The link between labor cost and price inflation in the euro area*

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Abstract

This paper documents, for the first time in a systematic manner, the link between labor cost and price inflation in the euro area and euro area countries. Using country and sector quarterly data over the period 1985Q1-2018Q1 we find a strong link between labor cost and price inflation in the four major economies of the euro area and across three sectors. The dynamic interaction between prices and wages is time-varying and depends on the state of the economy and on the shocks hitting the economy. Our results show that the pass-through from labor cost to price inflation tends to be on average higher with demand shocks than with supply shocks. However, the pass-through is systematically lower in periods of low inflation as compared to periods of high inflation. These results confirm that, under the current circumstances of predominantly demand shocks labor cost increases will be passed on to prices. Coming from a period of low inflation, however, this pass-through could be moderate at least until inflation stably reaches a sustained path.

JEL Classification: C32, E24, E31

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1 Introduction

To gauge inflationary pressures, policy makers generally pay close attention to labor cost developments. A key reason has been the widely held view that labor cost inflation (i.e. wage inflation adjusted for productivity developments)[1] is one of the main causes of price inflation. From a theoretical perspective, this assumption represents the post-Keynesian cost-push/price-markup view of the inflationary process whereby wage increases in excess of productivity are seen as putting upward pressure on prices, and wages are the exogenous variable determining the future direction of inflation.

Such a cost-push view of inflation was often invoked in the 1970s to explain inflationary dynamics[2] and to this date often remains the underlying assumption in policy communication on the outlook for inflation. For instance, in the years leading up to the 2008-2009 global financial crisis crisis, labor cost dynamics were closely monitored to sniff out signals of a possible build up of excessive inflation (ECB (2004)), in part due to concerns of a return of the 1970s type wage-spiral. More recently, with concerns having shifted from perceiving inflationary and wage pressures from being too high to too low, forecast narratives see a pickup in wage growth often as a necessary condition for rising inflation (see for instance ECB (2018a)).[3]

While these wage-based explanations of inflation dynamics continue to take a prominent place in the policy debate, the academic literature has expressed more skeptical views. Empirical studies - which generally focused on US data - have drawn mixed conclusions on the link between labor costs and inflation, in particular at shorter horizons. First, it remains unclear whether labor costs tend to precede or follow prices (see for instance Knotek and Zaman (2014) and Bidder (2015)). And second, studies suggest that the relationship between labor cost inflation and price inflation may have weakened over time, potentially due to an improved anchoring of inflation expectations (see for instance Peneva and Rudd (2017)).

However, when looking at the theoretical literature, it is rather unsurprising that empirical studies have not been able to draw any firm conclusions on the link between labor cost inflation and price inflation at shorter horizons. Theoretical models generally do not put into question that in the long run labor cost inflation and price inflation are closely interrelated and that we should eventually expect wage inflation, adjusted for productivity, to move together with

[1] In the paper we will refer to labor cost as compensation per employee developments adjusted for productivity, whereas wages will refer to compensation per employee.

[2] In the 1970s the so called wage-price spiral was seen as causing inflationary dynamics whereby higher labor cost growth resulted in higher price inflation which in turn led workers to push for higher wage growth and subsequently even faster price increases.

[3] Similar references were made in a Bank of England speech by the external MPC member Saunders (20/4/2018) who noted that the Committee forecasts a gradual pickup in domestic cost growth that would help keep inflation slight above target two and three years ahead even as currency effects fade. For the Bank of Japan, the Deputy Governor Iwata (31/1/2018) noted in a recent speech that the inflation rate is projected to rise in line with wage increases.

price inflation.[4] However, in the short to medium run it is not at all obvious that rising labor costs should translate into price inflation.

In the industrial organization literature, an alternative to the cost-push view is that firms will charge whatever the market will bear, regardless of their actual costs. If the markets acceptance of higher prices is the dominant determinant of inflation, the cost-push model would have less validity (see Banerji (2005)). Also, the cost-push view abstracts from any influences that monetary policy may have on the inflation process. For instance, if a central bank is pursuing a contractionary policy trying to keep inflation low, firms might not be able to pass on higher wages into prices. In fact, the causality between prices and wages might go the other way: in the case of excess demand, firms would be able to increase prices, which would lead to higher demand for wages. Reflecting these differentiations, in New Keynesian models, the correlation and lead-lag relationship between labor cost inflation and price inflation can be expected to depend not only on the degree of the prevailing price and wage rigidities in the economy but also on the type of shock that hits the economy. As a result, we should in fact expect that the link between labor cost inflation and price inflation varies across time, across countries and also across sectors.

Having a better understanding of the signal that labor cost developments provide for the inflationary process is of key relevance from a policy perspective. In the euro area for instance, it is well-known that the reaction of inflation dynamics to accelerating growth has been atypically slow in recent years (see Draghi, 2018). While there are a number of plausible explanations for this, it nevertheless sheds some uncertainty on the inflation outlook. Having a deeper understanding of the drivers of the inflationary process can help reduce this uncertainty. However, to date there exists no study that has systematically documented and analysed the empirical link between labor cost inflation and price inflation in the euro area.

In this paper, we aim to contribute to the literature by documenting and analyzing the link between labor cost inflation and price inflation for the largest four euro area countries, using quarterly data over the period 1985Q1-2018Q1 at the country-wide level and for the 3 largest sectors in each economy (namely manufacturing, construction and services). We argue that the link between labor cost inflation and price inflation is not only state but also shock dependent. The idea that the relationship between variables is shock dependent is not new. It has already been more extensively explored in the exchange rate literature (see Forbes et al.

[4] In the long run, the real wage is determined by factors such as productivity, bargaining power, and the ability of firms to mark up prices over costs. Consequently, prices and nominal wages must adjust relative to each other to be consistent with these fundamentals. In this case, long-run growth in the real wage can only come from productivity growth. Because of this, if nominal wages grow faster than productivity, they must, in the long-run, be associated with price inflation. Otherwise workers would ultimately claim all proceeds of production and business owners would be left with nothing. If wage inflation substantially exceeds productivity growth, then inflation must also be high to be consistent with real wages rising in line with long-run productivity improvements.

(2018), Comunale and Kunovac (2017)). However, its relevance for the link between labor cost and price inflation has also already been suggested. ECB (2018b) presents evidence based on one of the ECB core models for policy simulations that the response of the GDP deflator to wages is different for supply shocks (in this case wage markup shocks) than for demand shocks.

Our paper builds on these findings. Concretely, we analyse the link between labor cost and price inflation in the euro area, and check if the extent to which the link has changed over time depends on the level of inflation and the type of shocks that hit the economy. We focus on the developments in the total economy and three main sectors of the four largest euro area economies. As the link between labor cost and price inflation has been lesser documented for the euro area countries, we start by presenting some stylized facts and by conducting preliminary analyses that have become commonplace in the US literature on this topic. More specifically, we (i) look at the cross-correlation between labor cost and price inflation, (ii) test Granger causality, and (iii) conduct both a conditional and unconditional forecast evaluation. Subsequently, we consider the link between labor cost and price inflation in a dynamic and conditional set-up by estimating a 3 variable VAR model for each sector of each country. This allows us to answer questions, such as: (i) whether the conditional correlations are different from the unconditional ones; (ii) by how much price inflation rises when labor costs increase, and (iii) the extent to which this "pass-through" has evolved over time or depends e.g. on the level of price inflation. In the final part of the paper we move to a more structural set-up and analyze whether and how the link between labor cost and price inflation depends on the type of shocks that hit the economy.

Overall our results show that in the four biggest euro area countries, contrary to the US, there is a clear link between labor cost and price inflation. This result is confirmed across a battery of approaches and tests. The link has also remained overall rather stable over time, albeit with some differences across sectors and countries. However, at the same time, and in line with the findings in the literature on US data, the link appears to depend on the level of price inflation: when inflation is high, the link becomes stronger. Finally, the link is shock-dependent: When the economy is hit by a demand shock, there is a clear and relatively strong link between labor cost and price inflation. This is not the case for supply shocks, where the link is weaker, if at all present.

Our results have important policy implications. In particular, the results suggest that monitoring and analyzing labor cost developments in the euro area is indeed relevant to understand the evolution of price inflation. However the importance of these developments does depend on the level of price inflation and on the shocks that prevail in the economy. In an environment of expansionary demand the information contained in labor cost developments in much more relevant for price inflation than when the economy is hit by a technology or wage push shock. Under the current circumstances of predominantly demand shocks, we can be confident that unit labor cost increases will be passed on to prices. Coming from a period of low inflation, however, this pass-through could be moderate at least until inflation stably reaches a sustained path.

The remainder of the paper is organized as follows. Section 2 connects the paper to the existing literature. Section 3 discusses some preliminary analysis of the data and established unconditional stylized facts on the link between labor cost and price inflation. Section 4 analyses the link in a VAR set up and considers to what extent the link has changed over time or depends on the level of price inflation. Section 5 presents results based on a structural VAR model. Section 6 summarizes and concludes.

2 Link to the Existing Literature

Labor markets have been a focus of interest in the study of price inflation ever since Phillips uncovered the negative relationship between the rate of change in wages and the unemployment rate, i.e. the so called Phillips curve.[5] Since then an extensive literature has developed that studies the interrelationship between labor market developments and price inflation. An important share of this research has explored how informative labor cost inflation is for price inflation, in particular in the short to medium run.[6]

Studies have taken a number of avenues to analyze this question. A first important strand in the literature has focused on the causal relationship between wage inflation and price inflation. From a theoretical view, the post-Keynesian view would suggest that the excess of wage gains over productivity gains lead price inflation. Instead, according to the neoclassical theory, the causality between wages and inflation would run in the opposite direction. In this case, the real wage is considered the relevant wage variable in the wage-employment relationship and nominal wages are expected to respond to price changes so as to preserve the real wage, for a given productivity schedule. Empirically, in-sample analyses based on Granger causality type of tests tend to favor the idea that price inflation causes wage inflation and that the causality can differ across sectors. Hu and Toussaint-Comeau (2010) find that wage growth does not cause price inflation in the Granger causality sense, especially after the mid-80s. By contrast, price inflation does Granger cause wage growth. Similarly, Emery and Chang (1996) and Sbordone (2002) find some evidence that rising prices precede the growth in unit labor costs (see Bidder (2015)). Hess and Schweitzer (2000) find that price and wage changes are best predicted by their own lags, meaning that none Granger cause each other. This confirms the long standing findings of Gordon (1988) and Darrat (1994) who concluded that wages and

[5] Fisher (1926) already uncovered the link between price inflation and the unemployment rate earlier, however he saw price inflation as driving the rate of unemployment.

[6] In the long run, the relationship between labor cost inflation (i.e. wage inflation adjusted for productivity) and price inflation is rather uncontroversial, both from a theoretical and empirical point of view.

prices are irrelevant to each other and that they *"live a life of their own"*. Banerji (2005) approaches this changing relationship from a different angle, looking at cyclical turns. He finds that labor cost inflation leads price inflation at peaks, but lags it at troughs, which would make changes in labor cost a lagging indicator of upturns in price inflation. Finally, Rissman (1995) finds that only in manufacturing and trade services, wages granger cause inflation.

A second strand of the literature has investigated whether wages add any information when trying to forecast inflation (see for instance Stock and Watson (2008), Knotek and Zaman (2014)). Overall, these studies have found that for out-of-sample forecasts, wages do not provide significant additional information beyond what can already be gleaned from other sources, including prices themselves (Bidder (2015)). At the extreme, Stock and Watson (2008) even show that models using common wage measures may perform worse than their preferred benchmark without wages.

A final strand of the literature has examined whether the link between labor cost inflation and price inflation is time varying. Studies here tend to find that, while in the past (i.e. prior to the mid 1980s) labor cost inflation did provide signals for price inflation, there is little evidence that in recent years movements in average labor cost growth have been an important independent influence on price inflation. Concretely, Knotek and Zaman (2014) shows how the correlation between wages and prices has decreased since the mid-80s. Similarly, Peneva and Rudd (2017) show how the pass-through of labor cost growth to price inflation in the US has declined over the past several decades (to the point where it is currently close to zero). One explanation put forward has been the better anchoring of inflation expectations in recent years. Another one is that low levels of inflation changes the wage-price nexus because of downward wage ridigities (Daly and Hobijn (2014)). Such a view was also empirically uncovered by Mehra (2000) who finds that in periods of low inflation, wages do not help to predict inflation while it does in high inflationary environment. Zanetti (2007) found similar results using Swiss data.

From these studies it thus appears generally difficult to ascertain that over shorter horizons wages have an *independent* influence on prices and that the link has weakened over recent years. However, most of them are based on US data. Instead, for the euro area, only few studies have examined this link. Dees and Guntner (2014) explore the cost-push factors to inflation dynamics from the supply side across four sectors (industry, construction, services and agriculture) in the four largest euro area countries over the period 1995-2012. In their analysis the authors find that disaggregated information improves the inflation forecasting performance and that their model, which also accounts for unit labor cost developments, fares comparatively well against common alternatives. Forecast errors however do tend to be larger during the financial crisis period. Using a different approach, Tatierska (2010) finds by estimating a NKPC that in eight out of 11 euro area countries there is a plausible relationship between inflation and ULC growth. Finally, at the micro level, Druant et al. (2009) find that wage and price changes feed into each other. Around 40 percent of the firms survey acknowledge that there exists a relationship between wages and prices. However, only 15 percent state that this relationship is relatively strong. For half of them decisions on price changes follow those on wage changes. The opposite holds for another 3 percent, while decisions are simultaneous in the remaining 4 percent.

3 A Preliminary Look at Labor Costs and Inflation in the euro area

We concentrate in our analysis on the link between labor cost and inflation in the four largest euro area countries (Germany, France, Italy and Spain) for the economy as a whole and for the three main economic sectors, i.e. services, manufacturing and construction.[7]

For this purpose we collected quarterly data over the period 1981Q1-2018Q1. Details on the data sources and the data series included are provided in Appendix A. To measure labor costs, we use nominal compensation per employee adjusted for productivity (in line for instance with Peneva and Rudd (2017)) rather than nominal compensation per employee as the former is a better proxy of the true cost pressure faced by the firm.[8] For inflation, we use the implicit sectoral gross value added deflator.[9]

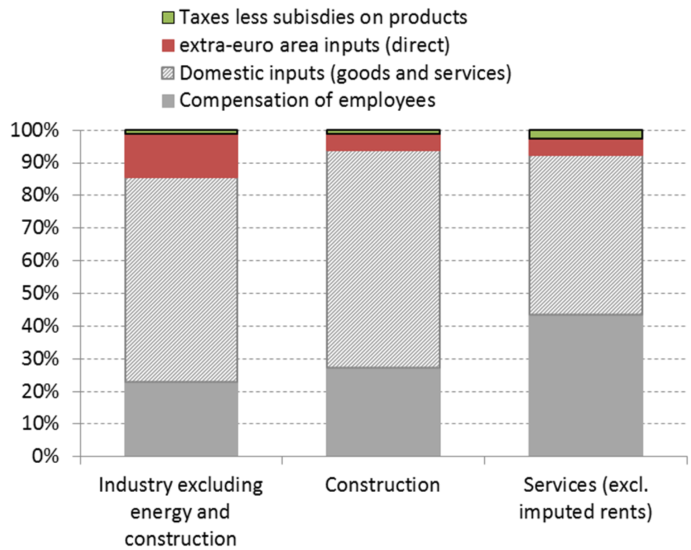
We conduct our investigation for each individual country, given the substantial heterogeneity in labour market institutions and in the wage formation process, with potential impact on the link between labour costs and price inflation. We believe that it is important not just to conduct the analysis at the country level but also to exploit the sectoral dimension. Sectors differ in terms of labor market tighteness and many other labor market characteristics that affect the pass-through of labor cost to price inflation. The cost structure of production firms is different, with services having a bigger share of labor costs (see Figure 1). At the same time, manufacturing is subject to a larger degree to international competition, which would in theory force firms to use mark-ups more to off-set the effect of wage increases on selling prices. Furthermore, other characteristics, such as workers' turnover rates, capital intensity or

[7]The three economic sectors combined represent between 70% (in Germany) and 80% (in France) of total value added. We did not include the agricultural sector which represents only between 0.7% (in Italy) and 2.9% (in Spain) of total value added.

[8]Our wage measure is compensation per employee. Alternative measures of wages across euro area countries exist, such as compensation per hour or hourly labor cost. The latter encompasses employee compensation (including wages, salaries in cash and in kind, employers social security contributions), vocational training costs, and other expenditure (such as recruitment costs, expenditure on work clothes, and employment taxes regarded as labor costs minus any subsidies received). However, these alternatives are generally available across sectors and countries on a quarterly basis only since 1995, hence our preference for compensation per employee to proxy wages.

[9]Note that CPI inflation is not available at sectoral level. The gross value added deflator at sectoral level has been obtained by dividing nominal value added by real value added at sectoral level.

Figure 1: Cost structure of production of manufacturing and services firms (percent)



Sources: Eurostat, authors' calculations. Latest observation: Input/output tables 2015.

the degree of wage bargaining institutions are also sector dependent. Finally, sectors differ in terms of their degree of wage rigidity. For instance Du Caju et al. (2009) show (on a Belgian firm-level data set) that wages in construction are particularly sticky, less so in services and even less in manufacturing. Tatierska (2010) also argues that the sensitivity of price to labor cost inflation differs across sectors, reflecting the different degree of price stickiness; the services sector exhibits stickier prices, so she finds that for most analyzed countries (out of 11 euro area countries), labor cost inflation Granger causes price inflation for the total economy in more instances than for services.

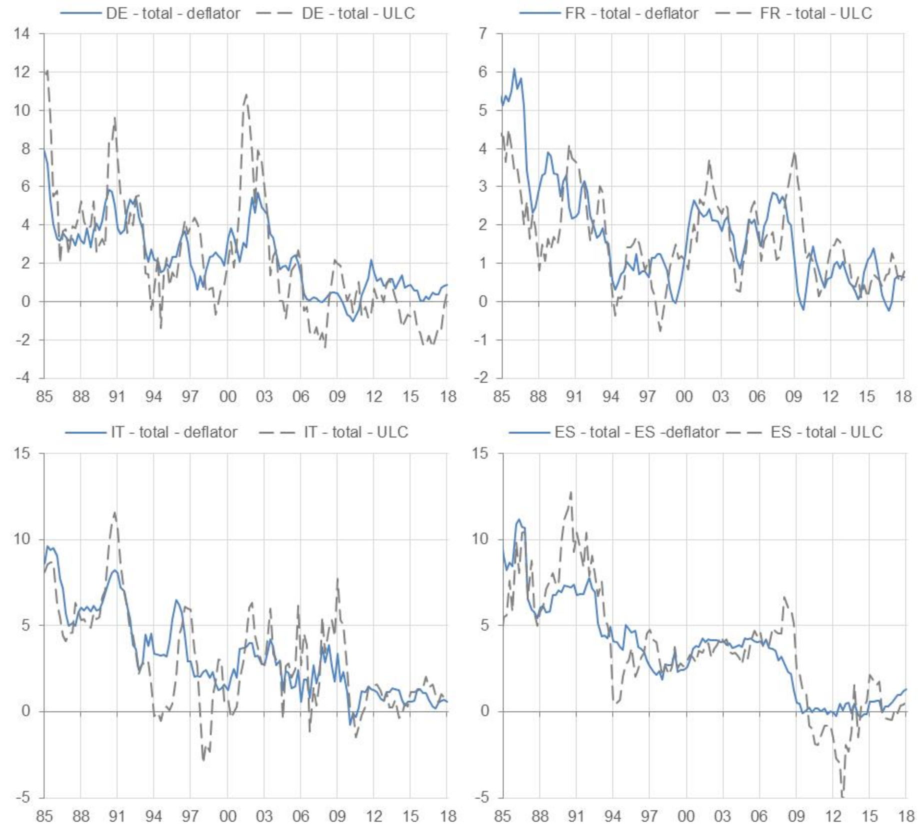
3.1 Data

Figure 2 plots the year-on-year growth rate of the labor cost and our measure of price inflation, for the total economy for each of the four countries. The high correlation (ranging between 0.85 and 0.91) between the two series demonstrates why analysts have paid close attention to labor costs when assessing inflation.[10] However, what is not clear from the figure is whether movements in labor costs precede movements in inflation, or vice versa.

At the same time, Figure 2 does clearly demonstrate that in part the high co-movement between the two data series can be explained by a strong common (downward) trend over im-

[10] These high correlations are generally also confirmed at sectoral level. The correlation is however somewhat lower for the construction sector, where it ranges between 0.31 (for Spain) and 0.64 (for Italy).

Figure 2: Unit Labor Cost and GDP deflator, year on year % change

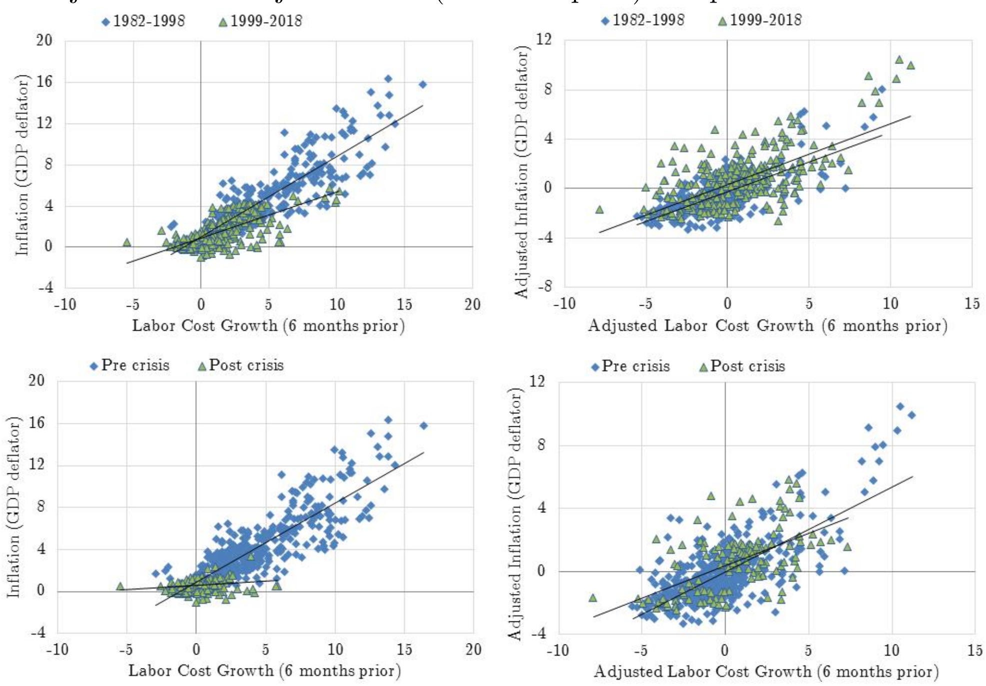


Sources: Various sources, authors' calculations. Latest observation: 2018Q1.

portant part of the sample (in particular in the 1980s and early 1990s) which can be attributed to the convergence process in the run-up to EMU and to subsequent improvements in the anchoring of inflation expectations towards lower levels. These common patterns are visible across all countries and sectors (not reported). Therefore, before choosing the appropriate level of aggregation where to remove the trend, we compute a single common factor across all price and labor cost inflations as well as within-country factors (common to labor cost and price inflations of all sectors belonging to the same country), and check the variance explained by these factors. It turns out that the variance of the two variables of interest explained by country factors is not only higher on average (60% vs 50%) but also more homogeneously higher across countries than the variance explained by a single common factor. The latter would explain a high variance of the two variables in France, Italy and Spain (and not in all sectors) but not in Germany.

Based on this evidence, we decided to remove trends which were common at the country level. To do so, we follow Knotek and Zaman (2014) which is in turn inspired by the forecasting literature that has found gains in inflation forecasting accuracy by specifying inflation in gap

Figure 3: Adjusted and unadjusted ULC (6 months prior) and price inflation in the euro area



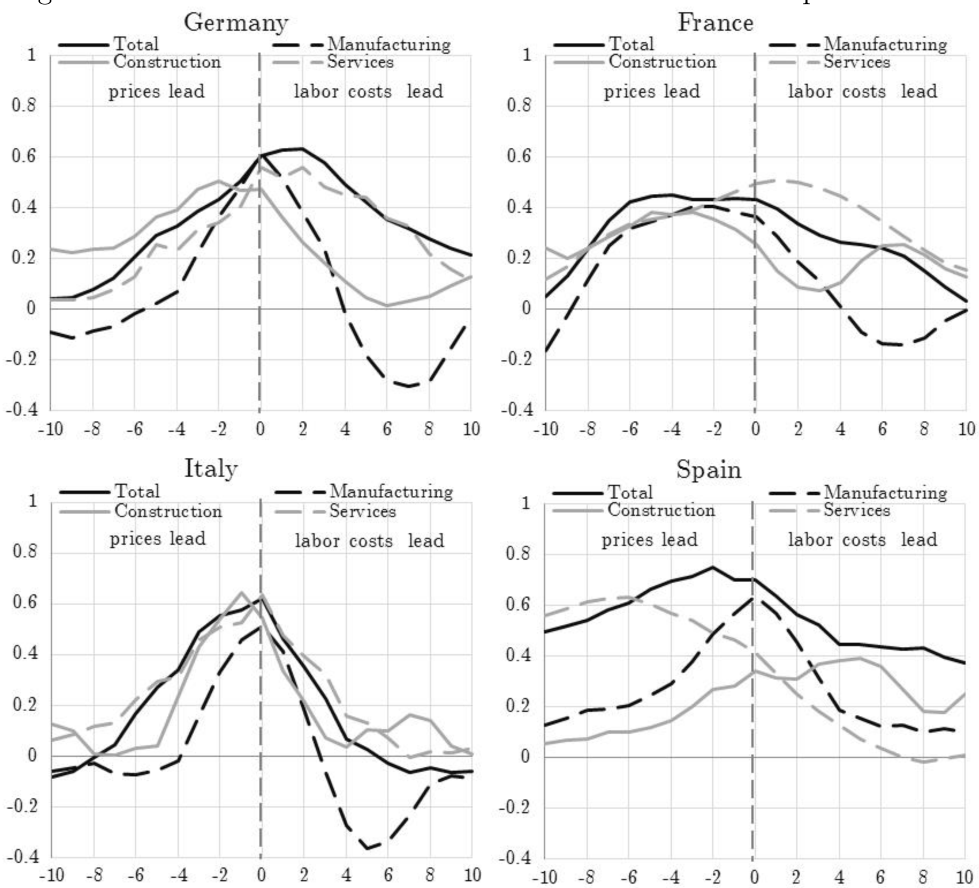
Sources: Various sources, authors' calculations. Latest observation: 2018Q1.

form as the deviation from a slow-moving long-run trend (Kozicki and Tinsley (2001) and Zaman (2013)). Concretely, we construct labor cost and price inflation gaps as the year-on-year growth rates in these variables minus the Consensus survey-based long-run inflation expectations. As inflation expectations for the countries in our sample are only available since 1989 (and for Spain even only since 1995), we rely on an unobserved components model to create labor cost and price inflation gaps in the period prior to that.[11] The adjusted series are shown in Appendix B. This adjustment also implies that the series are stationary, according to a standard ADF unit root test.[12] The common trend is crucial in understanding the link between labor cost and price inflation. As shown in Figure 3, the correlation between price and labor cost inflation appears to have changed after the crisis when looking at unadjusted data, but there is no striking difference when considering the adjusted series. For the remainder of the paper, we will base our analysis on the adjusted series of labor cost and price inflation.

[11] The unobserved component model is estimated on the price inflation series and assumes that the inflation trend follows a random walk. This trend estimate from the unobserved component model is then applied to both the labor cost and price inflation series.

[12] To ensure that our results do not depend on the approach taken, we also construct a number of alternative price inflation and labor cost inflation gaps as year-on-year growth in these variables less a series-specific or shared long-run trend. Specifically we use an HP filter to adjust the series for the time span where inflation expectations were not available considered. The results in the paper were unchanged when applying this approach.

Figure 4: Cross correlation between detrended labor cost and price inflation



Sources: Various sources, authors' calculations. Note: the charts show the cross correlation between price inflation gaps at time t and labor cost inflation gaps at time t-k. Sample period: 1985Q1-2018Q1.

3.2 Cross correlations

In this subsection, we analyze the unconditional connection between labor cost inflation and price inflation by looking at cross-correlations, which allow for a simple examination of the lead-lag structure between the two series as well as of the strength of the connections between the series. If labor cost inflation reliably comes ahead of price inflation in the data, then the strongest cross-correlation should be between labor cost inflation in quarter t and price inflation in some k-th quarter after t.

The unconditional cross-correlations (Figure 4) of the filtered series continue to show a high contemporaneous correlation (albeit lower than on the unfiltered series) ranging between 0.4 (France) and 0.8 (Germany).

At the same time, we do not observe a systematic lead/lag pattern across countries or sectors. While in Italy the highest correlations occur mostly contemporaneously, in the German total economy and service sector, labor costs seem to lead prices. In France, except for the service sector, prices lead labor costs. Similarly, in the Spanish service sector and the total economy, prices lead labor costs, while labor costs are clearly leading prices in the construction sector.

Examining the same cross-correlations on a rolling sample we noticed only small changes over time, though in the post-crisis period the correlations have tended to become more contemporaneous (except in the Spanish construction and the French service sector) (see the charts in Appendix C).

3.3 Granger Causality and Forecast Evaluation

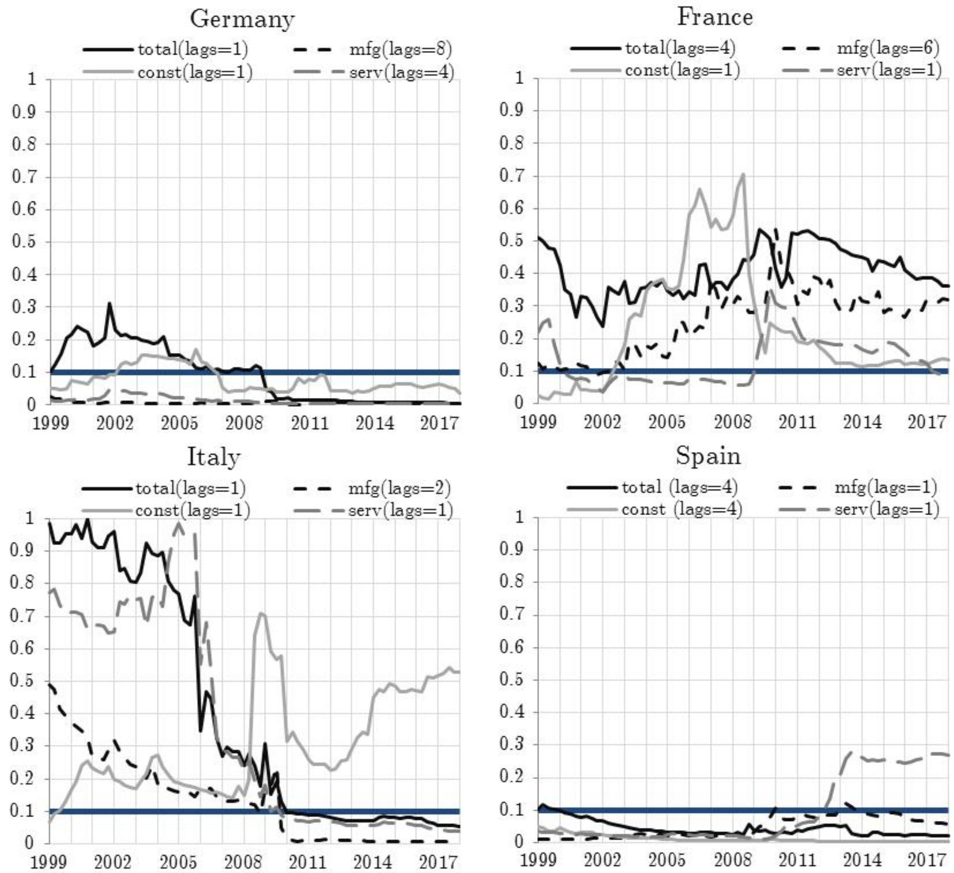
Another angle to look at the link between labor cost and price inflation is to ask whether past changes in labor costs contain useful information for predicting future changes in prices. We consider here two commonly adopted approaches to analyze this question from an in- and out-of-sample perspective, namely Granger Causality and a pseudo out-of-sample forecast evaluation.

As regards the Granger Causality test, we adopt here the classical approach whereby in a single equation model price inflation is regressed on p lags of price and labor cost inflation and the exclusion of labor cost inflation lags is tested. The test is performed on a recursive basis, starting by estimating the equation over the period 1985Q1 up to 1998Q4 and subsequently adding one quarter at a time. Lags are optimally chosen with a grid search to minimize the p-values of the Granger Causality test. In other words, we look for the best specification which is the most likely to result in labor cost inflation being Granger causally prior to price inflation.

Results (Figure 5) show that contrary to what found for US data (see section 2), we can find causality from labor cost to price inflation at 10 and 5% significance. Moreover, and confirming the conclusions from the unconditional cross-correlations, we see that the link between labor cost and price inflation link has not weakened in the recent period (the notable exceptions are the Italian construction and Spanish service sectors). In fact, in most cases the causality from labor cost to price inflation has strengthened over time. France is the only country where this causality has been less evident throughout the sample, except the construction sector at the beginning of 2000s and the service sector until the financial crisis.

In the second approach we focus on the out-of-sample forecasting power of labor cost inflation for price inflation. For this purpose we estimate a simple trivariate VAR model for each sector which includes: real value added growth, labor cost inflation and price inflation. We subsequently perform two exercises: an unconditional and a conditional forecast. In the first case we compare the unconditional forecast of price inflation from the trivariate VAR with a bivariate VAR (i.e. a model which only includes activity and prices). Our benchmark evaluation period is 1999-2018 but we also check the results for the periods 1999-2007 and 2008-2018. Besides the unconditional forecast, we also consider a conditional forecast exercise.

Figure 5: Recursive Granger Causality Test Results (p-values)



Note: mfg stands for manufacturing, const for construction and serv for services. The lags for the Granger causality test were optimally chosen. The horizontal dark blue line represents the threshold for the significance of the test at a 10% level. Sources: Authors' calculations.

In this case, we compare the inflation forecast from the trivariate VAR conditional on the true path of labor costs with the forecast of price inflation from the same model where we condition on a constant path for labor costs (i.e. we assume a random walk).[13]

The results from the unconditional and conditional forecasts are shown in the Tables in Appendix D. Overall, while the unconditional forecast presents mixed results and would seem to suggest that labor costs can add some useful but limited information to the price inflation forecasts across samples, the conditional forecasts strikingly show that labor cost inflation has indeed some forecasting power for price inflation in this setup. This result appears consistently across sectors and countries with the exceptions of the construction and service sectors in Spain.

[13]Concretely, the strategy is the following: (i) we run an initial estimate of the model until 1998Q4; (ii) we do a rolling estimate thereafter and project inflation (for each sector) 8 steps ahead conditional on the true path of labor cost inflation and conditional on a constant labor cost inflation; (iii) we evaluate the ratios of RMSE obtained in both cases.

Evaluating the forecast before and after (the beginning of the) global financial crisis we observe a tendency to improve the forecasting over the last sample for all countries except Italy (where we do not see a change). When checking the opposite direction (from prices to labor costs), overall we observe many more ratios bigger than 1 and a better forecasting performance over the last part of the sample for Germany and Spain.

3.4 Summary

This Section can easily be summarized: labor cost and price inflation show a consistent and strong (unconditional) link across euro area countries and sectors at a cyclical frequency, i.e. even after removing a common trend. In fact, without removing a common trend, the correlation between labor cost and price inflation would have spuriously changed after the real and financial crisis, as found for the US data by Peneva and Rudd (2017). The direction of causality is not obvious to ascertain but, contrary to the evidence typically based on US data, it is possible to find some in- or out-of-sample forecasting power of labor costs for price inflation. No obvious country or sector specific pattern emerges from this preliminary analysis.

4 A Simple VAR Analysis

4.1 Empirical Approach

To examine in a dynamic and more conditional manner the relationship between labor cost and price inflation we use VAR models for each sector of each country, in total of 16 VARs. We do not exclude the possibility of cross-countries/sectors interrelationships, which could be accounted for in a panel VAR approach as in Canova and Ciccarelli (2009), but the sparse number of dynamic interrelationship among countries and sectors can make a fully-fledged panel VAR setup inefficient for our aim. On the other hand, the heterogeneity in the data makes the approach used here preferable to approaches that restrict the dynamics of the endogenous variables to homogeneity in a pooling panel. Estimating sector by sector allows us to look at average results, if needed, by simply using consistent mean group estimators on the disaggregated results.

Our baseline VAR system contains three variables: the growth rates of (i) real value added, (ii) unit labor cost and (iii) the value added deflator. The latter two variables have been filtered as explained in Section 3 to remove a common trend. The baseline estimation period ranges from 1985Q1 to 2018Q1. The VARs are estimated with four lags and Bayesian techniques assuming a normal-diffuse prior with a Minnesota prior on the matrix of coefficients to deal with the curse of dimensionality (see e.g. Kadyiala and Karlsson (1998)).

In this simple set up we use the estimates of the 16 VARs to evaluate impulse response functions of inflation to a shock in unit labor cost inflation by means of a Choleski orthogonalization with the variables ordered as listed above. The dynamic responses are used to answer the question: how much does inflation rise when labor costs rise by one-standard deviation. Standardized multipliers are computed mimicking the fiscal literature (see e.g. Mountford and Uhlig (2009)) as the ratio of the cumulative responses of price and labor cost inflation over the horizons 1 (impact) through 28 quarters. With such standardization, the multipliers are comparable across countries and sectors.

4.2 Main Findings: Baseline VAR Specification

We first report the estimated contemporaneous correlations between labor cost and price inflation computed from the moving average representation of the VARs (i.e. the impulse response estimates) truncated to 40 lags.

Table 1: VAR based correlation between labor cost and price inflation

	conditional on	Total	Manufacturing	Construction	Service
DE	all shocks	**0.62**	**0.62**	**0.50**	**0.57**
	shock to y	**0.78**	**0.91**	**0.84**	**0.79**
	shock to ulc	**0.88**	**0.77**	**0.39**	**0.89**
	shock to p	0.03	0.06	**0.56**	**-0.18**
FR	all shocks	**0.40**	**0.35**	**0.27**	**0.48**
	shock to y	**0.49**	**0.39**	0.02	**0.52**
	shock to ulc	**0.82**	**0.83**	**0.83**	**0.70**
	shock to p	-0.04	**0.28**	**0.35**	0.29
IT	all shocks	**0.63**	**0.52**	**0.55**	**0.63**
	shock to y	**0.74**	**0.88**	**0.61**	**0.68**
	shock to ulc	**0.90**	**0.27**	**0.74**	**0.85**
	shock to p	**0.34**	**0.03**	**0.58**	**0.45**
ES	all shocks	**0.75**	**0.65**	**0.37**	**0.41**
	shock to y	**0.85**	**0.92**	**0.53**	**0.77**
	shock to ulc	**0.96**	**0.90**	**0.50**	0.42
	shock to p	**0.63**	**0.65**	0.31	**0.54**

Notes: Table 1 reports estimates of conditional correlations between labor cost and price inflation. Significance (values in bold) is based on 68% Bayesian credible intervals.

Table 1 reports the correlation estimates between the two variables of interest conditional on all shocks and on shocks to real value added growth, labor cost inflation and price inflation. These estimates are surprising similar to the unconditional ones computed in Section 3. In most cases the estimates point to relatively large, positive and significant correlations, confirming the previous results that over the sample of analysis the link between labor cost and price inflation across euro area countries and sectors is quite strong, also after controlling for the own dynamics and the dynamic relationships with a real activity indicator. The only exception is the correlation conditional on shocks to price inflation which in several occasions is insignificant or negative, and in any event almost consistently lower than the correlations conditional on other shocks. The same correlation conditional on shocks to labor cost inflation is instead always positive and significant and can be as high as 0.96 (Spain, total economy).

An interesting result based on the same estimates is given by the forecast error variance decomposition (see Appendix F) which indicates that almost systematically (with the exception of Italian construction) the variance of inflation explained by shocks to labor cost inflation is bigger than the variance of labor cost inflation explained by price inflation. These percentages are not very high on average but can reach values as high as 70% (in France).

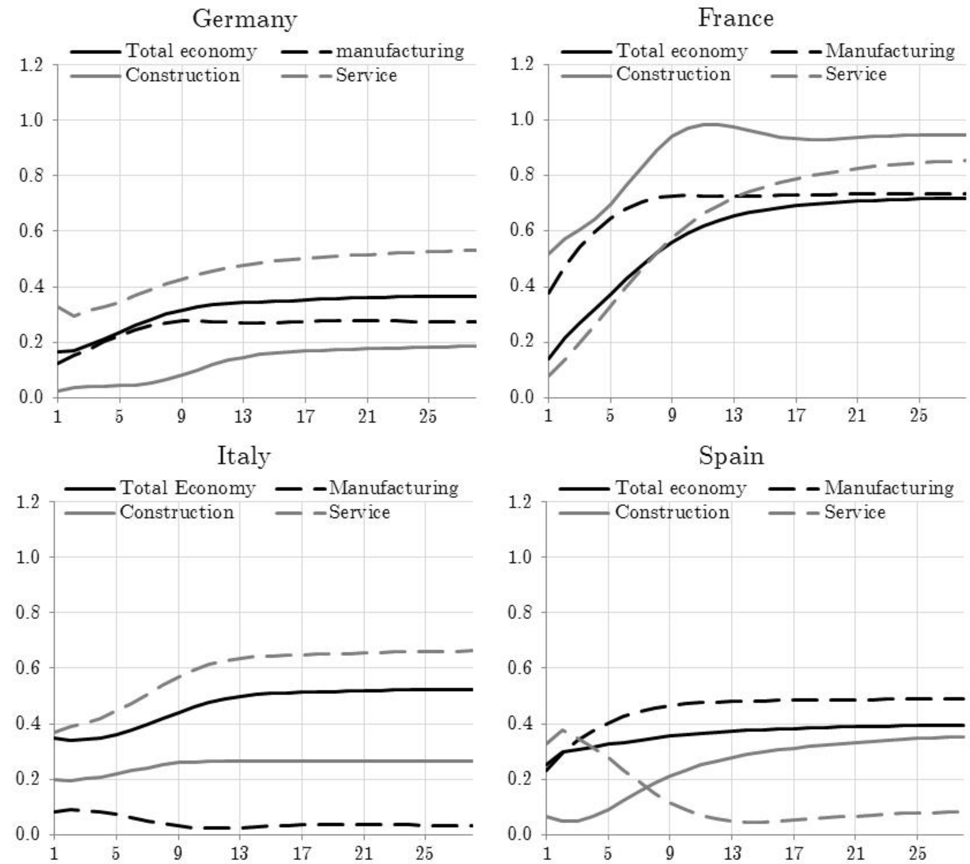
In order to better understand these results, Figure 6 plots the impulse response functions of price inflation to a shock to labor cost inflation, standardized as explained above in 4.1. The estimates can be interpreted as pass-through multipliers from labor cost to price inflation. The full set of results can be found in Appendix F where we also report the recursive estimates of the steady state pass-through distributions (median and 68% credible interval) for all sectors and countries.

These charts show that the steady state pass-through values are almost always significantly different from zero. Moreover, they confirm the finding from the unconditional cross-correlations (see Appendix C) that there is no apparent structural break or significant change in the link between labor cost and price inflation over time and that there are important heterogeneities across countries and sectors.

Concretely, France seems to have the highest pass-through values across all sectors. A cross check with the conditional and unconditional cross-correlations would confirm that the construction and manufacturing sector in France drive up the pass-through across the economy. By contrast, in Germany the service sector, where labor costs lead prices, drives the pass-through. The same goes for Italy, where the unconditional contemporaneous correlation was the highest for services. At the same time, unsurprisingly, in Spain the pass-through for the service sector diverges from the other sectors, in line with the fact that price inflation leads labor cost inflation by 6 quarters as reported in Figure 4.

In order to put in perspective these findings, we cross-checked them against two main results of the euro area Wage Dynamics Network (WDN), bearing in mind that those results are based on firm-level (survey) data that do not cover the post-crisis sample. First, our general result that on average across sectors and country the pass-through from labor cost to price inflation is positive and significant is consistent with the WDN result that a large

Figure 6: Choleski decomposition based pass-through from labor cost to price inflation



Sources: Authors' calculations.

percentage of firms surveyed declare that they use a strategy of increasing prices when faced with a (permanent) unexpected increase in wages, especially if firms produce intermediate goods. Second, the WDN finds that at the micro level the strength of the link between prices and labor cost depends on the labor share. In particular, firms with a high labor cost share report more frequently that there is a tight link between price and wage change. If we check the sectors that drive the highest pass-through across countries we are not able to confirm this result. With the exception of France, where the construction sector has the highest pass-through and the highest labor share, for the other countries the highest pass-through happens in sectors that have had the lowest labor share over the sample of the analysis (service in Italy and Germany; manufacturing in Spain, see Charts in Appendix E).

These results, together with the findings in Section 3 would suggest that, contrary to the results of the empirical literature based on US data (e.g. Peneva and Rudd (2017) and references therein), there is no evident or systematic decline in pass-through across euro area countries or sectors. One possible explanation for this divergent finding can simply be the consequence of the different detrending strategy that we adopt, by imposing a theory-based long-run restriction that the gap between productivity-adjusted nominal wage growth and price inflation disappears in the long-run because the two variables share a common trend.[14]

4.3 Main Findings: State-Dependent VAR Specification

Another important dimension in the context of the pass-through from labor cost to price inflation is to test the empirical proposition that this pass-through could depend on the level of price inflation. We look at this particular variable because reduced-form estimates of the pass-through from labor costs to price inflation capture the underlying nominal rigidities and the literature has highlighted that these rigidities may, inter alia, depend on the level of inflation. A low pass-through can be associated to a low inflation environment either because low inflation and low expected inflation persistence cause a low pass-through (Taylor (2000)), or because low levels of price inflation could be expected to reduce the pass-through due to downward wage rigidities (Daly and Hobijn (2014)).[15]

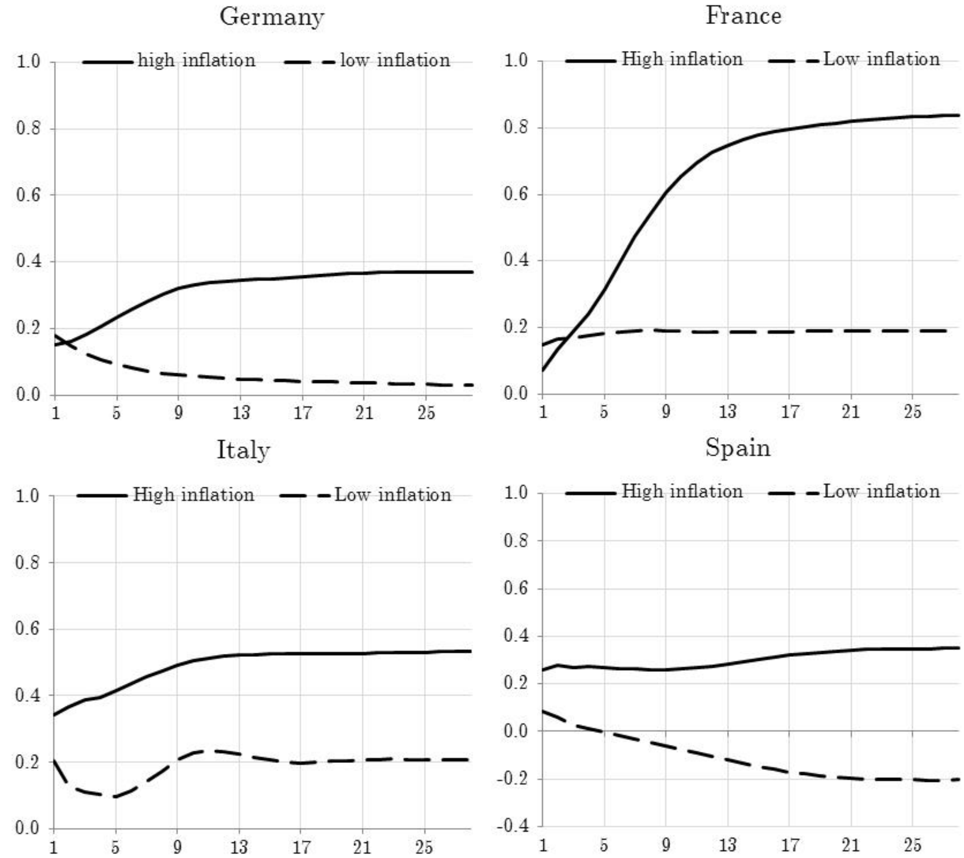
Our sample is not long enough to test this proposition on two regimes. However, in our VAR analysis we can directly test whether this is also the case for euro area countries as the reduced-form estimates of the pass-through from labor costs to price inflation would capture the underlying nominal rigidities. Therefore, we repeat the above exercise by estimating the VAR over two sets of observations, with the level of inflation in each set being above or below the corresponding historical averages, respectively. Results for the total economies are reported in Figure 7 (other sectors in Appendix G).

The findings support the theoretical and US based empirical literature. Across euro area sectors and countries (with the exception of the construction sector in Italy) the pass-through is systematically higher if it is estimated over samples when the inflation rate of the corresponding sector is higher than the historical average. The finding would also supports the current forecast narratives, which see a pickup in labor cost inflation as a necessary condition for rising inflation, to the extent that higher inflation expectations associated with a change from lower to higher inflation rates could raise the pass-through which in turn could speed up the inflationary process again.

[14] We have computed a time-varying pass-through for the US data using the same specification as in Peneva and Rudd (2017), removing a common trend from adjusted wages and price inflation and the results confirm this intuition.

[15] Another argument that has been suggested as to why the pass-through from costs to inflation could increase with the level of inflation is linked to the search intensity of consumers. Concretely, at low levels of inflation, a large fraction of buyers observe a single price. In that case, any given shock would increase price dispersion sharply, which would increase the search intensity of consumers, thereby reducing firm market power, which limits the ability of firms to pass on the cost increase to prices. At higher levels of inflation, price dispersion is higher and hence any given shock has only a limited impact on price dispersion and the search intensity of consumers. As a result, prices are at higher levels of inflation more responsive to shocks (see Head et al. (2010)).

Figure 7: Choleski decomposition based pass-through from labor cost to price inflation under low versus high price inflation



Sources: Authors' calculations.

These results have implications for the behaviour of profit margins. In a high-inflation environment profits might act less as a buffer than in a low-inflation regime due to an intertemporal smoothing of the profit path. For instance, when inflation is high and wages increase firms may expect an increase in interest rates which worsens their borrowing conditions and squeezes their future profit margins; hence, they will maintain their profits in the present, which would favor the pass-through from labour costs to prices. Conversely, the opposite might hold in a lower inflation regime where decreases in interest rates are expected. Another explanation could relate to the higher degree of economic uncertainty associated with a high inflation regime: in such a regime firms may simply not be prepared to buffer a labor cost increase with margins.

5 Is the link between labor costs and price inflation shock-dependent?

One of the challenges of empirically grasping the link between wages and prices arises from the fact that the pass-through may simultaneously depend on several factors. The previous sections allowed us to obtain a preliminary indication of the size of the pass-through from labor cost to price inflation and of the extent to which it has changed over time or has been dependent on the state of the economy (e.g. the level of inflation).

The analysis, however, could not allow us to identify the source of the correlation between labor cost and prices fluctuations or the nature of the exogenous shocks that were moving labor cost inflation and passed on to price inflation. In this section, we want to take a step further and argue that the pass-through is not a deep parameter underlying the economy, but a shock-dependent coefficient that reflects the mechanisms underlying macro fluctuations.

We know, for instance, that in a New Keynesian model the conditional correlation between labor cost and prices is different for demand and for supply shocks. The idea of the relationship between variables being shock dependent has also recently been advocated in the exchange rate empirical literature (see e.g. Forbes et al. (2018), Comunale and Kunovac (2017) and references therein). The same idea, translated to the labor cost pass-through to inflation, has recently become popular in policy circles.[16] ECB (2018b) presents evidence based on the New Area-Wide Model where the response of the GDP deflator to wages is different for supply shocks than for demand shocks, with this response being stronger to demand than to the supply shocks, where the latter capture frictions in the wage setting such as the impact of structural reforms or non-linearities like downward wage rigidity.

5.1 A structural VAR analysis

We address the question of the pass-through shock-dependence in the same 3-variable VARs and identify a supply and a demand-type shock for all countries and sectors using the most parsimonious set of sign restrictions as reported in 2.

Specifically, a positive demand shock is a shock that increases output growth and price inflation, whereas a supply shock reduces output growth but increases price inflation. A third

[16] The shock dependency of the pass-through should depend on the degree of both price and labor cost stickiness. The theoretical literature analyzing this issue is however scant. Most studies have focused on the impact of shocks on both labor cost and prices rather than on the pass-through of labor costs to price inflation following such shock. However, Bils and Chang (2000) did put forward a theoretical framework in which price rigidity differs with the nature of shocks, with prices being more responsive to increases in costs generated by factor prices than to an increase in marginal costs generated by an expansion of output. Model-based results show that prices react more to a technology (supply) shock than to a preference (demand) shock. Although this paper spells out clearly that it's important to disentangle between the nature of the shocks in seeing how prices react, it does not speak precisely to the question we are interested in, related to the wage pass-through to prices.

Table 2: The 2 shocks VAR: identification scheme

Variables	*Shocks*		
	Demand	Supply	Other
Real value added	+	+	•
Prices	+	-	•
ULC	•	•	•

Notes: • = unconstrained, + = positive sign, − = negative sign

shock in the model is left unidentified. The restrictions are imposed only for the first period and all restrictions are imposed as inequality restrictions. The VAR is estimated as in the previous section with Bayesian techniques and a normal-diffuse prior with a Minnesota prior for the mean and the variance of the VAR parameters. Impulse responses are computed based on 5000 draws from the posterior simulators.

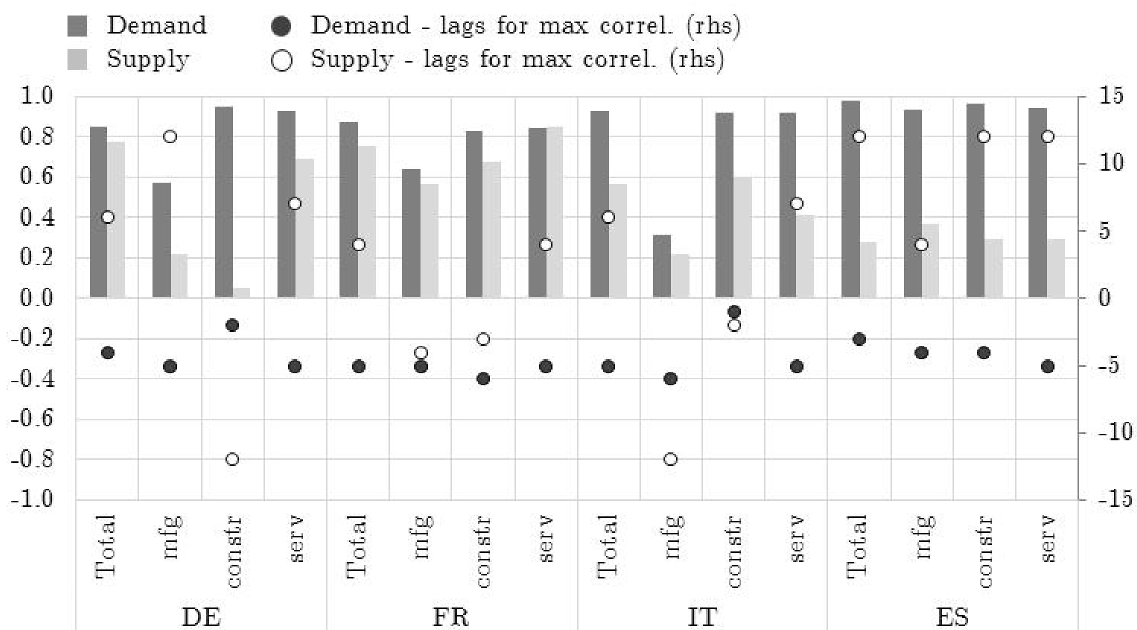
The baseline results from our estimation are reported in Appendix H. By construction, we find that output and price inflation rise after a positive demand shock, but that output falls and prices rise after a positive supply shock. In all cases we had left in the sign restriction estimation the response of labor costs unspecified. It turns out that labor cost growth tends to decrease immediately after a positive demand shock and rise thereafter (that can be due to the fact that the increase in wages is smaller than the one in productivity, as the output tends to grow more than employment, as suggested by ECB (2018b). After a positive supply shock, labor cost inflation increases.

Equipped with these estimates we run two counterfactual experiments. In the first experiment we compute the counterfactual labor costs and price inflation that would be generated by a demand or a supply shock and check how does the correlation structure between the counterfactual variables change according to the shock. In the second experiment we compute the counterfactual responses of price inflation to demand or supply shocks and check how much amplification we give up by shutting down the labor cost channel, i.e. the response of labor cost inflation to the same shock.

5.2 The correlation between labor costs and price inflation conditional on demand and supply shocks

The first experiment consists of computing a historical decomposition and isolating the counterfactual labor cost inflation and price inflation that would have been generated by demand or supply shocks only. The correlation structure between these counterfactual series is then checked as in Gali (1999). We compute the maximum correlation over a wider lead/lag struc-

Figure 8: Maximum correlation between price inflation at (time t) and labor cost inflation (time t-k) and the lag for maximum correlation



Note: The chart shows the cross correlation between counterfactual price inflation at time t and labor cost inflation at time t-k. Sample period: 1985Q1-2018Q1.

ture. Results are reported in Figure 8 which shows the cross-correlation between the counterfactual price inflation at time t and labor cost inflation at time t-k. From the Figure one can see that demand shocks affect prices and labor costs in a similar manner and prices appear to lead labor costs in their response to demand shocks. Conversely, supply shocks appear to affect prices and labor costs differently, with in most cases labor costs leading price inflation. The Figure also shows that the correlation between labor cost inflation and price inflation tends to be higher for demand than for supply shocks. This simple fact can help to shed some light on the lack of consensus in the empirical literature that has tried to disentangle the direction of causality in the wage-price inflation nexus (Knotek and Zaman, 2014): results are likely to depend on the sample and on the combination of shocks hitting the economy over that particular sample.

5.3 The amplification due to the labor cost channel

In the second experiment, we check the importance of the labor cost channel as an amplifier for the response of price inflation. In this case, we identify the same demand and supply-type of shocks and then compare the response of price inflation in a system where all variables endogenously react to the initial shock with the response of price inflation in a system where the response of labor costs has been shut down. This will tell us how much of the shock is passed on to prices via labor costs.

To give an intuition for this approach, consider a positive demand shock which boosts prices as firms have a higher pricing power and their demand for inputs of production also increases. Of all the mechanisms through which demand shocks affect prices, one particular channel relates to higher labor costs. We would like to isolate this channel by gauging the impact of demand shocks on prices through labor costs. We will compute an impulse response function (IRF) where the response of wages to a demand shock is zero and check the difference between the unrestricted IRF for prices and the IRF for prices when labor costs do not react to demand shocks. This difference is an indication of how much of the impact of demand shocks on inflation is driven by labor costs.

This is similar to Wong (2015), who analyzes the second round effects on prices coming from oil price shocks by shutting down the inflation expectations channel. He computes counterfactual $IRFs$ assuming that inflation expectations do not react to oil price movements; this is implemented by *modifying the inflation expectations shocks* to offset the impact coming from oil shocks (all in a Choleski identification scheme).

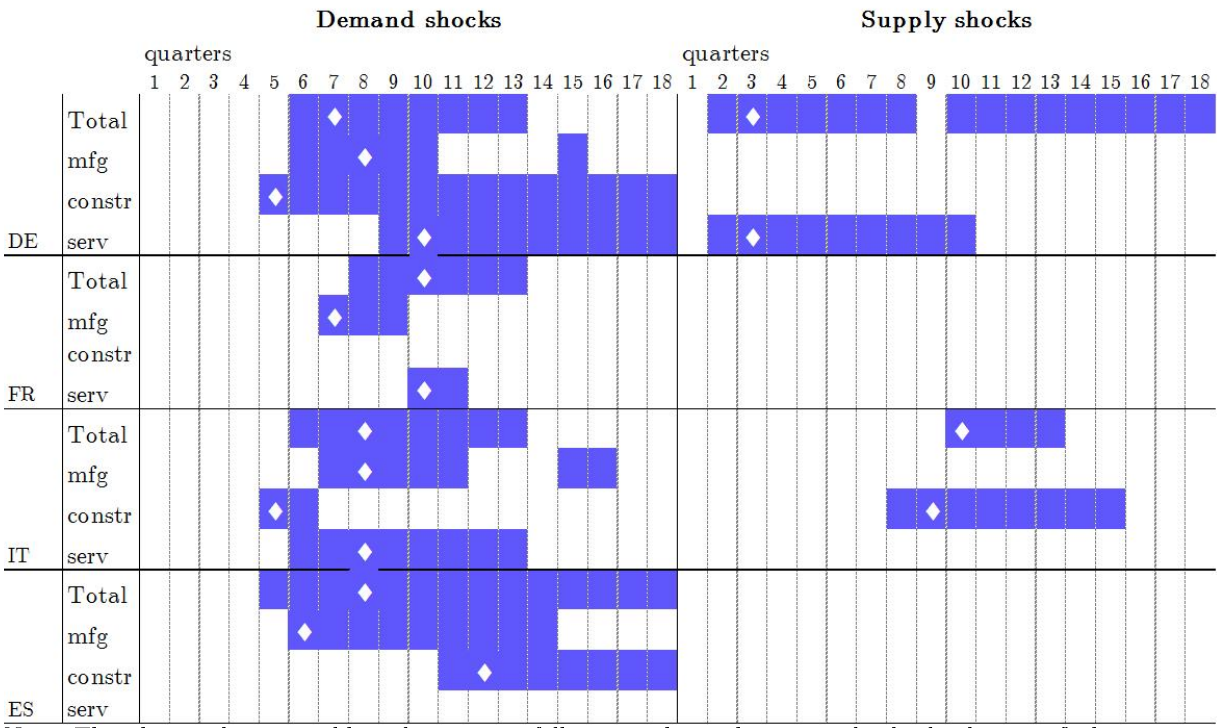
If we move away from the Choleski identification scheme to one based on sign or zero restrictions things get more complicated. Lets say we want labor costs not to react to demand shocks; there is no *labor cost shock* to offset the response of labor costs to demand shocks. One would have to make certain assumptions on which other shocks are doing the offsetting (is it the technology, the labor supply or, our preferred version, a combination of the two). Appendix J shows how we derive the counterfactual $IRFs$.

Results of the counterfactual exercise are summarized in Figure 9. This Figure shows in a synthetic manner the quarters we find a statistically significant difference between the impulse responses with and without the labor cost channel. A missing number shows a statistically insignificant effect in that specific quarter, a blue cell indicates that a statistically significant difference. The white diamond shows the quarter for which this amplification reaches its peak.

The striking feature is that under demand shocks we see an almost systematically significant amplification which is also consistently higher than the amplification under supply shocks. In other words, when the economy is predominantly hit by demand-type shocks, the increase in wages above productivity is passed on to inflation more than when the economy is predominantly hit by supply-type shocks. It is worth noting that the picks of this pass-through tends to occur at a higher lag for demand-type shocks than for supply-type shocks and the pass-through is also more persistent.

The question that arises from these results is: Why would the pass-through of labor costs to prices be bigger or more significant when the economy is hit by a demand than by a supply shock? This analysis cannot provide a definite answer. But it can be reconciled with previous

Figure 9: Amplification of price inflation response due to the wage channel



Note: This chart indicates, in blue, the quarters following a demand or a supply shock where we find a statistically significant difference between the impulse responses to price inflation with and without the labor cost channel. The white diamond indicates the quarter for maximum impact of the price inflation response.

findings whereby the willingness of firms to increase prices after labor cost increases is larger when positive demand shocks dominate. In such an environment, the share of higher income consumers with lower demand elasticity increases, which in turn raises firms ability and power to pass-through cost increases to prices (see for instance Dornbusch (1987) and Bergin and Feenstra (2001)). This has implications for the differentiated behavior of profit margins. In an environment where labour costs increase due to demand shocks, profits would act as a buffer to a smaller extent than when the increase occurs due to supply shocks.

We also acknowledge the caveat that the trivariate VAR is insufficient to properly identify supply-type shocks which in our parsimonious representation are identified based on the negative co-movement between output and prices. This simple identification scheme can in fact hide various supply shocks. One can imagine three types of such shocks, all of them increasing output and reducing prices: (i) a positive technology/productivity shock, which increases wages; (ii) a negative wage mark-up shock, which reduces wages; and (iii) a positive labor supply shock, which also reduces wages. The next subsection (partially) deals with this idea.

Table 3: The 4 shocks VAR: identification scheme

Variables	*Shocks*				
	Demand	Supply	Labor supply	Wage mark-up	Other
Real value added	+	+	+	+	•
Prices	+	-	-	-	•
Wages	+	+	-	-	•
Productivity	+	+	•	•	•
Unemployment rate	-	•	+	-	•

Notes: • = unconstrained, + = positive sign, − = negative sign

5.4 Robustness check: A structural VAR with labor market shocks

In this subsection we check the robustness of the results obtained above along 2 dimensions: first, we enrich the identification scheme with more shocks on the labor market and second, instead of a VAR including labor cost inflation we consider a VAR including both wage and productivity growth separately, and we construct counterfactual $IRFs$ where we impose that the difference in wage and productivity growth is shut down after a certain shock hits (see details in the Appendix).

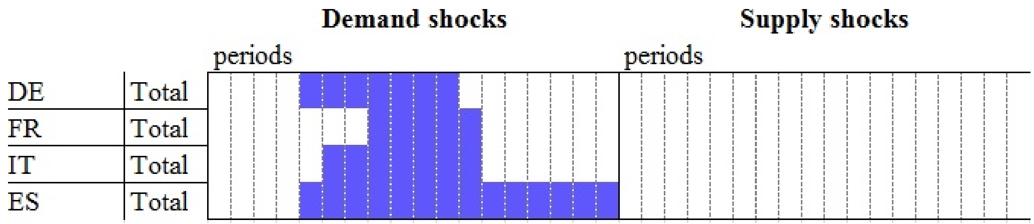
The first issue we address is particularly important, because, what we identify as a "supply shock" based on the negative co-movement between output and prices could in fact bundle together various types of shocks, as said above, and this complicates the computation of a proper pass-through coefficient.

The VAR is now composed of 5 variables, namely: real value added, deflator inflation, nominal compensation per employees, labor productivity, and unemployment rate. The system can only be estimated on the total economies, because we don't have unemployment data at sectoral level.

Besides the *classical* demand and supply shocks, this system allows us to identify two more labor market shocks, as shown in Table 3. A positive labor supply would increase the labor force participation, which translates into a positive impact on output and on the unemployment rate. Wage growth falls, and so does inflation; the different wages response allows disentangling labor supply from technological shocks, as explained in Peersman and Straub (2009). A wage mark-up shock, or a wage bargaining shock, is a shock that allows firms to capture a larger share of the bargaining surplus, which contributes to lower marginal costs, wage growth and inflation. Output increases and the unemployment rate decreases, as detailed in Foroni et al. (2018).

Results are reported in Figure 10. Overall, the results from the larger VAR model confirm

Figure 10: Amplification of price inflation response due to the wage channel in the 4 variable VAR



the findings in the previous subsection, namely that the pass-through from labor cost to price inflation the case of a demand shock is consistently higher than under a supply shock.

6 Summary and conclusions

Understanding the signal labor cost developments is providing for the euro area inflationary process is of key relevance from a policy perspective. For instance, the projections for euro area inflation are based on the expectation that increasing labor market tightness will push up wage growth and, given a rather flat outlook for labor productivity, the resulting higher unit labor cost increases should be passed on, at least partly, to prices. However, to date, there does not exist a study which systematically analyses the empirical link between labor cost inflation and price inflation for the euro area and the euro area countries. In this paper we document this link for the first time.

Using country and sector quarterly data over the period 1985Q1-2018Q1 we uncover a number of facts. First, somewhat contrary to the current view that the labor market indicators do not seem to contain information for inflation beyond the one already contained in other indicators, we find that the cost-push view of inflation found in the economic theory can have some support in the data. We document a strong link between labour cost and price inflation in the four major economies of the euro area and across three sectors (manufacturing, construction and service).

Second, the analysis supports an average high pass-through from costs to prices, in line with available firm-level evidence which documents a statistically significant relationship from the frequency of wage changes to that of prices, and a common strategy by several firms of increasing prices when faced with unexpected increases in wages (Druant et al. (2009)).

Third, the link between price and ULC is quite heterogeneous across countries and sectors. France is the country where this pass-through is higher with the link being stronger in the construction sector. In Germany and Italy the driving sector is service, while in Spain the manufacturing sector shows the highest pass-through. Hence, with the exception of France, this evidence contrasts with the idea that the pass-through of wages into prices should be particularly strong in firms/sectors with a high labor share, i.e. sectors which should also be characterized by a higher degree of price stickiness (Druant et al. (2009)).

Fourth, the dynamic interaction between prices and wages is time-varying and depends on the state of the economy. In particular, the pass-through is systematically lower in periods of low inflation as compared to periods of high inflation. This results would be in line with an expectation theory as e.g. proposed by Taylor (2000), whereby *a decline in the degree to which firms pass through changes in costs to prices is frequently characterized as a reduction in the pricing power of firms.*

Fifth, the wage-price pass-through also depends on the shocks hitting the economy. The results presented show that the pass-through from ULC to price inflation tends to be higher and more significant with demand shocks than with supply shocks on average across countries and sectors. This result holds also when we augment the dynamic system to disentangle more clearly various types of supply shocks, e.g. to capture frictions in the wage setting such as the impact of structural reforms or non-linearities like downward wage rigidity. Rationalizing this result is not simple as there is no comprehensive theoretical literature which focuses on the difference in the wage pass-through to inflation according to different shocks. Some limited theoretical frameworks are available where price rigidity differs with the nature of shocks, with prices being more responsive to increases in costs generated by factor prices driven by technology than to increases in marginal costs generated by an expansion of output driven by preferences (see e.g. Bils and Chang (2000)), but nothing can be inferred about the pass-through from wages to prices.

Overall, our results support the current Eurosystem forecast narrative (see ECB (2018a)), which relies on the pick-up in wage growth for the one in underlying inflation. Concretely, our results would support the idea that under the current circumstances of predominantly demand shocks (as documented in ECB (2018b)) labor cost increases will be passed on to prices. Coming from a period of low inflation, however, this pass-through could be moderate at least until inflation stably reaches a sustained path.

Appendix A Data documentation

Most standard data (i.e. nominal value added, real value added, compensation of employees, total employees) were obtained in seasonally and working day adjusted level format from the national accounts over the period 1985Q1-2018Q1 for the 4 biggest euro area countries. All series were obtained for the aggregate economy and three sectors: manufacturing, construction and services. For the Netherlands, these series were only available for the period 1987Q1-2018Q1.[17] The euro area aggregate was constructed on the basis of the five biggest countries for the period 1987Q1-2018Q1 using real value added weights.

Nominal and real effective exchange rate series were obtained from the BIS and Brent oil prices from the Energy Information Agency. National import prices for goods and services and unemployment rates were also obtained from national sources through Haver Analytics, with the exception of the Germany unemployment rate for which the long history was obtained through the IMF IFS. The Spanish unemployment rate historical series were not seasonally adjusted. The adjustment was made using X-12-ARIMA.

A number of series were derived on the basis of the national accounts data. The value added deflator was calculated as the ratio of the nominal to real value added. Labor productivity was measured as the ratio of real value added to total employees while compensation per employee was calculated as the ratio of compensation of employees to total employees. The real value added gap was obtained through an HP filtering approach. Finally, two measures of unit labor costs were considered: one was calculated as the ratio of compensation per employee to labor productivity. Alternative, trend unit labor cost was defined by the ratio of compensation of employees to a measure of trend labor productivity growth (obtained through the HP filtering approach).

More details on the country specific national accounts data are listed below:

Germany: Official aggregate data on unemployment rate and import prices, and aggregate and sectoral data on real value added, nominal value added, compensation of employees and total employees were obtained from the Federal Statistical Office through Haver Analytics. In the case of the services sector and total employees, all long time series were constructed by chain linking the ESA2010 (NACE2) and ESA1995 (NACE1) databases. The series were adjusted for the structural break due to unification. Data prior to 1991 is for West Germany only. For services, data prior to 1991 is the sum of hotels and transport, finance and business services and public and personal services.

France: Official aggregate data on unemployment rate and import prices, and aggregate and sectoral data on real value added, nominal value added, compensation of employees and

[17] Prior to 1987, compensation of employee data at sectoral level is only available on an annual basis for the Netherlands

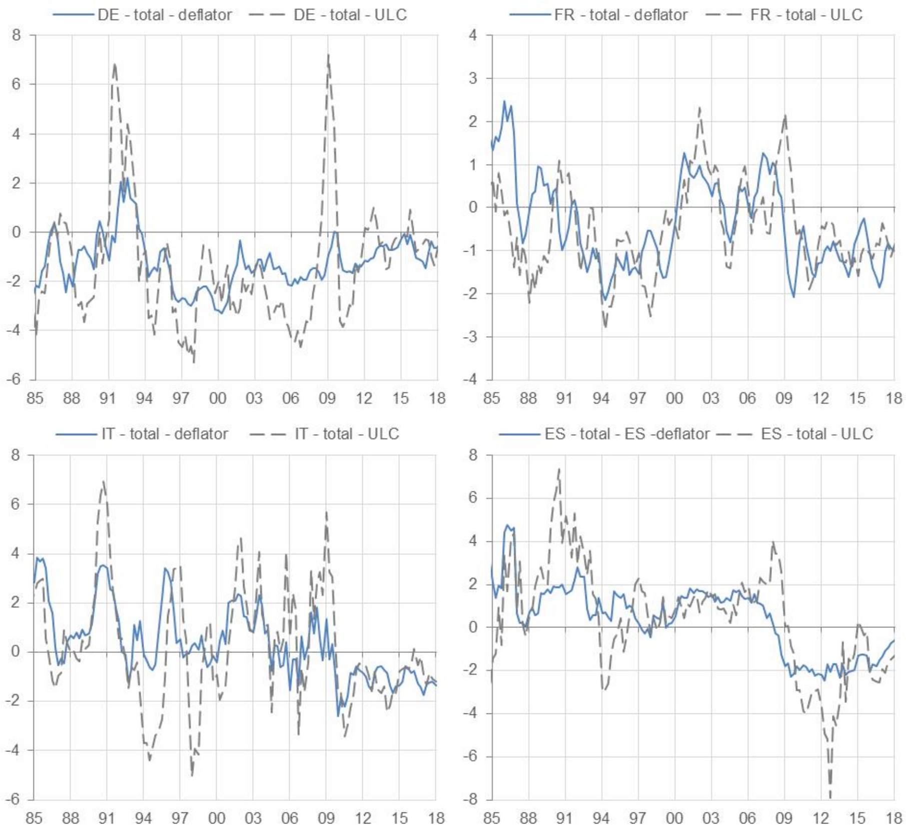
total employees were obtained from the INSEE through Haver Analytics. Services sector data were calculated as the sum of market and non-market services.

Italy: Official aggregate data on unemployment rate and import prices, and aggregate and sectoral data on real value added, nominal value added, compensation of employees and total employees were obtained from the INE through Haver Analytics. In the case of the services sector, all long time series were constructed by chain linking the ESA2010 (NACE2) and ESA1995 (NACE1) databases.

Spain: Official aggregate data on unemployment rate and import prices, and aggregate and sectoral data on real value added, nominal value added, compensation of employees and total employees were obtained from the INE through Haver Analytics. With the exception of the total economy data, long series were constructed by chain linking the ESA2010 (NACE2) and ESA1995 (NACE1) databases. For services, data prior to 1995 is the sum of market and non-market services series. Historical data on real value added and compensation of employees was obtained from the INE website. Note that in the case of Spain, long historical data on the manufacturing sector was not available, the data shown is for the industry .

Appendix B Detrended Series

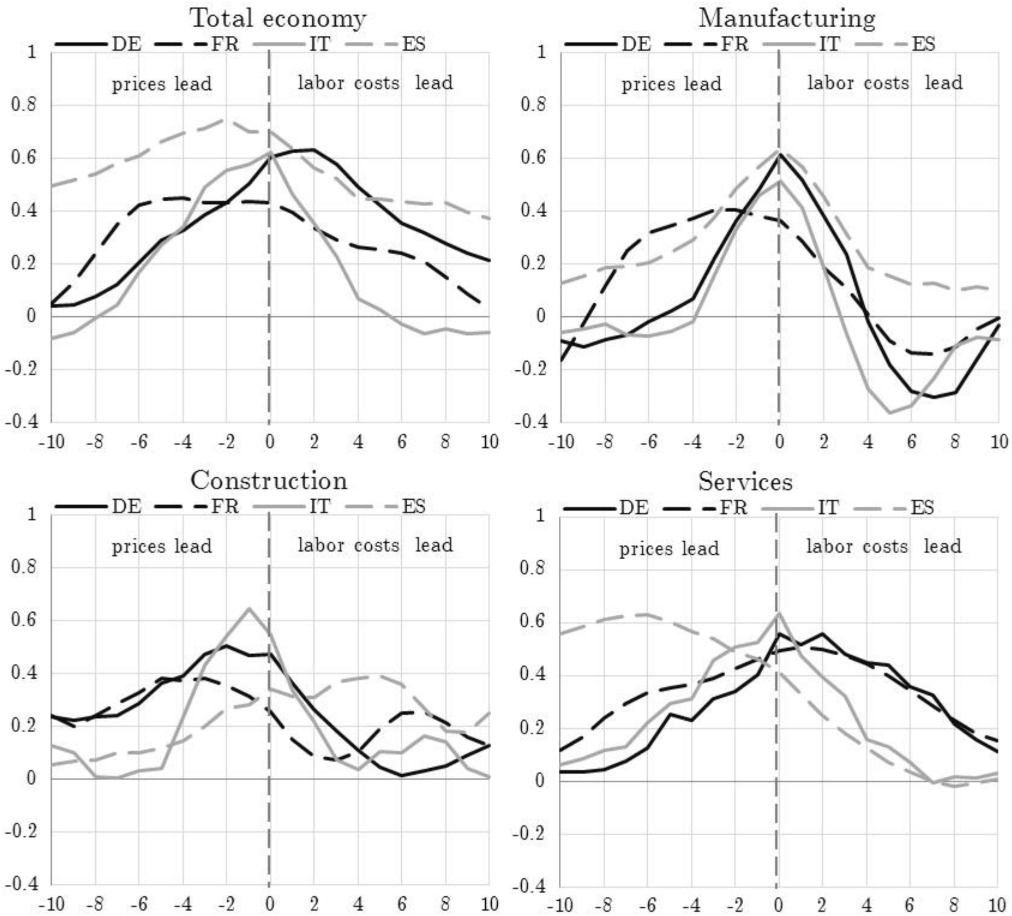
Figure 11: Detrended Unit Labor Cost and GDP deflator, year on year % change



Sources: Various sources, authors' calculations. Latest observation: 2018Q1.

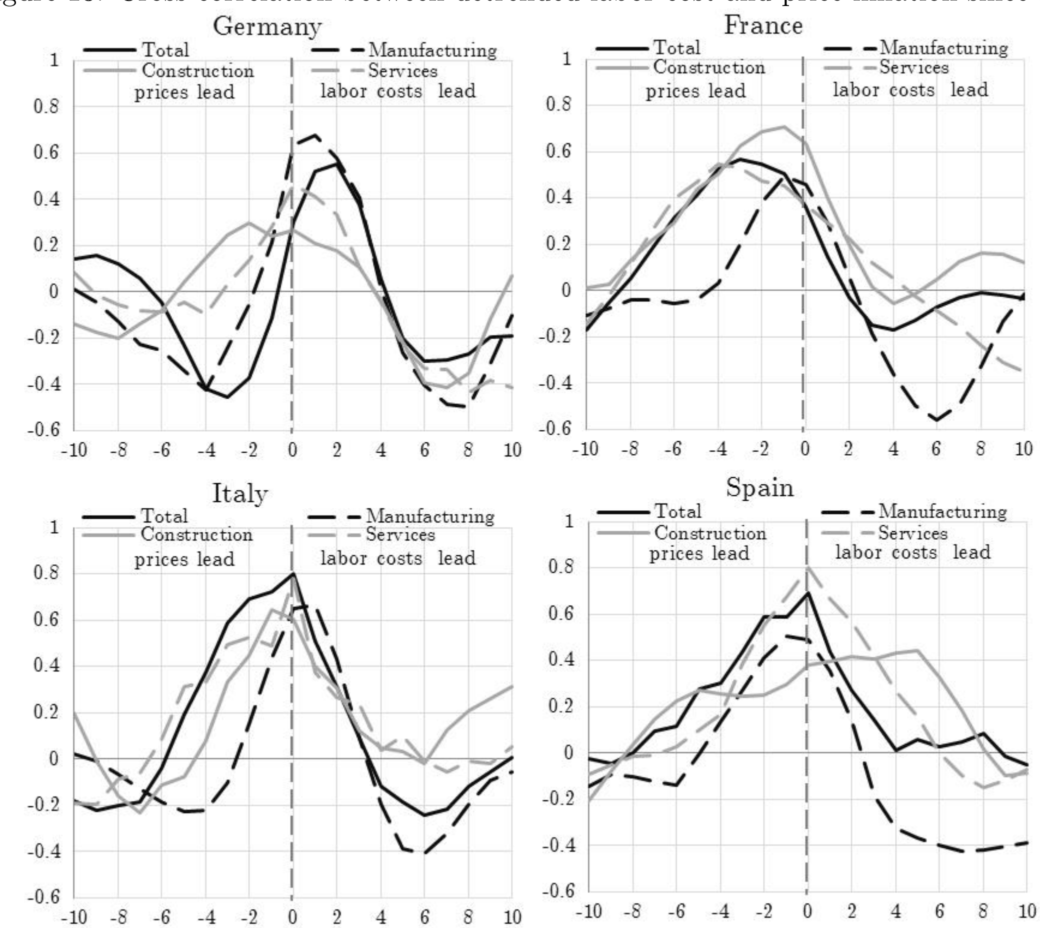
Appendix C Cross correlations by sectors and across time

Figure 12: Cross correlation between detrended labor cost and price inflation



Sources: Various sources, authors' calculations. Note: the charts show the cross correlation between price inflation gaps at time t and labor cost inflation gaps at time t-k. Sample period: 1985Q1-2018Q1.

Figure 13: Cross correlation between detrended labor cost and price inflation since 2008



Sources: Various sources, authors' calculations. Note: the charts show the cross correlation between price inflation gaps at time t and labor cost inflation gaps at time t-k. Sample period: 2008Q1-2018Q1.

Appendix D Forecast evaluation

Table 4: Forecasting power of labor costs for price inflation. Ratio of RMSE of inflation forecasts of models with to models without labor cost.

	199Q1-2018Q1				**1999Q1-2007Q4**				**2008Q1-2018Q1**			
					GERMANY							
steps	total	mfg	const	serv	total	mfg	const	serv	total	mfg	const	serv
1	1.01	0.96	1.04	0.99	1.12	0.93	1.02	1.01	0.90	0.97	1.07	0.95
2	0.97	0.97	1.02	0.98	1.13	0.91	0.99	1.02	0.83	1.01	1.04	0.93
3	0.93	0.90	1.01	0.99	1.10	0.85	0.99	1.02	0.81	0.94	1.02	0.95
4	0.91	0.90	1.01	0.99	1.05	0.82	0.99	1.01	0.80	0.96	1.02	0.96
5	0.89	0.87	1.00	0.99	1.05	0.82	0.99	1.01	0.78	0.93	1.00	0.98
6	0.87	0.84	0.99	0.99	1.04	0.82	0.99	1.00	0.77	0.83	0.99	0.99
7	0.85	0.77	0.99	1.00	0.99	0.89	0.99	0.99	0.77	0.68	0.99	1.00
8	0.87	0.75	0.99	1.00	0.98	0.99	0.99	1.00	0.79	0.62	1.00	1.01
					FRANCE							
steps	total	mfg	const	serv	total	mfg	const	serv	total	mfg	const	serv
1	1.00	1.02	1.04	0.96	1.04	1.01	1.06	0.99	0.96	1.03	1.00	0.94
2	0.96	1.01	1.07	0.91	0.95	1.01	1.12	0.90	0.96	1.01	1.01	0.93
3	0.93	1.02	1.07	0.88	0.88	1.01	1.12	0.80	0.96	1.02	1.02	0.92
4	0.91	1.01	1.05	0.85	0.83	0.99	1.09	0.72	0.97	1.01	1.05	0.92
5	0.88	0.99	1.04	0.84	0.77	0.97	1.07	0.69	0.96	0.99	1.06	0.91
6	0.87	0.97	1.02	0.86	0.78	0.95	1.05	0.74	0.95	0.98	1.06	0.91
7	0.88	0.97	1.01	0.89	0.81	0.95	1.05	0.83	0.94	0.97	1.03	0.91
8	0.90	0.98	1.01	0.92	0.86	0.96	1.06	0.93	0.93	0.99	1.00	0.90
					ITALY							
steps	total	mfg	const	serv	total	mfg	const	serv	total	mfg	const	serv
1	0.95	1.09	1.00	1.00	0.92	1.06	1.00	1.01	0.99	1.11	1.00	0.99
2	0.99	1.04	1.00	1.01	0.95	1.06	1.00	1.02	1.05	1.04	1.00	0.98
3	1.05	1.01	1.00	1.01	1.05	1.01	1.00	1.03	1.06	1.01	1.00	0.99
4	1.07	1.01	0.99	1.03	1.07	1.02	1.01	1.06	1.08	1.01	0.99	0.99
5	1.06	1.01	0.99	1.02	1.04	1.00	0.99	1.05	1.08	1.01	0.99	1.00
6	1.06	1.01	0.99	1.00	1.03	0.99	0.98	1.01	1.09	1.02	0.99	1.00
7	1.05	1.01	0.98	1.01	1.04	0.98	0.97	1.01	1.07	1.03	0.98	1.00
8	1.04	1.02	0.98	0.99	1.01	0.98	0.95	0.98	1.06	1.04	0.98	1.00
					SPAIN							
steps	total	mfg	const	serv	total	mfg	const	serv	total	mfg	const	serv
1	0.95	1.03	1.01	1.40	0.97	1.19	1.01	1.26	0.94	0.96	1.00	1.47
2	0.88	1.04	1.01	1.61	0.94	1.23	1.02	1.46	0.87	0.98	0.99	1.66
3	0.81	1.00	1.00	1.70	0.93	1.16	1.01	1.62	0.79	0.96	0.98	1.73
4	0.80	0.97	1.00	1.71	0.96	1.08	1.01	1.58	0.77	0.95	0.97	1.74
5	0.80	0.97	1.00	1.73	1.05	1.04	1.01	1.57	0.76	0.96	0.96	1.77
6	0.81	1.00	1.00	1.71	1.17	1.04	1.01	1.57	0.76	0.99	0.98	1.76
7	0.83	1.03	1.01	1.69	1.21	1.03	1.01	1.54	0.78	1.03	1.00	1.73
8	0.85	1.04	1.01	1.66	1.21	1.06	1.01	1.45	0.79	1.03	1.01	1.71

Table 5: Forecasting power of labor costs for price inflation. Theil-U of inflation forecasts conditional on observed path of labor cost

	199Q1-2018Q1				**1999Q1-2007Q4**				**2008Q1-2018Q1**			
GERMANY												
steps	total	mfg	const	serv	total	mfg	const	serv	total	mfg	const	serv
1	1.00	0.91	0.89	0.99	1.00	0.86	1.09	1.07	1.03	1.03	1.09	0.98
2	0.98	0.95	0.85	0.97	0.97	0.78	1.04	1.07	1.06	1.13	1.12	0.96
3	0.96	0.95	0.82	0.94	0.94	0.72	0.94	1.11	0.98	1.15	1.08	0.85
4	0.96	0.85	0.81	0.93	0.97	0.66	0.89	1.16	0.79	1.03	1.04	0.81
5	0.93	0.79	0.80	0.86	0.96	0.64	0.82	1.12	0.59	0.86	0.97	0.75
6	0.89	0.77	0.82	0.79	0.94	0.62	0.81	1.07	0.49	0.83	0.93	0.72
7	0.87	0.76	0.87	0.73	0.96	0.66	0.84	1.04	0.44	0.80	0.94	0.72
8	0.84	0.72	0.91	0.66	0.96	0.71	0.88	0.88	0.46	0.73	0.94	0.69
FRANCE												
steps	total	mfg	const	serv	total	mfg	const	serv	total	mfg	const	serv
1	0.78	0.94	0.83	0.99	0.90	0.96	0.95	1.07	0.90	0.95	0.73	0.99
2	0.75	0.88	0.78	1.00	0.88	0.93	0.98	1.07	0.86	0.84	0.63	1.01
3	0.74	0.83	0.77	0.99	0.86	0.90	1.04	1.05	0.88	0.77	0.60	1.03
4	0.77	0.80	0.79	0.98	0.87	0.85	1.09	1.01	0.93	0.74	0.60	1.04
5	0.83	0.80	0.86	0.97	0.96	0.83	1.17	0.98	0.96	0.75	0.63	1.05
6	0.90	0.84	0.94	0.95	1.03	0.89	1.23	0.98	0.99	0.79	0.67	1.04
7	0.95	0.91	0.99	0.92	1.06	0.97	1.18	0.99	1.00	0.85	0.70	1.01
8	0.99	0.94	0.99	0.88	1.03	1.00	1.11	0.99	1.01	0.88	0.70	0.96
ITALY												
steps	total	mfg	const	serv	total	mfg	const	serv	total	mfg	const	serv
1	0.69	0.96	0.82	0.58	0.76	0.87	0.75	0.65	0.72	0.98	0.75	0.60
2	0.73	0.89	0.84	0.69	0.78	0.71	0.76	0.72	0.79	0.89	0.71	0.79
3	0.71	0.83	0.82	0.72	0.75	0.65	0.70	0.75	0.77	0.81	0.68	0.84
4	0.67	0.79	0.78	0.68	0.69	0.61	0.60	0.66	0.74	0.73	0.66	0.80
5	0.71	0.76	0.79	0.73	0.71	0.62	0.64	0.67	0.76	0.67	0.69	0.86
6	0.73	0.78	0.76	0.79	0.77	0.65	0.70	0.75	0.75	0.68	0.67	0.82
7	0.76	0.82	0.80	0.81	0.78	0.71	0.83	0.75	0.76	0.73	0.74	0.84
8	0.77	0.84	0.97	0.82	0.76	0.75	1.23	0.74	0.77	0.75	0.93	0.84
SPAIN												
steps	total	mfg	const	serv	total	mfg	const	serv	total	mfg	const	serv
1	0.96	0.93	1.03	1.05	0.80	0.87	0.95	1.25	0.82	0.94	1.16	1.24
2	1.02	0.89	1.06	1.07	0.87	0.81	0.97	1.36	0.76	0.89	1.06	1.33
3	0.97	0.87	1.07	1.07	0.86	0.80	0.96	1.49	0.70	0.84	1.01	1.34
4	0.99	0.88	1.07	1.07	0.86	0.83	0.98	1.55	0.69	0.82	0.99	1.31
5	0.96	0.91	1.02	1.09	0.86	0.92	0.98	1.71	0.67	0.80	0.86	1.22
6	0.94	0.93	0.94	1.09	0.86	1.04	0.97	1.86	0.68	0.76	0.73	1.16
7	0.95	0.93	0.87	1.09	0.90	1.09	0.96	1.89	0.73	0.73	0.67	1.06
8	0.94	0.95	0.82	1.05	0.92	1.08	0.92	1.57	0.77	0.71	0.60	1.02

Table 6: Forecasting power of price inflation for labor cost inflation. Ratio of RMSE of labor cost inflation forecasts of models with to models without price inflation.

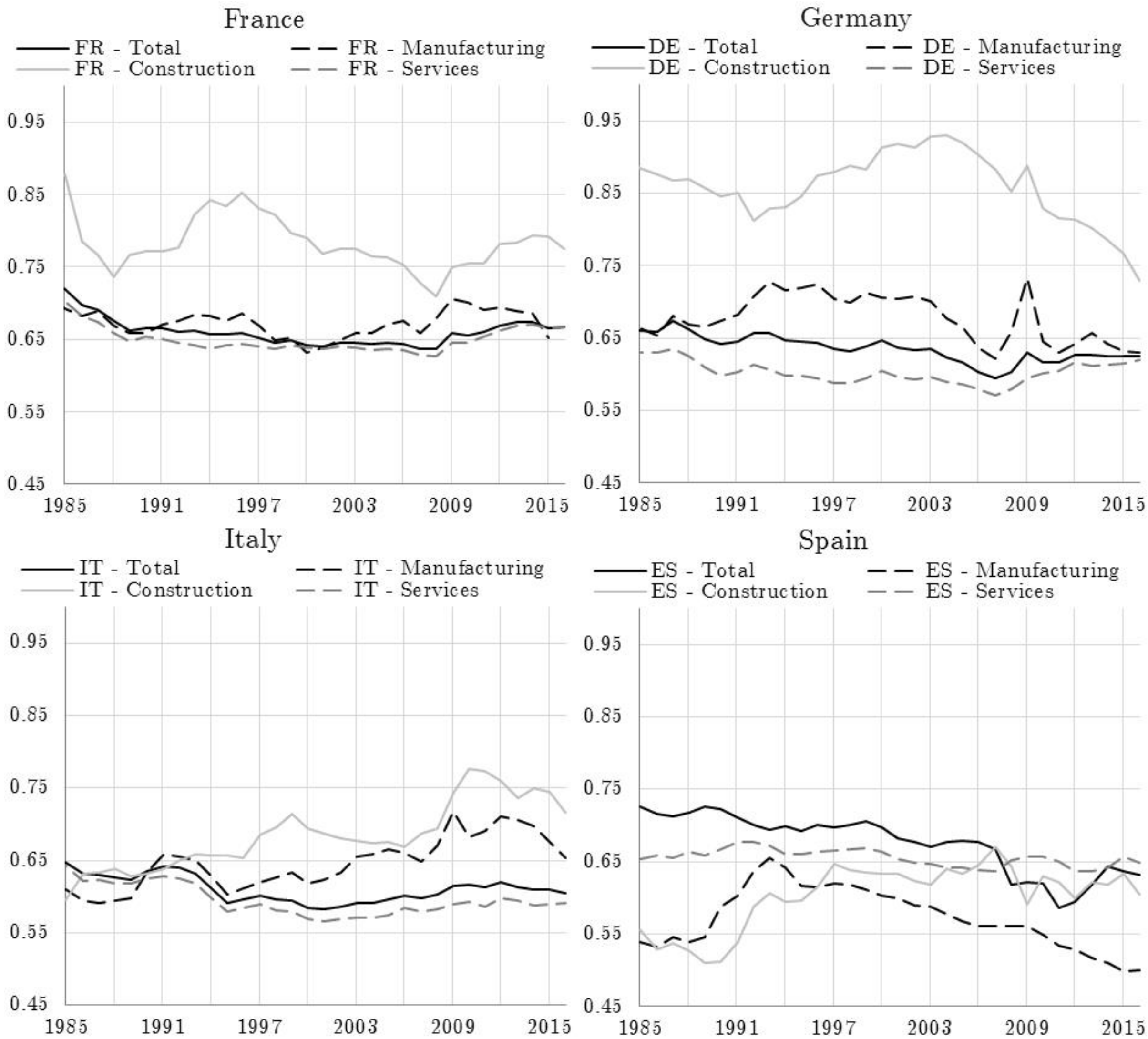
	199Q1-2018Q1				**1999Q1-2007Q4**				**2008Q1-2018Q1**			
					GERMANY							
steps	total	mfg	const	serv	total	mfg	const	serv	total	mfg	const	serv
1	1.04	1.06	1.04	1.01	0.96	0.90	1.04	1.04	1.07	1.08	1.03	0.98
2	1.04	1.10	1.01	1.01	0.89	0.88	0.99	1.05	1.08	1.12	1.00	0.98
3	1.03	1.12	0.99	1.02	0.83	0.89	0.91	1.05	1.09	1.15	0.98	1.00
4	1.03	1.09	0.96	1.01	0.85	0.93	0.81	1.04	1.08	1.11	0.95	1.00
5	1.00	1.05	0.98	1.01	0.84	1.02	0.84	1.03	1.05	1.06	0.96	1.00
6	0.97	1.01	1.04	1.00	0.87	1.06	0.87	1.01	0.96	1.02	1.07	1.00
7	0.96	1.00	1.02	1.00	0.91	1.07	0.82	1.00	0.84	1.00	1.15	1.01
8	0.96	0.99	0.99	1.00	0.99	1.07	0.84	0.98	0.78	0.97	1.16	1.01
					FRANCE							
steps	total	mfg	const	serv	total	mfg	const	serv	total	mfg	const	serv
1	1.00	1.01	1.00	1.02	1.01	0.99	1.00	1.02	1.00	1.01	1.00	1.02
2	1.01	1.00	0.98	1.04	1.01	0.99	1.00	1.04	1.00	1.01	0.97	1.04
3	1.01	0.99	0.97	1.05	1.02	0.97	0.99	1.06	1.01	1.01	0.96	1.04
4	1.01	0.97	0.97	1.06	1.01	0.96	0.99	1.07	1.01	0.99	0.95	1.05
5	1.01	0.97	0.97	1.09	1.01	0.99	1.01	1.10	1.01	0.99	0.94	1.07
6	1.01	1.00	0.97	1.11	1.00	1.05	1.00	1.11	1.02	1.02	0.95	1.12
7	1.01	1.02	0.97	1.12	1.00	1.10	0.99	1.10	1.04	1.05	0.96	1.17
8	1.01	1.02	0.97	1.11	1.00	1.09	0.98	1.09	1.05	1.01	0.97	1.20
					ITALY							
steps	total	mfg	const	serv	total	mfg	const	serv	total	mfg	const	serv
1	0.98	1.04	0.93	1.15	0.96	0.93	0.93	1.12	1.05	1.10	0.92	1.26
2	1.06	1.04	1.00	1.04	1.01	0.90	0.98	1.03	1.26	1.09	1.01	1.14
3	1.13	1.01	1.01	0.90	1.06	0.86	0.97	0.87	1.29	1.05	1.03	0.94
4	1.11	0.98	0.99	0.88	1.04	0.88	0.90	0.86	1.30	1.01	1.03	0.93
5	1.12	0.95	1.02	0.81	1.02	0.93	1.00	0.79	1.39	0.97	1.03	0.87
6	1.14	0.94	0.99	0.77	1.02	1.00	0.99	0.69	1.57	0.92	0.99	0.90
7	1.15	0.96	0.96	0.81	1.07	1.08	0.93	0.77	1.51	0.89	0.96	0.89
8	1.09	0.98	0.97	0.80	1.02	1.10	0.99	0.76	1.32	0.95	0.95	0.93
					SPAIN							
steps	total	mfg	const	serv	total	mfg	const	serv	total	mfg	const	serv
1	0.98	0.96	0.93	1.02	1.00	1.00	0.92	0.81	0.98	0.93	0.93	1.08
2	0.94	0.93	0.96	1.02	0.96	0.99	0.92	0.79	0.92	0.88	0.97	1.08
3	0.92	0.90	1.00	0.97	0.96	0.99	0.93	0.71	0.90	0.83	1.02	1.02
4	0.90	0.87	1.03	1.00	0.95	1.00	0.94	0.64	0.88	0.77	1.05	1.06
5	0.88	0.85	1.04	1.00	0.94	1.01	0.94	0.60	0.87	0.77	1.06	1.06
6	0.89	0.84	1.05	1.00	0.95	1.00	0.94	0.60	0.88	0.78	1.08	1.05
7	0.90	0.83	1.04	0.99	0.95	0.99	0.95	0.63	0.89	0.79	1.08	1.04
8	0.91	0.85	1.03	0.98	0.95	0.99	0.97	0.67	0.90	0.82	1.06	1.01

Table 7: Forecasting power of price inflation for labor cost inflation. Theil-U of labor cost inflation forecasts conditional on observed path of price inflation

	199Q1-2018Q1				**1999Q1-2007Q4**				**2008Q1-2018Q1**			
GERMANY												
steps	total	mfg	const	serv	total	mfg	const	serv	total	mfg	const	serv
1	0.95	0.78	1.02	0.99	1.19	0.98	1.15	1.07	0.86	0.82	0.99	0.90
2	0.95	0.78	1.02	0.98	1.22	0.92	1.16	1.06	0.85	0.83	1.01	0.93
3	0.94	0.77	1.04	0.97	1.20	0.85	1.24	1.04	0.85	0.83	1.00	0.95
4	0.94	0.73	1.07	0.94	1.19	0.80	1.33	0.99	0.85	0.80	0.99	0.95
5	0.94	0.72	1.08	0.95	1.18	0.76	1.47	1.00	0.84	0.78	0.97	0.98
6	0.94	0.71	1.05	0.93	1.12	0.73	1.45	1.01	0.82	0.74	0.90	0.99
7	0.93	0.69	1.05	0.89	1.06	0.77	1.38	0.97	0.82	0.69	0.85	0.99
8	0.92	0.70	1.07	0.85	0.98	0.79	1.32	0.87	0.91	0.69	0.81	1.02
FRANCE												
steps	total	mfg	const	serv	total	mfg	const	serv	total	mfg	const	serv
1	0.92	1.00	0.88	1.02	0.93	1.03	0.94	1.00	1.00	1.00	0.87	1.12
2	0.93	0.98	0.84	1.00	0.93	1.07	0.96	0.98	0.98	0.97	0.83	1.14
3	0.97	0.96	0.85	0.99	0.95	1.13	0.96	0.96	1.01	0.93	0.86	1.14
4	1.01	0.92	0.86	1.01	0.95	1.14	0.99	0.97	1.04	0.89	0.90	1.12
5	1.05	0.87	0.88	1.04	0.97	1.14	0.99	0.98	1.05	0.82	0.94	1.13
6	1.09	0.81	0.90	1.08	0.98	1.04	1.04	1.00	1.07	0.76	0.97	1.16
7	1.11	0.80	0.92	1.11	0.98	0.95	1.07	1.00	1.10	0.83	0.98	1.26
8	1.05	0.79	0.91	1.09	0.95	0.88	1.08	0.97	1.03	0.89	0.96	1.29
ITALY												
steps	total	mfg	const	serv	total	mfg	const	serv	total	mfg	const	serv
1	0.72	0.88	1.01	0.64	0.81	0.99	1.05	0.75	0.66	0.81	0.94	0.54
2	0.79	0.83	0.91	0.80	0.87	0.90	0.96	0.86	0.79	0.76	0.81	0.90
3	0.79	0.80	0.88	0.85	0.87	0.85	1.00	0.91	0.79	0.74	0.75	1.06
4	0.71	0.79	0.83	0.77	0.79	0.80	0.99	0.83	0.73	0.71	0.69	0.95
5	0.74	0.80	0.79	0.84	0.81	0.77	0.89	0.89	0.75	0.70	0.65	1.38
6	0.72	0.82	0.80	0.86	0.85	0.72	1.03	0.99	0.66	0.68	0.65	1.14
7	0.69	0.83	0.76	0.81	0.78	0.68	1.00	0.92	0.60	0.64	0.63	1.18
8	0.70	0.83	0.76	0.86	0.80	0.68	0.88	0.95	0.57	0.67	0.65	1.11
SPAIN												
steps	total	mfg	const	serv	total	mfg	const	serv	total	mfg	const	serv
1	1.01	0.99	0.98	0.98	0.97	1.00	1.00	1.01	0.99	1.06	0.99	0.99
2	1.05	0.99	0.97	0.99	1.03	1.09	1.08	1.01	1.02	1.02	0.99	0.99
3	1.04	0.94	0.92	0.99	1.11	1.04	1.05	1.02	1.01	0.94	0.98	0.99
4	1.03	0.90	0.89	0.96	1.16	0.95	1.08	1.02	1.01	0.87	0.98	0.99
5	1.03	0.84	0.86	0.95	1.22	0.83	1.10	1.01	0.99	0.79	0.94	0.99
6	1.01	0.82	0.82	0.94	1.21	0.77	1.11	1.00	0.95	0.70	0.89	0.98
7	1.02	0.83	0.81	0.93	1.22	0.75	1.12	0.98	0.95	0.71	0.84	0.98
8	1.02	0.86	0.81	0.93	1.28	0.83	1.09	0.97	0.93	0.72	0.80	0.97

Appendix E Labor Share Developments

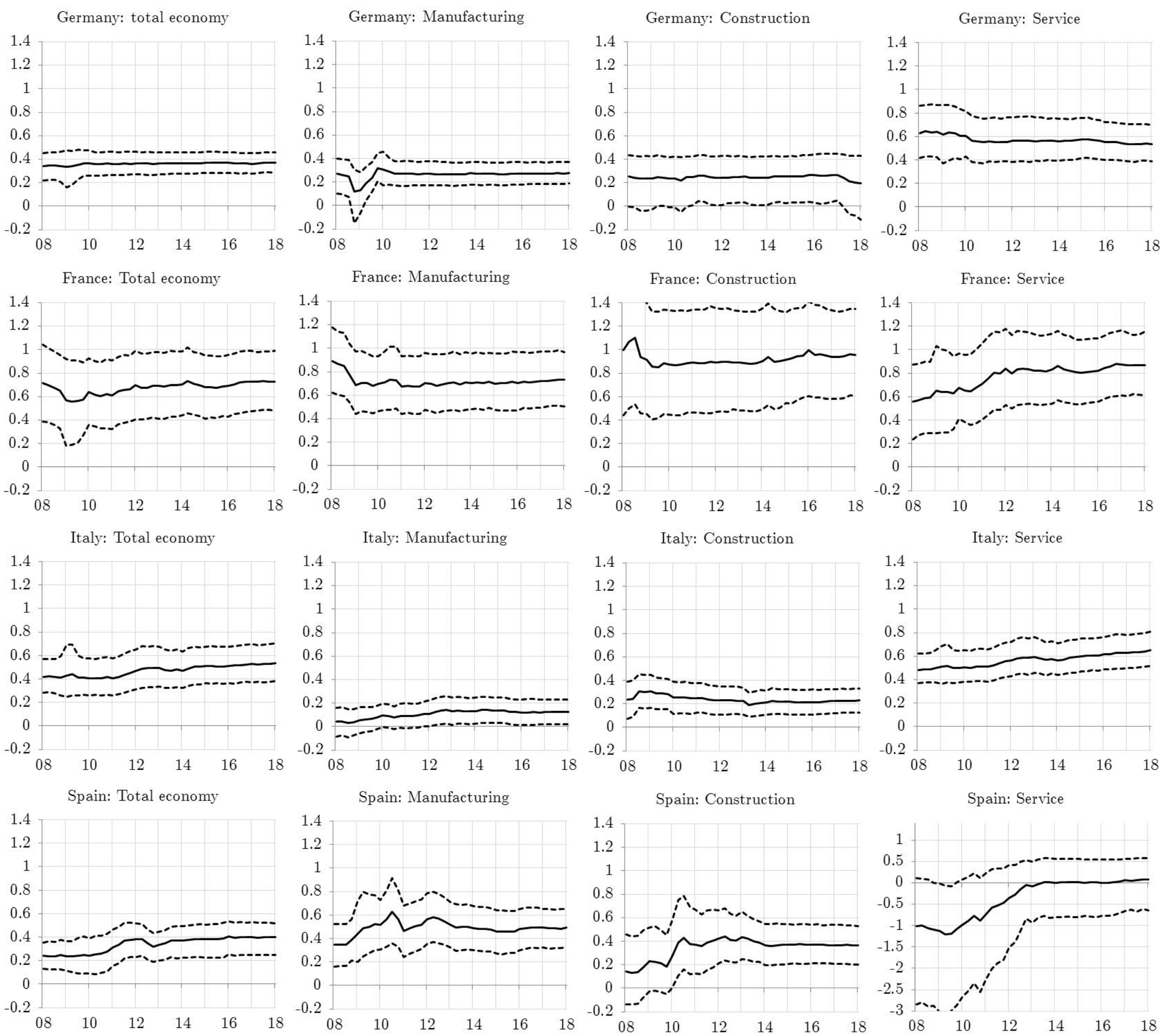
Figure 14: Labor Share across countries and sectors



Sources: Authors' calculations based on OECD data.

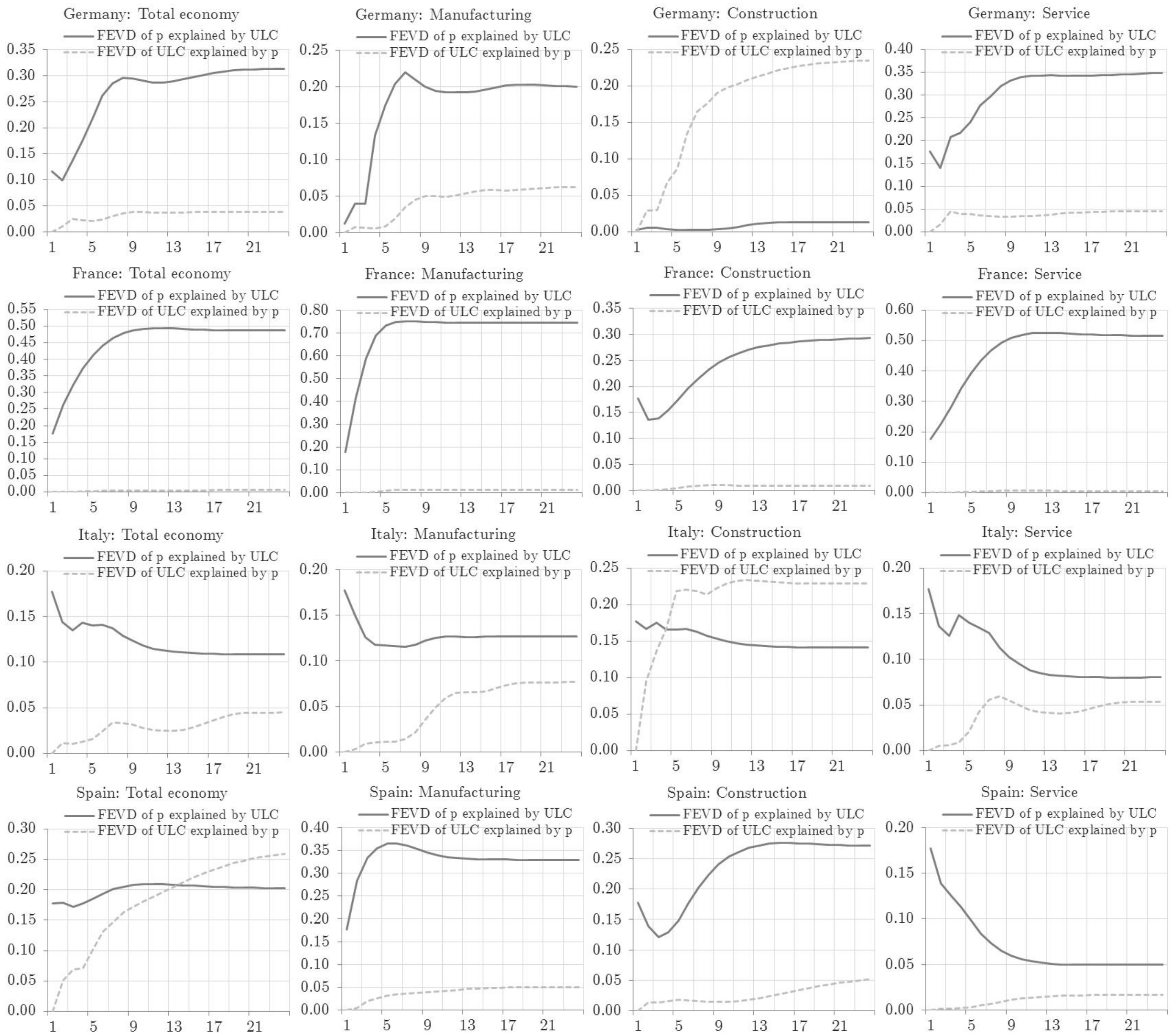
Appendix F VAR-based Analysis: Impulse Responses from Choleski Orthogonalization and the Forecast Error Variance Decomposition

Figure 15: Steady state pass-through from unit labor cost inflation to price inflation



Sources: Authors' calculations. Note: The results show the steady state impulse response (at quarter 40) from a time varying approach whereby the first sample covered 1985Q1-2008Q1 and thereafter one quarter at a time was recursively added. Sample period: 1985Q1-2018Q1.

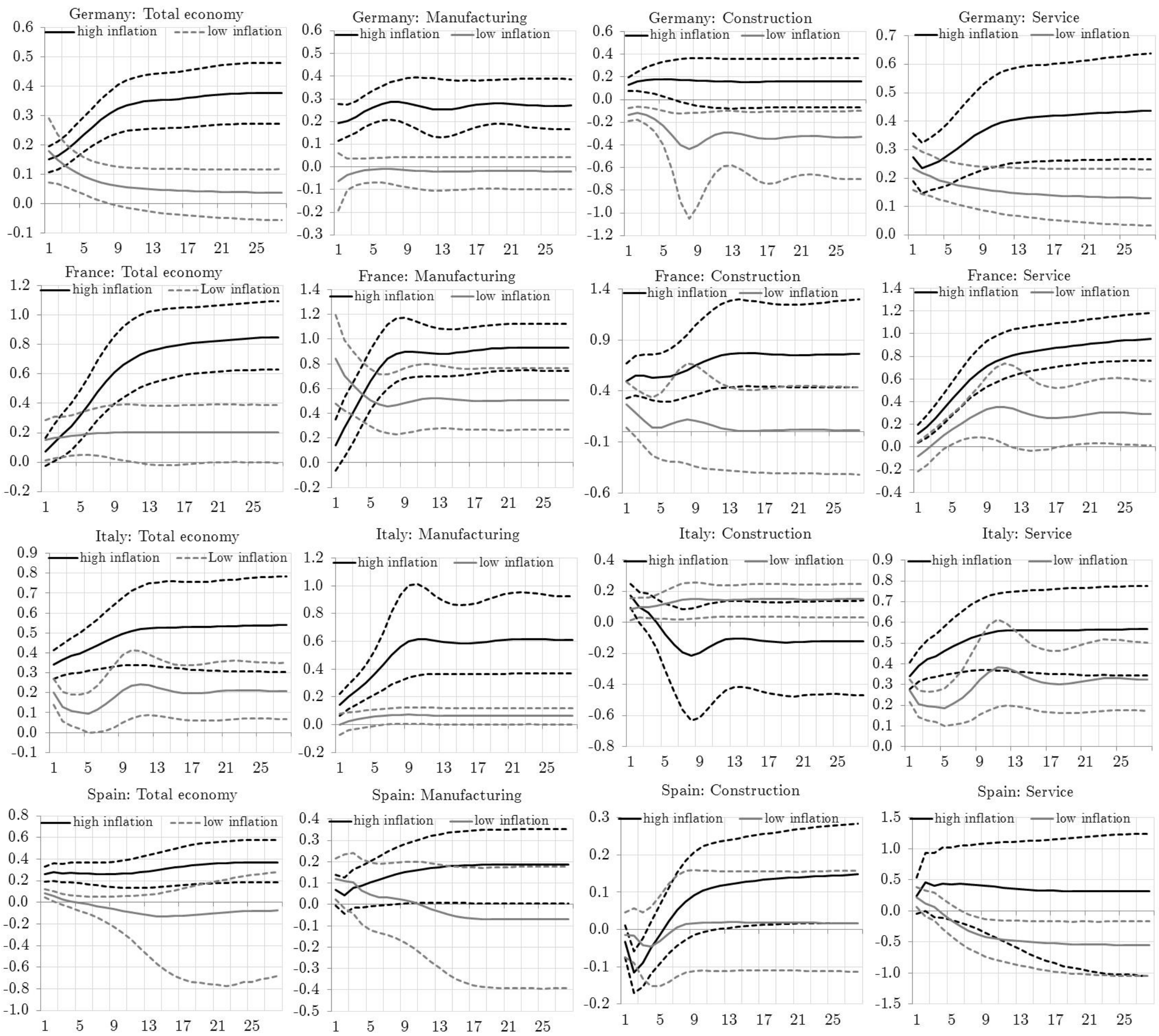
Figure 16: Forecast Error Variance Decomposition



Sources: Authors' calculations. Note: The results show the steady state impulse response (at quarter 40) from a time varying approach whereby the first sample covered 1985Q1-2008Q1 and thereafter one quarter at a time was recursively added. Sample period: 1985Q1-2018Q1.

Appendix G VAR-based Analysis: Impulse Responses from Choleski Orthogonalization under high versus low inflation

Figure 17: Pass-through from unit labor cost inflation to price inflation for high versus low inflation



Sources: Authors' calculations. Sample period: 1985Q1-2018Q1.

Appendix H SVAR with sign restrictions: Impulse response functions

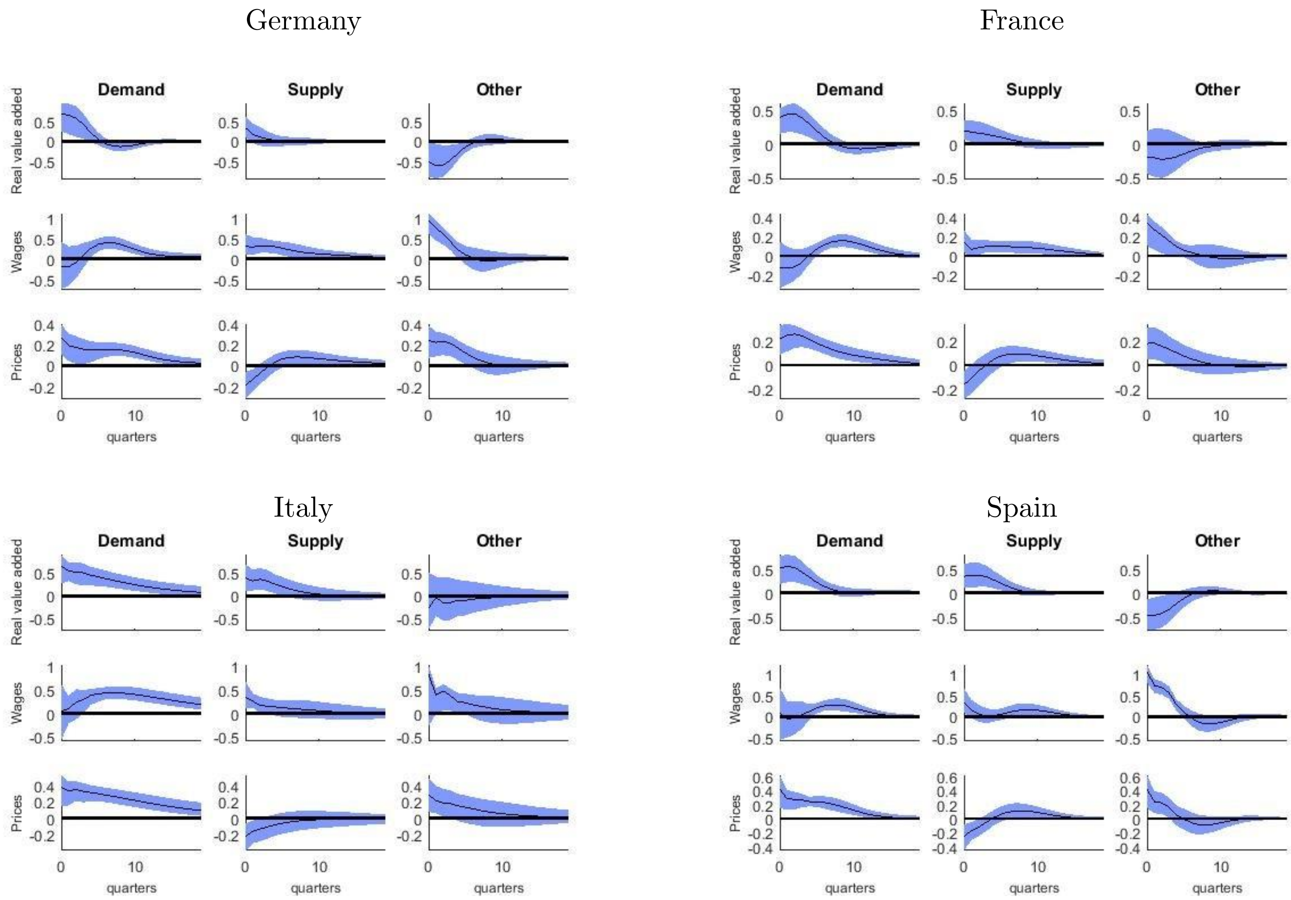
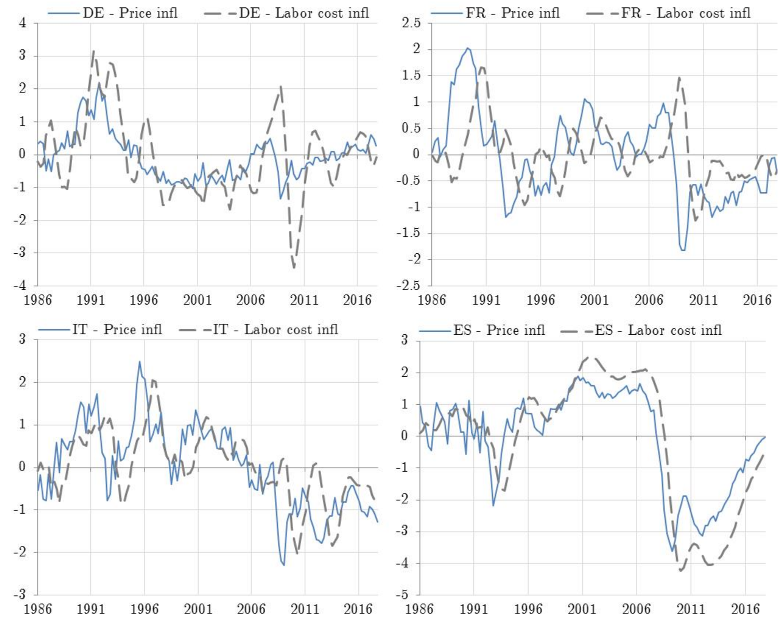


Figure 18: Impulse response functions for the total economy

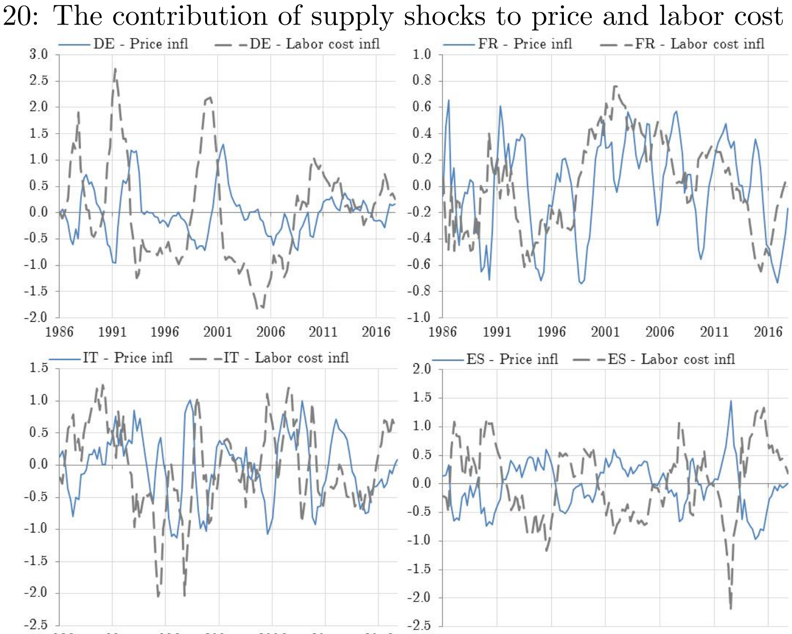
Appendix I Sign restricted SVAR: Historical contributions

Figure 19: The contribution of demand shocks to price and labor cost inflation



Sources: Authors' calculations. Sample period: 1985Q1-2018Q1.

Figure 20: The contribution of supply shocks to price and labor cost inflation



Sources: Authors' calculations. Sample period: 1985Q1-2018Q1.

Appendix J The derivation of the counterfactual IRFs

Consider the following VAR(1)[18] :

$$A_0 Y_t = A_1 Y_{t-1} + \epsilon_t \quad \forall t = 1, ..., T \tag{1}$$

where Y_t is the vector of endogenous variables, A_0, A_1 the matrices of contemporaneous and lag coefficients, respectively and ϵ_t are structural shocks.

$$Y_t = (A_0)^{-1} A_1 Y_{t-1} + (A_0)^{-1} \epsilon_t \tag{2}$$

$$Y_t = B Y_{t-1} + (A_0)^{-1} \epsilon_t, B = (A_0)^{-1} A_1 \tag{3}$$

We choose the i-th variable for which the counterfactual responses to shock j are set to zero.

A simple way to calculate $IRFs$ is to iterate starting with $t = 0$.

$$Y_0 = (A_0)^{-1} \epsilon_0 \tag{4}$$

$$Y_1 = B \cdot (A_0)^{-1} \epsilon_0 + (A_0)^{-1} \epsilon_1 \tag{5}$$

$$Y_k = B^k \cdot (A_0)^{-1} \epsilon_0 + B^{k-1} \cdot (A_0)^{-1} \epsilon_1 + ... + B \cdot (A_0)^{-1} \epsilon_{k-1} + (A_0)^{-1} \epsilon_k \tag{6}$$

$$Y_k = \sum_{h=0}^{k} B^{k-h} \cdot (A_0)^{-1} \epsilon_h \tag{7}$$

The IRF of variable i following a certain shock j at period h (IRF_{ij}^h) is achieved by setting $\epsilon_0 = e_j$, where e_j is an identification column vector with 1 on the j-th position and zero otherwise.

In order to offset the IRF of variable i to shock j, we produce a set of counterfactual shocks. Hence, we set:

$$\epsilon_0 = e_j + \hat{\epsilon_0} \cdot \sum_{l \neq j} e_l \tag{8}$$

[18] Lag 1 was selected for illustration purposes, the formulas derived for the counterfactual $IRFs$ hold also in the general VAR(p) case.

where e_l is a column vector with 1 on the l position and zero otherwise.

This is the point where we depart from Wong (2015), who offsets the impact of the oil shocks on inflation expectations by modifying only one shock, the Choleski one corresponding to inflation expectations (the variable that is being shut down). We implement the offsetting by assuming that all other remaining shocks contribute. One assumption that we make in order to ensure the determinacy of the system is that we impose that the remaining shocks have an equal contribution in off-setting the impact of shock j on variable i.

$$\epsilon_1 = \hat{\epsilon_1} \cdot \sum_{l \neq j} e_l \tag{9}$$

$$\epsilon_k = \hat{\epsilon_k} \cdot \sum_{l \neq j} e_l \tag{10}$$

We determine $\hat{\epsilon_0}, \hat{\epsilon_1}, ...\hat{\epsilon_k}$ such that $I\hat{RF}^h_{ij} = 0$ for all periods $h = 0, 1, ..., k$.

$$IRF^h_{ij} = e'_i \cdot Y_h \tag{11}$$

$$Y_0 = (A_0)^{-1} e_j + \hat{\epsilon_0} \cdot (A_0)^{-1} \cdot \sum_{l \neq j} e_l \tag{12}$$

The counterfactual IRF of variable i to shock j at the moment 0 is $I\hat{RF}^0_{ij}$:

$$I\hat{RF}^0_{ij} = e'_i \cdot Y_0 = e'_i (A_0)^{-1} e_j + \hat{\epsilon_0} e'_i \cdot (A_0)^{-1} \cdot \sum_{l \neq j} e_l \tag{13}$$

but $e'_i \cdot (A_0)^{-1} \cdot e_l = IRF^0_{il}$, therefore:

$$I\hat{RF}^0_{ij} = IRF^0_{ij} + \hat{\epsilon_0} \cdot \sum_{l \neq j} IRF^0_{il} \tag{14}$$

Notation: $IRF^h_{i\bar{j}} = \sum_{l \neq j} IRF^h_{il}$ (the sum for the period h of all $IRFs$ of variable i to all other shocks, except j).

$$I\hat{RF}^0_{ij} = IRF^0_{ij} + \hat{\epsilon_0} \cdot IRF^0_{i\bar{j}} = 0 \tag{15}$$

$$\hat{\epsilon_0} = -\frac{IRF^0_{ij}}{IRF^0_{i\bar{j}}} \tag{16}$$

$$Y_1 = B \cdot (A_0)^{-1} e_j + \hat{\epsilon_0} \cdot B \cdot (A_0)^{-1} \cdot \sum_{l \neq j} e_l + \hat{\epsilon_1} \cdot (A_0)^{-1} \cdot \sum_{l \neq j} e_l \tag{17}$$

$$\hat{IRF}^1_{ij} = e'_i \cdot Y_1 = e'_i \cdot B \cdot (A_0)^{-1} e_j + \hat{\epsilon_0} \cdot e'_i \cdot B \cdot (A_0)^{-1} \cdot \sum_{l \neq j} e_l + \hat{\epsilon_1} \cdot e'_i \cdot (A_0)^{-1} \cdot \sum_{l \neq j} e_l \quad (18)$$

$$\hat{IRF}^1_{ij} = IRF^1_{ij} + \hat{\epsilon_0} \cdot \sum_{l \neq j} IRF^1_{il} + \hat{\epsilon_1} \cdot \sum_{l \neq j} IRF^0_{il} = 0 \quad (19)$$

$$\hat{\epsilon_1} = -\frac{IRF^1_{ij} + \hat{\epsilon_0} \cdot IRF^1_{i\bar{j}}}{IRF^0_{i\bar{j}}} \quad (20)$$

In general:

$$\hat{IRF}^k_{ij} = IRF^k_{ij} + \hat{\epsilon_0} \cdot IRF^k_{i\bar{j}} + \hat{\epsilon_1} \cdot IRF^{k-1}_{i\bar{j}} + ... + \hat{\epsilon_{k-1}} \cdot IRF^1_{i\bar{j}} + \hat{\epsilon_k} \cdot IRF^0_{i\bar{j}} = 0 \quad (21)$$

$$\hat{\epsilon_k} = -\frac{IRF^k_{ij} + \sum_{h=0}^{k-1} \hat{\epsilon_h} \cdot IRF^{k-h}_{i\bar{j}}}{IRF^0_{i\bar{j}}} \quad (22)$$

As shown in equation 21, for a given variable i the counterfactual IRF is the following:

$$\hat{IRF}^k_{ij} = IRF^k_{ij} + \sum_{h=0}^{k} \hat{\epsilon_h} \cdot IRF^{k-h}_{i\bar{j}} \quad (23)$$

Appendix K Counterfactual IRFs: e.g. Italy, total economy

Figure 21: Conterfactual IRFs: e.g. Italy, total economy

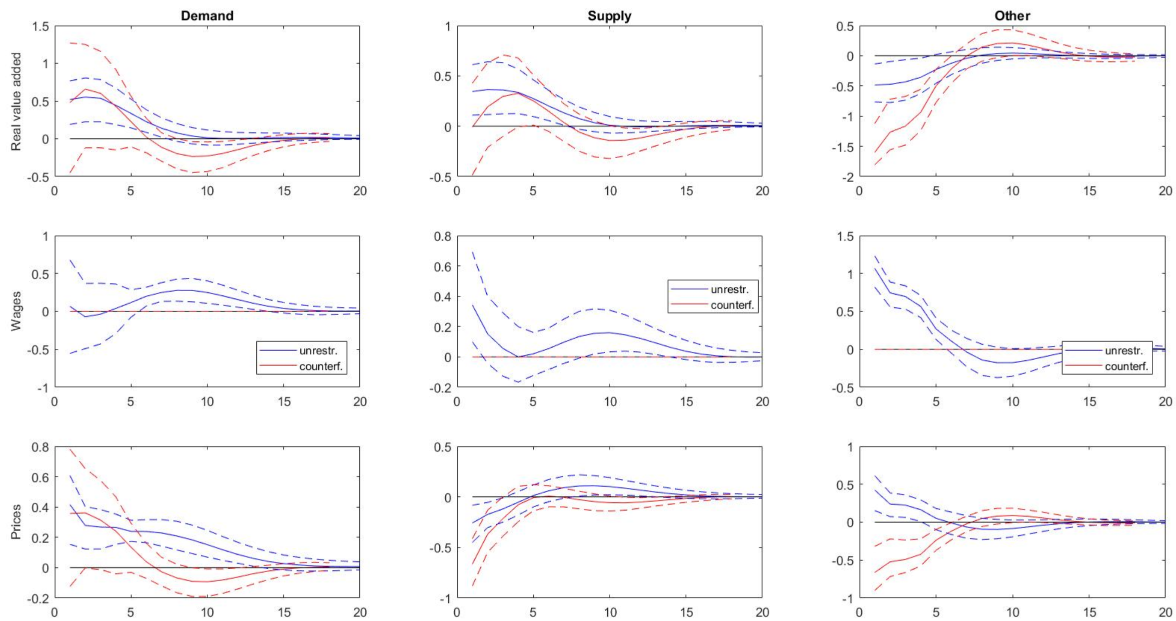
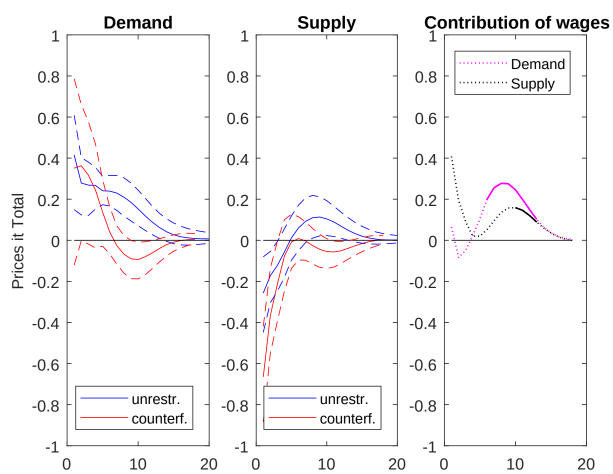


Figure 22: Conterfactual IRFs of price inflation: e.g. Italy, total economy



References

Banerji, A. (2005). The Relationship Between Labor Costs and Inflation: A Cyclical Viewpoint. Economic cycle research institute, U.S. Bureau of Labor Statistics.

Bergin, P. R. and Feenstra, R. C. (2001). Pricing-to-market, staggered contracts, and real exchange rate persistence. *Journal of International Economics*, 54(2):333–359.

Bidder, R. (2015). Are wages useful in forecasting price inflation? *FRBSF Economic Letter*.

Bils, M. and Chang, Y. (2000). Understanding how price responds to costs and production. *Carnegie-Rochester Conference Series on Public Policy*, 52(1):33–77.

Canova, F. and Ciccarelli, M. (2009). Estimating Multicountry VAR Models. *International Economic Review*, 50:921–969.

Comunale, M. and Kunovac, D. (2017). Exchange rate pass-through in the euro area. Working Paper Series 2003, European Central Bank.

Daly, M. C. and Hobijn, B. (2014). Downward Nominal Wage Rigidities Bend the Phillips Curve. Working Paper Series 2013-08, Federal Reserve Bank of San Francisco.

Darrat, A. (1994). Wage Growth and the Inflationary Process: A Reexamination. *Southern Economic Journal*, 61(1):181–190.

Dees, S. and Guntner, J. (2014). Analysing and forecasting price dynamics across euro area countries and sectors: a panel VAR approach. Working Paper Series 1724, European Central Bank.

Dornbusch, R. (1987). Exchange Rates and Prices. *American Economic Review*, 77(1):93–106.

Druant, M., Fabiani, S., Kezdi, G., Lamo, A., Martins, F., and Sabbatici, R. (2009). How are Firms' Wages and Prices Linked: Survey Evidence in Europe. Working Paper Series 1084, European Central Bank.

Du Caju, P., Fuss, C., and Wintr, L. (2009). Understanding sectoral differences in downward real wage rigidity: workforce composition, institutions, technology and competition. Working Paper Series 1006, European Central Bank.

ECB (2004). Recent developments in unit labour costs and their implications for euro area inflation. Monthly Bulletin September 2004, European Central Bank.

ECB (2018a). ECB staff macroeconomic projections for the euro area. Projections article March 2018, European Central Bank.

ECB (2018b). The role of wages for the pick-up in inflation. Box in the Economic Bulletin Issue 5, European Central Bank.

Emery, K. and Chang, C.-P. (1996). Do Wages Help Predict Inflation. Economic Review First Quarter 1996, Dallas Fed.

Fisher, I. (1926). A Statistical Relation between Unemployment and Price Changes. *Internatinonal Labour Review*, 13(6):785–792.

Forbes, K., Hjortsoe, I., and Nenova, T. (2018). The shocks matter: improving our estimates of exchange rate pass-through. Working Paper 24773, National Bureau of Economic Research.

Foroni, C., Furlanetto, F., and Lepetit, A. (2018). Labor Supply Factors And Economic Fluctuations. *International Economic Review*, 59(3):1491–1510.

Gali, J. (1999). Technology, Employment, and the Business Cycle: Do Technology Shocks Explain Aggregate Fluctuations? *American Economic Review*, 89(1):249–271.

Gordon, R. J. (1988). The Role of Wages in the Inflation Process. *American Economic Review*, 78(2):276–283.

Head, A., Kumar, A., and Lapham, B. (2010). Market Power, Price Adjustment, And Inflation. *International Economic Review*, 51(1):73–98.

Hess, G. and Schweitzer, M. (2000). Does Wage Inflation Cause Price Inflation? *Federal Reserve Bank of Cleveland, Policy Discussion Paper*, no. 00-01.

Hu, L. and Toussaint-Comeau, M. (2010). Do labor market activities help predict inflation? *Economic Perspectives*, (Q II):52–63.

Kadyiala, R. and Karlsson, S. (1998). Numerical Methods for Estimation and Inference in Bayesian VAR Models. *Journal of Applied Econometrics*, 12:99–132.

Knotek, E. S. and Zaman, S. (2014). On the Relationships between Wages, Prices, and Economic Activity. *Economic Commentary*, (Aug).

Kozicki, S. and Tinsley, P. (2001). Shifting Endpoints in the Term Structure of Interest Rates. *Journal of Monetary Economics*, 47(3):613–652.

Mehra, Y. P. (2000). Wage-price dynamics : are they consistent with cost push? *Economic Quarterly*, (Sum):27–43.

Mountford, A. and Uhlig, H. (2009). What Are the Effects of Fiscal Policy Shocks. *Journal of Applied Economics*, 24(6):960–992.

Peersman, G. and Straub, R. (2009). Technology Shocks And Robust Sign Restrictions In A Euro Area Svar. *International Economic Review*, 50(3):727–750.

Peneva, E. V. and Rudd, J. B. (2017). The Passthrough of Labor Costs to Price Inflation. *Journal of Money, Credit and Banking*, 49(8):1777–1802.

Rissman, E. R. (1995). Sectoral Wage Growth and Inflation. *Federal Reserve Bank of Chicago Economic Review*, pages 16–28.

Sbordone, A. (2002). Prices and Unit Labor Costs: A New Test of Price Stickiness. *Journal of Monetary Economics*, 49:265–292.

Stock, J. H. and Watson, M. W. (2008). Phillips Curve Inflation Forecasts. NBER Working Papers 14322, National Bureau of Economic Research, Inc.

Tatierska, S. (2010). Do Unit Labor Costs Drive Inflation in the Euro Area? Working Paper Series 2/2010, National Bank of Slovakia.

Taylor, J. (2000). Low Inflation, Pass-Through and the Pricing Power of Firms. *European Economic Review*, 44:1389–1408.

Wong, B. (2015). Do Inflation Expectations Propagate the Inflationary Impact of Real Oil Price Shocks?: Evidence from the Michigan Survey. *Journal of Money, Credit and Banking*, 47(8):1673–1689.

Zaman, S. (2013). Improving Inflation Forecasts in the Medium to Long Term. Economic commentary, Federal Reserve Bank of Cleveland.

Zanetti, A. (2007). Do Wages Lead Inflation? Swiss Evidence. *Swiss Journal of Economics and Statistics*, 143(1).