

Labour productivity and the wageless recovery*

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Abstract

We document that the feeble relation between wage growth and unemployment experienced by the euro area since the Global Financial Crisis has been coupled with a change in the response of labour productivity (output per worker) to an increase in employment, from nil up to 2009 (acyclical) to negative since then (countercyclical). We argue that both facts can be explained by the strong persistence of the last recession and of the subsequent recovery. The relevance of the duration of the cyclical phase can be rationalized in a theoretical model where firms use both the extensive and intensive margin of labour and face employment adjustment costs. When demand shocks are persistent firms adjust relatively more the extensive margin, leading to a countercyclical response of labour productivity and only to a small reaction of wages. We take the model to the data using a Bayesian VAR, where persistent demand shocks are identified exploiting the theoretical prediction which associates them with a countercyclical profile of labour productivity. We show that persistent demand shocks (*i*) induce a lower reaction of wages to employment and (*ii*) have been a non-negligible driver of employment and wage dynamics in the aftermath of the Global Financial Crisis.

JEL classification: C32, E32, F34.

Keywords: missing wage growth, productivity, demand shocks, Bayesian VAR models, DSGE models.

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Contents

1	Introduction	3
2	Empirical Evidence	6
2.1	Stylized facts on economic activity, productivity and wages	6
2.2	Bayesian VAR framework	10
2.3	Data, specification and recursive identification	11
2.4	Findings	12
2.5	A VAR model with both extensive and intensive margins	15
3	Theoretical model	17
3.1	Shocks persistence, the cyclicity of labour productivity and compensation per employee	19
4	Testing the model predictions	23
5	Robustness	26
5.1	Cholesky identification	27
5.2	Sign restrictions	27
5.3	Real wages and different identifying assumptions	28
6	Discussion: other explanations of missing wage growth	29
7	Conclusions	30
A	Supplementary Material	37
A.1	Dataset	37
A.2	3–variables Cholesky VAR	38
A.3	Larger specifications: Cholesky VAR	40
A.4	Baseline Bayesian VAR with sign restrictions: Further results	43
A.5	Robustness on SVAR analysis: Considering Real wages and Different identifying assumptions	45

1 Introduction

The failure of wage dynamics to respond sufficiently to the tightening of the labour market is widely perceived to be at the heart of the so-called “twin puzzle”: missing disinflation from 2009 to 2011 and missing inflation thereafter. Since the beginning of 2013, the euro area economy has been going through a long, slow recovery, with employment steadily rising, at a somewhat stronger rate than economic growth would normally suggest. Yet, despite tight labour markets and unemployment at a post-crisis low, wage growth has remained sluggish, insomuch that the current upswing has been described as a “wageless recovery”.¹ Nominal wage growth has somewhat recovered only since the end of 2017.²

In last years, unveiling the sources of missing wage growth has been at the centre of the policy (Yellen 2015; Coeuré 2017; Financial Times 2017) and research debate (see, among others, Daly and Hobijn 2014; Bell and Blanchflower 2018, and references therein). Indeed, the relevance of this phenomenon lies both in the role that the outlook for wages has for private consumption as well as in the fact that stagnant wage growth has been one of the determinants of missing inflation after 2012, which made stronger wage dynamics centre-stage for the sustainability of the recovery (see, for instance, Draghi, 2016).

In this paper we propose a novel explanation by investigating the joint dynamics of nominal wages, employment and labour productivity (defined as output per worker). We argue that the duration of the business cycle plays a crucial role in affecting the employment-wages pass-through: when the business cycle phase is very persistent firms incentive to hoard labour vanishes thus leading to countercyclical behaviour of labour productivity and a lower employment-wages multiplier.

Let us give the intuition of the mechanism at play before introducing the empirical evidence and theoretical foundations which support it. After the Great Recession, which inflicted persistent scars on the economy, the euro area has been experiencing a long-lasting recovery. Since 2008 the observed macroeconomic dynamics can thus be attributed to more persistent demand shocks, which are found to be major drivers of euro area business cycle fluctuations (see, for example, Conti, Neri, and Nobili (2015) and Ciccarelli and Osbat (2017)). The persistence of the shocks hitting the economy affects the composition of total labour input as long as firms can vary both the extensive (employment) and the intensive margin (hours per worker, observable effort) of labour utilization. In highly regulated labour markets such as the european one, adjusting heads employment is costly due to firing restrictions and training costs, while it is relatively easy to

¹Policymakers, professional analysts and researchers agree that, based on past experiences, wages should have grown much faster than they did on the back of the ongoing recovery. European Commission (2017) diagnosed a “wage-poor recovery”; the Financial Times (2017) referred to the “Eurozone’s strange low-wage employment boom”; Bloomberg (2017) called it the “mystery of missing wage growth”.

²Nominal compensations per employee stand at 2.65% y-o-y in 2018:Q2, the last available observation in our analysis – as in the pre-crisis period (1995:Q1–2008:Q2). They instead averaged a 1.8% y-o-y growth over the period 2008:Q3–2018:Q2.

change the intensive margin. This circumstance leads to a labour hoarding behaviour: in response to a short-lived shock firms prefer to adjust the intensive rather than the extensive margin, hence output per worker behaves procyclically. However the cost of varying heads employment becomes worth paying if firms expect the shock to have long-lasting consequences on aggregate demand. Hence, our interpretation is that since 2008 firms reacted to increasingly persistent demand shocks by adjusting employment relatively more than what they had been doing in the pre-crisis period.³ We show that this shift in employment setting decisions can be responsible for significant changes in macroeconomic correlations. Most notably, they can explain a new stylized fact (to the best of our knowledge) that we uncover, which appears key to interpret the vanishing relationship between wages and employment: a sign switch in the cyclicity of labour productivity.

In more detail, estimates of a simple Bayesian Vector Autoregression model (BVAR) identified through a recursive scheme show significant differences between the pre- and post-crisis period in the responses of labour productivity and nominal wages to an increase in employment. After the Great Recession the response of output per worker has become countercyclical (from acyclical) and the reaction of wages has become significantly more muted; in other words, the pass-through from employment to wages has become almost nil. We thus contribute to the widespread debate on the wage Phillips curve (Galí 2011; Galí and Gambetti 2018; Bulligan and Viviano 2017) by showing that the weaker relationship between wages and employment has come together with a change in the cyclical response of labour productivity.⁴

A dynamic general equilibrium model (DSGE) based on Galí (1999) allows us to explain why the sign of the correlation between employment and productivity drives the wage-employment multiplier. We conduct this analysis conditional on demand shocks, which have been advocated as the major drivers of business cycle fluctuations in the euro area (Conti, Neri, and Nobili 2015).⁵ We show that this correlation crucially depends on the expected duration of the cyclical phase

³In the early stages of the financial crisis (2008-2009), when the depth of the recession and the length of the recovery were still uncertain, labour hoarding was used by firms and encouraged in some countries in order to save jobs. German firms made an extensive use of the short-time-work (STW) scheme called *Kuzarbeit*. An investigation of the impact of STW during the Great Recession can be found in Boeri et al. (2011); Hijzen and Martin (2013) provide a cross country analysis. However, our study suggests that the length of the double-dip recession and of the ensuing recovery pushed firms to rely less on labour hoarding when facing demand shocks.

⁴Most studies on the relationship between wage and employment rely on univariate models. A notable exception is the paper by Galí and Gambetti (2018) who also use VAR techniques on US data. A large body of literature has recently investigated the price Phillips curve as well: among others, one may look at Ball and Mazumder (2011), Ball and Mazumder (2018), Riggi and Venditti (2015) which all use fixed or time-varying coefficients univariate models. A multivariate state-dependent analysis is performed on US data by Laseen and Sanjani (2016).

⁵In our theoretical analysis, in order to capture demand disturbances we rely on discount factor shocks since, as argued by Hall (2017) among many others, they entail similar effects to an increase in financial risks being intertemporal disturbances that lead households to postpone consumption and drive down all types of investment, including employers' investment in job creation. On top of that, Primiceri, Schaumburg, and Tambalotti (2006) provide evidence that shocks affecting agents' intertemporal substitution are the key driving forces of business cycle and that, among them, shocks to the stochastic discount factor are the most important in explaining consumption fluctuations. As a shortcut, and with the aim of keeping the model as simple as possible to let our key intuition emerge, we believe that it is reasonable to describe both the double-dip recession and the subsequent ongoing recovery as the result of shocks affecting agents' intertemporal substitutions.

(i.e. the persistence of demand shocks), which we regard as a plausible reason behind the sign switch occurred in the latest years.

In the model firms' production function combines the extensive (number of employees) and the intensive (effort or hours) margins of labour, with convex hiring and firing costs. In this context, procyclical labour productivity would result from labour hoarding, that is, variations in workers' effort which substitute for changes in the number of employees over the business cycle. Clearly the more transitory a cyclical phase is perceived to be, the stronger is the incentive for firms to hoard labour. Putting it differently, a key element of the labour hoarding behaviour is that, in a recession, firms must believe that demand will recover soon and, symmetrically, in a boom they must believe that the increase in demand will rapidly wane.⁶ In other words, the optimal degree of labour hoarding (and hence the procyclicality of labour productivity) decreases with the expected duration of the cyclical phase: because the cost of adjusting the labour force increases faster than the amount of labour to be adjusted, firms want to make small, gradual changes to the number of employees, and thus are more willing to do that the more the cyclical phase is expected to last, while substituting variations in employment with variations in workers' effort the more transitory the cyclical phase is perceived to be. As the theoretical model clarifies, the reaction of wages to the business cycle fades as the correlation between labour productivity and employment turns negative.

Finally, as a last step we test the theoretical predictions of the DSGE model on euro area data, imposing in the BVAR framework a structural identification with a clear economic interpretation (demand, technology, labour supply) by means of sign restrictions derived from the theoretical model, consistently with the macroeconomic literature (Dedola and Neri 2007; Peersman and Straub 2009). The data support the presence of demand shocks which entail a countercyclical response of labour productivity (the *persistent* ones according to the theoretical model); these shocks induce a mild wage response, much lower than demand shocks which are instead associated with a procyclical profile of labour productivity (the *short-lived* ones according to the theoretical model). Furthermore, among demand shocks, the persistent ones become relevant drivers of both employment and wage growth over the recent years, accounting, relative to the short-lived disturbances, for a larger share of labour market developments in the ongoing recovery.

Our analysis is fully consistent with the argument in Bulligan, Guglielminetti, and Viviano (2017), who provide evidence that the intensive margin of labour utilization plays a relevant

⁶The role of the expected persistence of the cyclical phase in driving the "labour hoarding" attitude of firms has been somewhat neglected in the literature. A notable exception is Ohanian (2002), who questioned the validity of the labour hoarding explanation of procyclical labour productivity over the Great Depression, on the basis of its duration. "*The duration of the Depression, however, raises questions about the plausibility of the labour-hoarding explanation. It is difficult to reconcile the labour-hoarding thesis, which is based on the temporary nature of recessions, with a major depression that lasted well over a decade. It seems unlikely that firms hoarded workers because they mistakenly expected the Depression to end quickly; consumption data suggest that the Depression was expected to last a long time.*" For a literature review of the emergence of the labour hoarding concept and its implications for the cyclicity of labour productivity see Biddle (2014) and references therein.

role for wage growth and that the decline in the cyclical component of the intensive margin since 2015 helps explaining the modest euro area wage growth in 2016-2017. The mechanism we propose is consistent with this work, since it implies that the informational content of head-count employment for wage dynamics has changed after the Great Recession as the intensive margin has been used less procyclically than before. We add to this line of research by shedding light on the relevance of the persistence of the recent cyclical phases in affecting the relative adjustment of the extensive and intensive margins of labour utilization and showing consistent evidence on the dynamics of labour productivity.

Our paper is further related to the empirical studies using Bayesian VAR models to investigate labour market dynamics (Hairault and Zhutova 2018; Foroni, Furlanetto, and Lepetit 2018; Galí and Gambetti 2018) and to theoretical models who focus on the cyclical properties of hours worked (Cacciatore, Fiori, and Traum 2019) or the persistence of shocks (Roys 2016). However, not only these papers study the US economy, while we are focusing on the euro area but we are using both these macroeconomic tools (Bayesian VARs and DSGE) to show that the "missing wage growth puzzle" in the euro area is related to a change in the cyclical behaviour of labour productivity. The theoretical model provides us with insights on the mechanism at play and allows us to derive identifying restrictions exploitable in the econometric strategy.

The remainder of the paper is organized as follows. Section 2 describes some stylized facts which motivate and instruct our analysis. In Section 3 we use a general equilibrium theoretical model to rationalize why the sign of the correlation between output per worker and employment affects the reaction of wages over the cycle and to show why the expected persistence of the shock driving the business cycle is a key variable to determine that sign. Section 4 tests the predictions of the model by using BVAR models identified with sign restrictions. In Section 5 we discuss robustness checks across several dimensions of interest. Section 6 reviews other explanations of the "missing wage growth" puzzle. Finally, a roadmap for future research is outlined in the Conclusions.

2 Empirical Evidence

In this Section we provide a first look at data on low wage growth and labour market dynamics in the euro area. We first rely on descriptive evidence before moving to present some multivariate conditional correlations.

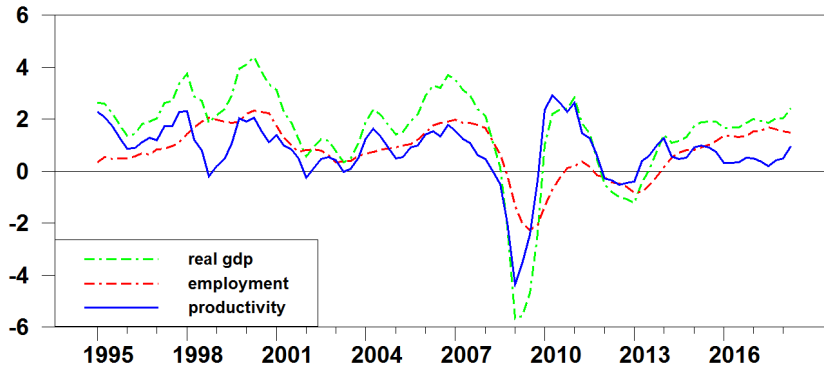
2.1 Stylized facts on economic activity, productivity and wages

Figure 1 plots the annual growth rates of real GDP, employment and labour productivity in the euro area over the period 1995:Q1 – 2018:Q2 (panel a). While both labour productivity and employment experienced a huge drop from the second half of 2008 until the beginning of 2009,

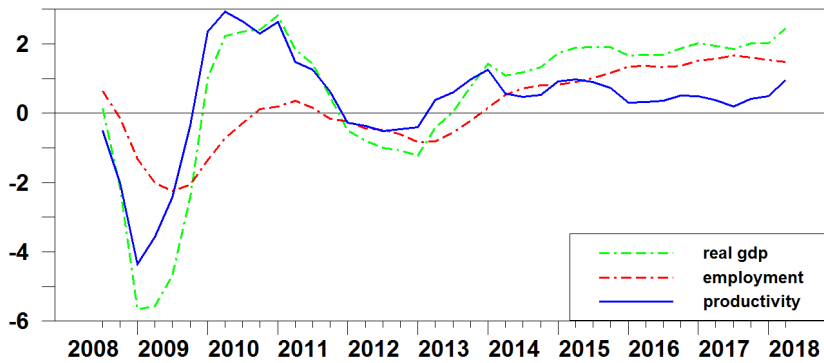
output per worker recovered sooner and faster (panel b).⁷ Since the start of 2009, changes in labour productivity and in employment often have the opposite sign, with the sample correlation between the two variables going from 0.4 between 1995 and 2008 to -0.2 between 2009 and 2018.

Figure 1: REAL GDP, EMPLOYMENT AND WAGE GROWTH

a. Full sample: 1995:Q1 – 2018:Q2



b. Post-crisis sample: 2008:Q3 – 2018:Q2

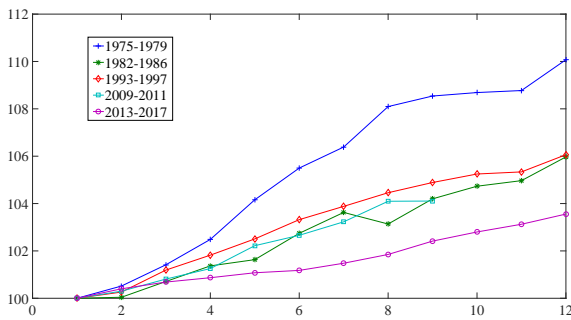


Notes: y-o-y percentage growth rates.

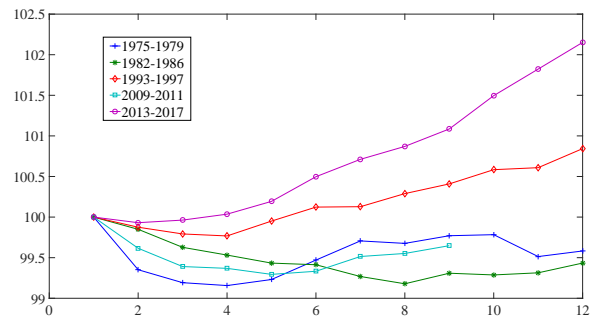
⁷The increase in labour productivity may also signal a change in the composition of skills due to the cleansing effect of the recession, which destroyed the less productive jobs.

Figure 2 compares real GDP, employment, labour productivity and compensation per employee in all the euro area expansion periods.⁸ The current recovery stands out as the weakest in terms of real GDP growth (panel a). Yet, in contrast with the US, the recovery in the euro area is far from being jobless, as employment has been expanding at the fastest pace among all the expansion periods (panel b). Modest GDP growth coupled with the exceptional pace of employment recovery entails a very weak increase in labour productivity (panel c). Also, against the background of a strongly tightening labour market, the flat trajectory of wage growth (panel d) is another distinctive feature of the recovery since 2013. This appears less puzzling in the light of the feeble productivity growth.

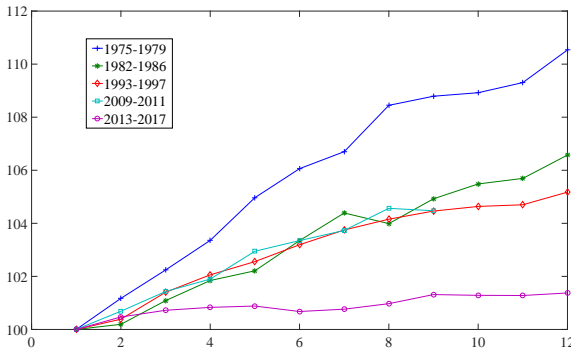
Figure 2: EURO AREA RECOVERIES



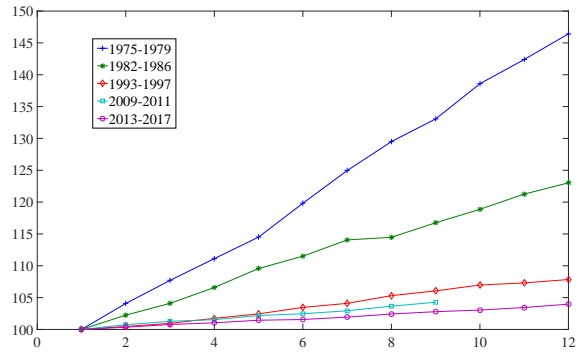
(a) GDP



(b) EMPLOYMENT



(c) LABOUR PRODUCTIVITY



(d) WAGES

Notes: The figure reports a comparison among GDP (panel a), employment (panel b), output per worker (panel c) and compensation per employee (panel d) in all the expansion periods dated by the CEPR business cycle dating committee. Each variable is computed as index with reference period the quarter of the different troughs. The x-axis measures the number of quarters after the troughs. Data are taken from the AWM database.

To shed more light on the relationship between nominal wage growth and changes in employment, Table 1 shows their unconditional dynamic correlation in two different periods. As a break date we choose 2008:Q3, which corresponds to Lehman's failure and the first drop in labour productivity; we will use the same breakdown in the VAR analysis. In the first subsample,

⁸We use compensation per employee, wages and compensations interchangeably to indicate nominal compensation per employee (the variable named WRN in the Area Wide Model database).

ranging from 1995:Q1 to 2008:Q2, labour input and compensation per employee are strongly and positively correlated: the unconditional correlation between the two variables peaks at around 5 lags and hovers around 0.5–0.7, depending on whether y-o-y differenced or filtered data are considered. By contrast, the correlation fades out in the most recent years.

Table 1: UNCONDITIONAL CORRELATION BETWEEN WAGES AND EMPLOYMENT

filtered data		
Lag	1995:Q1 - 2008:Q2	2008:Q3 - 2018:Q2
0	0.28	0.40
1	0.38	0.26
2	0.44	0.12
3	0.49	0.14
4	0.52	0.18
5	0.51	0.14
6	0.48	0.09
7	0.43	0.12
8	0.37	0.13
Ljung-Box Q-Stat		
1 to 8	101.01 (0.00)***	8.77 (0.36)
0 to 8	105.49 (0.00)***	15.47 (0.08)*
differenced data		
Lag	1995:Q1 - 2008:Q2	2008:Q3 - 2018:Q2
0	0.04	0.10
1	0.19	0.11
2	0.34	0.07
3	0.49	0.04
4	0.60	0.04
5	0.67	0.04
6	0.66	0.05
7	0.62	0.06
8	0.53	0.06
Ljung-Box Q-Stat		
1 to 8	144.30 (0.00)***	1.48 (0.99)
0 to 8	144.37 (0.00)***	1.90 (0.99)

Notes: Unconditional correlation between wages and employment before and after 2008:Q2. Filtered data: series obtained applying a Baxter-King filter. Differenced data: y-o-y growth rates. The Q-stat is the Ljung-Box test computed over a window of 8 lags, excluding or including (respectively) the contemporaneous cross-correlation. P-values in brackets; ***, **, * denote significance at 1%, 5%, 10%.

To summarize, since the end of the Global Financial Crisis labour productivity and employment have been characterized by opposite dynamics; at the same time, the unconditional correlation between nominal wage growth and employment growth has strongly declined. A salient feature of the recent years is the length of the cyclical phases. It looks fairly innocuous to con-

sider a persistent cyclical phase the one characterized by the Global Financial Crisis and the following Sovereign Debt Crisis; moreover, the subsequent recent recovery has been exceptionally long-lasting. In the next Section we provide additional evidence on how the relationship between employment, labour productivity and wages has changed in the last years.

2.2 Bayesian VAR framework

To empirically address our research question we rely on Vector Auto Regression (VAR) models, which provide us with a flexible tool to deal with the interlinkages between labour and macroeconomic variables without imposing too much structure on the data. Our reference model is

$$\mathbf{Y}_t = \mathbf{B}_0 + \mathbf{B}_1 \mathbf{Y}_{t-1} + \mathbf{B}_2 \mathbf{Y}_{t-2} + \dots + \mathbf{B}_p \mathbf{Y}_{t-p} + \boldsymbol{\varepsilon}_t, \quad \boldsymbol{\varepsilon}_t \sim \mathcal{N}(0, \boldsymbol{\Sigma}) \quad (1)$$

or, in terms of polynomial matrix form,

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

where \mathbf{Y}_t is a $m \times 1$ vector, \mathbf{B}_0 is a matrix of constant and (possibly) deterministic trends, $\mathbf{B}_1, \dots, \mathbf{B}_p$ are $m \times m$ matrix of coefficients and $\boldsymbol{\varepsilon}_t$ is a vector of residuals normally distributed with zero mean and variance-covariance matrix $\boldsymbol{\Sigma}$. These reduced-form residuals are linearly linked to the structural orthogonal shocks driving the economy according to the following equation

$$\boldsymbol{\varepsilon}_t = \mathbf{A} \mathbf{u}_t, \quad (3)$$

where $\mathbf{u}_t \sim \mathcal{N}(0, \mathbf{I}_m)$ and \mathbf{A} is the $m \times m$ matrix of contemporaneous relations between the endogenous variables.

We choose a Bayesian framework, since it is particularly useful when a large number of parameters has to be estimated. This class of models allows to attenuate over-fitting problems and has become the standard for macroeconomic analysis of the euro area economy, both in a forecasting environment (Giannone et al. 2014; Bobeica and Jarocinski 2017) and for structural analysis (Conti, Neri, and Nobili 2015).

For our baseline specification, we consider conjugate prior distributions that belong to the Normal-Wishart family, where the prior for the vector of coefficients is Normal while the prior for the variance-covariance matrix is inverse-Wishart. 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. In our baseline specification we choose standard values of priors as recommended by the literature: in particular, the degree of overall tightness is equal to 0.1, the decay is 1.0 and the tightness on cross-variable coefficients is 0.5.

2.3 Data, specification and recursive identification

The specification of the VAR model aims at capturing the most relevant dynamic relations between labour market and the macroeconomy. The data are taken from the Area Wide Model Database (Fagan, Henry, and Mestre 2005) and the ECB Statistical Datawarehouse. As we are interested in gaining more insights on low wage dynamics in association to a prolonged and robust expansion of employment like the one presented in Section 2, we start from the following 3-variable specification:

$$\mathbf{Y}_t = [(x_t - n_t), n_t, w_t] \quad (4)$$

where x_t is real GDP, n_t is employment, their difference $(x_t - n_t)$ is labour productivity and w_t denotes nominal compensation per employee. Lower letters stand for logs; indeed the model is estimated in log-levels to allow for cointegration between variables. The specification reminds of the bivariate model in Galí (1999) and Galí and Gambetti (2009), but we augment it with nominal wages since we are interested in investigating also nominal wage growth. In this way we can study how the unconditional and conditional correlations between labour productivity and employment interact with the ones between employment and wages.

The sign of the response of output per worker to an increase in the number of employees is ambiguous on a priori ground. Indeed, a positive response may signal either short-run increasing returns to labour or labour hoarding. In the first case output rises more than changes in measured labour input because of genuine increasing returns in the production function (for a fixed level of technology), as, for instance, in theoretical models that characterize the cycle as a period of optimal bunching of production. Moreover, increasing returns might be internal to firms, requiring the existence of firms with market power (as in Hall 1988), or external to firms as, for example, in Murphy, Shleifer, and Vishny (1989) or in Baxter and King (1991). Alternatively, output may rise more than changes in employment, if firms use labour more intensively in booms than in recessions, thus creating the “illusion” of short run increasing returns to labour. This is entangled with a wider debate about the cyclical behaviour of labour productivity at the unconditional level.⁹

As a starting point, we adopt a recursive identification scheme, i.e. a Cholesky decomposition of the variance–covariance matrix of the residuals of model (2). This is equivalent to say that wages respond contemporaneously to both productivity and employment, whereas the first two variables are affected by shocks to wages only with a lag. This identification scheme has two

⁹For a long while, the unconditional correlation between employment and output per worker was found to be positive and the procyclicality of labour productivity (firstly documented by Hultgren 1960) achieved the status of a basic stylized fact of macroeconomics. While in the real business cycle theory labour productivity is procyclical because changes in technology are the driving force of the business cycle (i.e. production function itself shifts over the cycle), the Keynesian view is more akin to the labour hoarding explanation. In the US a relevant change occurred around mid-1980s: the large drop in macroeconomic volatility known as “the Great Moderation” was accompanied by substantial changes in the correlation structure between labour input and labour productivity, as their correlation, which was positive before, became negative since mid- 1980s (see Galí and Gambetti (2009), Stroh (2009), Barnichon (2010), Galí and Rens (2010), Nucci and Riggi (2013) among many others).

appealing features for our purposes: first, in spite of its limitations, it is widely used in the economic literature (Christiano, Eichenbaum, and Evans 1999; Banbura, Giannone, and Reichlin 2010), but, more importantly, it allows for a stylized wage Phillips curve in which compensation per employee depends on employment and productivity. At this stage, we do not take any stance on the driving force of employment. In Section 4 we will be able to identify structural shocks by exploiting the insights of the theoretical model. We therefore estimate the model to verify whether the descriptive *unconditional* evidence presented in Section 2 can be explained by a change in the *conditional* correlations summarised by the Impulse Response Functions. If this holds, we should expect some changes in the IRFs around the Global Financial Crisis. For simplicity we estimate a linear model over two different sub-samples. We have experimented with several break dates: depending on the specification and the identifying assumptions, the date of the break in the conditional correlation between employment, productivity and wages lies in the period 2008:Q3 – 2009:Q4. Here we present the results with 2008:Q3 as break point.¹⁰ This choice has several advantages. First, it doesn't shorten too much the second sub-sample (also taking into account the lag structure of the VAR), thus permitting to reduce the uncertainty around the estimates. Second, it allows to capture the whole cyclical phase initiated with the downturn in labour productivity, thus helping for a better and more complete characterization of the economic developments.

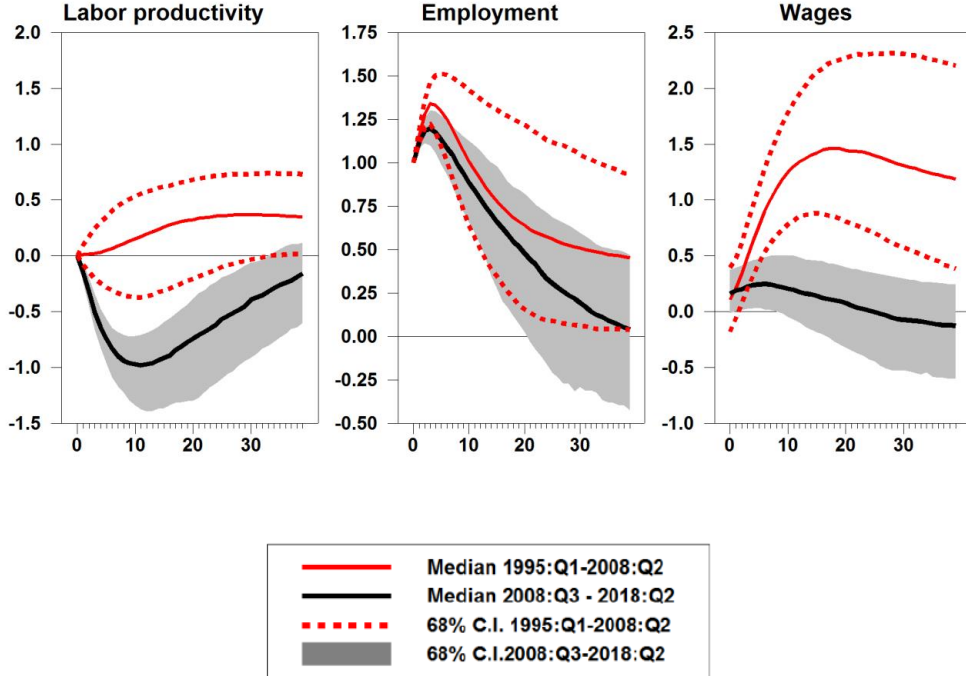
2.4 Findings

In Figure 3 we present the IRFs to an increase in employment over two different periods, the same considered in Table 1. We normalize the shock to employment so that on impact it increases by 1% in both periods. The dynamic behaviour of employment following the shock looks pretty similar across subsamples. The picture is strikingly different when looking at the reaction of the other two variables in the system, nominal wages and labour productivity. Compensations display a hump-shaped response before the Global Financial Crisis, starting to grow with a lag of two quarters and peaking at 1.0% after about three years, before starting to gradually slow down and revert back to their pre-shock level. After the crisis, wages barely move, as is evident by the mildly positive and significant response to the increase in employment. Hence, these findings corroborate the evidence on the so-called “*death*” of the Phillips curve – i.e. the insensitivity of wage or price dynamics to economic activity (according various measures), here defined in terms of wages and employment (see also Coibion and Gorodnichenko 2015; Galí and Gambetti 2018). Analogously, the reaction of labour productivity is different when looking at the pre-crisis or post-crisis sample: while in the former labour productivity displays a mildly positive but statistically not significant reaction to a 1% increase in employment, hence being labeled as *acyclical*, it decreases after about one quarter until reaching a minimum effect of almost -1.0% after 8 quarters. Thus, after 2008:Q3

¹⁰Figures with different break points are available upon request.

labour productivity displays a *countercyclical* behaviour conditional on a shock to employment.¹¹

Figure 3: IRF TO A 1% EXPANSIONARY SHOCK IN EMPLOYMENT (HEADS): CHOLESKY SVAR



Notes: The figure reports the results of a 3-variables BVAR including $\log(\text{labour productivity})$, $\log(\text{employment})$ and $\log(\text{nominal compensation per employee})$ identified recursively. The red line is the median derived from the posterior distribution of the Bayesian VAR (1995:Q1–2008:Q2). The dashed red lines represent the 16th and 84th percentiles derived from the posterior distribution of the Bayesian VAR (1995:Q1–2008:Q2). The black line is the median derived from the posterior distribution of the Bayesian VAR (2008:Q3–2018:Q2). The grey shaded area represents the 16th and 84th percentiles derived from the posterior distribution of the Bayesian VAR (2008:Q3–2018:Q2).

We can gain more insights on the dynamic conditional correlation between wages and employment by borrowing the definition of *shock-dependent cumulative multiplier* from the most recent literature on the transmission of exchange rate shocks to import and consumer prices (Forbes, Hjortsoe, and Nenova 2018), which in turn builds on the fiscal policy literature (see, for example, Ramey and Zubairy 2018, who rely on local projections techniques). A similar definition studying the inflation–unemployment trade–off is also adopted in a recent methodological and empirical contribution by Barnichon and Mesters (2019), who also use local projections. Turning back to the multiplier, its definition coincides with the ratio between the cumulated IRFs of two variables of interest at a horizon h , in our case wages and employment.

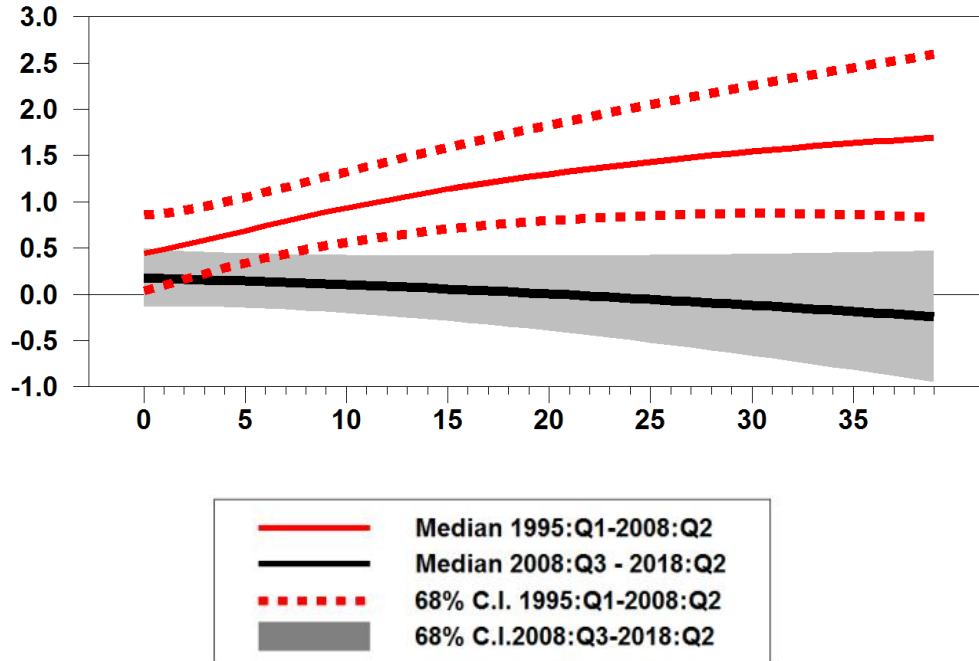
$$M(h) = \frac{\sum_{h=1}^H IRF_{t+h}^k(i)}{\sum_{h=1}^H IRF_{t+h}^k(j)}, \quad i = \text{wages}, j = \text{employment}, H = \bar{H} \quad (5)$$

where \bar{H} is the maximum number of quarters of interest and, in the following graphs, will be set

¹¹Here the cyclicity of labour productivity is assessed in terms of reaction to employment shocks. In other terms, we label labour productivity as procyclical when it increases following an expansionary shock to employment and countercyclical if the opposite is true.

to 40. In Figure 4 we report the multiplier of nominal wages to employment computed according to the former definition from the baseline 3–variables VAR model. This statistics summarizes the evidence based on the IRFs, confirming that in the period 1995:Q1–2008:Q2 after a 1% increase in employment, wages cumulatively grow by 1.5%, then stabilizing at the new level. By contrast, the same computations show a 0.1% increase of wages following the same shock to employment over the period 2008:Q3–2018:Q2.¹²

Figure 4: THE WAGE–EMPLOYMENT MULTIPLIER: CHOLESKY SVAR MODEL



Notes: The figure reports the multiplier of nominal wages to employment (ratio of the cumulative IRFs of wages and employment), conditional on a shock to employment. The result is derived from a 3-variables BVAR including $\log(\text{labour productivity})$, $\log(\text{employment})$ and $\log(\text{nominal compensation per employee})$ identified recursively. The red line is the median derived from the posterior distribution of the Bayesian VAR (1995:Q1–2008:Q2). The dashed red lines represent the 16th and 84th percentiles derived from the posterior distribution of the Bayesian VAR (1995:Q1–2008:Q2). The black line is the median derived from the posterior distribution of the Bayesian VAR (2008:Q3–2018:Q2). The grey shaded area represents the 16th and 84th percentiles derived from the posterior distribution of the Bayesian VAR (2008:Q3–2018:Q2).

¹²We repeated the analysis by ordering employment before productivity. By doing so, we preserve the existence of a wage Phillips curve in the model, but test the robustness of our findings when allowing for a contemporaneous response of productivity to employment. In Figures A.1 – A.2 we present the results of this additional analysis.

2.5 A VAR model with both extensive and intensive margins

As a final step of this Section, we extend the baseline specification in equations (2)–(4) to include hours per worker. To support our interpretation the change in the response of the intensive margin of labour should resemble the one of productivity, leaving unaffected the previous results.

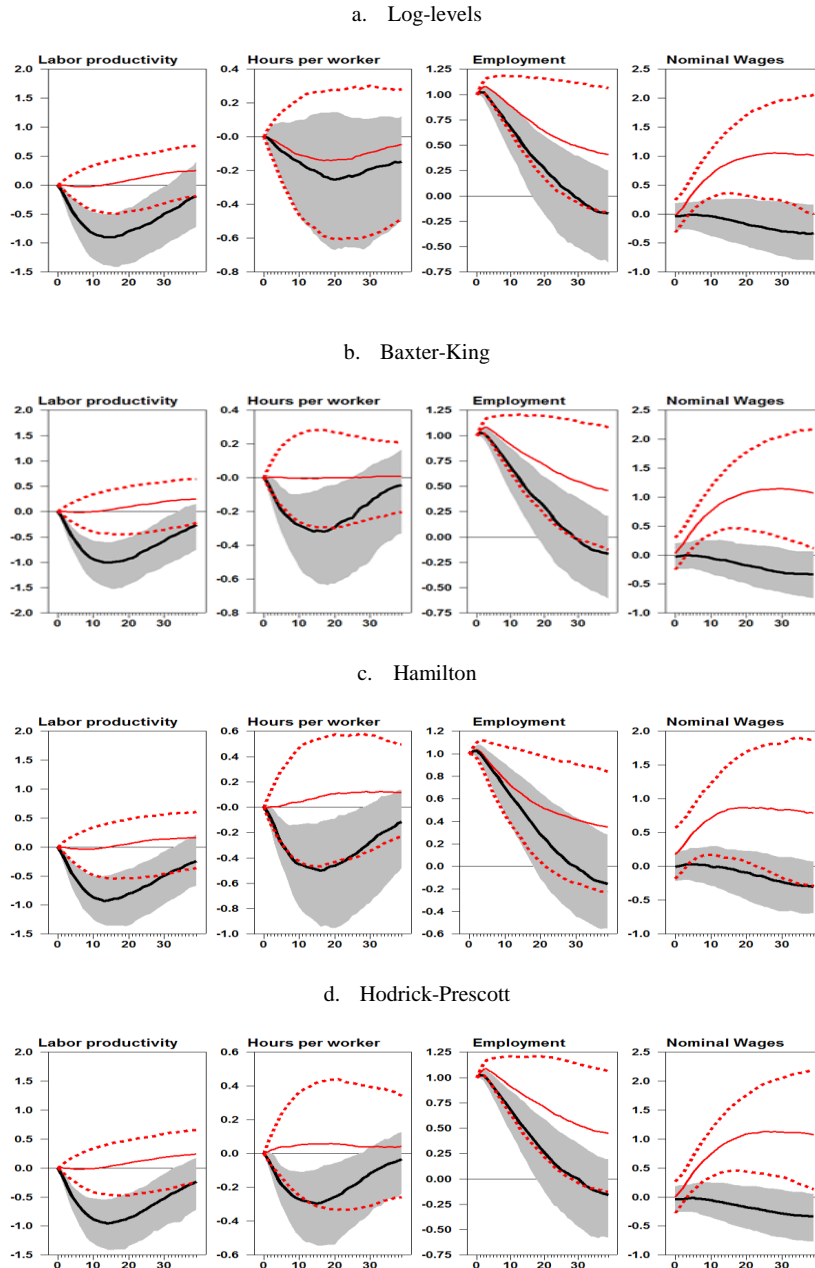
The specification is now as follows

$$\mathbf{Y}_t = [(x_t - n_t), h_t, n_t, w_t] \quad (6)$$

where h_t denotes (log)hours per worker. We run the same exercise with the same settings as in Section 2.3, simulating the effects of a 1% increase in *heads*, before and after 2008:Q2. The results are shown in Figure 5a and confirm the evidence obtained from the 3-variables VAR: after the Global Financial Crisis the vanishing of the wage Phillips curve is even more pronounced, as wage display a muted reaction to the increase in heads employment, and it is still associated to a countercyclical reaction of labour productivity. As for the response of hours worked, there is a lot of uncertainty surrounding the median, which is estimated to be basically nil before the Crisis and then a bit more negative since 2008:Q3. It is however well known that the behaviour of hours in structural VAR models is largely dependent on the treatment of long cycles in their dynamics (see Canova, Lopez-Salido, and Michelacci 2010, and references therein). We therefore re-estimate the VAR using three different filters: a band-pass filter (Baxter and King 1999), a Hodrick and Prescott (1997) filter applied twice in order to replicate the approach adopted by the OECD and followed by Bulligan, Guglielminetti, and Viviano (2017), among others, and, lastly, the recent filter proposed by Hamilton (2018). In Figure 5b–d we present the results: we now observe that, although a large degree of uncertainty is present for the subsample 1995:Q1–2008:Q2, with a median IRF muted or even positive, after the crisis hours decrease by roughly 0.3% in response to a 1% rise in heads.¹³ Overall, from the VAR including both the extensive and the intensive margin of labour market we draw two main conclusions. First, the countercyclical reaction of labour productivity to an increase in employment (heads) and the associated flattening of the wage Phillips curve after 2008:Q3 hold in this extended setup. Second, after the Global Financial Crisis there is a negative correlation between the intensive and extensive margin. This seems to suggest that after the Global Financial Crisis there is no evidence of labour hoarding by firms. In the next Section we build a model to shed light on the mechanisms underlying the empirical evidence.

¹³In Figure 5 the band-pass filter is computed with frequencies 2–40 quarters, while the tuning parameter of the Hodrick and Prescott (1997) filter is set to 1600. We also employed different frequencies for the band-pass and a simple Hodrick and Prescott (1997) filter: the results are robust and confirm the decrease of hours following a rise in heads, when considering the aftermath of the Global Financial Crisis. We also estimated the model applying filters to each of the variables considered. The results are qualitatively not affected.

Figure 5: IRF TO A 1% EXPANSIONARY SHOCK IN EMPLOYMENT (HEADS): INCLUDING HOURS WORKED



Notes: Each panel of the figure reports the results of a 4-variables BVAR including (log) labour productivity, (log) hours per worker, (log) employment (heads) and (log) nominal compensation per employee. Identification is achieved recursively. Panel a: hours per worker are taken in simple logs. Panel b: hours worked are taken in logs and the filtered by using Baxter-King filter. Panel c: hours worked are taken in logs and the filtered by using the Hamilton filter. Panel d: hours worked are taken in logs and the filtered by using Hodrick-Prescott filter. The red line is the median derived from the posterior distribution of the Bayesian VAR (1995:Q1–2008:Q2). The dashed red lines represent the 16th and 84th percentiles derived from the posterior distribution of the Bayesian VAR (1995:Q1–2008:Q2). The black line is the median derived from the posterior distribution of the Bayesian VAR (2008:Q3–2018:Q2). The grey shaded area represents the 16th and 84th percentiles derived from the posterior distribution of the Bayesian VAR (2008:Q3–2018:Q2).

3 Theoretical model

We now use a general equilibrium model in order to give an interpretation to the empirical evidence presented in the previous section. The theoretical model is based on Galí (1999) extended to allow for convex costs of adjusting labour as in Nucci and Riggi (2018). A caveat is in order: with the use of the theoretical model we do not aim at providing a quantitative match of the exact empirical moments observed in the euro area in the different samples. Our goal, instead, is on a qualitative ground: first, we clarify why the sign of the correlation between employment and labour productivity shapes the magnitude of the equilibrium response of wages to shocks and, second, we show that the sign of the correlation between labour productivity and employment hinges upon the persistence of the shock which drives the business cycle, as the change in this parameter moves firms' incentive to adjust the number of employees relative to the intensive margin. For this reason, we stick to the simpler model able to convey these intuitions.

Consider a continuum of households uniformly distributed on the unit interval. Household j maximizes her lifetime utility

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \xi_t \{ \log[C_t(j)] - g[N_t(j), E_t(j)] \}, \quad (7)$$

where $C_t(j)$ is household j 's consumption in period t of the usual Dixit-Stiglitz aggregate of goods with elasticity of substitution ϵ , the function $g(\cdot)$ measures the disutility from work (which depends on employment N_t and the effort exerted E_t), β is the discount factor and ξ_t is a preference disturbance term with mean unity which follows the stationary first order autoregressive process $\log \xi_t = \rho_\xi \log \xi_{t-1} + \varepsilon_t$, where ε_t are zero-mean, i.i.d. innovations. As in Galí (1999), the period disutility of labour takes the form

$$g(N_t(j), E_t(j)) = \frac{\lambda_n}{1 + \sigma_n} N_t^{1+\sigma_n}(j) + \frac{\lambda_e}{1 + \sigma_e} E_t^{1+\sigma_e}(j)$$

where λ_n , λ_e , σ_h , and σ_e are positive parameters.

The period budget constraint, conditional on the optimal allocation of expenditures among different goods, is given by $P_t C_t + Q_t B_t = (W_t + V_t F_t) N_t + B_{t-1} + \Pi_t$, where P_t is the price level, Q_t is the price of a one-period nominally riskless bond, paying one unit of money, B_t is the amount of that bond purchased in period t and Π_t denotes the households' profits from ownership of firms. As in Galí (1999), W_t and V_t represent the nominal wage received by each employed family member and the nominal price of a unit of effort, respectively, where $F_t \equiv \frac{E_t}{N_t}$ is a measure of effort per worker.

The optimal consumption/savings and labour supply decisions are described by

$$Q_t = \beta E_t \frac{\xi_{t+1}}{\xi_t} \frac{C_t}{C_{t+1}} \frac{P_t}{P_{t+1}} \quad (8)$$

$$W_t^r \equiv \frac{W_t}{P_t} = C_t \lambda_h N_t^{\sigma_h} \quad (9)$$

$$V_t^r \equiv \frac{V_t}{P_t} = C_t \lambda_e E_t^{\sigma_e} \quad (10)$$

Equation (8) is the Euler equation which defines the optimal consumption pattern. Equations (9) and (10) represent the optimal labour supply decisions with respect to employment and effort, with the usual conditions that the compensation for one unit of labour should be equal to the marginal rate of substitution with consumption.

There are two sectors: retail and wholesale firms. Households are employed by wholesale firms which face convex costs of varying the number of employees and operate in a competitive market in relation to the goods they produce. Wholesale firms sell their output to retailers, which are monopolistically competitive and set prices in a staggered fashion, as in Calvo (1983). Production by wholesale firm j is

$$Y_{jt}^w = A_t L_{jt}^\alpha \quad (11)$$

where $\alpha \in (0, 1]$ and L_{jt} denotes the effective labour input defined as a function of employment and effort: $L_{jt} = N_{jt}^\theta E_{jt}^{1-\theta}$. We assume that $Z_t \equiv \frac{A_t}{A_{t-1}}$ obeys the following exogenous stochastic process $\log Z_t = (1 - \rho_A) \log \tau_A + \rho_A \log Z_{t-1} + \varepsilon_t^A$, where τ_A defines the constant growth rate and ε_t^A is the i.i.d. technology shock.

Each firm j varies the number of employees by facing convex costs, which are measured in terms of the final good, according to the following adjustment cost function:

$$G_{jt} = \frac{\phi_h}{2} \left(\frac{N_{jt}}{N_{jt-1}} - 1 \right)^2 Y_t \quad (12)$$

where $\phi_h \geq 0$. This adjustment cost function implies that the firm wants to smooth variations in employment because big changes are costly. The wholesale firm chooses employment N and effort E firm to maximize her expected discounted flow of profits

$$E_t \sum_{k=0}^{\infty} \beta^k \frac{\xi_{t+k}}{\xi_t} \frac{C_t}{C_{t+k}} \left(\frac{1}{\mu_t} Y_{jt}^w - \frac{W_t}{P_t} N_{jt} - \frac{V_t}{P_t} E_{jt} + \frac{\phi_h}{2} \left(\frac{N_{jt}}{N_{jt-1}} - 1 \right)^2 Y_t \right) \quad (13)$$

subject to (11), where $\mu_t = \frac{P_t}{P_t^w}$ is the markup of retail over wholesale prices.

The first order conditions are:

$$V_t^r = \frac{\alpha (1 - \theta) A_t N_{jt}^{\alpha\theta} E_{jt}^{\alpha(1-\theta)-1}}{\mu_t} \quad (14)$$

and

$$\begin{aligned}
W_t^r &= \frac{MPN_{jt}}{\mu_t} - \phi_h \left(\frac{N_{jt}}{N_{jt-1}} - 1 \right) \frac{Y_t}{N_{jt-1}} + \\
&+ \beta \mathbb{E}_t \frac{\xi_{t+1}}{\xi_t} \frac{C_t}{C_{t+1}} \phi_h \left(\frac{N_{jt+1}}{N_{jt}} - 1 \right) \frac{N_{jt+1}}{N_{jt}^2} Y_{t+1}
\end{aligned} \tag{15}$$

where $MPN_{j,t}$ is the marginal product of employment ($MPN_{j,t} \equiv \alpha \theta A_t N_{jt}^{\alpha\theta-1} E_{jt}^{\alpha(1-\theta)}$). In symmetric equilibrium $N_{j,t} = N_t$ and $E_{j,t} = E_t$ for all j , since all wholesale firms are identical and make the same decisions. As described by equations (14) and (15), the wholesale firm equates the compensation of labour to its marginal productivity for each of the two utilization margin. The marginal productivity of effort depends only on the production function and the markup, while for the extensive margin the firm further takes into account the marginal cost.

There is a continuum of monopolistically competitive retailers, indexed by i on the unit interval. The retail firm purchases the wholesale output and converts it into a differentiated final good, according to the following technology: $Y_t(i) = Y_t^w(i)$, where $Y_t^w(i)$ is the quantity of the (single) wholesale good.

Following Calvo (1983), retailers can reset their price at random dates: in each period only a randomly chosen fraction $(1 - \varsigma)$ of retailers adjusts their prices. The remaining ones keep their prices unchanged. The pricing decision of a retail firm obeys the following equilibrium condition:

$$E_t \sum_{k=0}^{\infty} \varsigma^k \beta^k \frac{\xi_{t+k}}{\xi_t} \frac{C_t}{C_{t+k}} \frac{P_t}{P_{t+k}} Y_{t+k/t} \left(\frac{P_t^*}{P_{t-1}} - \frac{\epsilon}{\epsilon - 1} MC_{t+k/t} \frac{P_{t+k}}{P_{t-1}} \right) = 0 \tag{16}$$

where $MC_{t+k/t}$ denotes the real marginal cost in $t+k$ for a firm that last set its prices in t . Assuming that hours' adjustment costs are distributed to the aggregate households, market clearing requires $A_t L_t^\alpha = C_t \int_0^1 \left[\frac{P_t(i)}{P_t} \right]^{-\epsilon} di$.

The model is closed by a monetary policy rule. We assume that monetary policy obeys a simple Taylor rule, in which the nominal interest rate reacts to the current level of inflation:

$$\frac{1 + i_t}{1 + \bar{i}} = \pi_t^{\phi_\pi}$$

where \bar{i} is the steady state nominal rate and ϕ_π is the Taylor parameter.

3.1 Shocks persistence, the cyclicity of labour productivity and compensation per employee

We now use the model to highlight the role that the relationship between output per worker and employment plays for the cyclical reaction of compensation per employee. The latter, in real terms, is given by:

$$\begin{aligned}
\Psi_t &= W_t^r + \frac{E_t}{N_t} V_t^r = \\
&= C_t \left(\lambda_h N_t^{\sigma_h} + \frac{E_t}{N_t} \lambda_e E_t^{\sigma_e} \right)
\end{aligned} \tag{17}$$

Log-linearizing around a balanced growth steady state¹⁴ and defining $\Upsilon \equiv \frac{\lambda_h \bar{N}^{\sigma_h}}{\lambda_h \bar{N}^{\sigma_h} + \frac{\bar{E}}{\bar{N}} \lambda_e \bar{E}^{\sigma_e}}$ (where \bar{E} and \bar{N} denote steady state variables), we get:

$$\tilde{\psi}_t = \tilde{c}_t + \sigma_h \Upsilon n_t + (1 - \Upsilon) [(1 + \sigma_e) e_t - n_t] \quad (18)$$

Taking into account the aggregate resource constraint $A_t L_t^\alpha = C_t \int_0^1 \left[\frac{P_t(i)}{P_t} \right]^{-\epsilon} di$, we rewrite (18) as

$$\tilde{\psi}_t = \widetilde{m\dot{p}n}_t + (\sigma_h + 1) \Upsilon n_t + (1 + \sigma_e) (1 - \Upsilon) e_t \quad (19)$$

Finally, using the relationship between e_t and $\widetilde{m\dot{p}n}_t$, equation (19) can be rewritten as follows:

$$\tilde{\psi}_t = A * \widetilde{m\dot{p}n}_t + B * n_t \quad (20)$$

where $A \equiv \frac{\alpha(1-\theta)+(1-\Upsilon)(1+\sigma_e)}{\alpha(1-\theta)}$ and $B \equiv \Upsilon(1 + \sigma_h) + \frac{(1+\sigma_e)(1-\Upsilon)(1-\alpha\theta)}{\alpha(1-\theta)}$ are positive convolutions of deep parameters.

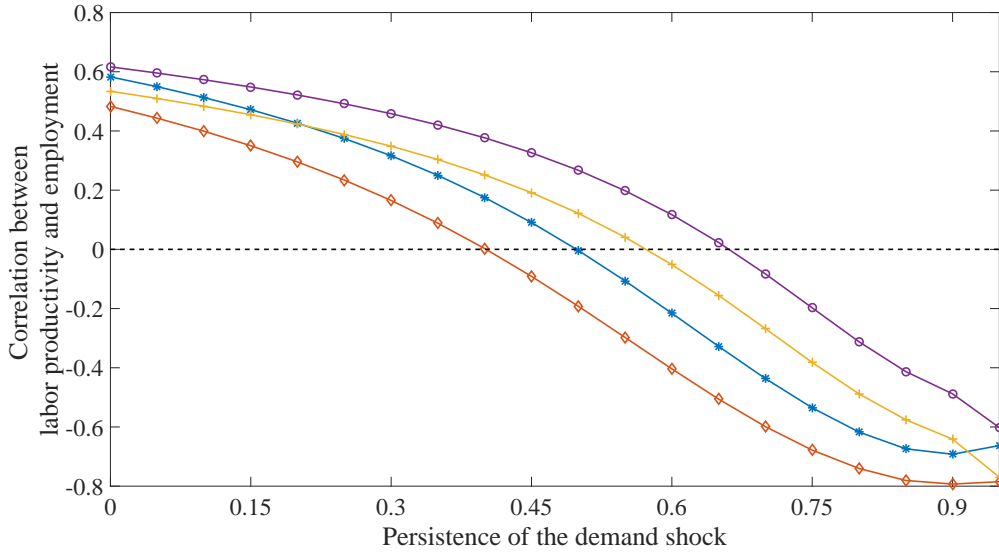
Equation (20) characterizes the log-deviation of compensation per employee from its steady state $\tilde{\psi}_t$ as a function of the log-deviations of labour productivity ($\widetilde{m\dot{p}n}_t$) and employment (n_t). It follows that the “pass-through” from employment to wages, which can be measured as $\frac{\partial \tilde{\psi}_t}{\partial n_t} = A * \frac{\partial \widetilde{m\dot{p}n}_t}{\partial n_t} + B$, hinges upon the sign of $\frac{\partial \widetilde{m\dot{p}n}_t}{\partial n_t}$. Conditional on a demand shock, labour productivity behaves procyclically ($\frac{\partial \widetilde{m\dot{p}n}_t}{\partial n_t} > 0$) when firms prefer to vary their employees’ effort rather than the number of employees to meet fluctuations in demands: i.e. when firms “hoard labour”. Intuitively, when the number of employees goes up, the magnitude of the increase in compensation per employee would be larger if labour productivity behaved procyclically ($\frac{\partial \widetilde{m\dot{p}n}_t}{\partial n_t} > 0$) because, relative to the case of a countercyclical response ($\frac{\partial \widetilde{m\dot{p}n}_t}{\partial n_t} < 0$), this would mean an increase in effort per worker.

Figure 6 shows the correlation between the equilibrium response of labour productivity and the equilibrium response of employment conditional on a demand shock, for different degrees of the shock’s persistence. The demand shock is modelled as a positive shock to the discount factor (i.e. a positive shock to ξ_t), an intertemporal disturbance which induces households to move up consumption, leading to an increase in both output and inflation. Other things being equal, lower values of ρ_ξ are associated with a procyclical response of labour productivity, while the larger is ρ_ξ the more likely is to observe a countercyclical response.

The intuition is straightforward. To the extent firms face convex costs of adjusting the number of employees, their incentive to react to shocks by varying the intensive margin relative to the extensive one depends on the persistence of the cyclical phase. The more transitory the shock

¹⁴Lower case letters are proportional deviations from steady state, lower case letters with a \sim denote that the variable has been rescaled by the level of technology A_t , to obtain the stationary representation, before being log-linearized around the balanced growth steady state.

Figure 6: THE CYCLICALITY OF LABOUR PRODUCTIVITY AND THE PERSISTENCE OF THE BUSINESS CYCLE



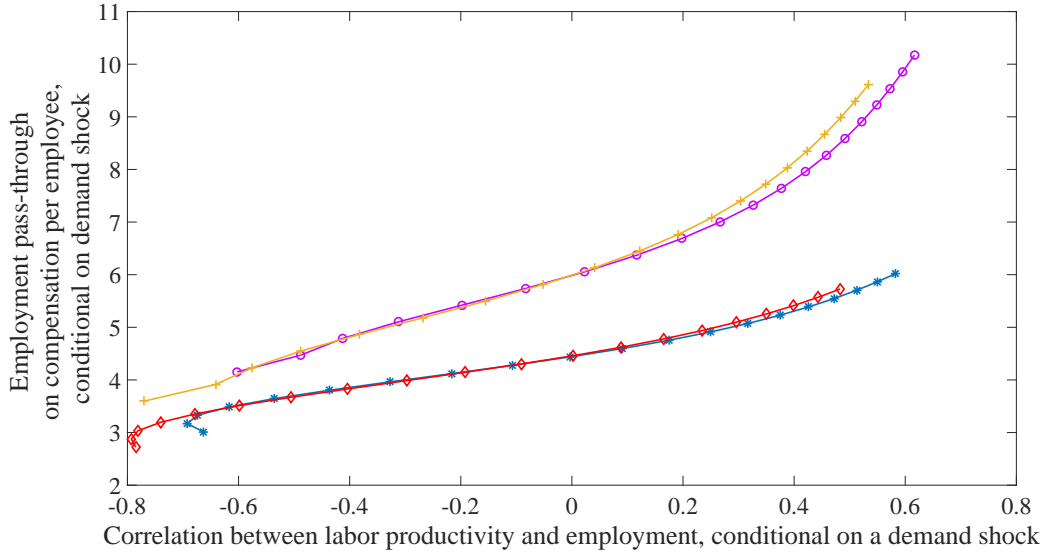
Notes: The figure reports the correlation between labour productivity \widehat{mpn}_t and employment n_t (y-axis) for different degrees of ρ_ξ (x-axis). The other deep parameters are calibrated as follows: $\beta = 0.99$, $\alpha = 2/3$, $\theta = 0.6$, $\sigma_h = 0.5$, $\sigma_e = 1$, $\lambda_e = 0.5$, $\epsilon = 6$, $\phi_\pi = 1.2$. Each line corresponds to a different calibration for the sticky price parameter ζ and employment adjustment cost ϕ_h : $-\circ-$ $\zeta = 0.8$ $\phi_h = 4$; $-* -$ $\zeta = 0.8$ $\phi_h = 2$; $-+ -$ $\zeta = 0.5$ $\phi_h = 4$; $-\diamond-$ $\zeta = 0.5$ $\phi_h = 2$.

(i.e. low values of ρ_ξ), the more firms will hoard labour, satisfying changes in demand by varying the intensive margin. Indeed, firms' willingness to change the number of employees increases with the expected duration of the business cycle, as the presence of hiring and firing costs gives an incentive to make small gradual changes in the number of employees, which are rational to bear only when the cyclical phase is expected to be long-lasting.

While the persistence of the shock is not the sole parameter that might affect the magnitude of $\frac{\partial \widehat{mpn}_t}{\partial n_t}$ conditional on a demand shock, it is the one with the greatest effect on the sign of this correlation. When the persistence of the shock is high, it is not possible to get a procyclical response of labour productivity, without assuming implausibly larger values for the labour adjustment cost parameter.

Figure 7 reports the relationship between the cyclicality of labour productivity, measured by its correlation with employment, and the employment pass-through into compensation per employee in real terms, measured by the ratio between the impact response of compensation per employee and of employment. As it is evident from equation (20), the more procyclical is labour productivity the larger is the response of wages relative to that of employment.

Figure 7: THE WAGE-EMPLOYMENT MULTIPLIER: DSGE MODEL



Notes: The figure reports the ratio between the impact response of compensation per employee $\tilde{\psi}_t$ and employment n_t (y-axis) to a demand shock as a function of the correlation between labour productivity \widetilde{mpn}_t and employment n_t (x-axis). The other deep parameters are calibrated as follows: $\beta = 0.99$, $\alpha = 2/3$, $\theta = 0.6$, $\sigma_h = 0.5$, $\sigma_e = 1$, $\lambda_e = 0.5$, $\epsilon = 6$, $\phi_\pi = 1.2$. Each line corresponds to a different calibration for the sticky price parameter ζ and employment adjustment cost ϕ_h : $- \circ - \zeta = 0.8 \phi_h = 4$; $- * - \zeta = 0.8 \phi_h = 2$; $- + - \zeta = 0.5 \phi_h = 4$; $- \diamond - \zeta = 0.5 \phi_h = 2$. The correlation between \widetilde{mpn}_t and n_t vary by means of different degrees of the shock persistence.

While we do not rule out that other factors may lie behind the vanishing relationship between employment growth and wage dynamics (see Section 6), our analysis stresses that the higher persistence of the cyclical phase, by itself, can account for this stylized fact. Indeed, Figures 6 and 7 show that if it had been the sole structural shift in the economy, then it would fully account for the observed changes in the relationship between labour productivity, employment and wages. Variations in other structural parameters, like the degree of price stickiness and the employment adjustment costs, are not able to induce a change of a similar dimension.

Overall, up to this point the theoretical model rationalized both the empirical facts documented by Section 2: the change in the conditional correlation between employment and labour productivity and the associated flattening of the wage Phillips curve. However, it does so *conditional on a demand shock*, whereas in Section 2 we presented evidence of an employment shock. The latter raises both employment and wages, hence resembling a demand-type disturbance. However, in order to dig deeper into the mechanism highlighted by the DSGE model, in the next Section we evaluate its theoretical predictions using a more refined battery of VAR models in which the structural shocks are the counterpart of the DSGE.

4 Testing the model predictions

To test the predictions of the theoretical model presented in Section 3 on euro area data we rely on the same Bayesian VAR framework described by equations (2)–(3), but we move one step further as we adopt more refined identification schemes in order to map as close as possible the intuitions stemming from the calibrated theoretical model onto the VAR structure. This allows us to investigate the crucial findings of the model, namely the link between missing wage growth – i.e. a nil or mild reaction of nominal wages to increases in the number of heads employed – and a countercyclical reaction of labour productivity, conditional on a demand shock. Other than deepening the evidence already provided by using the Cholesky identification, this would allow us to properly separate the structural shocks driving wage and employment dynamics in the euro area.

For the predictions of the DSGE model to be supported by the data, two conditions would have to be met since 2009: (i) first, the response of wages to employment conditional on a *persistent* demand shock should be lower than the same response conditional on a *non-persistent* demand shock; (ii) second, persistent demand shocks should have become prevalent over non-persistent ones in explaining labour market dynamics in the euro area.

The main challenge that we face when empirically addressing these two conditions is related to translating the concept of persistent demand shock adopted in the DSGE context into the VAR framework. The answer is not immediate, as it is hard to directly test this channel in a linear VAR model. Nevertheless, we opt for keeping the econometric model as simple as possible and stick to a linear fixed-coefficient VAR model in which identification of the shocks of interest is achieved by means of sign restrictions.¹⁵ In particular, we can think of employment and wages as being affected by two different demand shocks, one generating a *procyclical* response of labour productivity and the other a *countercyclical* reaction. In the light of the model we define the former as a *non-persistent* demand shock and the latter as a *persistent* one. Shocks are identified by imposing sign restrictions on the impact matrix (Uhlig 2005; Rubio-Ramirez, Waggoner, and Zha 2010), as reported in Table 2. The identification strategy is quite standard and consistent with the predictions of the theoretical model.

Labour supply and technology shocks differ in terms of productivity behaviour: while expansionary labour supply shocks determine a positive reaction of output per worker, technology shocks imply a negative correlation between productivity and employment, as in Galí (1999). Both the restrictions are consistent with the theoretical IRFs obtained in the DSGE model. The novelty lies in the distinction of *persistent* demand shocks from the short-lived ones, since the

¹⁵We could instead rely, for example, on a model in which sign restrictions are imposed on the structural parameters of the VAR, as recommended by Baumeister and Hamilton (2018) or use a more complicated non-linear framework where shocks may affect not only the level but also second moments of variables, as in Mumtaz (2018). We do however prefer to test the relevance of the mechanism highlighted by the theory in a simple and more tractable framework. We plan to experiment with the aforementioned techniques in future research.

Table 2: TESTING DSGE ON SVAR (4 VARIABLES): SIGN RESTRICTIONS ON IMPACT

	Persistent Demand	Labour supply	Non-persistent demand	Technology
Productivity	–	+	+	–
Employment	+	+	+	+
Wages	+	–	+	–
Interest rate	+	–	+	–

Notes: All the shocks are identified showing an increase in employment, to ease the comparison for the reader.

former are assumed to lower labour productivity after an expansionary demand shock. After having obtained the IRFs, which are well behaved and shown in Figure A.5 (see Appendix A.4) we present the evidence in form of the cumulative multiplier, as defined in eq. (5).

To test conditions (i) and (ii) above, we are going to rely on the IRFs and on the historical decomposition, respectively. In this regard, we need to clarify an important aspect. While the IRFs describe *average developments* and they are therefore not affected by the starting point of the simulation, this is not the case for the historical decomposition, which instead shows *for a certain point in time* the contribution of a shock of interest to the deviation of an endogenous variable from its unconditional forecast as computed by the VAR (i.e. *baseline*). The longer the sample used to obtain the unconditional forecast, the better is the decomposition in contributions from identified shocks. Hence, we are facing a sort of trade-off: while for dealing with condition (ii) we would need to rely on the full sample in order to get better estimates of the contribution of the shocks, to evaluate condition (i) we need to estimate the VAR in the aftermath of the Global Financial Crisis (as in Section 2). Indeed, the subsample 2008:Q3–2018:Q2 is the period in which persistent demand shocks are supposed to be at play, as suggested from both the empirical evidence in Section 2 and the mechanism highlighted by the model. When considering both periods jointly we get less precise estimates of these multipliers, as it is not clear how frequent non-persistent demand shocks have been in the first period, given that labour productivity was acyclical.¹⁶

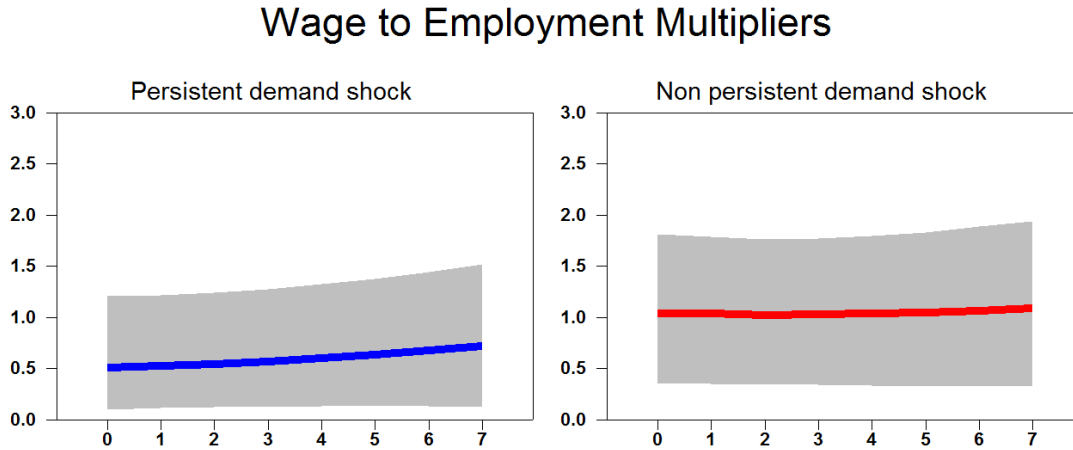
We thus proceed as follows: first we conduct the historical decomposition over the full sample, and then we repeat the analysis on the subsample 2008:Q3 – 2018:Q2, so to have the same time span for the estimated wages to employment multipliers and the relevance of the shocks underlying them.¹⁷ Figure 8 compares the two types of demand shocks. The multiplier for the persistent shock is equal to about 0.5, meaning that after a 1% increase in employment wages grow by 0.5%. By contrast, a non-persistent shock has a cumulative multiplier of 1.1, more than double. This

¹⁶We have actually estimated this model on the full sample and on the pre-crisis period. The results confirm a higher multiplier for demand shocks that raise productivity (the non-persistent ones), although the gap with the multiplier associated with persistent shocks is less statistically significant. Our interpretation is that persistent demand shocks rarely occurred in the first subsample, increasing the uncertainty around their estimation. Results are available upon request.

¹⁷We present the latter historical decomposition in Section A.4, as a robustness to the full sample findings.

result confirms that the response of wages to employment is smaller when labour productivity is countercyclical, that is condition (i) stated above holds.

Figure 8: THE WAGE–EMPLOYMENT MULTIPLIER: SIGN–IDENTIFIED SVAR MODEL (PRODUCTIVITY RESTRICTED ON IMPACT TO DISENTANGLE PERSISTENT FROM NON–PERSISTENT DEMAND SHOCKS)



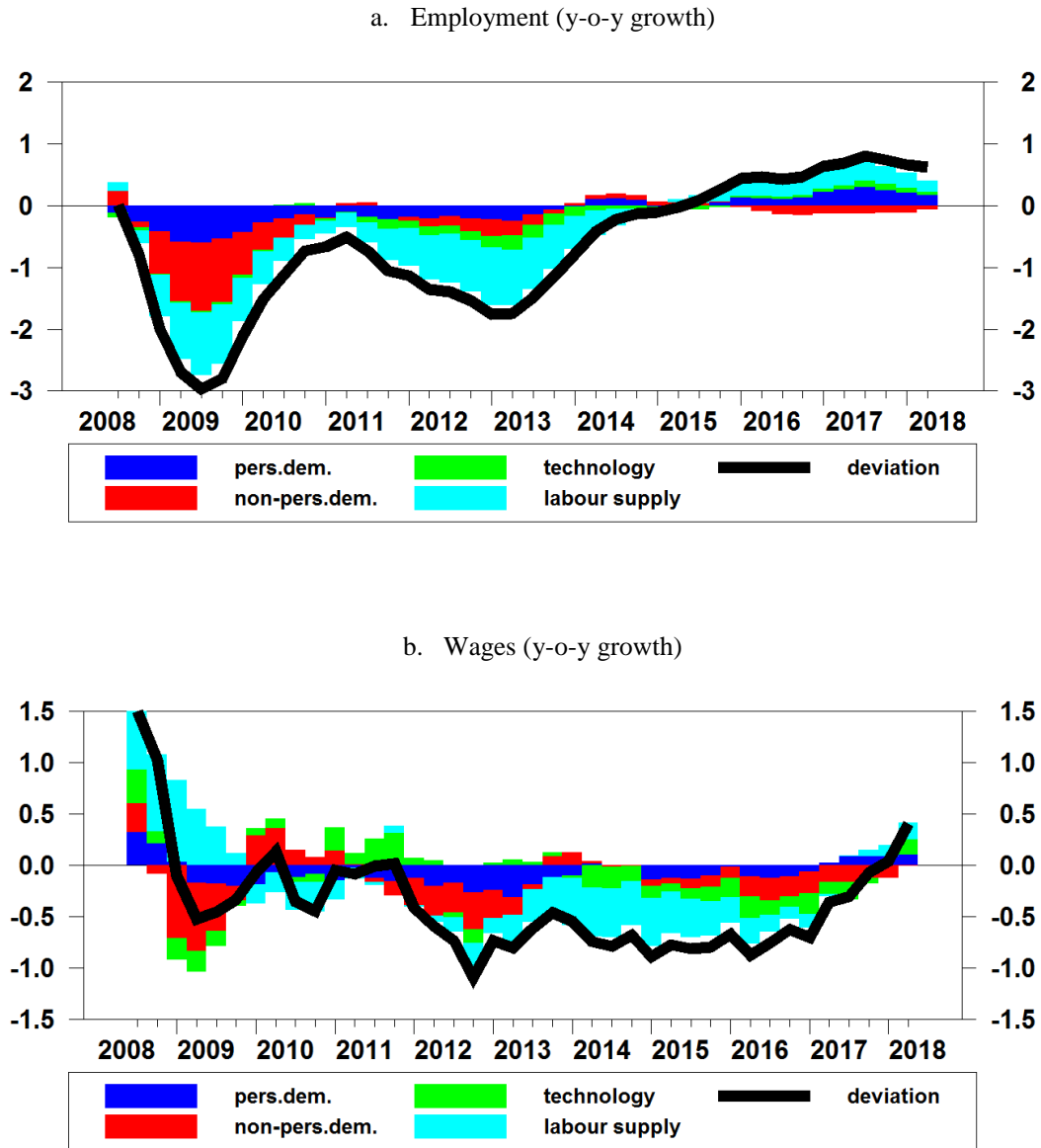
Notes: Estimation sample is 2008:Q3–2018:Q2. The VAR includes $\log(\text{productivity})$, $\log(\text{employment})$, $\log(\text{nominal compensation per employee})$ and the shadow rate by Krippner (2015) and is estimated with 4 lags. The multiplier is defined as the median ratio of cumulative impulse responses of nominal wages relative to employment. The dark blue line is the median multiplier pass-through from employment to nominal wages *conditional* on a persistent demand shock (i.e. a demand shock which *lowers* labour productivity) derived from the posterior distribution of the Bayesian VAR. The dark red line is the median multiplier pass-through from employment to nominal wages *conditional* on a non-persistent demand shock (i.e. a demand shock which *raises* labour productivity) derived from the posterior distribution of the Bayesian VAR. The grey shaded area represents the 16th and 84th percentiles derived from the posterior distribution of the Bayesian VAR.

We then test the second condition by looking at the historical decomposition of employment and wages stemming from the same identification scheme (Figure 9). Over the most recent period, the recovery in employment has been mainly driven by supply shocks (especially labour supply); however, among demand shocks the role of the persistent ones has outweighed that of the non-persistent disturbances. Given the low wage-employment multiplier associated with non-persistent demand shocks, this finding supports the mechanism of the theoretical model.¹⁸ Finally, when computing the historical decomposition over the subsample 2008:Q3–2018:Q2, the same time span considered for estimating the multipliers reported in Figure 8 we observe a similar picture to the one obtained on the full sample: to a certain extent, our findings are even reinforced, as persistent demand shocks provide a mildly positive contribution to wages, whereas non-persistent shocks negatively contribute to wage growth until the beginning of 2018 (see Figure A.6).¹⁹

¹⁸We have also performed the same analysis by comparing persistent demand shocks and monetary policy shocks. While the analysis is still in progress, and it could probably deserve a different paper in which the interaction between productivity, wages and conventional and unconventional policy shocks could be studied, preliminary evidence shows that (i) the monetary policy multiplier is higher than the persistent demand multiplier and (ii) monetary policy shocks have strongly supported the recovery in employment since 2013.

¹⁹It should be noted that the deviation from the VAR baseline looks different from the one computed on the full sample precisely because of the argument we noted above: the baseline (i.e. the unconditional forecast obtained by the VAR) is different because it is affected by the initial condition and by the considered subsample. Nevertheless, the contributions of the shocks are in line with the findings obtained on the full sample and shown in Figure 9.

Figure 9: THE RELEVANCE OF PERSISTENT AND NON PERSISTENT DEMAND SHOCKS FOR EMPLOYMENT AND WAGES



Notes: Estimation sample is 1995:Q1–2018:Q2. The VAR includes $\log(\text{productivity})$, $\log(\text{employment})$, $\log(\text{nominal compensation per employee})$ and the shadow rate estimated by Krippner (2015) and is estimated with 4 lags. Shocks are identified as in Table 2. Historical decomposition defined as the median contribution of each shock (colored bars) to the deviation of the actual series from the baseline of the VAR (black solid line).

5 Robustness

In this Section we check the robustness of our empirical findings under different respects. First, we verify that the results based on the recursive structure used in Section 2 hold when additional variables are included. Second, we verify whether our main results are robust to the inclusion of monetary policy and cost-push shocks identified through sign restrictions. Third, we show that results are robust to use real wages instead of nominal ones under different identification schemes.

5.1 Cholesky identification

We expand the recursive specification in order to control for macroeconomic variables which could affect the relation between labour productivity, wages and employment. Natural candidate are consumer prices and the policy rate. Figure A.3 plots the results.²⁰ As more variables are included, on such short samples there is an increase in the uncertainty surrounding the IRFs. However, both the countercyclical reaction of labour productivity and the muted response of wages to an increase in employment are confirmed. It is also worth noting that the response of consumer prices is not statistically significant from zero, whereas the policy rate rises in both periods. Coupled with the *sign* of the response of wages, the shock to employment resembles a demand-type exogenous innovation. This suggests that demand shocks are major candidate to explain the changes in the behaviour of both labour productivity and wages after the Global Financial Crisis, an intuition verified in Section 4. Finally, we also perform an even stronger test for addressing the concern that our findings may be driven by omitted variables, i.e. the small scale of the VAR model. In order to do so, we follow the procedure suggested by Forni and Gambetti (2014) and augment the baseline 3-variables VAR model with some common factors extracted by a panel of 20 global, financial and euro-area domestic variables including oil price, world gdp, exchange rates, stock prices, systemic stress, inflation expectations, interest rates, unit labour costs, negotiated wages, hours worked (see Appendix A.1 for details). In practice, we estimate a FAVAR model with 3 observables and 2 latent factors, which explain around 75% of the overall variance of the panel. The advantage of this procedure is twofold: first, it takes into account the influence of a large number of variables for the dynamics of wages, employment and productivity without excessively weighing on the estimation sample, which is of limited time depth; and, second, it addresses the concern that our model suffers from insufficient information and hence biases the results in terms of shock identification (Forni and Gambetti 2014). The results are plotted in Figure A.4 and show that our main finding is still valid, although the flattening of the wages Phillips curve is less precisely estimated due to both a slightly lower number of observations (the sample starts in 1999:Q1) and the added uncertainty given by including factors in the VAR (Bai and Ng 2006).

5.2 Sign restrictions

As an additional robustness check, we adopt a larger specification compared to the one presented in Section 2, including 5 variables: $\log(\text{output})$, $\log(\text{employment})$, $\log(\text{nominal wages})$, $\log(\text{HICP})$ and the EONIA rate. In this way we can separately identify monetary policy shocks and take into account inflation dynamics which may affect nominal wages through indexation mechanisms. The identification strategy is based on sign restrictions, as reported in Table A.2. Differently from

²⁰It is also interesting to verify whether the inclusion of hours worked can modify the results, as Bulligan, Guglielminetti, and Viviano (2017) find that they are crucial in restoring an appropriate trade-off between wages and labour slack in the euro area. We find that also when extending the model to 5 or 6 variables specifications, to account for hours and inflation expectations, the results still hold.

Section 4, we include monetary policy shocks and cost-push shocks, which capture residual wage dynamics originated from factors specific to the wage-setting process and affecting the rest of the economy with a delay.

Figure A.7 shows that in the period ranging from 1995:Q1 to 2008:Q2 labour productivity is pro-cyclical and wages strongly increase, while in recent years labour productivity becomes countercyclical and is associated with a muted and almost flat wage response. The sign switch in the response of labour productivity coupled with a feeble reaction of compensations was already uncovered by the Cholesky VAR. However these results confirm that, consistently with the theoretical model, the stylized facts presented in Section 2 are conditional to structurally identified demand shocks.

5.3 Real wages and different identifying assumptions

Since low inflation has been one of the key features of the recent years, one may be concerned that the *wageless recovery* is simply driven by lower inflation expectations. In this Section we test the robustness of our findings by replacing nominal with real wages and using different identification strategies based on the theoretical model. We start with a small Bayesian VAR in three variables, namely real GDP, employment and real wages, all expressed in log-levels and standardized. We identify three shocks using a mix of short-run sign restrictions and long-run zero restrictions consistent with the outcomes of the model. Technology shocks are identified through long-run restrictions, assuming that they are the only ones having a permanent effect on output. Labour supply and demand shocks are identified through sign restrictions imposed on the impact matrix, as reported in Table A.3: the first ones determine a rise in employment and output associated to a fall in real wages whereas the latter generate a positive co-movement of prices (wages) and quantities (employment and output).

The results confirm the previous findings (see Figure A.8): up to 2009 labour productivity is a-cyclical and wages rise on impact while later on labour productivity becomes counter-cyclical and wages barely react. The historical decomposition of employment and wages shows that the contribution of demand shocks (grey bars) has grown substantially from 2009 onwards: the long sequence of first positive and then negative demand shocks is also suggestive of increased persistence. Results still hold when we include the real interest rate to take into account monetary policy shocks with the identifying restrictions in Table A.4, though the difference in the IRFs between the two subsamples is no more significant (see Figure A.9). By replacing the real EONIA rate with a real shadow rate²¹, which should better account for unconventional measures, the contribution of monetary policy becomes more relevant and captures part of the variation in the responses of labour productivity and wages (Figure A.10).

²¹In this application we use the simple average between the shadow rate calculated by Wu and Xia (2017) and the one provided by Krippner (2015).

6 Discussion: other explanations of missing wage growth

A number of alternative explanations, different from ours, can be found in the literature to address the “missing wage growth” puzzle. One of them relies on the phenomenon of “pent-up wage deflation”, which in turn depends on downward nominal wage rigidities. During recessions firms might face limits in cutting nominal wages and, if firms face constraints in lowering compensation when the labour market is exceptionally weak, in the earlier part of the recovery they may do not need to raise wages to attract workers. As a result, wages might rise relatively slowly as the labour market strengthens. The theoretical model by Daly and Hobijn (2014) formalizes this idea, suggesting that downward nominal wage rigidities bend the Phillips curve in two ways. First, during downturns rigidities become binding and hence labour market disproportionately adjusts through the unemployment margin rather than through wages. Second, this leads to “pent-up wage deflation” which materializes in a simultaneous deceleration of wage inflation and a decline in the unemployment rate during the ensuing recovery period. According to their results, this bending of the Phillips curve appears to be especially pronounced in a low inflationary environment. Daly and Hobijn (2014) applied their model to US data to explain wage and unemployment dynamics in the last three cyclical phases. However Verdugo (2016) using longitudinal micro data finds no evidence of downward nominal wage rigidities during the Great Recession in most euro area countries.

Another relevant source of non-linearities in the relationship between wages and slack is the contribution to wage dynamics of wage changes of continuously full-time employed workers relative to wage changes of those moving into and out of full-time employment. Daly and Hobijn (2016) argue that the relative importance of these two margins varies over the business cycle. Wage growth of continuously full-time employed worker is procyclical and, during booms, when labour markets are tight, it drives wage dynamics. By contrast, during slumps, workers with lower earnings tend to exit from full-time employment, thus pushing up the median wage and offsetting the procyclicality of the other margin. This leads aggregate real wages to be largely acyclical. Because of such composition effects standard measures of unemployment may be inadequate to fully capture the labour market slack. Broader measures of unemployment, including under-utilisation of labour and discouraged worker effects might have increasingly mattered in recent years, as many new jobs over the recent employment recovery stand out for being of a lower “quality” compared with those seen before the crisis. For instance, evidence for the euro area shows that whereas employment ratios have rebounded strongly, employment of full-time workers with permanent contracts has declined, reaching a historical minimum. While workers in permanent positions typically aim at higher wages, the objectives of those in part-time positions, which are often involuntary, might be other than wage increases, such as full-time employment or an increase in hours worked (Coeuré 2017). In summary, it seems that the composition of the employed and the unemployed in the euro area has changed over the last years, implying subdued wage growth.

At the same time, the participation margin has remained broadly stable, in contrast to the fall occurred in the US (Coeuré 2017). Broader measures of slack, including the unemployed, underemployed and those marginally attached to the labour force, appear to be less sensitive to GDP growth than traditional measures (ECB 2017). Even if we do not distinguish between different measures of employment, our analysis is fully consistent with the increased importance of labour underutilization in recent years, when we claim that the extensive margin mattered more than the intensive one.

Along with cyclical drivers, long run structural factors might also lie behind the weak wage dynamics. Among them, workers' bargaining power has eroded in recent decades: union membership has fallen, collective bargaining has become much less common, and the real value of the minimum wage has decreased (see Krueger 2018, Lombardi, Riggi, and Viviano 2019). Demographic factors coupled with dwindling workers' bargaining power might have reduced the relationship between wages and unemployment in the recent recovery. Indeed, while higher-wage baby boomers have been retiring, lower-wage workers sidelined during the recession have been hired during the recovery (see Daly, Hobijn, and Pyle 2016).

Finally, beyond structural changes in the euro area labour market, the modest wage growth in the recent recovery may be partly explained by the subdued inflation dynamic. However, the persistence of low inflation is likely to have determined a de-anchoring of inflation expectations, relevant for wage setters, only at a late stage of the recovery (Natoli and Sigalotti 2017; Ciccarelli and Osbat 2017). Moreover, Section 5.3 shows that our results are robust to considering real instead of nominal wages.

Our explanation, which hinges on the persistence of the cyclical phase, is complementary to all these factors which might have played a role in the recent wageless recovery.

7 Conclusions

In this paper we tackled the question of the reduced sensitivity of wages to unemployment in the euro area, a topic which is increasingly debated in the macroeconomic literature and is highly relevant for policymakers.

We have contributed to this debate from both an empirical and a theoretical perspective, by unveiling a novel mechanism: the persistence of demand shocks affects the reaction of labour productivity and wages over the business cycle. Persistent shocks lead to a countercyclical behaviour of output per worker, slowing down wage growth. This mechanism has been clearly at work in the euro area after the Global Financial Crisis, making the subsequent ongoing recovery a wageless" one.

Additional factors, other than business cycle persistence, may affect firms' incentive to adjust the extensive or the intensive margin. Among them, the structure of relative costs, recently affected by labour market reforms, might have played an important role. This channel could be

investigated by using data at a national level, which allow to exploit cross-country heterogeneity. In this paper, instead, we stick to euro area data as our goal is to highlight a macroeconomic driver common to all countries rather than the role of idiosyncratic factors.

We acknowledge that potentially relevant aspects of the current macroeconomic developments deserve further analyses. In our opinion the most important ones relate to the presence of non-linear propagation of demand shocks to the economy or changes in the stochastic volatility of the underlying shocks. Moreover, since the last two recessions have been triggered by financial shocks, it could be worth empirically evaluating the interaction between labour and financial frictions, using a framework similar to Calvo, Coricelli, and Ottonello (2013). Finally, a topic which is worth a separate investigation is the role that monetary policy may have in counteracting the effects of persistent shocks on the cyclicalities of labour productivity and on the wage-employment multiplier. Shedding light on these aspects may lead to a better understanding of labour markets dynamics after the turbulent times ignited by the Global Financial Crisis.

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A Supplementary Material

A.1 Dataset

Table A.1: TIME SERIES USED IN THE EMPIRICAL ANALYSIS

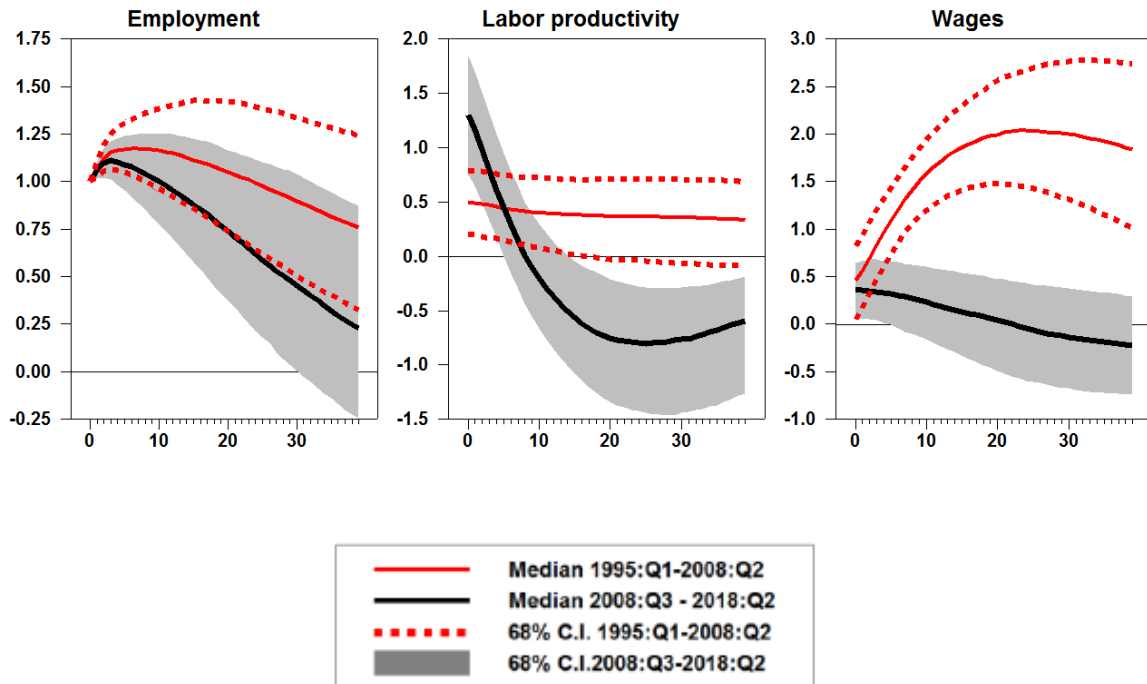
Variable	Sample	Source
Employment	1995:Q1 – 2018:Q2	ECB, AWM and SDW
Nominal Wages	1995:Q1 – 2018:Q2	ECB, AWM and SDW
Productivity	1995:Q1 – 2018:Q2	ECB, AWM and SDW
Euro Area Real GDP	1995:Q1 – 2018:Q2	ECB, AWM and SDW
Total Hours worked	1995:Q1 – 2018:Q2	ECB, AWM and SDW
Short-term interest rate	1995:Q1 – 2018:Q2	ECB, AWM and SDW
Shadow interest rate	1995:Q1 – 2018:Q2	ECB, AWM and SDW
HICP	1995:Q1 – 2018:Q2	ECB, AWM and SDW
Negotiated Wages	1995:Q1 – 2018:Q2	ECB, AWM and SDW
Unit Labour Costs	1995:Q1 – 2018:Q2	ECB, AWM and SDW
Inflation Expectations	1995:Q1 – 2018:Q2	ECB SPF and Consensus
Oil price	1995:Q1 – 2018:Q2	ECB, Bloomberg and Projection Database
Euro vs. US Dollar Exchange rate	1995:Q1 – 2018:Q2	ECB, AWM and SDW
Nominal Effective Exchange Rate	1995:Q1 – 2018:Q2	ECB, AWM and SDW
World Real GDP	1995:Q1 – 2018:Q2	ECB, AWM and Projection Database
CISS	1999:Q1 – 2018:Q2	ECB, SDW
Stock prices	1995:Q1 – 2018:Q2	ECB, SDW and Projection Database

Notes: For the several Bayesian VAR models estimated in the empirical analysis, data are taken in log-levels for quantities and in levels for interest rates. For the FAVAR models in Appendix A.3, data are appropriately transformed and standardized according the literature, i.e. quantities are in first (log) differences while interest rates, spreads and systemic stress indicators are in levels (Forni and Gambetti 2014, see).

A.2 3-variables Cholesky VAR

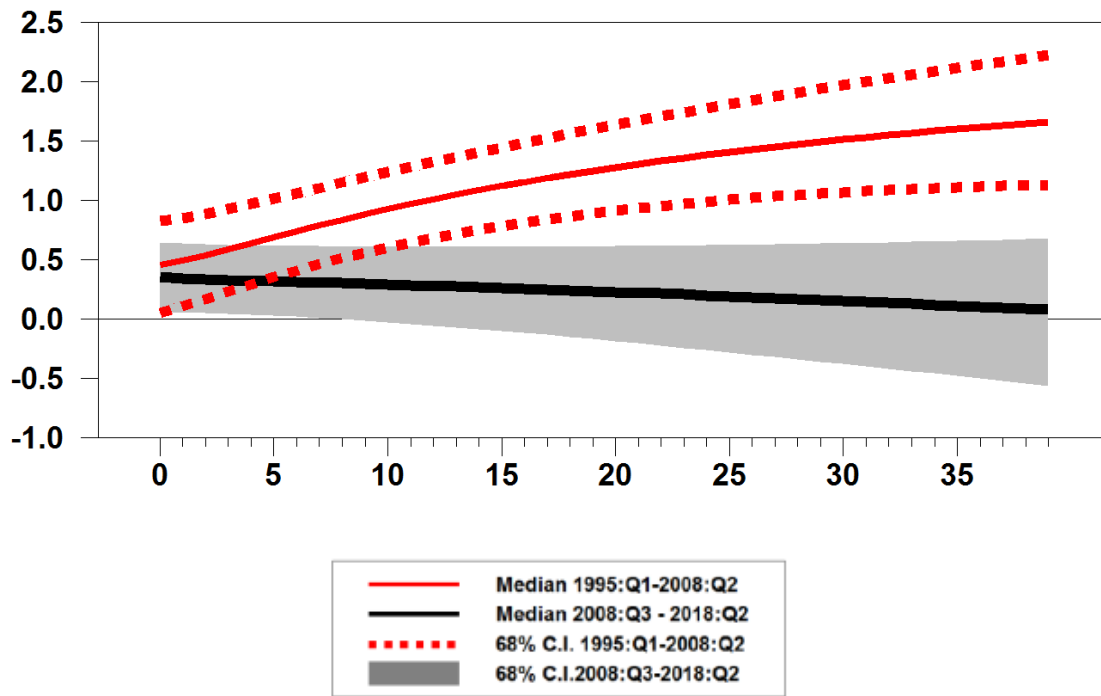
In this Appendix we present the empirical findings of the baseline 3 variables VAR when switching the order between productivity and employment. i.e. when employment (heads) can contemporaneously react to labour productivity.

Figure A.1: IRF TO A 1% EXPANSIONARY SHOCK IN EMPLOYMENT (HEADS): ALTERNATIVE CHOLESKY ORDERING



Notes: The figure reports the results of a 3-variables BVAR including $\log(\text{employment})$, $\log(\text{labour productivity})$ and $\log(\text{nominal compensation per employee})$ identified recursively. The red line is the median derived from the posterior distribution of the Bayesian VAR (1995:Q1–2008:Q2). The dashed red lines represent the 16th and 84th percentiles derived from the posterior distribution of the Bayesian VAR (1995:Q1–2008:Q2). The black line is the median derived from the posterior distribution of the Bayesian VAR (2008:Q3–2018:Q2). The grey shaded area represents the 16th and 84th percentiles derived from the posterior distribution of the Bayesian VAR (2008:Q3–2018:Q2). The overall tightness is 0.05 and the model is estimated with 4 lags.

Figure A.2: THE WAGE-EMPLOYMENT MULTIPLIER: ALTERNATIVE CHOLESKY ORDERING



Notes: The figure reports the multiplier of nominal wages to employment (ratio of the cumulative IRFs of wages and employment), conditional on a shock to employment. The result is derived from a 3-variables BVAR including log(employment), log(labour productivity) and log(nominal compensation per employee) identified recursively. The red line is the median derived from the posterior distribution of the Bayesian VAR (1995:Q1-2008:Q2). The dashed red lines represent the 16th and 84th percentiles derived from the posterior distribution of the Bayesian VAR (1995:Q1-2008:Q2). The black line is the median derived from the posterior distribution of the Bayesian VAR (2008:Q3-2018:Q2). The grey shaded area represents the 16th and 84th percentiles derived from the posterior distribution of the Bayesian VAR (2008:Q3-2018:Q2). The overall tightness is 0.05 and the model is estimated with 4 lags.

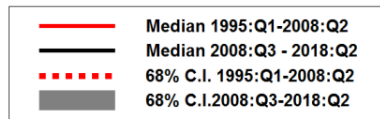
A.3 Larger specifications: Cholesky VAR

In this Appendix we present the empirical findings on the cyclicity of labour productivity and on missing wage growth when extending the baseline 3 variables VAR to (a) consumer prices; (b) the policy rate; (c) a number of static factors extracted by a panel of 20 time series, according to the procedure suggested by Forni and Gambetti (2014).

Figure A.3: IRF TO A 1% EXPANSIONARY SHOCK IN EMPLOYMENT: LARGER SPECIFICATIONS
 a. 4 variables: adding the policy rate



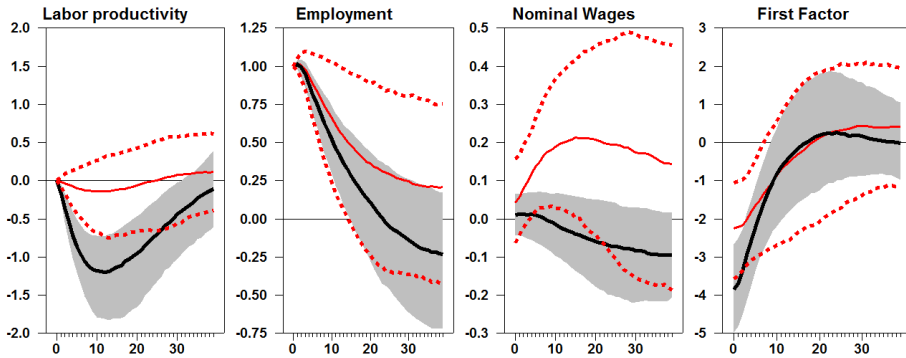
b. 4 variables: adding consumer prices



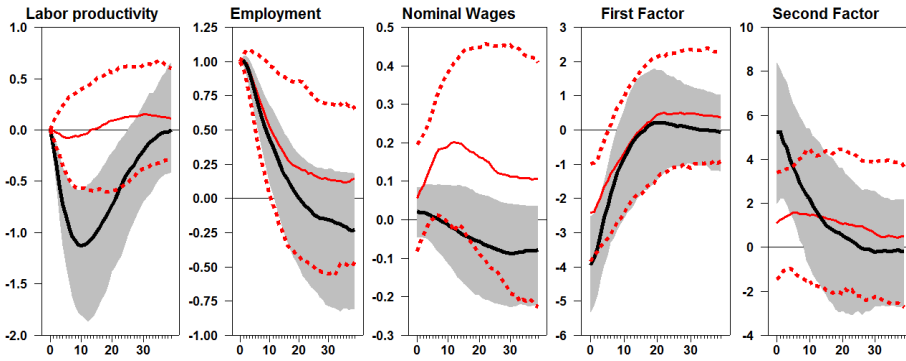
Notes: In both panels the VAR include log(output), log(employment) and log(compensation per employee). In panel a) the EONIA rate is also included; in panel b) the fourth variable is log(consumer prices). The red line is the median derived from the posterior distribution of the Bayesian VAR (1995:Q1–2008:Q2). The dashed red lines represent the 16th and 84th percentiles derived from the posterior distribution of the Bayesian VAR (1995:Q1–2008:Q2). The black line is the median derived from the posterior distribution of the Bayesian VAR (2008:Q3–2018:Q2). The grey shaded area represents the 16th and 84th percentiles derived from the posterior distribution of the Bayesian VAR (2008:Q3–2018:Q2).

Figure A.4: IRF TO A 1% EXPANSIONARY SHOCK IN EMPLOYMENT: FACTOR AUGMENTED SPECIFICATIONS

a. Adding one common factor



b. Adding two common factors

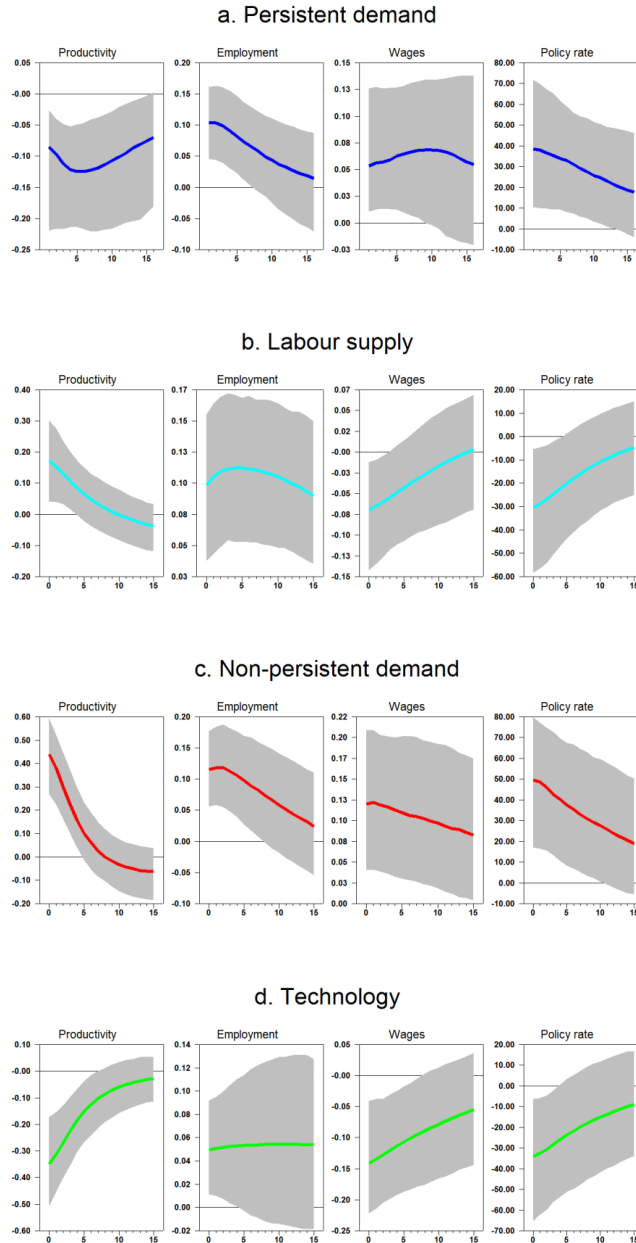


Notes: In both panels the FAVAR model includes productivity, employment compensation per employee, plus two common factors extracted by a panel of 20 global, financial and euro-area domestic variables including oil price, world gdp, exchange rates, stock prices, systemic stress, inflation expectations, interest rates, unit labour costs, negotiated wages, hours worked (see Appendix A.1 for details). The red line is the median derived from the posterior distribution of the Bayesian VAR (1995:Q1–2008:Q2). The dashed red lines represent the 16th and 84th percentiles derived from the posterior distribution of the Bayesian VAR (1995:Q1–2008:Q2). The black line is the median derived from the posterior distribution of the Bayesian VAR (2008:Q3–2018:Q2). The grey shaded area represents the 16th and 84th percentiles derived from the posterior distribution of the Bayesian VAR (2008:Q3–2018:Q2).

A.4 Baseline Bayesian VAR with sign restrictions: Further results

In this Appendix we present the IRFs underlying the wage to employment multipliers shown in Figure 8 and the historical decomposition obtained over the subsample 2008:Q3–2018:Q2, complementary to the one computed on the full sample and shown in Figure 9.

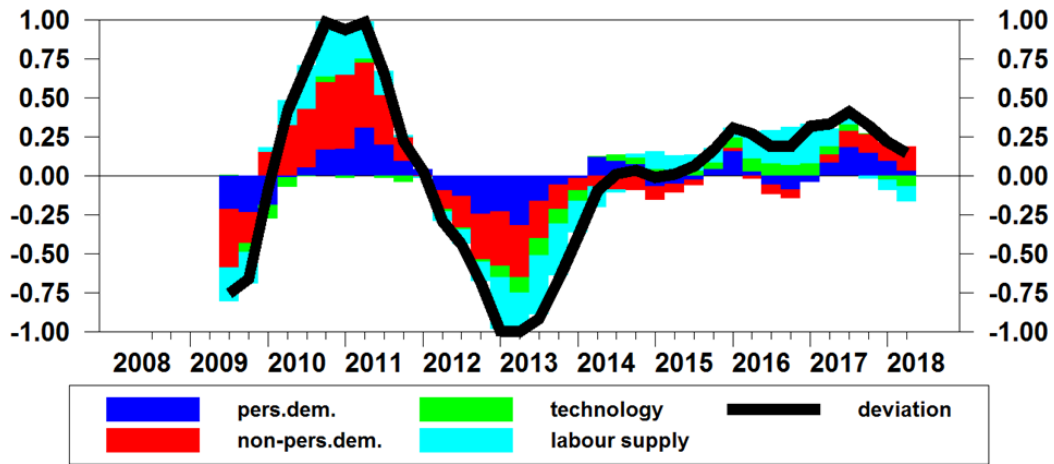
Figure A.5: IRF OBTAINED IN THE SIGN-RESTRICTIONS SVAR IDENTIFIED BASED ON TABLE 2



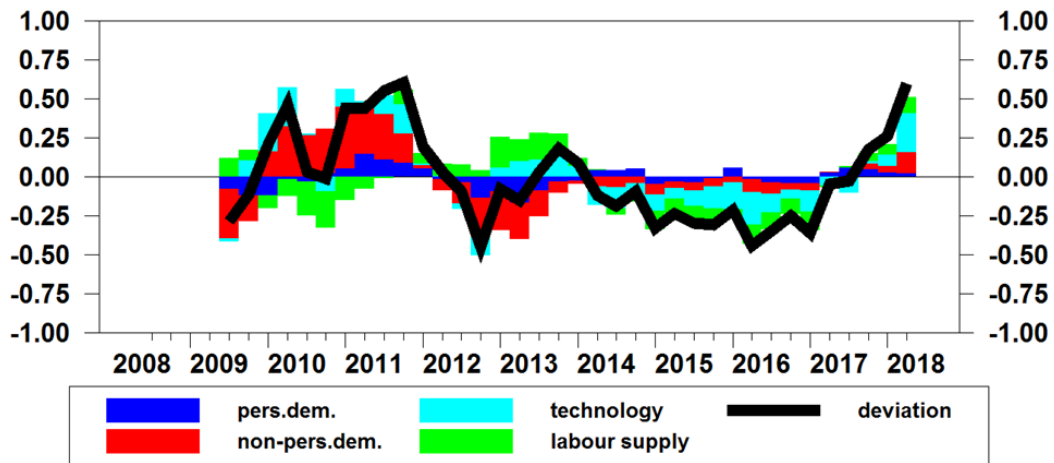
Notes: In both panels the VAR include $\log(\text{output})$, $\log(\text{employment})$ and $\log(\text{compensation per employee})$. In panel a) the EONIA rate is also included; in panel b) the fourth variable is $\log(\text{consumer prices})$. The red line is the median derived from the posterior distribution of the Bayesian VAR (1995:Q1–2008:Q2). The dashed red lines represent the 16th and 84th percentiles derived from the posterior distribution of the Bayesian VAR (1995:Q1–2008:Q2). The black line is the median derived from the posterior distribution of the Bayesian VAR (2008:Q3–2018:Q2). The grey shaded area represents the 16th and 84th percentiles derived from the posterior distribution of the Bayesian VAR (2008:Q3–2018:Q2).

Figure A.6: THE RELEVANCE OF PERSISTENT AND NON PERSISTENT DEMAND SHOCKS FOR EMPLOYMENT AND WAGES: SUBSAMPLE ANALYSIS

a. Employment (y-o-y growth)



b. Wages (y-o-y growth)

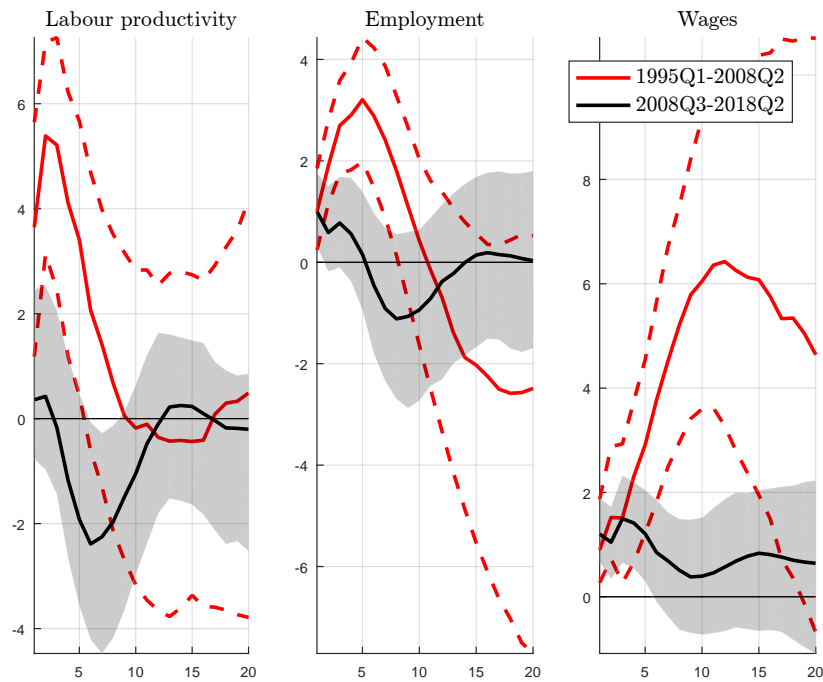


Notes: Estimation sample is 2008:Q3–2018:Q2. The VAR includes $\log(\text{productivity})$, $\log(\text{employment})$, $\log(\text{nominal compensation per employee})$ and the shadow rate estimated by Krippner (2015) and is estimated with 4 lags. Shocks are identified as in Table 2. Historical decomposition defined as the median contribution of each shock (colored bars) to the deviation of the actual series from the baseline of the VAR (black solid line).

A.5 Robustness on SVAR analysis: Considering Real wages and Different identifying assumptions

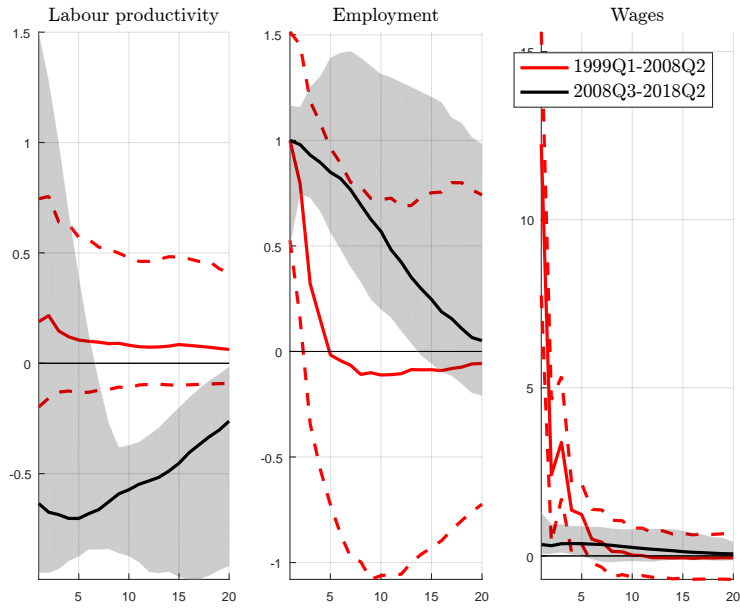
In this Appendix we test the robustness of the results obtained in Section 4 when (i) considering real instead of nominal wages (ii) using alternative identification schemes.

Figure A.7: IRF TO A POSITIVE DEMAND SHOCK: SIGN-IDENTIFIED SVAR MODEL WITH OUTPUT AND EMPLOYMENT (NO RESTRICTION ON PRODUCTIVITY)

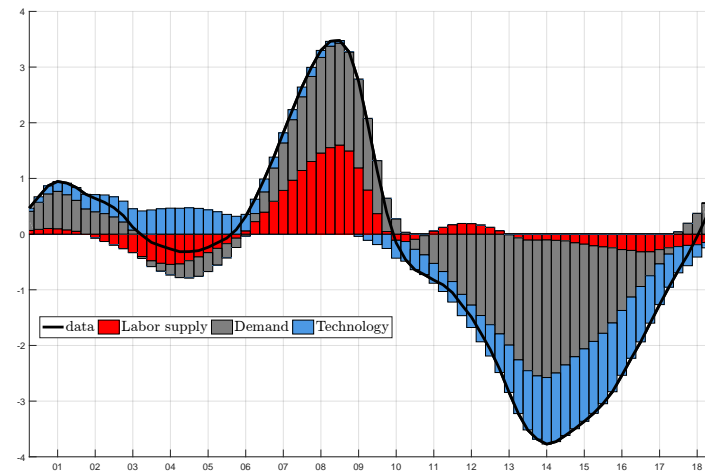


Notes: The VAR includes real GDP, employment, nominal wages, HICP and the EONIA rate; all variables except the EONIA rate are expressed in log-levels. Shocks are identified through sign restrictions imposed on the impact matrix as in Table A.2: demand shocks move all the variables in the same way, expansionary monetary policy shocks increase all variables but the interest rate, labour supply shocks move output and employment in the same direction and wages and prices in the opposite one, technology shocks move output and wages in the same direction and employment and HICP in the opposite one. The red line is the median derived from the posterior distribution of the Bayesian VAR (1995:Q1–2008:Q2). The dashed red lines represent the 16th and 84th percentiles derived from the posterior distribution of the Bayesian VAR (1995:Q1–2008:Q2). The black line is the median derived from the posterior distribution of the Bayesian VAR (2008:Q3–2018:Q2). The grey shaded area represents the 16th and 84th percentiles derived from the posterior distribution of the Bayesian VAR (2008:Q3–2018:Q2).

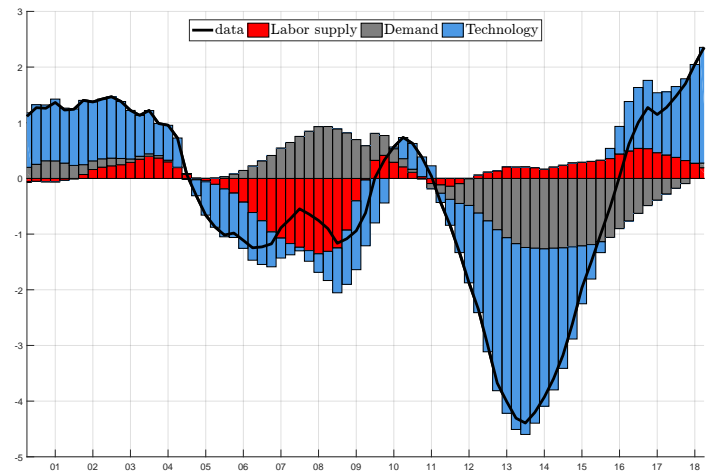
Figure A.8: SVAR WITH REAL WAGES (3 VARIABLES) IDENTIFIED WITH SIGN AND LONG-RUN RESTRICTIONS



(a) IRF TO A DEMAND SHOCK



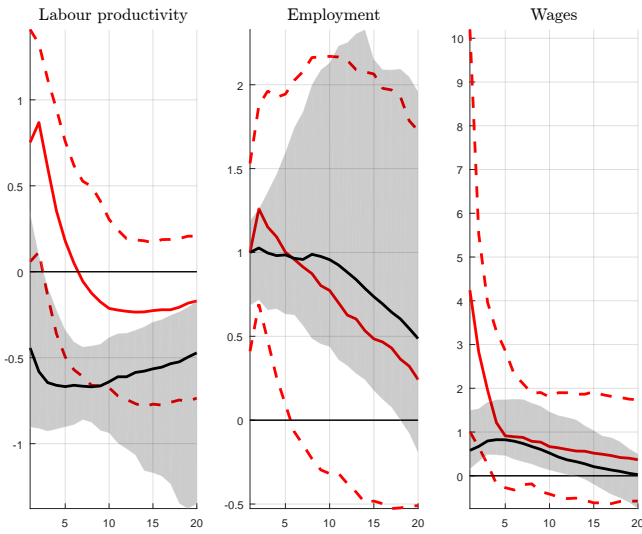
(b) HISTORICAL DECOMPOSITION: EMPLOYMENT



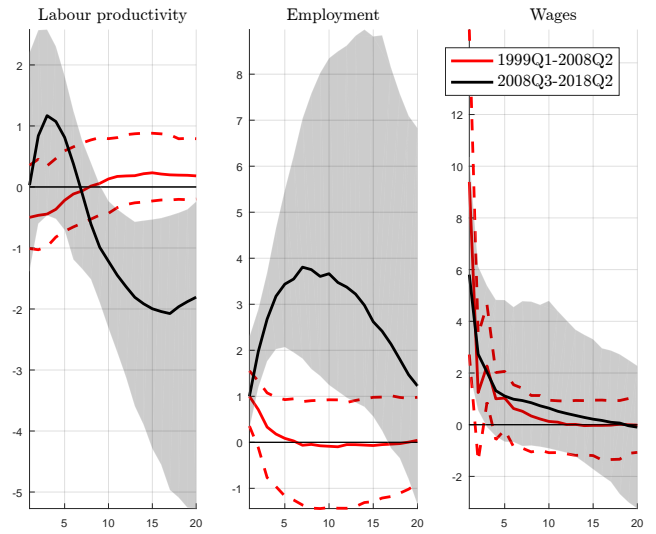
(c) HISTORICAL DECOMPOSITION: REAL WAGES

Notes: The VAR includes real GDP, employment and real wages; all variables are expressed in log-levels and standardized. Three shocks are identified: only technology shocks can affect output in the long-run. On impact, labour supply shocks move output and employment in the same direction and wages in the opposite one; demand shocks move all the variables in the same way. In panel a) the dashed red lines represent the 16th and 84th percentiles derived from the posterior distribution of the Bayesian VAR (1995:Q1–2008:Q2). The black line is the median derived from the posterior distribution of the Bayesian VAR (2008:Q3–2018:Q2). The grey shaded area represents the 16th and 84th percentiles derived from the posterior distribution of the Bayesian VAR (2008:Q3–2018:Q2).

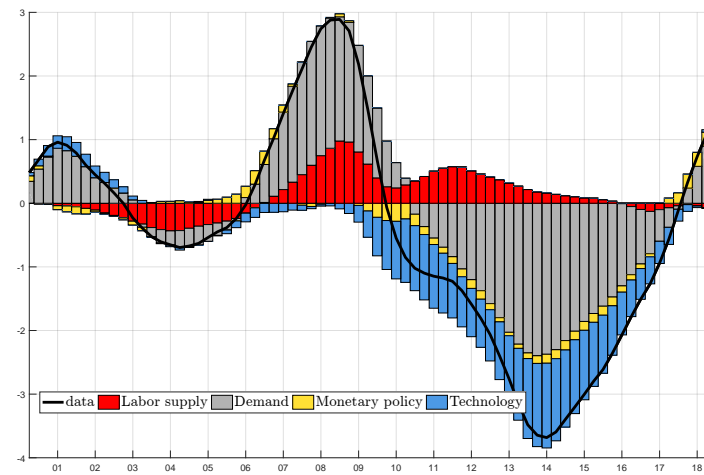
Figure A.9: SVAR WITH REAL WAGES AND EONIA RATE IDENTIFIED WITH SIGN AND LONG-RUN RESTRICTIONS



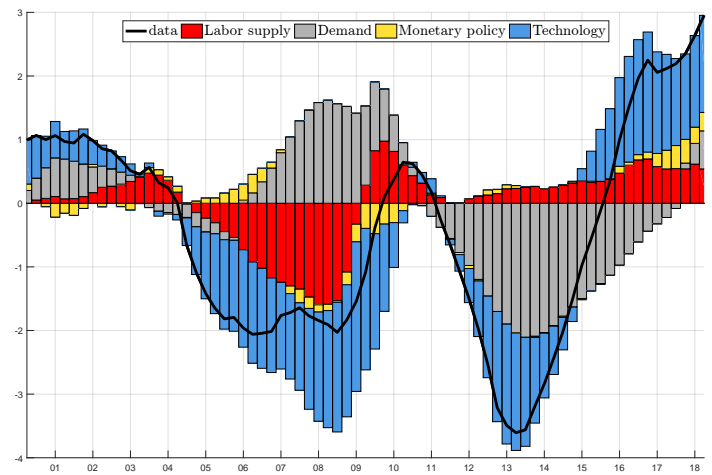
(a) IRF TO A DEMAND SHOCK



(b) IRF TO A MONETARY POLICY SHOCK



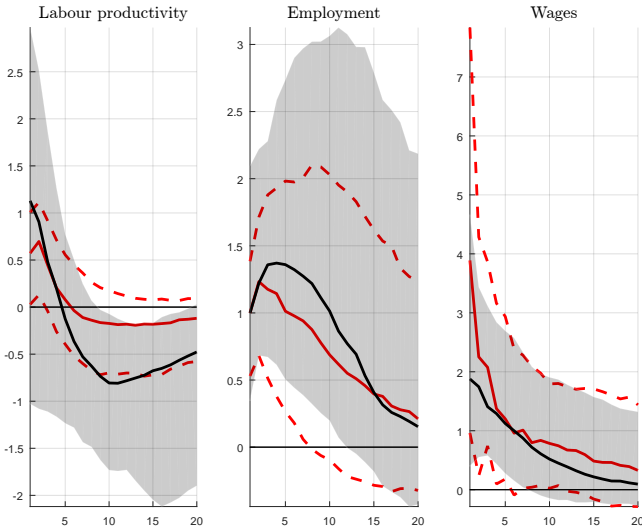
(c) HISTORICAL DECOMPOSITION: EMPLOYMENT



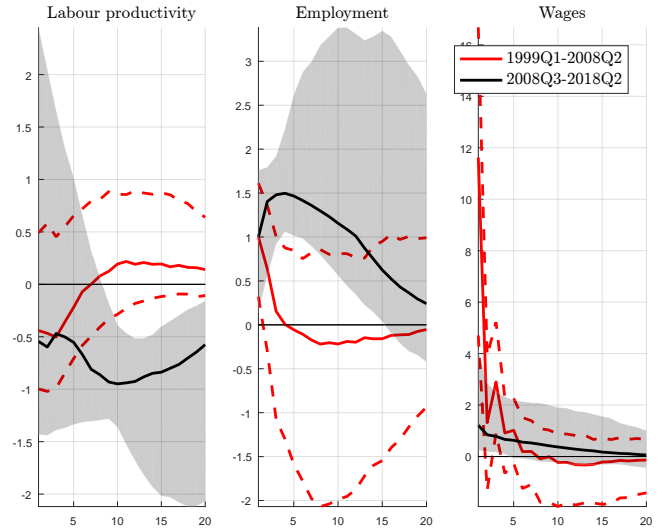
(d) HISTORICAL DECOMPOSITION: REAL WAGES

Notes: The VAR includes real GDP, employment, real wages and real EONIA rate; all variables are expressed in log-levels (except the interest rate) and standardized. Four shocks are identified: only technology shocks can affect output in the long-run. On impact, labour supply shocks move output and employment in the same direction and wages and the real interest rate in the opposite one; demand shocks move all the variables in the same direction; monetary policy shocks have an opposite effect on the real interest rate compared to the other variables. In panel a) the dashed red lines represent the 16th and 84th percentiles derived from the posterior distribution of the Bayesian VAR (1995:Q1–2008:Q2). The black line is the median derived from the posterior distribution of the Bayesian VAR (2008:Q3–2018:Q2). The grey shaded area represents the 16th and 84th percentiles derived from the posterior distribution of the Bayesian VAR (2008:Q3–2018:Q2).

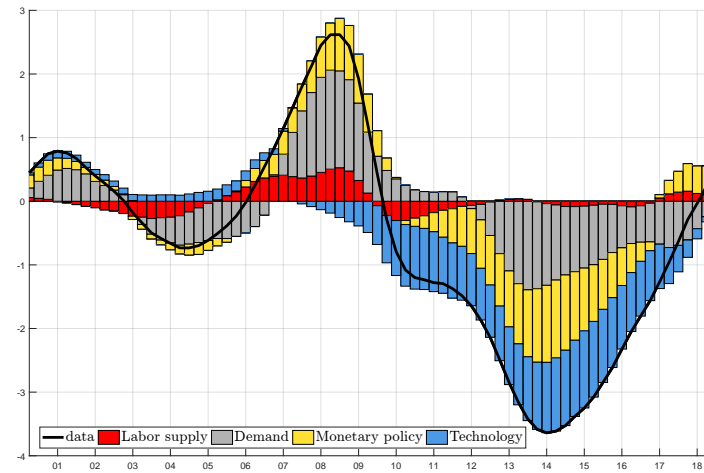
Figure A.10: SVAR WITH REAL WAGES AND SHADOW RATE IDENTIFIED WITH SIGN AND LONG-RUN RESTRICTIONS



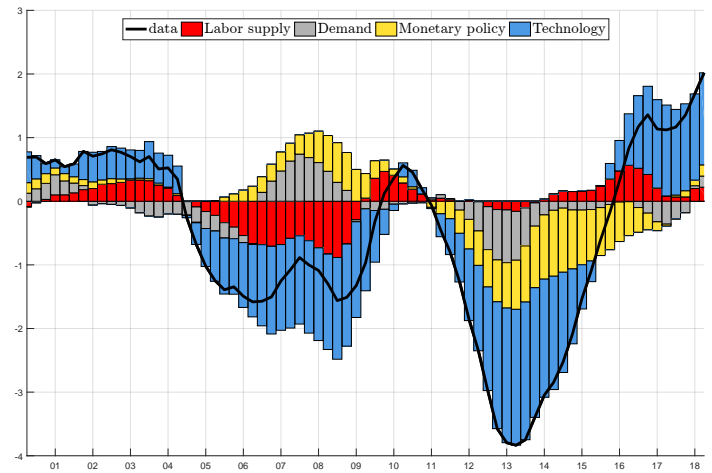
(a) IRF TO A DEMAND SHOCK



(b) IRF TO A MONETARY POLICY SHOCK



(c) HISTORICAL DECOMPOSITION: EMPLOYMENT



(d) HISTORICAL DECOMPOSITION: REAL WAGES

Notes: Estimation sample 1999Q1-2018Q2, overall tightness 0.1, nlags=2. The VAR includes real GDP, employment, real wages and real shadow rate (average of Wu & Xia and Krippner); all variables are expressed in log-levels (except the interest rate) and standardized. Four shocks are identified: only technology shocks can affect output in the long-run. On impact, labour supply shocks move output and employment in the same direction and wages and the real interest rate in the opposite one; demand shocks move all the variables in the same direction; monetary policy shocks have an opposite effect on the real interest rate compared to the other variables. In panel a) the dashed red lines represent the 16th and 84th percentiles derived from the posterior distribution of the Bayesian VAR (1995:Q1–2008:Q2). The black line is the median derived from the posterior distribution of the Bayesian VAR (2008:Q3–2018:Q2). The grey shaded area represents the 16th and 84th percentiles derived from the posterior distribution of the Bayesian VAR (2008:Q3–2018:Q2).

Table A.2: SVAR model with output and employment separated (5 variables): sign restrictions on impact

	Demand	Labour supply	Monetary policy	Technology	Cost-push
Output	+	+	+	+	0
Employment	+	+	+	-	0
Wages	+	-	+	+	+
HICP	+	-	+	-	0
Interest rate	+	?	-	?	0

Notes: A "?" means that no sign restriction is imposed on impact. Technology shocks are identified by assuming that they are the only shocks which affect output in the long-run.

Table A.3: SVAR with real wages (3 variables): sign restrictions on impact

	Demand	labour supply	Technology
Output	+	+	?
Employment	+	+	?
Wages	+	-	?

Notes: A "?" means that no sign restriction is imposed on impact. Technology shocks are identified by assuming that they are the only shocks which affect output in the long-run.

Table A.4: SVAR with real wages (4 variables): sign restrictions on impact

	Demand	Monetary policy	labour supply	Technology
Output	+	+	+	?
Employment	+	+	+	?
Wages	+	+	-	?
Interest rate	+	-	-	?

Notes: A "?" means that no sign restriction is imposed on impact. Technology shocks are identified by assuming that they are the only shocks which affect output in the long-run.