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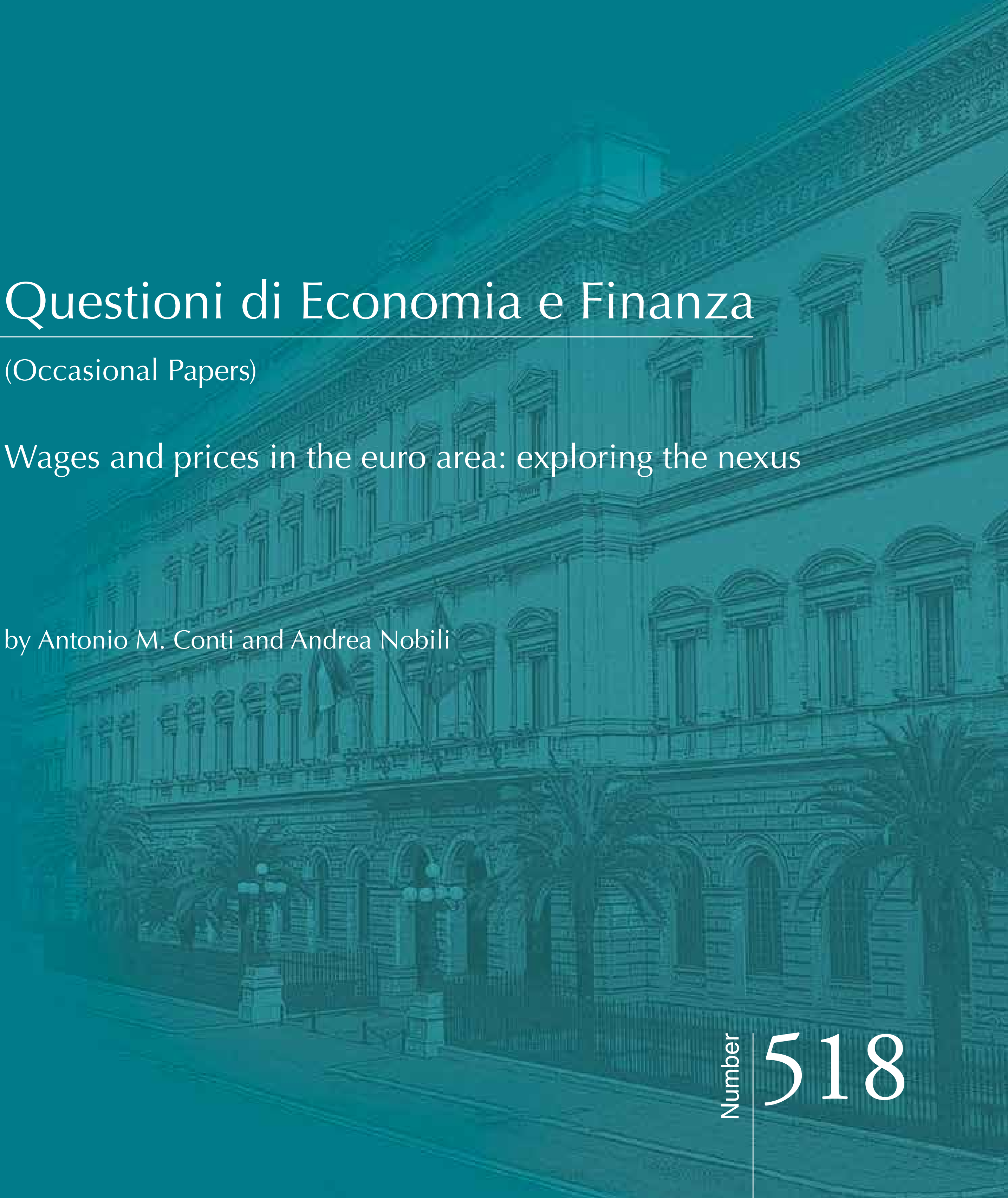

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WAGES AND PRICES IN THE EURO AREA: EXPLORING THE NEXUS

by Antonio M. Conti* and Andrea Nobili*

Abstract

We investigate the structural relationship between wages dynamics and core inflation in the euro area using Bayesian VAR models. We find that the pass-through from wages to consumer prices net of food and energy is less than unity and depends on the nature of the shocks hitting the economy. A monetary policy shock implies a positive co-movement between these variables, which is similar in magnitude to that stemming from an aggregate demand shock. Financial shocks, as captured by credit spreads and indicators of systemic stress, are instead associated with a negative co-movement between wages and prices and generate firms' countercyclical mark-ups, consistently with recent models featuring financial frictions and nominal rigidities. These findings may explain why the recent pick-up in wages is not associated with a sustained path of core inflation in the euro area.

JEL Classification: E30, E32, E51.
Keywords: wage-price pass-through, countercyclical mark-ups, financial shocks, Bayesian VAR.

Contents

* Banca d'Italia, Economic Outlook and Monetary Policy Directorate.

"*When the Governing Council met in October, we confirmed our confidence in the economic outlook. The underlying strength of domestic demand and wages continues to support our view that the sustained convergence of inflation to our aim will proceed. But in the light of the lags between wages and prices after a period of low inflation, patience and persistence in our monetary policy is still needed.*"

(*Mario Draghi, President of the ECB, Frankfurt European Banking Congress, Frankfurt am Main, 16 November 2018*).

1. Introduction*

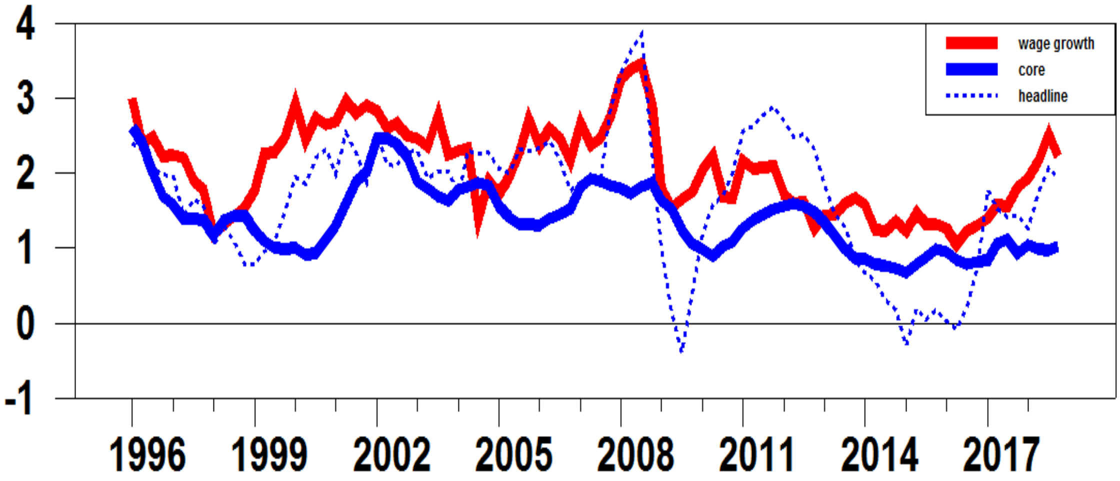
The empirical link between wage dynamics and inflation has gained novel attention in the macroeconomic literature as well as in the monetary policy debate. Following the Global Financial Crisis both nominal wage growth and inflation hovered around historically low values both in the US and the euro area, notwithstanding the gradual recovery of economic activity and the improvements in the labour market. Several contributions addressed the determinants of a "wageless recovery" (Calvo et al., 2012; Bell and Blanchflower, 2018; Conti et al., 2019) while other research tried to solve the "missing disinflation" puzzle, namely why price inflation did not decline by as much as conventional models would have predicted following the 2007–09 recession (Coibion and Gorodnichenko, 2015; Del Negro et al., 2015; Bobeica and Jarocinski, 2017). Another strand of the literature, largely inspired by the US case, assesses why the dynamics of labour cost had little even no independent effect for consumer price inflation in the most recent period once one accounts for labor market slack (Knotek and Zaman, 2014), mostly relating this evidence to a break in the relationship between labour costs and price measures after the early 1980 (Peneva and Rudd, 2017). This evidence casts doubts about both the reliability of the New Keynesian Phillips Curve, which lies at the heart of fully fledged DSGE models where inflation is driven by inflation expectations and a measure of unit labour cost (see, for example, Galì and Gertler, 1999) as well as about the pricing equation block included in many large-scale econometric models at central banks and used for forecasting exercise (see, for example, Mazumder, 2011; King and Watson, 2012; Peneva and Rudd, 2017, and references therein).[1]

* We thank Cristina Conflitti, André Kurmann, Alberto Locarno, Stefano Neri, Ekaterina Peneva, Stefano Siviero and Roberta Zizza for useful comments and suggestions. We are also grateful to Anna Maria Stellati for editorial assistance. This work has been written while Antonio M. Conti was Visiting Scholar at the Department of Economics of the Pennsylvania University, whose hospitality is gratefully acknowledged. All errors are the sole responsibility of the authors. *The views expressed in the paper do not necessarily reflect those of Banca d'Italia or the Eurosystem.*

[1] Peneva and Rudd (2017) offer a review of the existing literature for the US and analyze the empirical relationship between wages and prices using a small VAR model with time-varying parameters and stochastic volatility. The authors find that price inflation is currently tied down by a stable stochastic trend, to which it ultimately returns once resource

Wage dynamics is also at the heart of the current policy debate in the euro area. Figure 1 shows that since the end of 2016 compensation per employee has been accelerating, standing at 2.2% at the end of 2018. By contrast, core inflation continued to hover well below its historical average, disappointing again Eurosystem and professional projections[2]. The view of the ECB Governing Council is that a missing reaction of core inflation should not be a reason for concern: wage dynamics is supporting inflation, but the transmission is lagged and may be slower, particularly in times of low inflation, so that patience and persistence is needed in the ECB's monetary policy (Draghi, 2018).

Figure 1. HICP inflation and wage dynamics in the euro area
(*percentage points*)



Notes: the figure is based on quarterly data taken from the AWM dataset and the ECB Statistical data warehouse. Headline inflation is the year-on-year change in HICP. Core inflation is the year-on-year change in HICP excluding food, energy and tobacco. Wage growth is the year-on-year change in nominal compensation per employee.

The key challenge for both academics and policymakers is that labour cost dynamics and inflation involve a two-way nexus, which makes difficult to assess the direction of causality. On the one side, in some countries workers' pay is directly linked to previous rates of inflation and this mechanism can explain some of the increase in nominal wage growth over the past few years. Even

utilization rates return to normal levels and the influences of any other shocks dissipate. As a result, price inflation responds less persistently to changes in real activity or labour costs. In this regard, the joint dynamics of inflation and compensation no longer manifest the standard wage–price spiral that emerged in earlier decades. A related finding is that the change to the inflation process predates the 2007–09 recession and it is not related to the Great Recession itself.

[2] In the same time span unemployment rate dropped from 9.7% to 7.9%. While the pick-up of wages was initially driven by the drift component –which includes bonuses and overtime and tends to react more quickly to the cycle–, the subsequent acceleration was due to negotiated wages, which is the labour cost indicator linked to collective bargaining.

where there is no direct link, workers are likely to push for higher nominal wages when consumer prices rise. This implies that *current higher wages react to past higher inflation*. On the other side, if the rise in wage growth exogenously originates in the labor market, reflecting for example the collective bargaining, it is more likely that *current higher wages will lead to higher inflation*. Some recent contributions rely on VAR models to identify the structural shocks hitting the economy and to study the shock-dependency of the pass-through from wages to inflation. As for the euro area as a whole, Gumiel and Hahn (2018) use one of the ECB models for policy analysis (i.e. the New Area-Wide Model, NAWM) and argue that the pass-through of wages to the GDP deflator is higher following an aggregate demand shock with respect to a supply shock. Bobeica et al. (2019) build on this evidence and extend the empirical analysis to the three main sectors of economic activity (manufacturing, services and construction) and the four largest euro-area countries. They confirm a significant link between unit labour cost and inflation, as captured by the price measures from national accounts, which remains pretty stable over time, albeit with some differences across sectors and countries.[3] At the same time, they claim that the link appears weaker in the low-inflation period.

In this paper we contribute to both the academic literature and the policy debate by addressing the following research questions: does wage dynamics transmit to measures of underlying inflation in the euro area? If yes, to what extent? Is the pass-through shock-dependent? In this regard, what is the role of monetary policy and financial shocks, two factors which have been so far rather neglected? Indeed, to the best of our knowledge, our paper is the first macroeconometric study of the implications of financial shocks for the connection between wages and prices in the euro area, with a particular focus on a low inflation period[4].

[3] The authors find that the pass-through is higher in France, especially in the construction sector, in Germany and Italy as far as services are considered, and in the Spanish manufacturing sector.

[4] Abbate et al. (2017) study the impact of financial shocks on US inflation. However, they do not deal with labor variables and they only focus on the identification of a single shock (see Section 4).

For this purpose we adopt a Bayesian VAR framework to compute the pass-through from wages to prices conditional on several structural shocks and provide new quantitative evidence on their relative contribution to the recent evolution of inflation and wages. Building on developments in the literature on the transmission of exchange rate shocks to inflation (Forbes et al., 2018), we allow for the possibility that the empirical relationship between wages and core inflation depends on the nature of the shocks hitting the economy, computing multipliers from wages to prices conditional to several structural shocks, which are disentangled by means of a mix of zero- and sign-restrictions (Canova and De Nicolò, 2002; Uhlig, 2005; Mountford and Uhlig, 2009; Arias et al., 2018) which are derived from DSGE models (Foroni et al., 2018; Zanetti, 2019; Mumtaz and Zanetti, 2016). This allows us to improve upon the recursive identification scheme adopted by Peneva and Rudd (2017), although in a fixed-coefficient framework.

Our empirical approach is in the same vein of those adopted in recent studies for the euro area by Gumiel and Hahn (2018) and Bobeica et al. (2019). However, we differ from them in some crucial aspects. First, we focus on the pass-through of wage dynamics to measures of underlying inflation, which are those of main interest for policymakers as more closely related to the ECB's primary objective of price stability (Nickel and O'Brien, 2018). Second, we consider a larger set of structural shocks. Specifically, we extend the model to the identification of monetary policy shocks, which is particularly important given the wide range of measures implemented by the ECB in sustaining the euro-area recovery and preventing deflation (ECB, 2018, and references therein). Monetary policy shocks, indeed, generate a co-movement between wages and prices similar to that stemming from aggregate demand shocks but with very different policy implications. We furthermore consider financial shocks, as captured by developments in the credit spread proposed by Gilchrist and Mojon (2018), or alternatively, by the CISS indicator by Hollò et al. (2012). Recent theories suggests that financial frictions generate an incentive for firms to set counter-cyclical mark-ups, thus attenuating the response of inflation to business cycle fluctuations (see Gilchrist et al., 2017). As a result, financial shocks may act from the supply-side of the economy and generate a negative co-movement between wages and prices, which could help in explaining a pick-up in wages without upward pressures on core inflation in the short-run.

The main findings are the following. First, the pass-through from wages to consumer prices is in general lower than unity and, second, it varies according to the nature of the underlying structural shock. In particular, the pass-through is lower than unity and is higher following aggregate demand shocks.[5] Third, the constellation of shocks shows that wage growth in the most recent years is the result of the expansionary monetary policy and labor market-specific shocks, while the contribution of aggregate demand shocks is negligible and not strong enough to raise core inflation. Fourth, we show that financial shocks act as disturbances of supply nature, moving wages and consumer prices in opposite directions, a feature which translates into firms' countercyclical mark-ups, consistently with theoretical models in which firms face financial frictions and nominal rigidities (Gilchrist et al., 2017; Duca et al., 2017). All in all, our results (*i*) offer important implications for building theoretical models which address the relation between labor, financial and macroeconomic variables and (*ii*) provide an empirical explanation of why core inflation remains subdued despite a pick-up in wages and contribute to inform the policy debate.

The remainder of the paper is as follows. In Section 2 we briefly sketch the identification strategy and present the main empirical findings of the baseline model. In Section 3 we focus on alternative measures of inflation, while Section 4 extends the analysis to consider the role of financial shocks. Finally, Section 5 concludes.

[5] Recent contributions by Conflitti and Zizza (2018) and Santoro and Viviano (2018) estimate the pass-through from wages to prices using firm-level data for the Italian economy. They also find elasticities lower than unity and comparable to our estimates.

2. Empirical analysis

2.1 VAR set-up and identification

We use a Bayesian VAR model to study the two-way link between wage and consumer price dynamics at business cycle frequencies, with a specific focus on the transmission of wage pressures to core inflation. The model includes the following euro-area variables: real GDP, HICP inflation excluding energy, food and tobacco (i.e. the so-called *core* inflation), compensation per employee, labor productivity (defined as real GDP per employee), the unemployment rate and a measure of the shadow interest rate, which is included to account for the effects of both conventional and unconventional measures of monetary policy.[6] Consistently with standard practices, all variables are expressed in log-levels with the exception of the shadow rate and the unemployment rate which are taken in levels. Data are quarterly and cover the period 1995Q1-2018Q4, reflecting the availability of euro-area variables form National Accounts (for more details see Appendix A1).

The model resembles the one used to study low inflation in the euro area in Conti et al. (2015)[7] but is augmented with variables accounting for the functioning of the labor market; by contrast, global indicators, such as the nominal oil price and the rest-of-the-world real GDP, are not included in the baseline model for the sake of parsimony. The model is used to identify several structural shocks hitting the euro-area economy and potentially affecting the pass-through from wages to consumer prices. The identification scheme relies on sign restrictions imposed on the impulse responses on impact, following the methodology proposed by Canova and De Nicolò

[6] The shadow rate provides a measure of the monetary stance at the zero-lower-bound (ZLB) by parsimoniously summarizing the information that is embedded in the term structure of interest rates (see Pericoli and Taboga, 2015). Movements of the shadow rate tend to be broadly correlated with the events related to the adoption of non-standard monetary policy measures. Compared to the size of the central bank's balance sheet, this measure has the benefit of being able to capture the effects related to both the announcement and the implementation of non-standard measures. In this paper we use the indicator proposed by Krippner (2013), or, alternatively by Wu and Xhia (2017). The shadow rate has been used to analyze the determinants of low inflation in the euro area (Conti et al., 2015) and the US economy (Conti, 2017) and the bank lending channel of monetary policy (see Albertazzi et al., 2016).

[7] On this topic see, among others, Ciccarelli and Osbat (2017) and Mazumder (2018).

(2002) and Uhlig (2005) and then refined by Rubio-Ramirez *et al*. (2010). The estimation procedure is described in more details in Appendix A2.

The identifying assumptions are reported in Table 1 and follow the recent literature on the identification of labour market and domestic shocks. Accordingly, aggregate demand, aggregate supply and monetary policy shocks are disentangled by the standard restrictions proposed by the literature, while labor supply shocks are separated from wage mark-up shocks using the approach initially proposed by Foroni *et al*. (2018) and later borrowed by Bobeica *et al*. (2019).

Table 1. Sign restrictions used for the identification

	Shock				
Variable	Aggregate demand	Aggregate supply	Labor supply	Wage mark-up	Monetary policy
Real GDP	+	+	-	-	+
Core HICP	+	-	+	+	+
Compensation per employee	+	+	+	+	+
Labor productivity	+	+			+
Unemployment rate	-	-	-	+	-
Shadow interest rate	+				-

Notes: all the shocks have a positive impact on wages (i.e., compensation per employees increase on impact). A "+" (or "-") indicates that the impulse response of the variable in question is restricted to be positive (negative) on impact, while a blank entry indicates that no restrictions is imposed.

The first shock is an increase in aggregate demand, which is identified by imposing a positive co-movement on impact between output, inflation and wages. Since production increases, firms' higher demand for capital and labor inputs also leads to a decline in the unemployment rate. In the short-run, since the impact on employment is smaller than that on GDP, labor productivity also picks up with a dampening impact on unit labor costs (i.e. compensation per employee net of labour productivity). The shadow rate increases as monetary policy reacts to inflationary pressures stemming from a higher demand. The second shock is an aggregate supply shock, which boosts output, labor productivity and wages while reducing consumer prices and unemployment. The restrictions are broadly consistent with the effects of technology shocks, as in Dedola and Neri (2007) and Peersman and Straub (2009).

We also include structural shocks that are specific to the labor market, which may act as cost-push shocks and imply a positive co-movement between wages and prices. In particular, the third shock is a labor supply shock, which may capture the effects of structural reforms aiming at increasing the participation rate. Accordingly, output increases and unemployment declines while both wages and inflation decline. This shock differs from an aggregate demand shock since the response of output is opposite in sign. The fourth shock is a wage mark-up shock, which controls for other changes in the functioning of the labor market, such as longer-lasting effect of structural reforms as well as gains and losses in bargaining power of workers. Following a positive shock, both wages and inflation increase at the cost of a higher unemployment rate, while output declines.

We leave unconstrained the response of labor productivity to both labour shocks. However, since the labor market is likely to react at a slower pace than to the market of goods, the impact response of employment could be smaller than that of real GDP, implying an impact decrease in labor productivity in response to both shocks. In such case, the wage increase in the short-run could be amplified by the productivity losses with an immediate increase in unit labor cost and consumer prices. Our main results, however, remain unaffected when imposing sign-restrictions on the response of labor productivity to shocks that are specific to the labor market. As already mentioned, the baseline model does not consider oil shocks that are other type of cost-push shocks and may be observationally equivalent to supply shocks in the labor market.[8]

The fifth shock is a monetary policy shock, which captures the macroeconomic effects of both conventional and unconventional measures. Accordingly, a decline in the shadow rate leads to a reduction in the unemployment rate and an increase in real GDP, inflation and wages. Finally, a sixth shock, orthogonal to the others, is left unidentified and thus not given any economic meaning, and is treated as an unexplained residual in the historical decompositions presented below.

[8] For example, an oil supply shock could feed into the wage mark-up shock via second round effects of energy prices on both core inflation and wage dynamics. We checked the robustness of our results by including a measure of oil prices in the VAR and identifying an oil supply shock. However, we find that oil supply shocks have limited impact on the contribution of wage mark-up shocks.

We impose the sign-restrictions only on the impact responses of the variables as Canova and Paustian (2011) showed that this practice is robust to several types of model misspecification. As for the identification of the shocks, we rely on the algorithm developed by Rubio-Ramirez, Waggoner and Zha (2010) as it is more efficient in systems of size larger than four variables and has become the standard for VAR models. The results are based on 100,000 draws from the posterior distribution and 50,000 from the unit sphere. 5,000 successful draws are retained to produce median and quantiles of impulse response functions (IRF) and other statistics of interest.

2.2 Baseline results

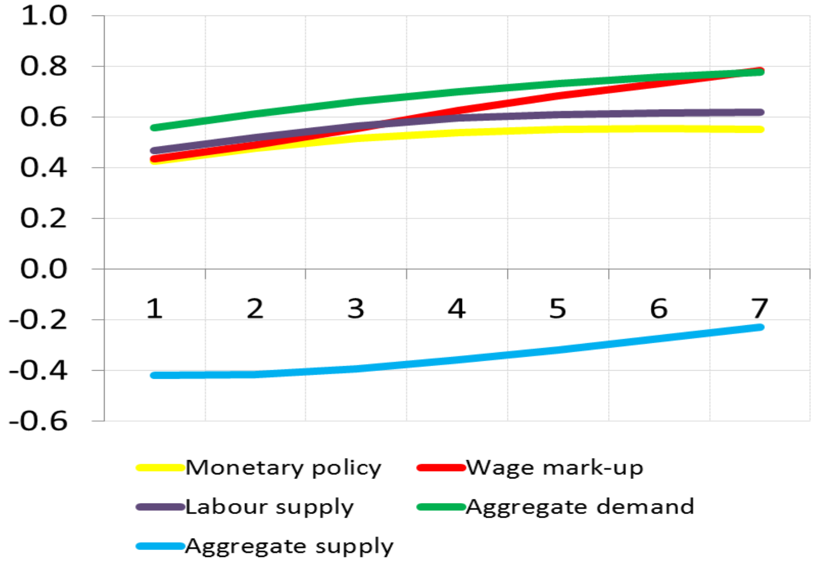
We use the VAR model to evaluate the conditional correlation between wages and core consumer prices, which we term *conditional wage-price pass-through* (CWPPT hereafter) borrowing from the recent literature on the exchange rate pass-through (Forbes et al., 2018). We first compute the estimated impulse responses to the different structural shock over a forecast horizon of two years. Then, we use these estimates to evaluate the *conditional* correlation between wage growth (*w*) and core prices (*p*) for each shock at a certain horizon (*h*) after the shock. Accordingly, we compute the ratio between the cumulated sum up of the impulse responses of core prices over the horizon *h* and the cumulated sum up of the IRFs of compensation per employee over the same horizon to the generic *j-th* shock at horizon *h* as follows:

$$CWPPT_h^{j-th\ shock} = \frac{\sum_{h=1}^{H} IRF\ (p)_h^{j-th\ shock}}{\sum_{h=1}^{H} IRF\ (w)_h^{j-th\ shock}} \tag{1}$$

where we focus on $H = 8$ quarters, a medium-term frequency of particular interest, as it is recalls the time horizon of ECB price stability.

Figure 2 shows the resulting CWPPT for each structural shock. We find that the pass-through of wages growth to core inflation is largely incomplete in the short-run and quite similar across shocks. The largest pass-through is associated with aggregate demand shocks and with wage mark-up shocks (from 0.6 on impact to 0.8 at the end of the forecast horizon). Monetary policy and labor supply shocks lead to intermediate values (from 0.4 on impact to 0.6 at *h=4*, i.e. after one year), while aggregate supply shocks move wages and prices in opposite directions, especially at shorter horizons (the CWPPT declines from -0.4 to -0.2 at the end of the considered horizon).

Figure 2. Cumulative wage-to-prices shock-dependent multipliers
(*percentage points*)



Notes: the multipliers are calculated as the ratio between the cumulative sum of impulse responses of core inflation and wages to the indicated shock. As for the impulse responses, the colored line denotes the median of the posterior distribution of the Bayesian VAR models. The model is estimated over the sample 1995Q1 – 2018Q4.

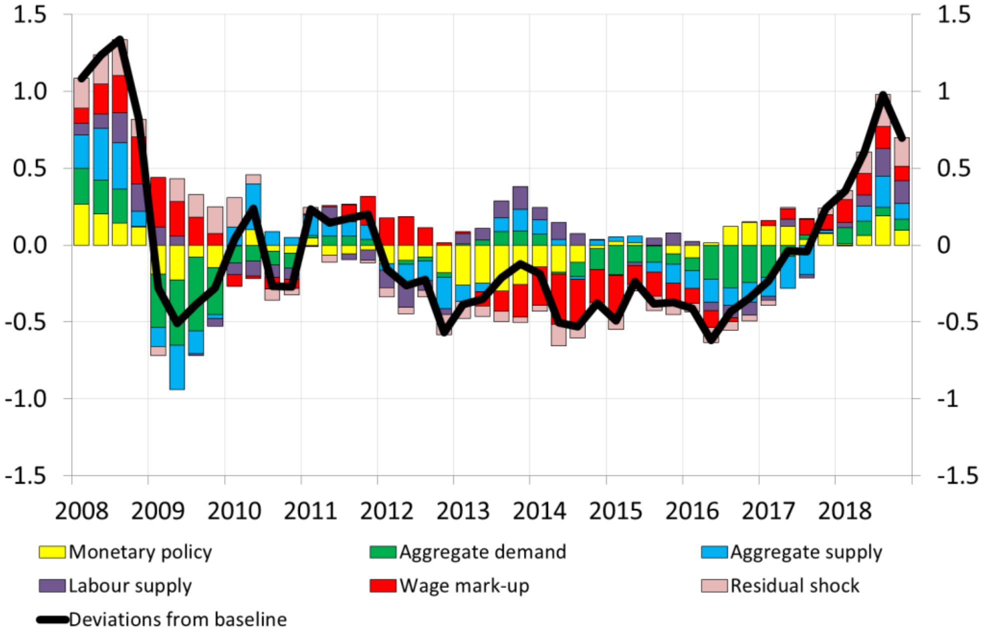
In order to complete our assessment of the wage-price nexus in the recent period, we need to estimate the role of the different shocks in driving the increase in euro-area wage growth and core inflation developments over the last two years. In Figure 3 we present the historical decomposition of the two variables, showing the estimated contribution of each shock to deviations of the variables from their VAR unconditional forecasts (i.e. *baseline forecasts*) at each point in time.

Euro-area wage growth started to increase above the unconditional forecast since mid-2017. This wage gap reached its peak of about 1.0 percentage point in 2018Q3, while moderating somewhat at the end of the year. The acceleration in wages was supported by a number of factors, especially shocks that are specific to the labour market and aggregate supply shocks, with the latter probably capturing a recovery in labour productivity. A relevant contribution also stemmed from the expansionary monetary policy, which appears to be more relevant than aggregate demand shocks. The latter shocks turned mildly positive only in the first half of 2018.

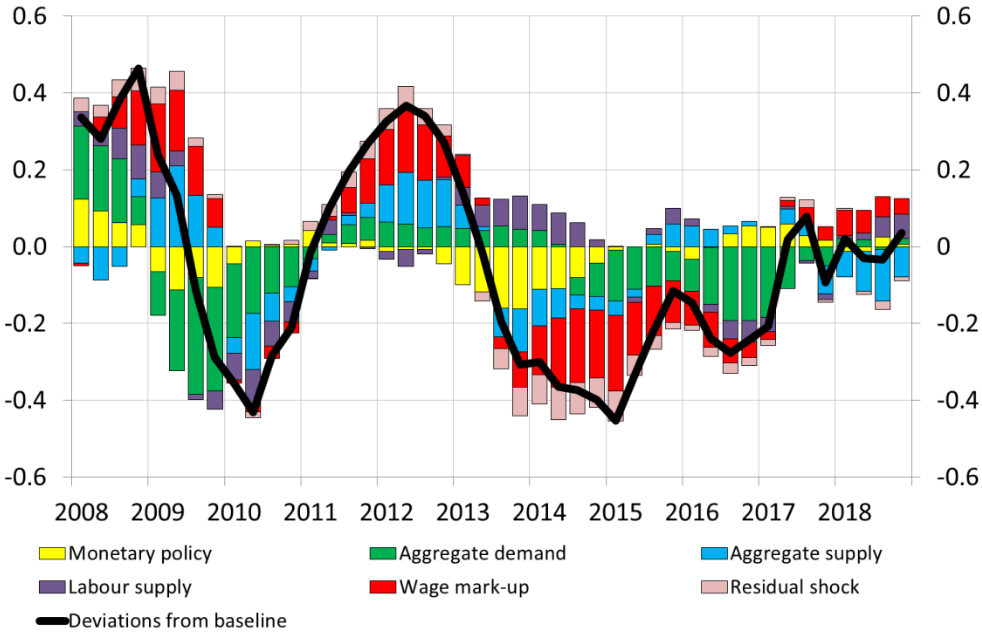
Figure 3. Historical decomposition of euro-area variables

(quarterly data; year-on-year percentage changes)

a) Compensation per employee



b) Core HICP inflation



Notes: the black line is the difference between the actual series and the unconditional forecast obtained by the VAR model (i.e. baseline forecast). The colored stacked bars denote the contribution of the considered structural shock, as captured by the median of the posterior distribution of the Bayesian VAR). The model is estimated over the sample 1995Q1 – 2018Q4.

The picture for core inflation looks rather different. Over the same period (2017Q2-2018Q4), actual core inflation stood broadly in line with its unconditional forecast, which is already rather low on historical standards[9]. The assessment of the long-term factors behind this pattern is difficult and goes beyond the scope of this paper. The constellation of shocks suggests that, over the last two years, wage pressures stemming from labor-specific shocks have been effectively transmitted on core inflation but they have been counterbalanced by the negative contribution of aggregate supply shocks. The positive albeit small contribution of monetary policy recorded in 2017 attenuated in the subsequent year. The contribution of aggregate demand shocks, which was negative in 2017, became broadly negligible in 2018. The joint look at the CWPPT and the main drivers of wages growth and core inflation provides an empirical explanation of the lack of pick-up in core inflation, notwithstanding a sustained expansion of compensation per employees.

3. Changing the price measure

In this section we explore the sensitivity of our results to the change of the price measure considered in the VAR specification. In particular, we re-calculate the estimated pass-through and the historical decomposition by replacing the core inflation index with alternative indicators of inflation. First, we use narrower and more pro-cyclical measures of core inflation - with respect to the harmonized Eurostat definition – that could be potentially more reactive to developments in the business cycle and, in turn, to wage changes. Second, we use the GDP deflator to assess whether our main results hold for price indicators from national accounts, thus corroborating end extending some recent studies conducted for the euro area (Gumiel and Hahn, 2018; Bobeica et al., 2019).

3.1 Using measures of underlying inflation

Some contemporary contributions try to derive alternative price measures that relate more closely to the Phillips curve framework, thus being more responsive to the degree of slack in the

[9] For core inflation the VAR model gives an unconditional forecast of about 0.9% over the last year of the sample; the historical mean of euro area core inflation over the period 1999-2018 is around 1.4%.

economy. The idea is that price developments in some sectors are not correlated with aggregate cyclical conditions, meaning that a Phillips curve may still hold for some components while disappearing at the aggregate level.[10]

We first consider the Supercore index proposed by the ECB and described in Nickel and O'Brien, (2018) and ECB (2018). This price indicator is calculated on very granular information, namely the 3-digit European Classification of Individual Consumption according to Purpose (i.e ECOICOP classification), which comprises 93 HICP items. An item contributes to the Supercore index if the inclusion of the output gap in its respective Phillips curve equation improves the out-of-sample forecasts at horizons between one and four quarters with respect to a simple autoregressive model. The Supercore index is available since 2002 and has been subject to large revisions, as the set of items included in the index can change even on a monthly basis, potentially undermining the comparability of its evolution over time.

We further consider a measure of underlying inflation for the euro area computed at Banca d'Italia following the approach by Mahedy and Shapiro (2017) for the United States (see Conflitti et al., 2019). The price indicator is obtained by aggregating only the items in the core basket of the core HICP whose developments are *pro-cyclical*, namely featuring a negative and statistically significant relationship with the unemployment gap (i.e. the difference between the unemployment rate and its natural rate, where the latter is computed using several methods in the context of a quarterly common projection exercise in the Eurosystem)[11]. We term this indicator as "pro-cyclical component of HICP core inflation". If a specific item is not significantly related to the unemployment gap, it is excluded from the measure of underlying inflation and contributes to the "a-cyclical component of HICP core inflation".[12] With respect to the approach used for the ECB Supercore index, Conflitti et al. (2019) consider less granular information, namely the components

[10] The alternative indicators of core inflation have been seasonally adjusted before being included in the VAR model.

[11] Conflitti et al. (2019) also show that using the output gap instead of the unemployment gap does not alter the results.

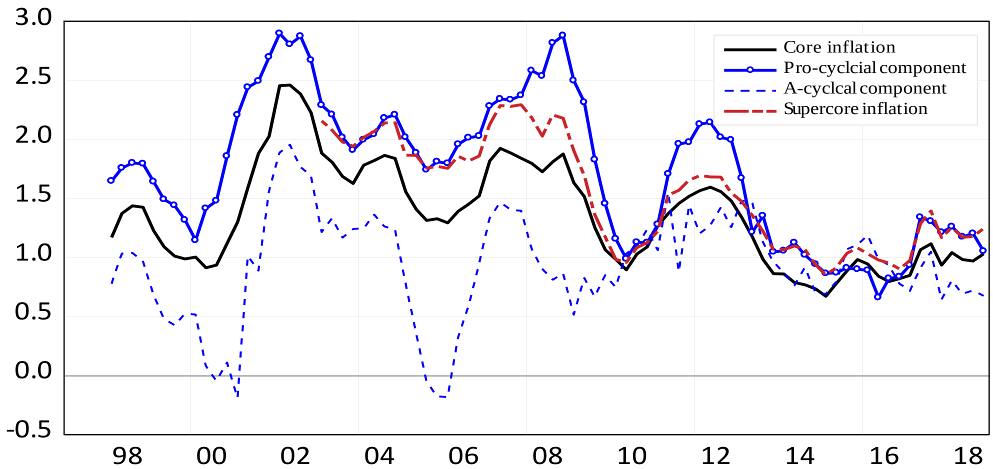
[12] While in principle some items could move counter-cyclically, in practice the authors find few of these cases and lump them together with the a-cyclical ones.

disaggregated at the 2-digit ECOICOP classification (i.e. 40 HICP items). Moreover, they choose the set of items on the basis of the *in-sample* fitting over the whole sample period rather than on the basis of an *out-of-sample* forecasting exercise. This implies that the composition of this measure of inflation does not change over time.

In Figure 4 we compare the developments in the different measures of underlying inflation. The correlation between the cyclical and the a-cyclical components of core inflation is 0.3 on the entire sample period; it was 0.7 up to 2007 and turned negative (-0.23) in the period 2014-2018. The dynamics of the pro-cyclical component of core inflation is very similar to that of the Supercore inflation especially in the low inflation period, namely since 2012. Both measures of underlying inflation exhibited a notable downward trend over this period. They turned to increase for few quarters in mid-2016 and then remained broadly stable on low values on historical standards. The a-cyclical component also started to decline since the sovereign debt crisis with no significant upward pressures in the most recent quarters.

Figure 4. Measures of underlying inflation

(*quarterly data; year-on-year changes; percentage points*)

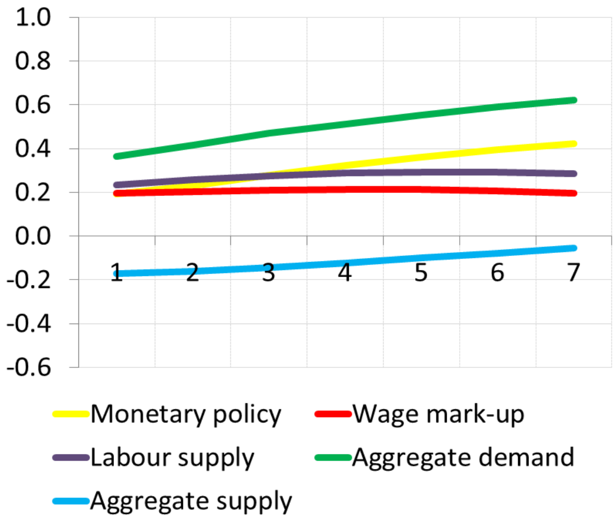


Notes: Core inflation and Supercore inflation are taken form the Statistical Data Warehouse. Both the pro-cyclical and the a-cyclical components of core inflation are computed in Conflitti et al. (2019).

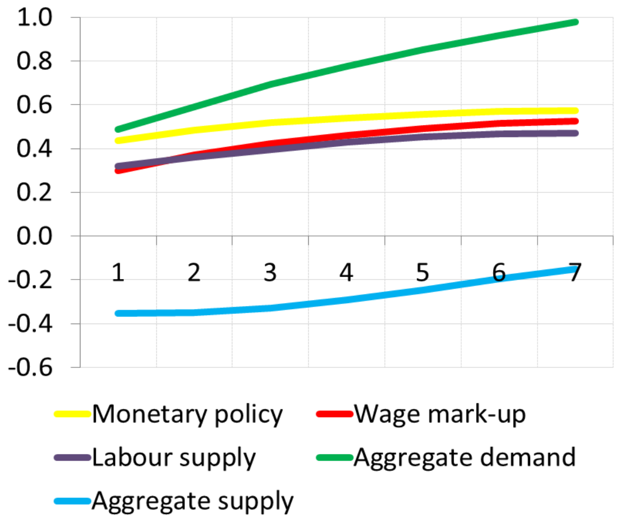
In Figure 5 we show the estimated pass-through for each structural shock. Overall, we confirm the baseline picture obtained with the HICP core inflation but with some exceptions. First, the estimated pass-through is weaker when considering the Supercore index conditionally to all structural shocks. Second, the shock-dependency of the pass-through becomes more visible when the model includes the pro-cyclical component of core inflation. In particular, the transmission is stronger following an aggregate demand shock, while more somewhat weaker following shocks originated in the labour market.

Figure 5. Cumulative wage-to-prices shock-dependent multipliers: alternative measures of underlying inflation
(*quarterly data; percentage points*)

a) ECB Supercore index



b) Pro-cyclical component of HICP core index

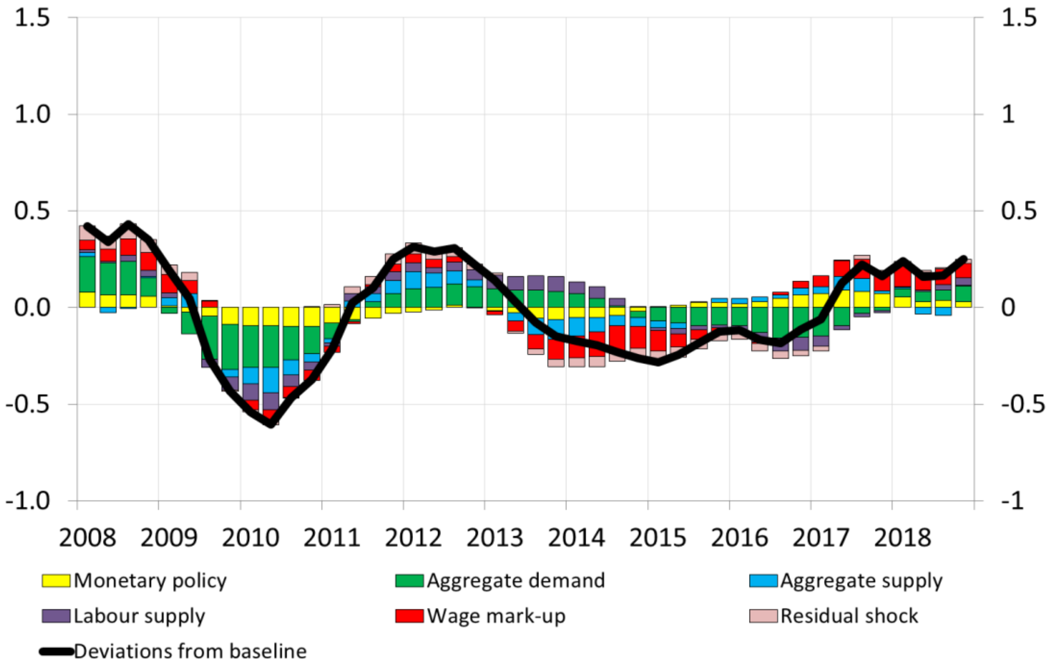


Notes: the multipliers are calculated as the ratio between the cumulative sum of impulse responses of core inflation and wages to the indicated shock. As for the impulse responses, the colored line denotes the median of the posterior distribution of the Bayesian VAR models. The model is estimated over the sample 2002Q1 – 2018Q4 in the case of the ECB Supercore index.

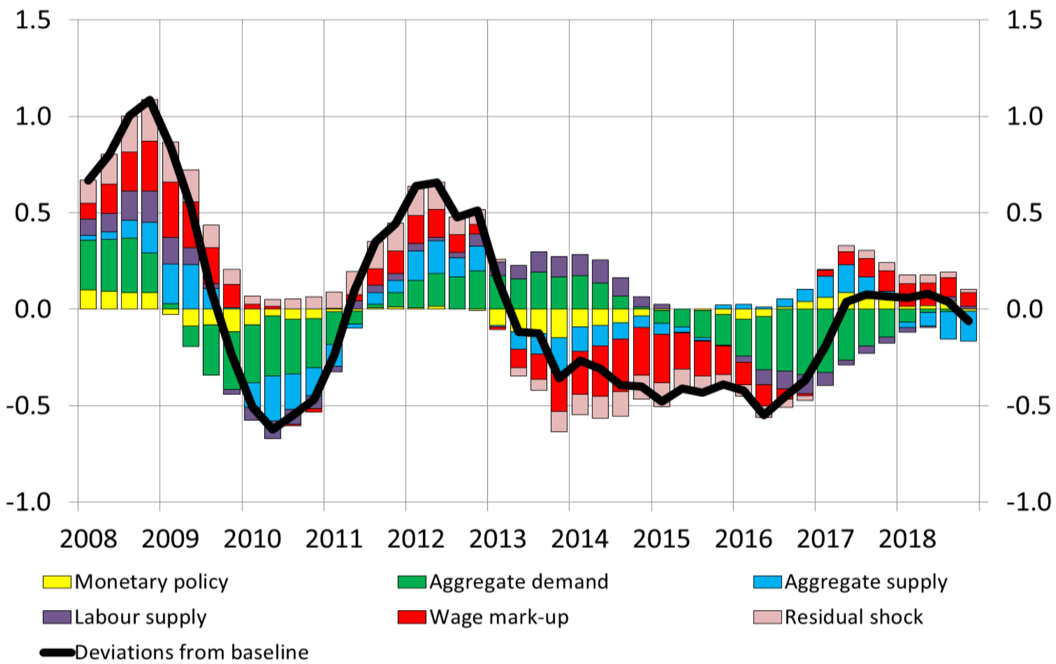
In Figure 6 we present the historical decomposition of the alternative measures of underlying inflation. Again, we find that the increase in wages originated in the labour market transmitted to price dynamics over the most recent period, with a prominent role of wage mark-up shocks. The contribution of aggregate demand shocks is positive but very small in the case of the Supercore index while null when considering the pro-cyclical component of core inflation. Monetary policy exerted positive but limited upward pressures on both measures of underlying inflation. Since our main results remain unaffected when using measure of core inflation which should be more sensitive to the business cycle, this seems to reinforce the conclusion that the wage-to-price pass-through would not strengthen in the near future, somewhat casting doubts on the arguments that since wages are expanding at a more robust pace this will automatically translate into core inflation.

Figure 6. Historical decomposition of alternative measures of underlying inflation
(quarterly data; year-on-year percentage changes)

a) Supercore inflation



b) Procyclical component of HICP core inflation

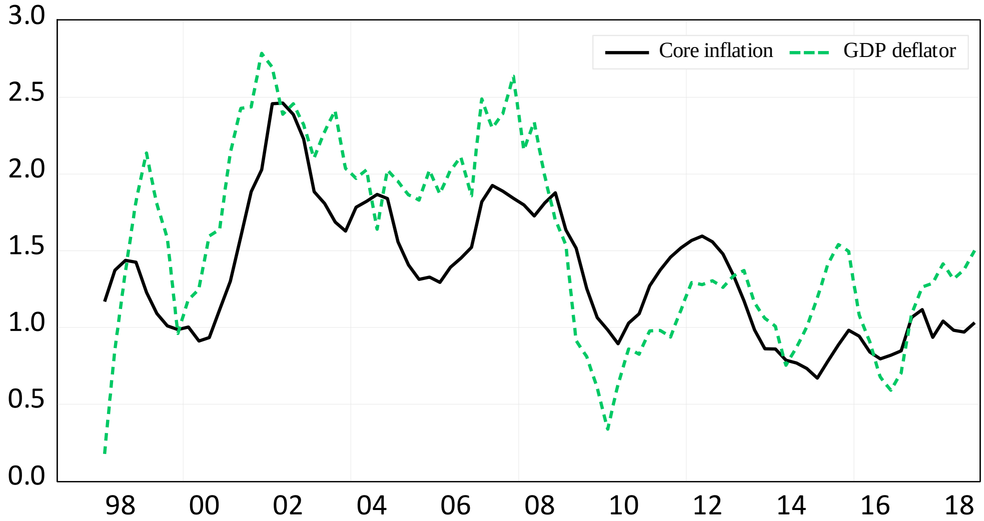


Notes: the black line is the difference between the actual series and the unconditional forecast obtained by the VAR model (i.e. baseline forecast). The colored stacked bars denote the contribution of the considered structural shock, as captured by the median of the posterior distribution of the Bayesian VAR). The model is estimated over the sample 2002Q1 – 2018Q4 in the case of the ECB Supercore index.

3.2. Exploiting the GDP deflator

We now consider as a measure of prices the GDP deflator, which has the same evolution of core inflation but is more volatile (the standard deviation is almost one and a half time that of core HICP inflation; see Figure 7).

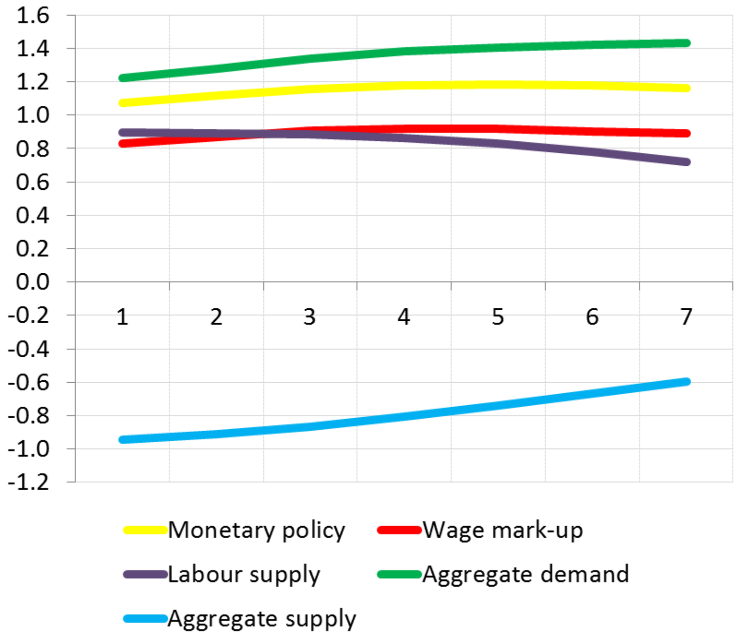
Figure 7. Core inflation and price indicator from national accounts
(*quarterly data; year-on-year changes; percentage points*)



***Notes**:* data are taken from the ECB SDW; see Appendix A1.

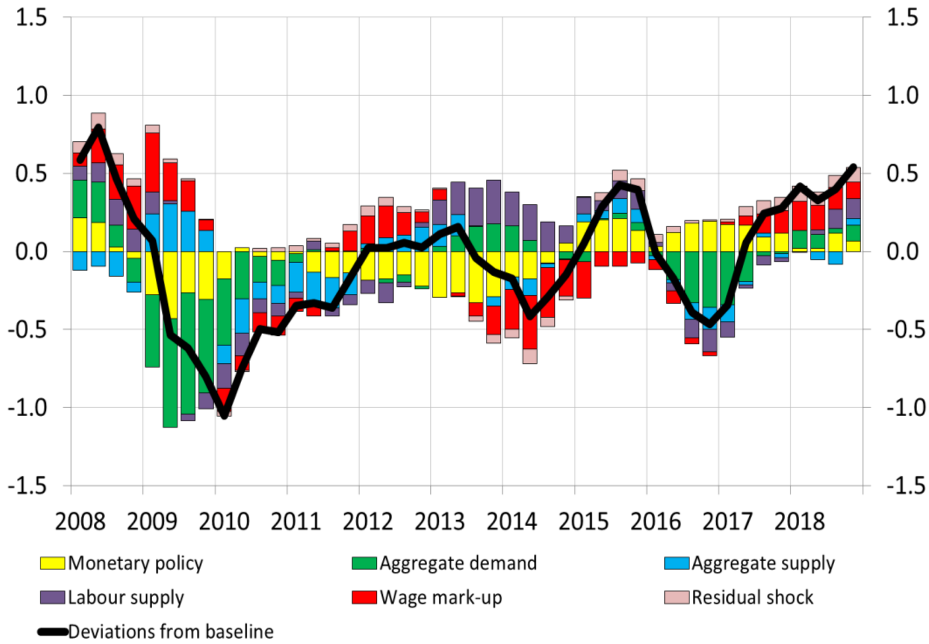
Figure 8 shows that conditional pass-through becomes stronger for all considered shocks, as they almost double in magnitude. Moreover, the differences across shocks are somewhat larger, thus suggesting that the choice of the price measure matters for the estimation of the conditional pass-through. As for the constellation of shocks, we report the historical decomposition of the GDP deflator in Figure 9. We observe limited differences with respect to estimates for the core inflation. The gap between actual GDP deflator and its unconditional forecast is more pronounced, reaching a peak by about 0.5 percentage points in the second half of 2018. The contribution of shocks that are specific to the labour market, namely wage mark-up and labour supply shocks, is positive and explains one-third of the overall gap, thus corroborating the view that the wage increases are transmitting to price dynamics. Monetary policy explains the remaining gap exerting upward contributions similar to the case of core inflation. Both aggregate demand and supply shocks provide negligible contributions.

Figure 8. Cumulative wage-to-prices shock-dependent multipliers: exploiting the GDP deflator
(*quarterly data; percentage points*)



Notes*:* the multipliers are calculated as the ratio between the cumulative sum of impulse responses of core inflation and wages to the indicated shock. As for the impulse responses, the colored line denotes the median of the posterior distribution of the Bayesian VAR models. The model is estimated over the sample 1995Q1 – 2018Q4.

Figure 9. Historical decomposition of GDP deflator
(quarterly data; year-on-year percentage changes)



Notes*:* the black line is the difference between the actual series and the unconditional forecast obtained by the VAR model (i.e. baseline forecast). The colored stacked bars denote the contribution of the considered structural shock, as captured by the median of the posterior distribution of the Bayesian VAR). The model is estimated over the sample 1995Q1 – 2018Q4.

4. The role of financial shocks

In our baseline VAR model we do not include financial variables to make the empirical analysis as much as comparable with previous studies for the euro area. However, there are both theoretical and empirical considerations which push for extending the model to financial variables. A first reason is a growing interest in theories explaining the interactions between labour and financial markets, which led to the construction of Real Business Cycle (RBC) models where frictions in both markets coexist and significantly affect the transmission of structural shocks on both wages and employment (Wasmer and Weil, 2004; Christiano et al., 2011; Petrosky-Nadeau and Wasmer, 2015; Mumtaz and Zanetti, 2016; Zanetti, 2019).[13] While these theories do not consider neither price setting behavior nor the role of monetary policy, they suggest that financial shocks generate substantial short-run fluctuations in wages. These predictions are corroborated by recent studies for the euro area based on microdata (Popov and Rocholl, 2018; Bodnár et al., 2018).

A second reason is that the evidence on the reaction of consumer prices to financial shocks is mixed and disputed in the literature and in the policy debate. While there is widespread agreement that adverse financial shocks have contractionary effects on output, theory is more ambiguous regarding the impact on prices and wages. The reaction of both variables depends on whether the *demand* channel - acting through wealth effects or changes in credit supply which affect consumption and investment (see Curdia and Woodford, 2010; Gertler and Karadi, 2011; Christiano et al., 2014) - prevails on *supply-side* mechanisms such as the cost channel for firms' mark-up (Gerali et al., 2010; Meh and Moran, 2010). In a recent contribution Gilchrist et al. (2017) develop a different theory in which firms experiencing a liquidity squeeze accompanying a fall in demand may find it optimal to increase their prices and sacrifice future sales in order to boost current cash-flows. This mechanism, which also acts from the supply-side of the economy and can coexist with

[13] According to these theories, firms need external funding to finance the cost of posting vacancies and attracting unemployed workers and react to financial strains by reducing unemployment and per-capita hours worked to face the reduction in borrowing ability; the decline in labor demand leads to a fall in nominal wages.

the cost channel, generates a counter-cyclical behavior of firms' mark-up, thus attenuating the aggregate response of inflation to business cycle fluctuations.[14] The implications for monetary policy are also very relevant since the model implies a meaningful trade-off between output and inflation stabilization in response to financial shocks, in sharp contrast to traditional New-Keynesian or financial accelerator models where inflation and output co-move positively and the central bank can stabilize both variables by lowering the nominal interest rate.[15]

As for the empirical evidence, previous studies based on VAR models mostly focused on the effects of financial shocks on economic activity and used different assumptions for the response of inflation and monetary policy. In this regard Conti et al., (2015), Darracq-Paries and De Santis, (2015), Furlanetto et al., (2017), Gambetti and Musso, (2017) and Hristov et al., 2012, took the demand-side perspective and impose a positive co-movement between output and inflation or between output and monetary policy in response to a financial shock. Other authors instead impose zero-restrictions on the impact response of both inflation and output (see, among others, Gilchrist and Zakrajsek, 2012 and Corsello and Nispi Landi, 2019)[16] or remained fully agnostic about the response of inflation (Fornari and Stracca, 2012; Abbate et al., 2017). The evidence is mixed but

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[14] A recent contribution by Duca et al. (2017) uses micro data for Italian firms participating in the 2014 Wage Dynamics Network Survey and also found that financially constrained firms charge higher mark-ups when faced with low demand. The authors show that the severity of financial constraints in Italy was one of the causes of the sustained growth of prices in 2010-2013, notwithstanding the considerable slack in the economy.

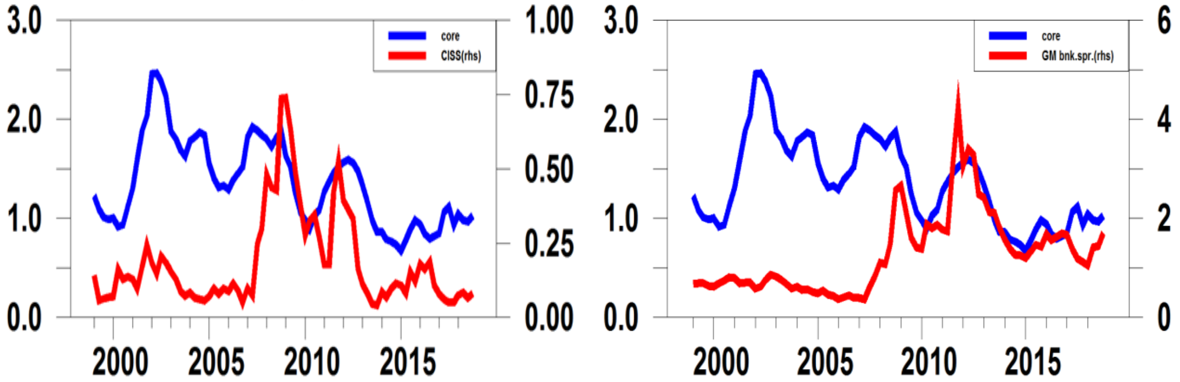
[15] Del Negro et al. (2015) also emphasize the role of monetary policy in the transmission of financial shocks. The authors estimate the workhorse DSGE model in Smets and Wouters (2007), extended to include financial frictions, with data up to 2008 and showed that the model successful predicts the subsequent sharp contraction in economic activity along with a relatively modest and protracted decline in inflation. The key to understanding their result is that inflation is more dependent on expected future marginal costs than on the current level of economic activity. Even though GDP and marginal costs contracted by the end of 2008, the reaction of monetary policy was so strong to ensure that marginal costs have been expected to rise.

[16] Corsello and Nispi Landi (2019) use a Choleski scheme in a time-varying VAR model with stochastic volatility for the US economy. Differently from our paper, they focus only on a financial shock and do not consider measures of monetary policy among endogenous variables. By contrast, they consider more labour-market variables (unemployment rate, participation rate, hours worked per employee, nominal wage and vacancy rate). They show that a tightening of financial conditions depresses the GDP and the labor market (i.e wages and employment), while the effect on inflation is positive. Interestingly, they provide evidence that the effects on the labor-market variables are strong following adverse financial shocks - which historically are not frequent, though more severe; positive financial shocks - historically more frequent but of a smaller size – feature a more modest impact.

mostly in favor of a negative response of prices to beneficial financial shocks, thus corroborating supply-side mechanisms.[17]

Based on these considerations, we evaluate the role of financial factors for wages and prices dynamics by adding to the baseline VAR model a measure of financial conditions in the euro area. We primarily use the bank spread recently computed by Gilchrist and Mojon (2018) but also run alternative experiments by using the Composite Indicator of Systemic Stress (CISS) developed by Hollò et al. (2012).[18] In Figure 10 we plot these indicators of financial conditions and the core HICP inflation rate. Changes in financial variables are not confined to the Global Financial Crisis and the Sovereign Debt Crisis, which effectively resulted in large jumps of these indicators, but also to the most recent years.

Figure 10. Financial indicators and euro-area core inflation
(*quarterly data; averages of daily data for financial variables*)



Notes: the blue line is y-o-y percentage changes in core inflation index, while the red line is the financial indicator (plotted on the right hand scale), which is the CISS indicator in the left panel and the Gilchrist and Mojon (2018) banking spread in the right one.

[17] Differently from our paper, Abbate et al. (2017) identify a single shock using more variables, namely stock price, the excess bond premium and credit growth. We could also add more financial variables, but this would come at the cost of enlarging the model: not only this would increase the number of shocks making it even more difficult to disentangle them, but would require putting restrictions on financial variables for each other identified shock. We refrain from this, since our aim is to highlight the comovement between wages and prices, and we therefore stick to the simplest framework.

[18] We could obviously model a financial shock in many other alternative ways, such as, for example, as a loan supply shock (Gambetti and Musso, 2017; Abbate et al., 2017). However, we choose to model a financial shock as changes in composite indicators of stress for two reasons: (*i*) credit spreads look more immediate indicators of restrictions in credit markets than loan quantities (Gilchrist and Zakrajsek, 2012; Gertler, 2013) and (*ii*) they provide a sort of shortcut, as they allow for identifying a financial shock without adding too many variables (loans, lending rates, stock prices) to the VAR. This is a precious feature, since the larger the size of the model, the growing the difficulties of imposing meaningful and economically derived sign restrictions to properly disentangle the structural shocks.

An interesting feature is that we observe a positive correlation among variables in the data, namely financial tensions are mostly associated to higher instead of lower inflation rates, which is particularly strong in the aftermath of the financial crisis. This simple unconditional evidence may corroborate the view that supply-side mechanisms prevailed in the euro area.

On the basis of these considerations, we identify an additional shock in the VAR model that we label "financial factor". As for the identification scheme, which is reported in Table 2, we take the "supply-side" perspective in Gilchrist *et al.* (2017) and Zanetti (2019) and assume that a reduction in the measure of financial stress has a positive impact on real GDP and on compensation per employees as opposed to a negative effect on core inflation. This scheme gives the model a chance to assess whether financial conditions matter in explaining opposite developments in wages and prices in the recent period. In doing so, a related and crucial issue is that a financial shock could be observationally equivalent to other supply shocks. The sign restriction imposed on real GDP is sufficient to separate financial shocks from labour supply and wage mark-up shocks but not from other types of aggregate supply shocks. We thus impose a zero restriction on the impact response of both labor productivity and unemployment to financial shocks.[19] This ensures that the negative co-movement between prices and wages does not reflect a technology shock. These short-run restrictions look reasonable also because the frictions in the labour markets imply a sluggish adjustment to changes in financial conditions, consistently with theoretical models (see, for example, Zanetti, 2019).[20]

[19] The zero restrictions are imposed by using the algorithm suggested by Mountford and Uhlig (2009) and in particular the so called "rejection method" (see Appendix A2); we obtain very similar results by using the procedure by Arias et al., (2018).

[20] A possible concern is related to the zero constrain imposed on impact on labour productivity, as the transmission of financial shocks could be faster to this variable than to unemployment. We remark that the financial shocks would be identified even removing this restriction and letting labour productivity free to react: we then re-estimate the model with financial factors by using this alternative scheme. The results are basically not altered, neither for the cumulative multipliers neither for the historical decompositions, and they are available upon request from the authors. We therefore stick to the identifying assumptions presented in Table 2 as our baseline.

Table 2. Sign restrictions used for identification: model including financial factors

	Shock					
Variable	Aggregate demand	Aggregate supply	Labor supply	Wage mark-up	Monetary policy	Financial factor
Real GDP	+	+	-	-	+	+
Core HICP	+	-	+	+	+	-
Compensation per employee	+	+	+	+	+	+
Labor productivity	+	+			+	0
Unemployment rate	-	-	-	+	-	0
Shadow interest rate	+				-	
Financial indicator						-

Notes: all the shocks have a positive impact on wages (i.e., compensation per employees increase on impact). A "+" (or "-") indicates that the impulse response of the variable in question is restricted to be positive (negative) on impact, while a blank entry indicates that no restrictions is imposed. A"0" indicates that the impulse response of the variable in question is restricted to be null on impact. Core HICP is defined as the HICP excluding food, energy and tobacco. The financial indicator is the CISS indicator by Hollò et al. (2012) or, alternatively, the bank spread used in Gilchrist and Mojon (2018).

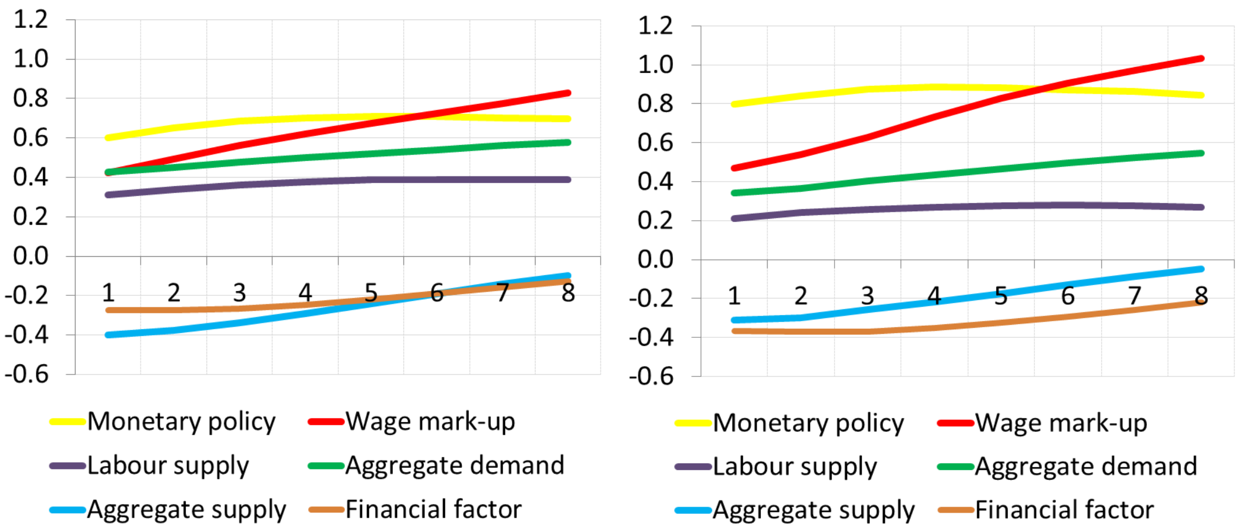
As for the reaction of monetary policy, we opt for leaving unrestricted the response of the shadow rate to a financial shock, as policymakers face the usual dilemma generated by a supply shock. This issue is relevant also because in the sign restrictions approach, leaving the response of some variables unrestricted could hamper the detection of significant effects, especially when the variance of the shocks is low in the data (Paustian, 2007). We, however, test the robustness of our findings by using an identification scheme in which we restrict monetary policy to ease on impact in response to a beneficial financial shock consistently with the theoretical predictions by Gilchrist *et al.* (2017) for the case of a central bank that is concerned only about inflation. Finally, in order to capture financial accelerator mechanisms, we allow the financial indicator to respond on both aggregate demand and monetary policy shocks.[21] We report the impulse response functions in Appendix A4. An interesting result is that the shadow rate significantly falls in response to an easing in financial conditions, notwithstanding we were agnostic in the identification scheme. In Figure 11 we show the estimates of wage-to-prices pass-through obtained using the identification scheme described in Table 2.

[21] It should be considered that our identification scheme probably does not fully capture all type of monetary policy shocks experimented by the euro area. The most challenging issue is to take into account for the effects of the announcement of the Outright Monetary Transactions (OMT) which may not be captured by shadow rate models.

Figure 11. Cumulative wage-to-prices shock-dependent multipliers: VAR model including financial shocks
(*quarterly data; percentage points*)

a) Identification scheme with sign-restrictions on prices and agnostic monetary policy

b) Identification scheme with sign-restrictions on both prices and monetary policy



Notes: the multipliers are calculated as the ratio between the cumulative sum of impulse responses of core inflation and wages to the indicated shock. As for the impulse responses, the colored line denotes the median of the posterior distribution of the Bayesian VAR models. The model is estimated over the sample 1999Q1 – 2018Q4. The financial shock is identified using the bank spread used in Gilchrist and Mojon (2018).

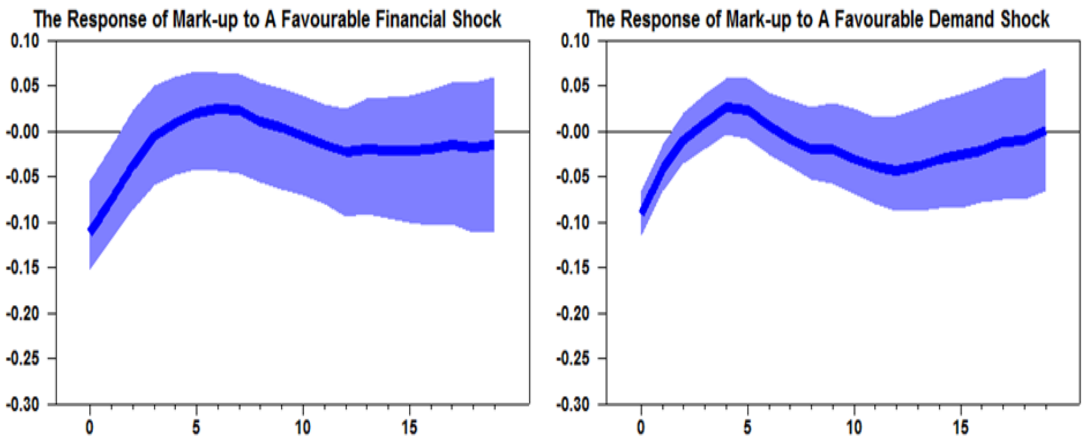
The most relevant difference with respect to the model without financial variable is a higher pass-through conditionally to a monetary policy shock and a corresponding reduction of the one related to an aggregate demand shock. Moreover, a financial shock generates a negative co-movement between wages and prices that is similar in magnitude to that originated by an aggregate supply shock, albeit more persistent when we allow the monetary policy measure to respond on impact to the financial shock.[22]

Our model also allows evaluating the cyclical behavior of firms' mark-up conditionally to each structural shock. To this end, we calculate the mark-up as the difference between the response of consumer prices and the response of the unit labour cost, which, in turn is the difference between

[22] We could also be agnostic regarding the response of both core inflation and the shadow rate, at the cost of reaching a weaker identification of the shocks. However, we find that our main findings are not affected. The cumulative multiplier from wages to prices conditional to a financial shock does contain the zero in its Bayesian credible interval, but the historical decomposition shows positive contributions of financial shocks to wage dynamics and negative contributions to core inflation over the period 2017-2018. We interpret this finding as further evidence that financial shocks in the data tend to move wages and prices in opposite directions. These results are available upon request.

the response of compensation per employee and that of labour productivity. Figure 12 shows that the mark-up declines for a while following both a financial shock and an aggregate demand shock. This evidence corroborates the theory in Gilchrist *et al.* (2017) , according to which financial constraints induce firms to set countercyclical mark-ups in response to both demand and financial shocks. In Appendix A5 we report the response of firms' mark-up to the other shocks. The mark-up stands persistently above the baseline in response to a favorable monetary policy shock while it shows a more delayed reduction following an aggregate supply shock as well as adverse shocks that are specific to the labour market. These results are very similar when using the identification scheme with sign restrictions on both prices and monetary policy.

Figure 12. Estimated response of firms' mark-up to financial and demand shocks
(*quarterly data; percentage points*)

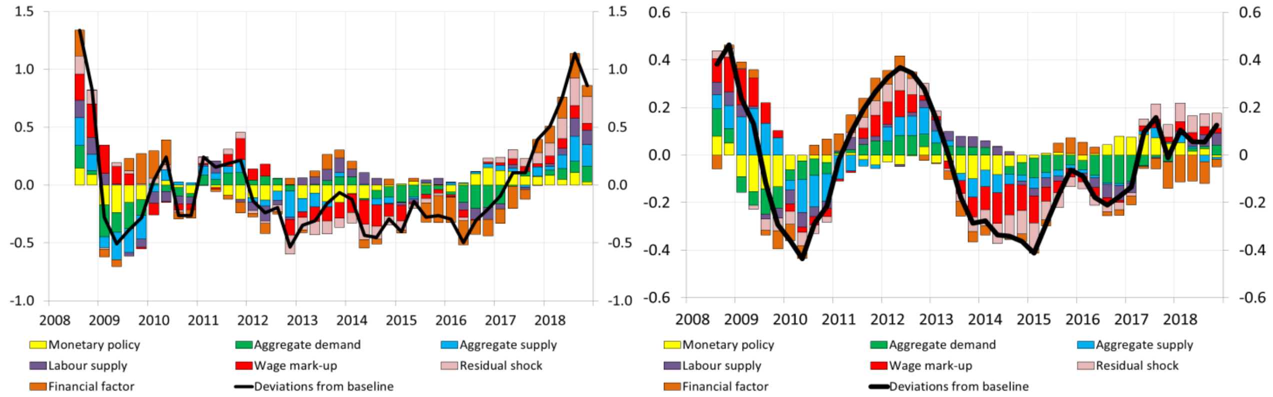


Notes: Since the model is estimated in log-levels, the response of mark-up is obtained by difference between the response of core inflation and the one of unit labour cost (nominal wage net of labour productivity). The blue line is the median of the posterior distribution of the Bayesian VAR models, while the shaded area is the 68% credibility interval. The model is estimated over the sample 1999Q1 – 2018Q4. The financial indicator is the banking spread by Gilchrist and Mojon (2018).

Finally, in Figure 13 we present the historical decomposition of changes in compensation per employee and core inflation in the model augmented with financial factors. We find that financial shocks explain a significant part of the negative co-movement between wages and prices in the recent periods and crowd-out the role of aggregate supply shocks compared to the specification which does not include financial variables (see Figure 3b). We also confirm previous evidence that financial tensions sustained inflation over the period 2011-2013 (see Duca et al., 2017 and references therein).

Figure 13. Historical decomposition of euro-area variables:
VAR model including financial shocks
(*quarterly data; year-on-year percentage changes*)

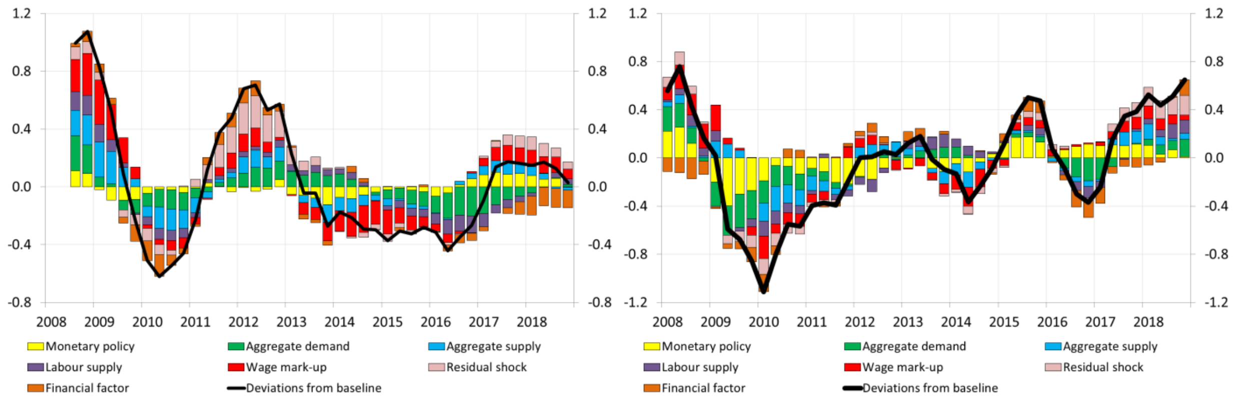
a) Compensation per employee *b) Core HICP inflation*



Notes: the black line is the difference between the actual series and the unconditional forecast obtained by the VAR model (i.e. baseline forecast). The colored stacked bars denote the contribution of the considered structural shock, as captured by the median of the posterior distribution of the Bayesian VAR. The model is estimated over the sample 1999Q1 – 2018Q4.

Figure 14. Historical decomposition of alternative measures of inflation:
VAR model including financial shocks
(quarterly data; year-on-year percentage changes)

a) Procyclical component of HICP core inflation *b) GDP deflator*



Notes: the black line is the difference between the actual series and the unconditional forecast obtained by the VAR model (i.e. baseline forecast). The colored stacked bars denote the contribution of the considered structural shock, as captured by the median of the posterior distribution of the Bayesian VAR. The model is estimated over the sample 1999Q1 – 2018Q4.

The main findings presented in this Section are robust to the adoption of alternative measures of underlying inflation such as in Section 3. In particular, when using the procyclical index built by Conflitti et al. (2019), or the ECB supercore index the negative contribution of financial shocks to core inflation is magnified, suggesting that the negative co-movement between wages and prices conditional to financial shocks is particularly relevant when looking at the most cyclically sensitive items of core inflation (see Figure 14). Therefore, taking a broader perspective, it is interesting to assess the robustness of our results by considering an identification scheme in which we impose zero restrictions on the impact response of all macroeconomic variables, as in Corsello and Nispi Landi (2019). Interestingly, this identification scheme is strongly rejected by data, as the algorithm described in Appendix A2 finds only a single rotation of the initial identification matrix satisfying these restrictions notwithstanding we consider 50,000 draws from the posterior distribution of the reduced-from VAR and 50,000 draws from the independent standard normal.

5. Concluding remarks

We assess the empirical relationship between wages and consumer prices net of food and energy in the euro area, motivated by the recent weakness of core inflation in spite of robust wage dynamics. To this aim, we use a Bayesian VAR model in which we identify several shocks to provide a structural interpretation of this puzzling evidence. We find that the pass-through from compensation per employee to measures of underlying inflation is lower than unity and varies conditionally on the underlying shock hitting the economy. The pick-up in wage growth observed over the period 2017-18 is mainly the result of upward pressures stemming from monetary policy and wage mark-up shocks, partially counterbalanced by downward pressures from aggregate supply shocks, which also exerted downward pressures on consumer prices. In contrast, aggregate demand shocks, which usually imply a higher pass-through, play only a negligible role. Financial conditions, as captured by innovations in bank spread or indicators of systemic risk, explain part of the disconnect between wage and price dynamics. The estimated impulse responses indeed suggest that non-financial firms are likely to adjust their mark-up in a countercyclical way, leading consumer prices to respond to financial shocks in an opposite direction than unit labour cost. When aggregate demand is not robust and firms face easing conditions in raising external funds or have ample liquidity, they may find optimal to decrease their mark-ups lower, exploiting market shares at the expense of current profits. These findings are consistent with the predictions of recent theoretical models featuring financial frictions and nominal rigidities (Gilchrist et al., 2017; Duca et al., 2017) and emphasize the *supply-side* mechanisms generated by changes in financial conditions. A potential limitation of our framework is that we use a linear model. It could be worth to investigate the conditional pass-through between wages and prices in a non-linear framework where the effects on firms' mark-ups may differ depending on the sign and the magnitude of the financial shocks. We plan to deal with these issues in future research.

All in all, our results have important implications, for researchers and policymakers. First, it is important to consider the dynamic interactions between labour market conditions and developments in financial markets as they significantly affect the transmission mechanism of structural shocks on both wages and prices. In particular, the documented negative comovement between wages and prices conditional on a financial shock poses a challenge for monetary authorities. Second, we corroborate the evidence that the pass-through of wages to consumer prices is shock-dependent but it is largely incomplete when considering measures of underlying inflation. Third, since the euro area economic outlook is still widely dependent on the monetary policy accommodation, core inflation could remain subdued even in presence of sustained wage dynamics. In this regard, downward risks for core inflation could materialize, should business cycle conditions worsen or the monetary policy stance become less expansionary.

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Appendix A1. The Dataset

Data are quarterly and seasonally adjusted, and they are taken from the Area Wide Model Dataset or the ECB SDW. In case of monthly data, they are transformed to quarterly by taking the average value. More specifically:

- **Real GDP**: Gross domestic product at market prices - Euro area 19 (fixed composition) - Domestic (home or reference area), Total economy, Euro, Chain linked volume (rebased), Non transformed data, Calendar and seasonally adjusted data. Data Source in SDW: https://sdw.ecb.europa.eu/quickview.do?SERIES_KEY=320.MNA.Q.Y.I8.W2.S1.S1.B.B1GQ._Z._Z._Z.EUR.LR.N&start=&end=&submitOptions.x=0&submitOptions.y=0&trans=PC&periodSortOrder=ASC. 1995Q1-2018Q4.
- **Employment**: Total employment - Euro area 19 (fixed composition) - Domestic (home or reference area), Total economy, Total - All activities, Persons, Not applicable, Non transformed data, Calendar and seasonally adjusted data. Data Source in SDW: https://sdw.ecb.europa.eu/quickview.do?SERIES_KEY=390.ENA.Q.Y.I8.W2.S1.S1._Z.EMP._Z._T._Z.PS._Z.N&periodSortOrder=ASC. 1995Q1-2018Q4.
- **Labour productivity (per persons)**: defined as the ratio between Real GDP and Employment, as in the Area Wide Model Database. 1995Q1-2018Q4.
- **Unemployment rate**: Euro area 19 (fixed composition) - Standardised unemployment, Rate, Total (all ages), Total (male and female); unspecified; Eurostat; Seasonally adjusted, not working day adjusted, percentage of civilian workforce. Data Source in SDW: https://sdw.ecb.europa.eu/quickview.do?SERIES_KEY=132.STS.M.I8.S.UNEH.RTT000.4.000&periodSortOrder=ASC. 1998:M4-2018M12 (converted into quarterly data, see above).
- **Nominal wages**: Compensation per employee - Euro area 19 (fixed composition) - Domestic (home or reference area), Total economy, Total - All activities, Index, Current prices, Non transformed data, Calendar and seasonally adjusted data. Data Source in SDW: https://sdw.ecb.europa.eu/quickview.do;jsessionid=FDCBE6D1DB4939EF396B1C3398D07D80?SERIES_KEY=320.MNA.Q.Y.I8.W2.S1.S1._Z.COM_PS._Z._T._Z.IX.V.N&start=&end=&submitOptions.x=0&submitOptions.y=0&trans=YPC&periodSortOrder=ASC. 1995Q1-2018Q4.
- **Core prices**: Euro area (changing composition) - HICP - All-items excluding energy and food, Monthly Index, Eurostat, Neither seasonally nor working day adjusted. Data Source in SDW: https://sdw.ecb.europa.eu/quickview.do?SERIES_KEY=122.ICP.M.U2.N.XEF000.4.INX&periodSortOrder=ASC. 1996M1-2018M12. Backdated to 1995 using the Euro Area Projection Database, seasonally adjusted by meanas of TRAMO-SEATS; (converted into quarterly data, see above).
- **GDP Deflator**: Gross domestic product at market prices - Euro area 19 (fixed composition) - Domestic (home or reference area), Total economy, Index, Deflator (index), Non transformed data, Calendar and seasonally adjusted data. Data Source in SDW: https://sdw.ecb.europa.eu/quickview.do?SERIES_KEY=320.MNA.Q.Y.I8.W2.S1.S1.B.B1GQ._Z._Z._Z.IX.D.N&start=&end=&submitOptions.x=0&submitOptions.y=0&trans=N&periodSortOrder=ASC. 1995Q1-2018Q4.

- **Supercore**: Euro area (changing composition) - HICP - Supercore (output gap sensitive HICP excluding energy and food items), Monthly Index, European Central Bank, Neither seasonally nor working day adjusted. Data Source in SDW: https://sdw.ecb.europa.eu/quickview.do?SERIES_KEY=122.ICP.M.U2.N.SPRXEF.3.INX&periodSortOrder=ASC. 2002M1-2018M12; (converted into quarterly data, see above).
- **Procyclical and acyclical component of core inflation**: details available in Conflitti et al.(2019). 1996M1-2018M12; (converted into quarterly data, see above).
- **EONIA**: Euro area (changing composition) - Money Market - Eonia rate - Historical close, average of observations through period - Euro, provided by ECB. Data Source in SDW: https://sdw.ecb.europa.eu/quickview.do?SERIES_KEY=143.FM.M.U2.EUR.4F.MM.EONIA.HSTA&periodSortOrder=ASC. 1994M1-2018M12; (converted into quarterly data, see above).
- **Shadow rates**: see Leo Krippner (https://www.rbnz.govt.nz/research-and-publications/research-programme/additional-research/measures-of-the-stance-of-united-states-monetary-policy/comparison-of-international-monetary-policy-measures) and Cynthia Wu (https://sites.google.com/view/jingcynthiawu/shadow-rates) website, 1995M1-2018M12 and 2004M9-2018M12, respectively.
- **CISS**: Euro area (changing composition), Systemic Stress Composite Indicator, Index. Data Source in SDW: Data Source in SDW: https://sdw.ecb.europa.eu/quickview.do?SERIES_KEY=290.CISS.D.U2.Z0Z.4F.EC.SS_CI.IDX. 1999M1-2018M12; (converted into quarterly data, see above).
- **Gilchrist and Mojon banking spread**: see Gilchrist and Mojon (2018) for further details. 1999M1-2018M12; (converted into quarterly data, see above). https://publications.banque-france.fr/en/economic-and-financial-publications-working-papers/credit-risk-euro-area.

Appendix A2. Estimation and inference in the Bayesian VAR Model

To address our research question we adopt a Vector Auto Regression (VAR) model, which provides us with a flexible tool to deal with the interlinkages between macroeconomic, financial and labour-market variables without imposing too much structure on the data. Our reference model in the rest of the paper is given by the structural representation of the VAR:

$$\mathbf{Y}_t = \mathbf{A}_0 + \mathbf{A}_1 \mathbf{Y}_{t-1} + \mathbf{A}_2 \mathbf{Y}_{t-2} + \ldots + \mathbf{A}_p \mathbf{Y}_{t-p} + \boldsymbol{\varepsilon}_t \qquad \boldsymbol{\varepsilon}_t \sim \text{WN}(0, \boldsymbol{\Sigma}) \tag{1}$$

or in terms of polynomial matrix form:

$$\mathbf{Y}_t = \mathbf{B}(\text{L})\, \mathbf{Y}_{t-1} + \boldsymbol{\varepsilon}_t, \tag{2}$$

where $\mathbf{Y}_t$ is a $m*1$ vector, $\mathbf{A}_{0,..,}$ $\mathbf{A}_p$ are $m*m$ matrix of coefficients and $\boldsymbol{\varepsilon}_t$ is a vector of residuals normally distributed with zero mean and variance-covariance matrix $\boldsymbol{\Sigma}$, and where $\mathbf{X}$ contains the constant and the lags of the endogenous variables, whereas $\mathbf{B}$ contains the matrices $\mathbf{A}_{0,..,}$ $\mathbf{A}_p$.

We consider a Normal-Wishart prior distribution, namely the distribution assigned to the vector of coefficients is Normal while the prior distribution of the variance-covariance matrix is inverse Wishart. Let $\boldsymbol{\alpha}$ be the vector that stacks the reduced-form coefficients in $\mathbf{B}$(L). We impose the restrictions of the so-called Minnesota prior on $\boldsymbol{\alpha}$. All coefficients in $\boldsymbol{\alpha}$ are equal to zero except the first own lag of the dependent variable in each equation, which is equal to one. The logic of this prior is that each time series is a-priori represented by a random-walk process. However, the random walk hypothesis is imposed a-priori: a posteriori, each time series may follow a more complicated process if there is sufficient information in the data to require it. The posterior distribution of the reduced-form parameters of the VAR, which is obtained by combining the (normal) likelihood of the VAR with the prior distribution, is normal conditional on the covariance matrix of the residuals, which has an inverse Wishart distribution. We set the "overall tightness" to 0.1, the "decay factor" to 1.0, and the "other coefficients" to 0.5. We set the number of lags in the VAR to four, based on the serial correlation of the residuals.

To achieve the identification of the structural shocks for the baseline model, we use the algorithm described in Rubio-Ramirez et al. (2010) that is particularly efficient when the number of variables included in the system and the number of shocks to be identified are relatively large. Operationally the algorithm uses a two-step procedure. In the first step it generates a random draw from the posterior distribution of the of the reduced-form parameters of the VAR. In the second step, starting from one candidate identification matrix $\mathbf{A}_0$ (i.e. a Choleski decomposition), the algorithm draws an arbitrary independent standard normal matrix **X** and, using its **QR** decomposition, generates an orthogonal matrix **Q**. Impulse responses are then computed using $\mathbf{A}_0\mathbf{Q}$, the rotation of the initial identification matrix, and reduced-form parameters of the VAR. If these impulse responses do not satisfy the sign restrictions the algorithm generates a different draw of **X**. In our simulations we consider 50,000 draws from the posterior distribution of the reduced-from VAR and 50,000 draws from the independent standard normal matrix **X** and save all the matrices $\mathbf{A}_0\mathbf{Q}$ that satisfy the sign restrictions. We report the median and the 16th and the 84th percentiles of the distribution of impulse responses produced by the algorithm described above for each variable over a forecast horizon of 8 quarters.

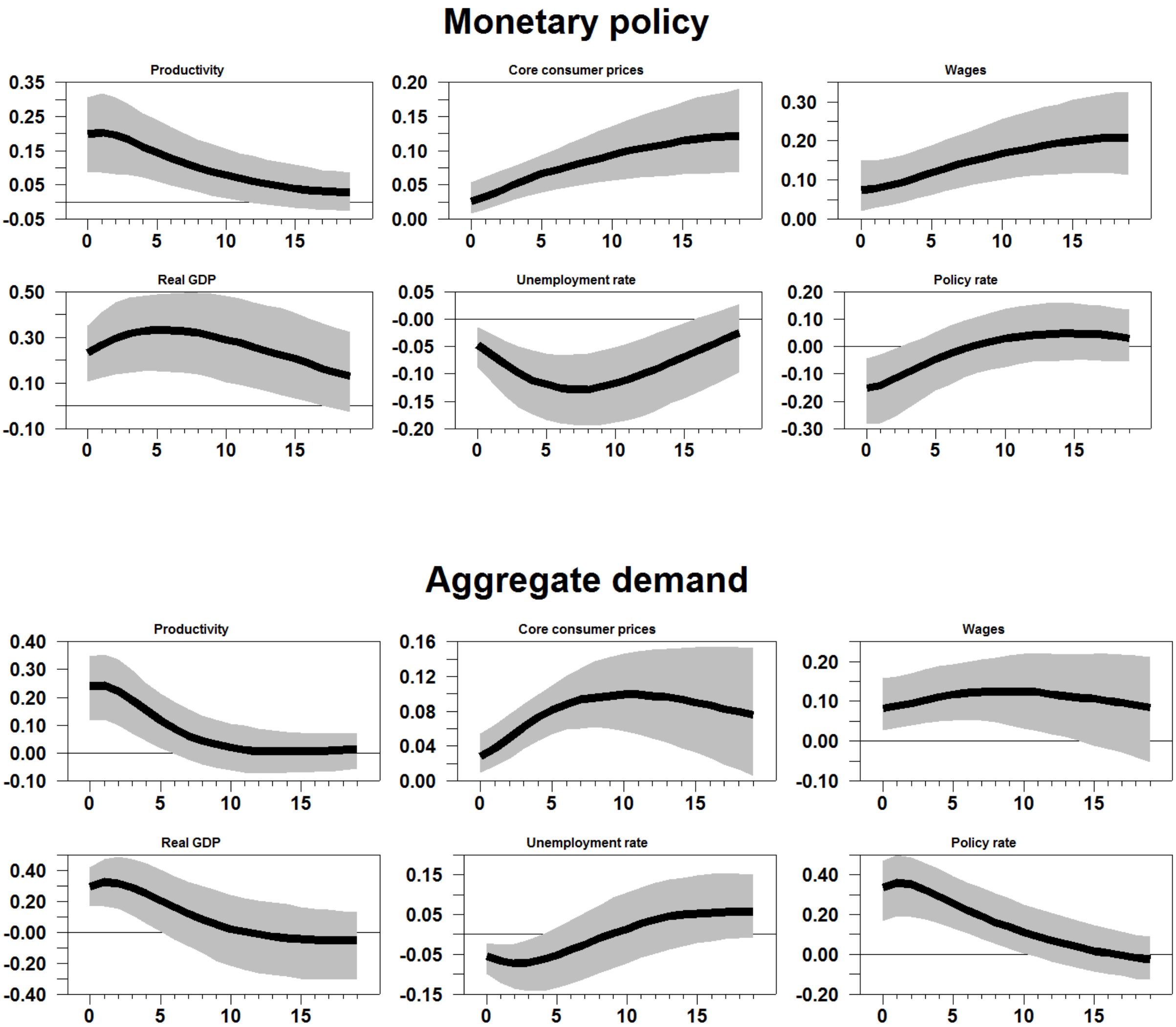
When we turn to the model with financial shocks, in which we exploit zero restrictions as well, we rely on the sequential algorithm by Mountford and Uhlig (2009) called "rejection method"[23] and we also check that the main findings hold when using the procedure suggested by Arias et al., (2018).

[23] The rejection method is largely preferable to the penalty approach by Uhlig (2005), as documented among others by Rubio-Ranirez et al. (2010).

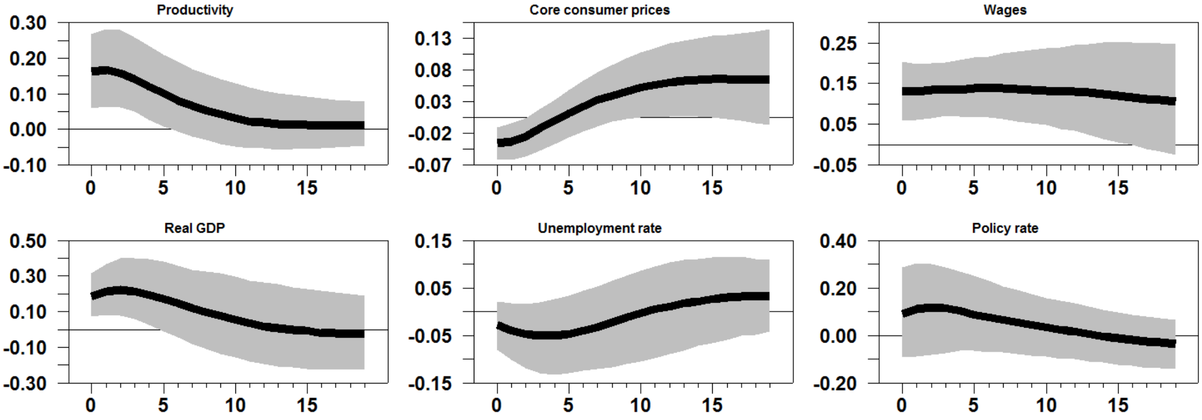
Appendix A3. Impulse response functions to shocks in the baseline VAR model

This Section reports the IRFs on which is based the computation of the wages-to-core prices multipliers.

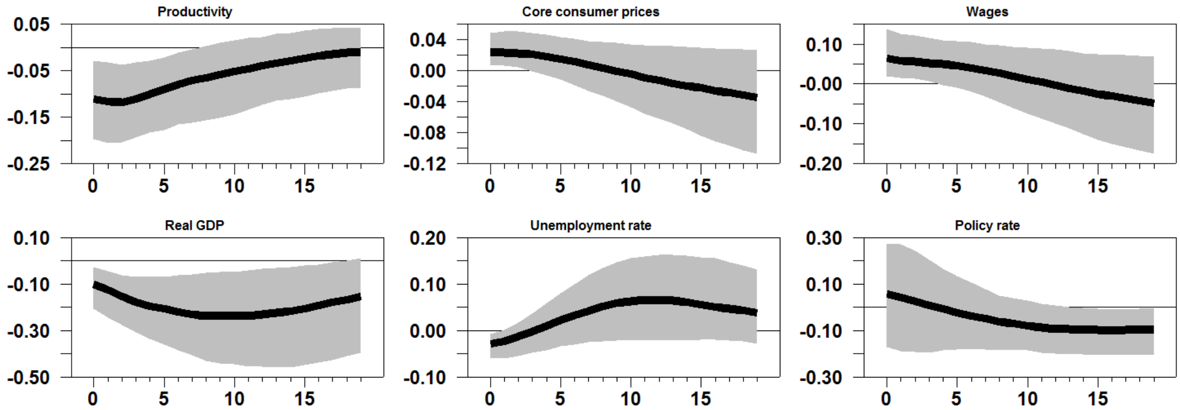
Figure A3.1. Estimated IRFs in the baseline VAR model to identified structural shocks
(*quarterly data; percentage points*)



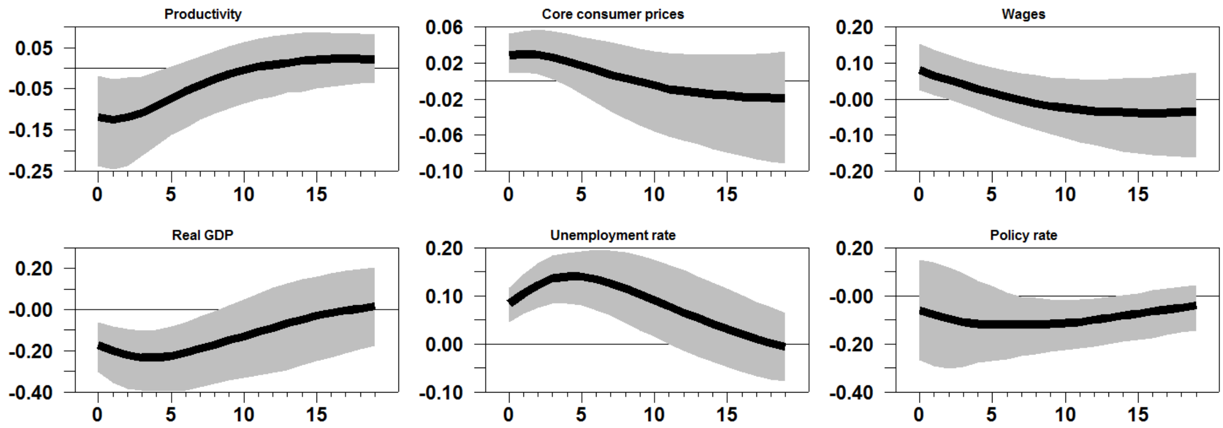
Aggregate supply



Labour supply



Wage mark-up



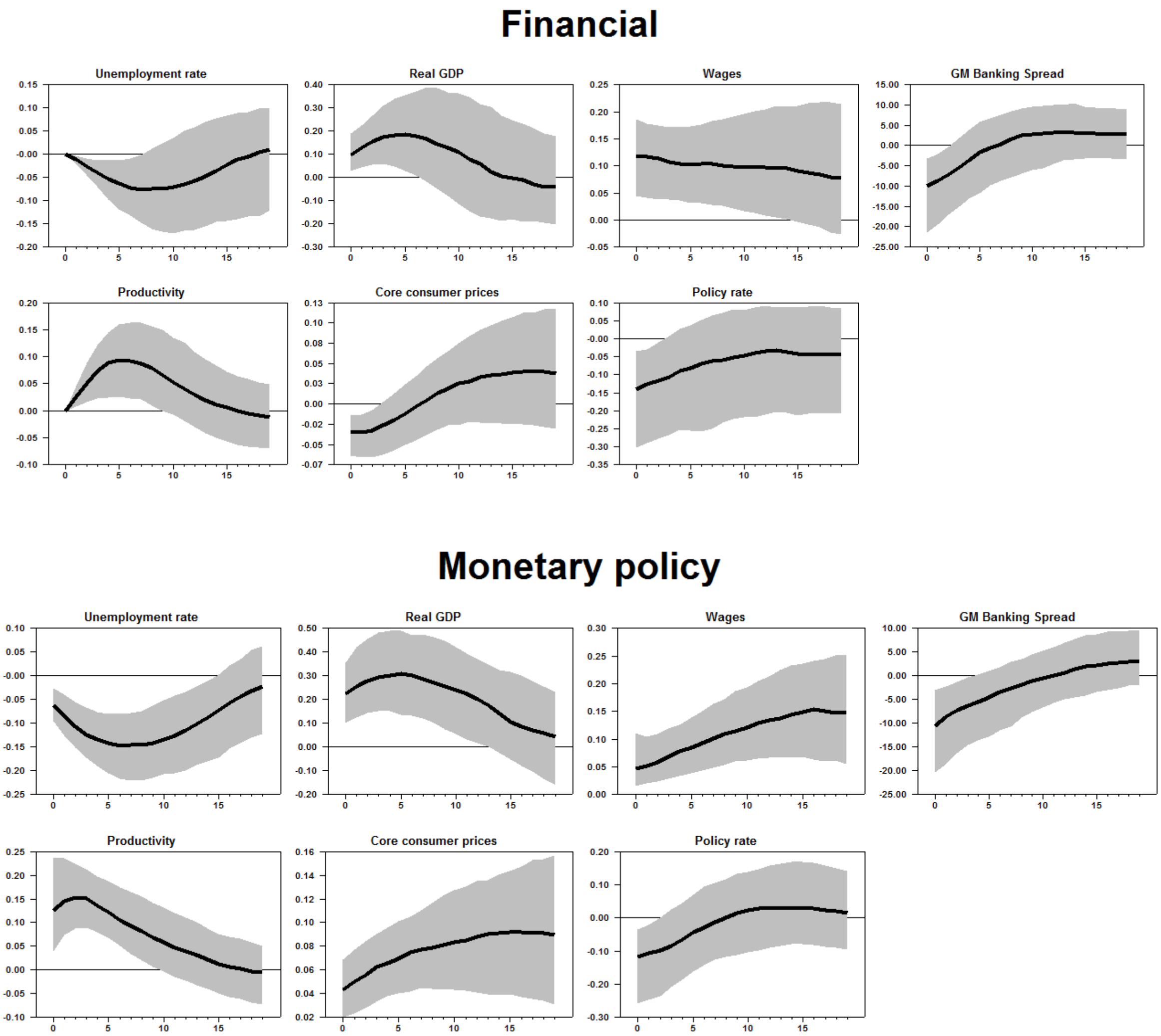
Notes: the black solid line is the median of the posterior distribution of the Bayesian VAR to selected shocks. The grey dashed area represents the 16th and 84th percentiles of the posterior distribution.

Appendix A4. Impulse response functions to shocks in a VAR model with financial variables

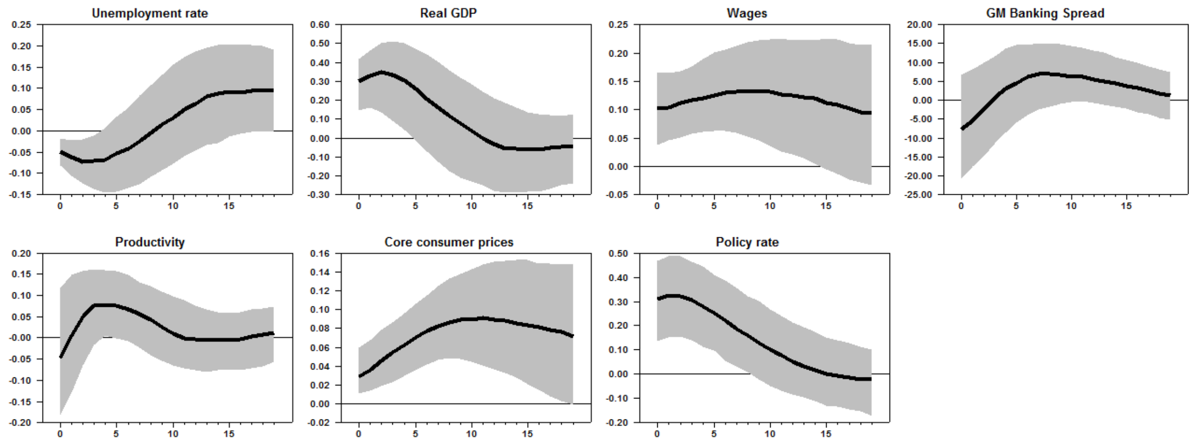
This Section reports the IRFs on which is based the computation of the wages-to-core prices multipliers in the model including financial variables.

Figure A4.1. Estimated IRFs in the VAR model with financial variables to the identified structural shocks

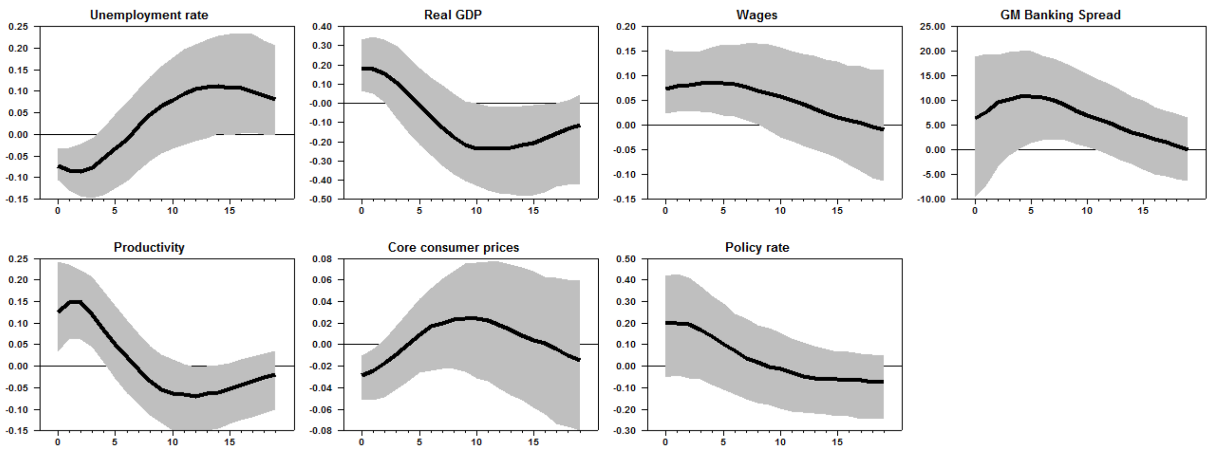
(*quarterly data; percentage points*)



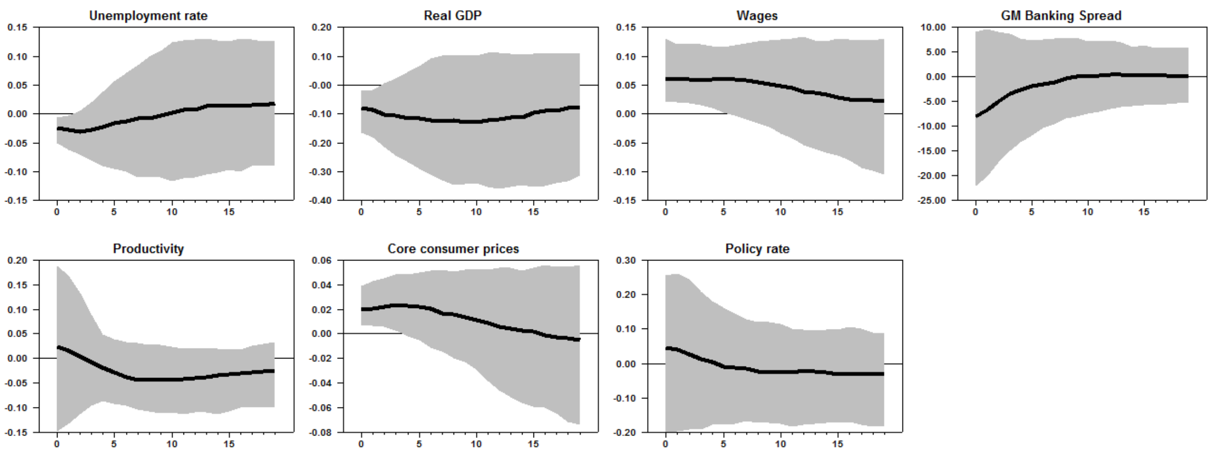
Aggregate demand



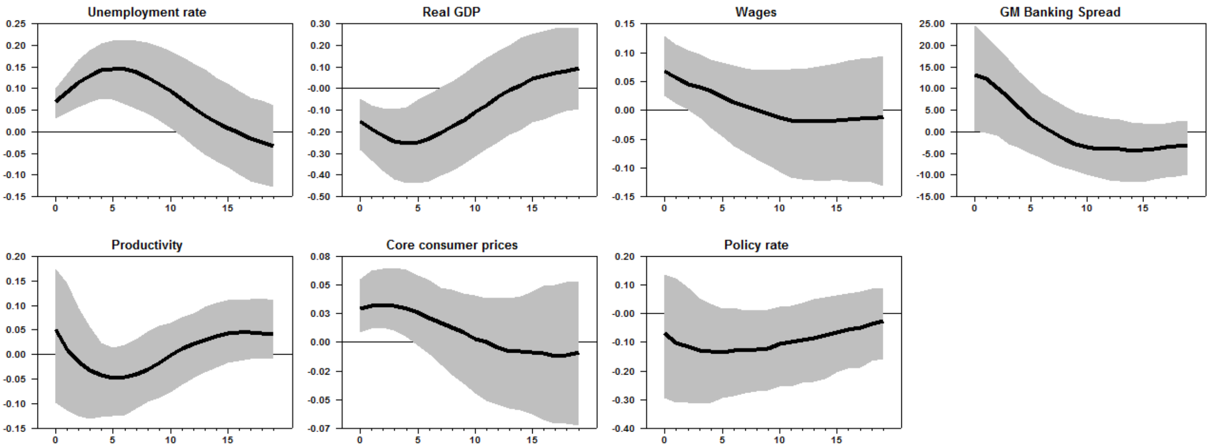
Aggregate supply



Labour supply



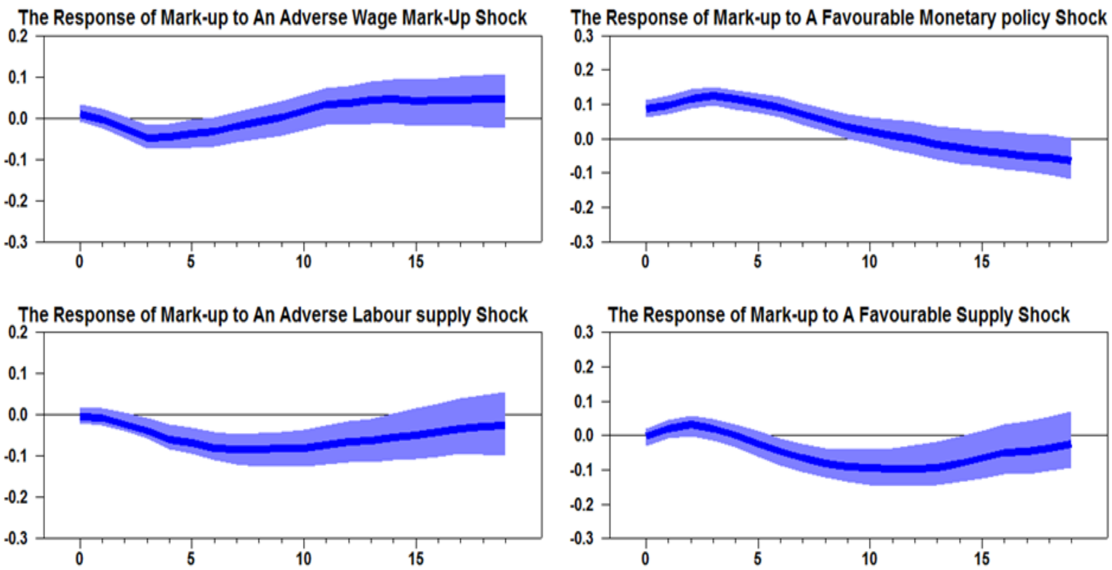
Wage mark-up



Notes: the black solid line is the median of the posterior distribution of the Bayesian VAR to selected shocks. The grey dashed area represents the 16th and 84th percentiles of the posterior distribution.

Appendix A5. The cyclicality of mark-up conditioning to other structural shocks

Figure A5.1. Estimated response of firms' mark-up to other structural shocks in the VAR model with financial factors



Notes: Since the model is estimated in log-levels, the response of mark-up is obtained by difference between the response of core inflation and the one of unit labour cost (nominal wage net of labour productivity). The blue line is the median of the posterior distribution of the Bayesian VAR models, while the shaded area is the 68% credibility interval. The model is estimated over the sample 1999Q1 – 2018Q4. The financial indicator is the banking spread by Gilchrist and Mojon (2018).