the BLS Employment Report. Earlier data from Barnichon (2010)	Job vacancies-to-unemployed ratio, backcasted using EU Commission survey-based measure of labour shortage as a factor limiting production in industry, working day and seasonally adjusted
S_t	An index of supply chain problems based on Google searches for “shortages”	NY Fed Global Supply Chain Pressure Index, first lag
A_t^{LT}	Trend productivity growth, measured by the change in the eight-quarter moving average of nonfarm business value-added divided by nonfarm employee hours, from the BLS	Long-tern productivity growth, measured by the eight-quarter moving average of the quarterly change in gross value-added divided by total employment, from Eurostat

Chart 14

Endogenous variables

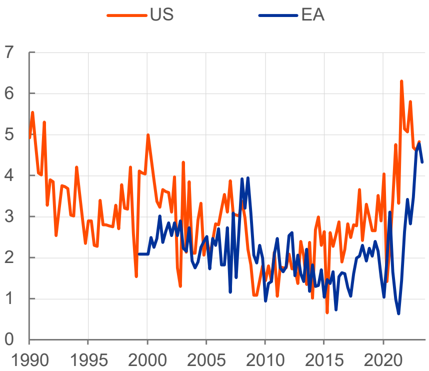
a) Price inflation

(quarter-on-quarter, annualised, working day and seasonally adjusted)



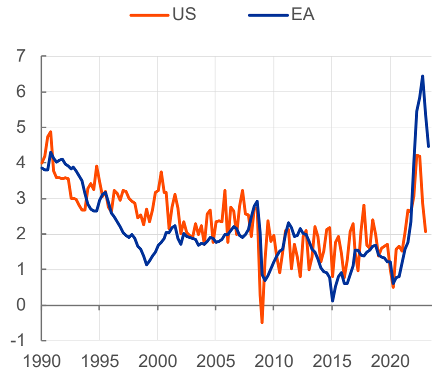
b) Wage growth

(quarter-on-quarter, annualised and seasonally adjusted)



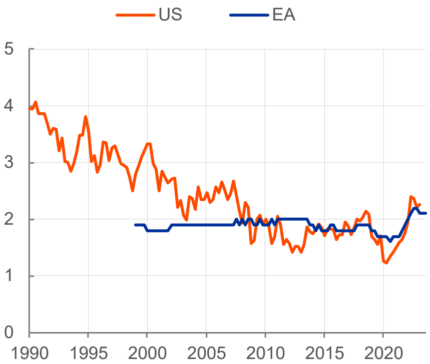
c) Expected inflation, one year ahead

(quarter-on-quarter, annualised, calendar and seasonally adjusted)



d) Expected inflation, long-term

(quarter-on-quarter, annualised, calendar and seasonally adjusted)



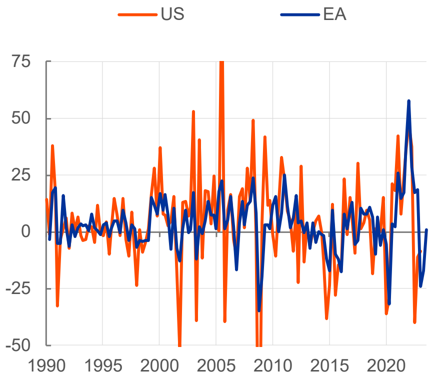
Notes: Price inflation: US: Consumer Price Index for All Urban Consumers: All Items in U.S. City Average, Index 1982-1984=100 EA: Euro area (changing composition) - HICP - Overall index, European Central Bank, Seasonally and working day adjusted. Wage growth: US: Employment Cost Index: Wages and Salaries: Private Industry Workers, with data from 1982 to 2001 from David R. EA: Euro area (changing composition) - Indicator of negotiated wage rates, Total - Annual rate of change; European Central Bank; Seasonally adjusted. Expectations: US: One-year inflation expectations, Federal Reserve Bank of Cleveland EA: One-year inflation expectations, Consensus. US: Ten-year inflation expectations, Federal Reserve Bank of Cleveland EA: Inflation expectations above 5 years, European Central Bank, Survey of Professional Forecasters

Chart 15

Exogenous variables

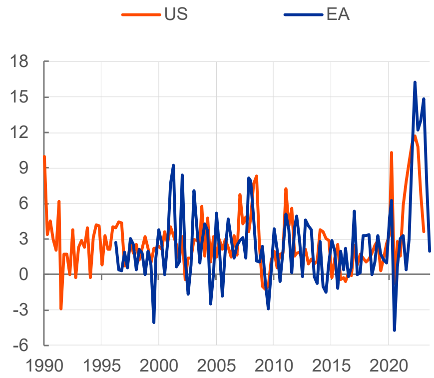
a) **Energy price inflation**

(quarter-on-quarter, annualised, neither working day and seasonally adjusted)



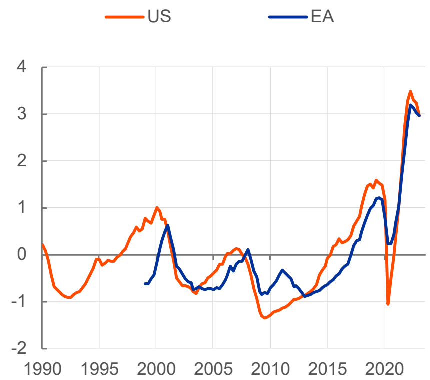
b) **Food price inflation**

(quarter-on-quarter, annualised, working day and seasonally adjusted)



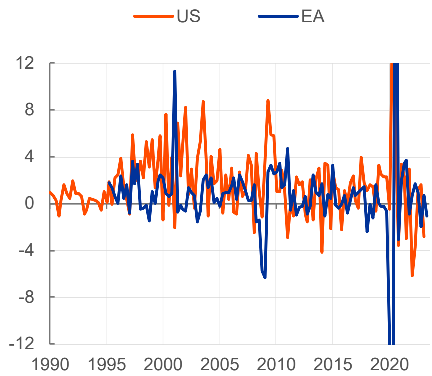
c) **Job vacancies / unemployed**

(standardised)



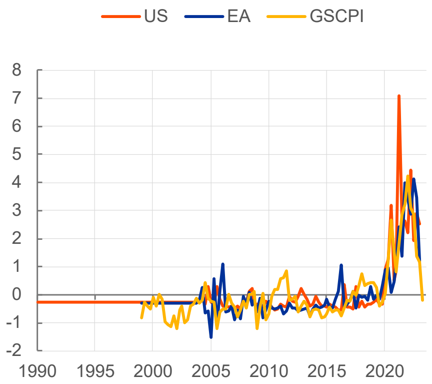
d) **Labour productivity**

(quarter-on-quarter, annualised, calendar and seasonally adjusted)



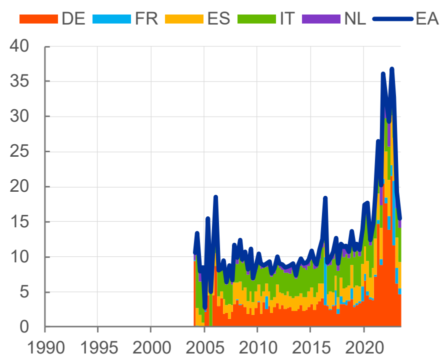
e) **Shortage and global supply chain pressure**

Index



f) **Shortage, euro area aggregation**

Google index, contributions by country



Notes: Energy inflation: US: Consumer Price Index for All Urban Consumers: Energy in U.S. City Average, Index 1982-1984=100, Quarterly, Seasonally Adjusted. EA: Euro area (changing composition) - HICP - Energy, Quarterly average of monthly index, Eurostat, neither seasonally nor working day adjusted. Food inflation: US: Consumer Price Index for All Urban Consumers: Food in U.S. City Average, Index 1982-1984=100, Quarterly, Seasonally Adjusted. EA: Euro area (changing composition) - HICP - Food incl. alcohol and tobacco, Quarterly average of monthly index, European Central Bank, Working day and seasonally adjusted. Labour market tightness: US: Ratio of job vacancies to unemployment, from the BLS Job Openings and Labor Turnover survey (JOLTS) and the BLS Employment Report. Earlier data from Barnichon (2010). EA: Composite indicator of the ratio of job vacancies to unemployment, from Eurostat IESS quarterly data for EA19 and Haver and the European Commission indicator of "labour shortage as a factor limiting production" in industry. Productivity: US: Nonfarm Business Sector: Labour Productivity (Output per Hour) for All Employed Persons, Index 2012=100, Quarterly, Seasonally Adjusted. EA: Value-added, gross per worker - Euro area changing composition - Total economy, Euro, Chain linked volume, Calendar and seasonally adjusted. Shortages: US/EA: An index of supply chain problems based on Google searches or NY Fed Global Supply Chain Pressure Index (GSCPI).

7.2 Full regression table

	Wage growth	Price inflation	Short-term inflation expectations	Long-term inflation expectations
Wage growth (t-1)	0.19*	-0.08		
	(0.12)	(0.10)		
Wage growth (t-2)	0.13	0.05		
	(0.11)	(0.11)		
Wage growth (t-3)	0.03	0.12		
	(0.11)	(0.11)		
Wage growth (t-4)	-0.05	-0.01		
	(0.11)	(0.11)		
Wage growth (t)		0.24**		
		(0.10)		
Short-term inflation expectations (t-1)	-0.45		0.77***	
	(0.32)		(0.11)	
Short-term inflation expectations (t-2)	0.30		-0.00	
	(0.40)		(0.15)	
Short-term inflation expectations (t-3)	-0.47		-0.19	
	(0.46)		(0.16)	
Short-term inflation expectations (t-4)	1.32***		0.14	
	(0.38)		(0.09)	
Long-term productivity growth (t-1)	0.08			
	(0.07)			
Long-term productivity growth (t)		0.07		
		(0.06)		
Vacancies/unemployed (t-1)	0.27			
	(0.51)			
Vacancies/unemployed (t-2)	-0.98			
	(0.89)			
Vacancies/unemployed (t-3)	2.01**			
	(0.91)			
Vacancies/unemployed (t-4)	-1.24**			
	(0.54)			
Unexpected inflation (t-1)	0.50***			
	(0.18)			
Unexpected inflation (t-2)	-0.26			
	(0.18)			
Unexpected inflation (t-3)	0.17			

	(0.19)			
Unexpected inflation (t-4)	-0.34***			
	(0.12)			
Lockdown dummy (2020Q2)	0.50			
	(0.60)			
Lockdown dummy (2020Q3)	1.85**			
	(0.76)			
Price inflation (t-1)		0.32**	0.10***	0.01*
		(0.12)	(0.02)	(0.00)
Price inflation (t-2)		0.33**	-0.02	0.00
		(0.13)	(0.02)	(0.00)
Price inflation (t-3)		0.10	0.01	-0.01*
		(0.12)	(0.02)	(0.00)
Price inflation (t-4)		-0.06	-0.01	-0.00
		(0.13)	(0.02)	(0.00)
Price inflation (t)			0.12***	0.01***
			(0.01)	(0.00)
Relative energy price inflation (t)		0.11***		
		(0.00)		
Relative energy price inflation (t-1)		-0.03**		
		(0.01)		
Relative energy price inflation (t-2)		-0.03*		
		(0.01)		
Relative energy price inflation (t-3)		-0.02*		
		(0.01)		
Relative energy price inflation (t-4)		0.01		
		(0.01)		
Relative food price inflation (t)		0.16***		
		(0.03)		
Relative food price inflation (t-1)		-0.00		
		(0.03)		
Relative food price inflation (t-2)		-0.04		
		(0.03)		
Relative food price inflation (t-3)		0.02		
		(0.03)		
Relative food price inflation (t-4)		-0.12***		
		(0.03)		
Global supply chain pressure (t)		0.08		
		(0.12)		
Global supply chain pressure (t-1)		0.11		
		(0.14)		
Global supply chain pressure (t-2)		0.13		
		(0.15)		
Global supply chain pressure (t-3)		0.01		
		(0.14)		
Global supply chain pressure (t-4)		-0.11		
		(0.12)		

Long-term inflation expectations (t)			0.20	
			(0.35)	
Long-term inflation expectations (t-1)			0.00	0.55***
			(0.39)	(0.11)
Long-term inflation expectations (t-2)			-0.21	0.38***
			(0.42)	(0.12)
Long-term inflation expectations (t-3)			0.28	-0.03
			(0.39)	(0.12)
Long-term inflation expectations (t-4)			-0.20	0.09
			(0.36)	(0.11)
Intercept	0.21	-0.14		
	(0.13)	(0.10)		
R-squared				
Observations	89	90	93	93

Notes: Sample covers the period from the first quarter of 1999 to the second quarter of 2023. Clustered standard errors in parentheses, * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

7.3 Robustness check

7.3.1 Pre-pandemic estimates

Table 5

Wage growth equation

Sample period: first quarter 1999 – fourth quarter 2019

(Sum of coefficients)

Independent variables	Wage growth	Labour market tightness	Unexpected inflation	Short-term inflation expectations	Long-term productivity	Lockdown (2020Q2 and 2020Q3)
Lags	-1 to -4	-1 to -4	-1 to -4	-1 to -4	-1	Omitted
Sum of coeff.	0.212	0.308	0.043	0.788	0.134	
p-stat (sum)	0.341	0.037	0.765	0.001	0.124	
p-stat (joint)	0.243	0.010	0.002	0.000	0.124	
R-squared	0.638					
N (obs)	75					

Notes: p-value (sum) is the p-value for the null hypothesis that the sum of coefficients is zero, p-value (joint) is the p-value for the joint hypothesis that each of the lag coefficients separately equals zero.

Table 6
Price inflation equation

Sample period: first quarter 1999 – fourth quarter 2019

(Sum of coefficients)

Independent variables	Price inflation	Wage growth	Relative energy price inflation	Relative food price inflation	Supply chain pressure	Long-term productivity
Lags	-1 to -4	0 to -4	0 to -4	0 to -4	0 to -4	-1
Sum of coeff.	0.531	0.469	0.032	0.084	0.102	0.189
p-stat (sum)	0.004	0.011	0.080	0.212	0.394	0.005
p-stat (joint)	0.066	0.009	0.000	0.000	0.863	0.005
R-squared	0.967					
N (obs)	76					

Notes:. p-value (sum) is the p-value for the null hypothesis that the sum of coefficients is zero, p-value (joint) is the p-value for the joint hypothesis that each of the lag coefficients separately equals zero.

Table 7
Short-term inflation expectations equation

Sample period: first quarter 1999 – fourth quarter 2019

(Sum of coefficients)

Independent variables	Short-term inflation expectations	Long-term inflation expectations	Price inflation
Lags	-1 to -4	0 to -4	0 to -4
Sum of coeff.	0.805	0.055	0.139
p-stat (sum)	0.000	0.062	0.002
p-stat (joint)	0.000	0.148	0.000
R-squared	0.967		
No. observations	79		

Notes:. p-value (sum) is the p-value for the null hypothesis that the sum of coefficients is zero, p-value (joint) is the p-value for the joint hypothesis that each of the lag coefficients separately equals zero.

Table 8
Long-term inflation expectations regression

Sample period: first quarter 1999 – fourth quarter 2019

(Sum of coefficients)

Independent variables	Long-term inflation expectations	Price inflation
Lags	-1 to -4	0 to -4
Sum of coeff.	0.985	0.015
p-stat (sum)	0.000	0.026
p-stat (joint)	0.000	0.014
R-squared	0.688	
No. observations	79	

Notes:. p-value (sum) is the p-value for the null hypothesis that the sum of coefficients is zero, p-value (joint) is the p-value for the joint hypothesis that each of the lag coefficients separately equals zero.

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