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The changing link between labor cost and price inflation in the United States

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Abstract

The link between US labor cost and price inflation has weakened notably over the past three decades. In this paper we document this decline and analyse potential contributing factors. We consider four important trends that have shaped the US economy of late: (i) improved anchoring of inflation expectations; (ii) the changing constellation of shocks hitting the economy; (iii) increased trade integration and (iv) rising firm market power. We find that the improved anchoring of inflation expectations has played a particularly relevant role but also that the latter two trends offer promising avenues to understand the decline in pass-through from labor cost to price inflation. Our results also bring supportive evidence to the view taken by the FED in the context of its monetary policy strategy review that a robust job market can be sustained without causing an outbreak of inflation.
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Non-technical summary

In this paper we revisit the link between labor cost and price inflation in the United States and confirm that the pass-through has significantly weakened over the past three decades. We show this empirically by estimating a parsimonious VAR over the period 1960-2018 that controls for real activity.

Several explanations have been put forward for this weakening link between labor cost and price inflation. However, to date, no study has consistently and comprehensively cross-checked the relevance of the various hypotheses that have been put forward.

In this paper, we complement the existing literature by formally investigating to what extent the declining pass-through of labor cost to price inflation should be seen in connection to other important trends that have shaped the US economy, namely: (i) the improved anchoring of inflation expectations; (ii) the changing constellation of shocks that hit the economy; (iii) the increased trade openness and (iv) the rise in firm market power. To test the latter two hypotheses we construct a novel industry-level database which allows to exploit differences at a disaggregated level.

We confirm the conjecture in the literature that the pass-through tends to be lower when inflation - in our case expressed as a deviation from long term inflation expectations - is low. However, we also find that the nature of the shock driving labor cost developments matters: the pass-through is strongest under demand shocks and weakest under supply shocks. Supply shocks became in particular during the 1990s more prominent and may hence have contributed over that period to the declining pass-through. Yet, we also find that across all types of shocks, the pass-through has declined in recent years, suggesting that there are factors above and beyond the type of underlying macroeconomic shocks that have driven the aggregate decline in pass-through. Third, we find that increased trade openness is associated with a lower pass-through. In the manufacturing sector the pass-through has decreased most in industries where trade openness increased most. Moreover, we unveil a level effect: pass-through is lower in more trade open industries. Yet, the differences in the estimated pass-through across manufacturing industries are not large enough to allow us to ascertain sizable effects. Finally, we unveil a striking correlation between the dynamics of the economy-wide estimated pass-through to that of a measure of aggregate firms' markup; we complement this analysis by making use of the level of concentration in each industry and show that the pass-through decreased in industries where concentration was on the rise.

Overall we thus find that all four investigated hypotheses have contributed to the declining pass-through from labor cost to price inflation in the United States. However, the improved anchoring of inflation expectations appears to have played a particularly relevant role. At the same time, the increase in trade openness and in firm market power also offer particularly

promising avenues for understanding the decline in pass-through and warrant further analysis. These two factors, according to some narratives, may even be interrelated as rising markups have been concentrated among large international companies (see for instance Autor et al. (2017)) who benefit from global networks of factors of production and are able to offset the impact of wage shocks.

An understanding of the drivers of the pass-through of labor cost to price inflation is key in particular for central banks, given their price stability mandate. We show that the decline in the pass-through is in part linked to structural trends which are unlikely to revert in the near future (in fact the increase in market power and concentration might be even exacerbated after the COVID-19 crisis, as mentioned for instance by Tenreyro (2020) or Akcigit et al. (2021)). This offers the central bank the opportunity to pursue expansionary policies without the fear of inflation via the labor cost channel, provided that inflation expectations remain well anchored. It also brings supportive evidence to the view taken by the FED in the context of its monetary policy strategy review (see Powell (2020)) that a robust job market can be sustained without causing an outbreak of inflation.

1 Introduction

Our revised statement says that our policy decision will be informed by our 'assessments of the shortfalls of employment from its maximum level' rather than by 'deviations from its maximum level' as in our previous statement. This change may appear subtle, but it reflects our view that a robust job market can be sustained without causing an outbreak of inflation. (Powell, 2020)

A key policy question in the post-2007/2008 period is whether labour costs (i.e. productivity adjusted wages) are still a useful gauge for inflation developments in the United States. This question arises as the decade long expansion which followed the Global Financial Crisis was accompanied only by muted inflationary developments, despite the strong labour market performance. Reflecting this, the Federal Reserve has been revisiting the role that labor market developments play in generating inflation. Indeed, while in 2018 FED officials were still expecting upward inflationary pressures coming from the labor market tightness,[1] by 2020, in the context of the FED's strategy review, they have dramatically weighted down the ability of a tight labor market to generate inflation (Powell (2020)).

It is intuitive to expect that as the labor market tightens, labor costs pick up and translate into higher prices. Labor costs constitute a substantial share of business expenses and hence could be an important element in a firm's pricing decision. Theoretically, this perspective is rooted in the cost-push view of inflation 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.

This theoretical link, whereby rising labor costs should lead to higher prices in the short to medium run, was empirically grounded in the 1970s when the so-called wage price spiral was seen as lifting inflation. To this day, the cost-push view of inflation remains the main narrative of a number of central banks when communicating about the outlook for inflation.[2] For instance, forecasters see a pickup in labor cost growth often as a necessary condition for rising inflation (see e.g. ECB (2020)).[3]

However, there have been increasing doubts as to whether labor costs systematically have an independent influence on prices over shorter horizons, in particular in the United States. Analyses based on in-sample Granger causality type of tests have yielded mixed conclusions on the link between labor cost and price inflation,[4] whilst studies focused on out-of-sample forecasting find it difficult to ascer-

[1]See Powell (2018): *'If unemployment were to remain this low for this long, employers would be pushing up wages as they compete for scarce workers, and rising labor costs would feed into more rapid price inflation faced by consumers'*.

[2]Similar references on the link between labour cost and price inflation developments 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.'*

[3]ECB (2020) writes: *'Over the medium term, HICP inflation excluding energy and food should be supported by the gradual recovery in activity, relatively robust wage growth in a context of tight labour markets, and recovering profit margins.'*

[4]For instance Emery and Chang (1996), Sbordone (2002), Bidder (2015), Hess and Schweitzer (2000), Gordon (1988) and Darrat (1994) all conclude that there is no causal link from labor cost to price inflation. More concretely, the former three studies find that the link goes in the other direction whereas the latter three find no causal link in either direction. Banerji (2005) instead does find that labor cost inflation leads price inflation, but only at peaks, whereas it lags at troughs. Finally, Rissman (1995) finds that only in manufacturing and trade services, wages Granger cause inflation.

tain that wages add additional information to inflation forecasts (see for instance Stock and Watson (2008), Knotek and Zaman (2014)).[5] Empirical studies also find that the link between labor cost and price inflation has weakened in recent decades. Concretely, Knotek and Zaman (2014) show that the correlation between wages and prices has decreased since the mid-80s, while Hu and Toussaint-Comeau (2010) find that wage growth does not cause price inflation in the Granger causality sense, especially after the mid-80s. Similarly, Peneva and Rudd (2017) and Heise et al. (2020) document a decline in the pass-through of labor cost growth to price inflation over the past several decades (to the point where it is currently close to zero).

Several explanations have been put forward for the weakening link between labor cost and price inflation. These include the better anchoring of inflation expectations (Peneva and Rudd (2017)), the presence of downward wage rigidities (Daly and Hobijn (2014)) and more recently the increase in market power and import penetration (Heise et al. (2020)). However, no study to date has consistently and comprehensively cross checked the relevance of these different hypotheses.

In this paper we revisit the link between labor cost and price inflation in the United States. We confirm empirically - based on a parsimonious SVAR model - that the link has significantly weakened over the past three decades.

We then analyze to what extent the declining pass-through of labor costs to price inflation should be seen in connection with other important trends that have shaped the US economy over this period. We formally test and examine four hypotheses with the aim to establish their plausibility. Concretely, we look into the role of: (i) the improved anchoring of inflation expectations; (ii) the changing constellation of shocks that hit the economy; (iii) the increased trade openness and (iv) the rise in firm market power.

In order to analyze these hypotheses, we propose empirical analyses designed to capture the role of each individual factor by adapting our baseline parsimonious SVAR model and also construct a novel industry-level database which allows to map the link between the labour cost-price inflation pass-through on the one hand and trade openness and market power, respectively, on the other hand.

We find that all factors contributed to the weakening of the link between labor cost and price inflation in the United States. However, the increased anchoring of inflation expectations appears to have played a particularly relevant role. Moreover, two hypotheses, related to stronger trade openness and increasing firm market power, also offer particularly promising avenues for understanding the declining link between labor cost to price inflation in the US and warrant further investigation. These two factors, according to some narratives, may even be interrelated as rising markups have been concentrated among large international companies (see for instance Autor et al. (2017)) who benefit from global networks of factors of production and are able to offset the impact of wage shocks. These companies also base their production less on labour and more on other factors, such as capital or technology.[6]

Our findings have important policy implications. Given that the pass-through of labor costs to inflation appears, at least to some extent, to be linked to structural trends which are unlikely to revert

[5] 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.

[6] Autor et al. (2017) show that employment concentration has grown notably more slowly than sales concentration especially in manufacturing. This suggests that the firms with the highest market share achieved it with a relatively small workforce.

in the near future (in fact the increase in market power and concentration might be even exacerbated after the COVID-19 crisis, as mentioned for instance by Tenreyro (2020) or Akcigit et al. (2021)), this offers the central bank the opportunity to pursue expansionary policies without the fear of inflation via the labor cost channel, provided that inflation expectations remain well anchored. Our findings also provide supporting evidence in favour of the related recent change in the FED's monetary policy communication. The declining labor cost pass-through, including in response to monetary policy shocks, also has implications how monetary policy affects the economy. When pass-through from labor cost to price inflation is lower, the impact of expansionary monetary policy is stronger on employment while more dampened on inflation.[7]

The remainder of the paper is organized as follows. Section 2 presents the data. Section 3 presents our baseline VAR set-up used to extract the relation between labor cost and price inflation. Section 4 puts forward several hypotheses for rationalizing the observed decline in the labor cost pass-through and brings evidence to assess their plausibility. Section 5 summarizes and concludes.

2 Measuring labor cost and price inflation developments

There exist a variety of ways to measure labor cost and price inflation. In our analysis, we follow the approach of Peneva and Rudd (2017). As our price measure, we use the core PCE price index.[8] This is the chain price index for market-based Personal Consumption Expenditures excluding food and energy costs.

To measure labor costs, we use hourly labor compensation in the nonfarm business sector.[9] We prefer this series since it is available since 1948. In our robustness analysis, we also consider the Employment Cost Index (ECI), which is available only since 1981. Both series are comprehensive measures of labor related production costs. The former is more comprehensive as it also covers proprietors, self-employed workers and those with substantial discretion over their own pay. The latter measure has the advantage that it is a fixed-weight Laspeyres index, that corrects for the effects of shifts in employment between high wage and low wage jobs.

To arrive at our labor cost measure, we subtract from our compensation series an estimate of the trend growth rate of average labor productivity.[10] We prefer to subtract an estimate of *trend* rather than of actual productivity growth given that productivity growth is extremely noisy at a quarterly

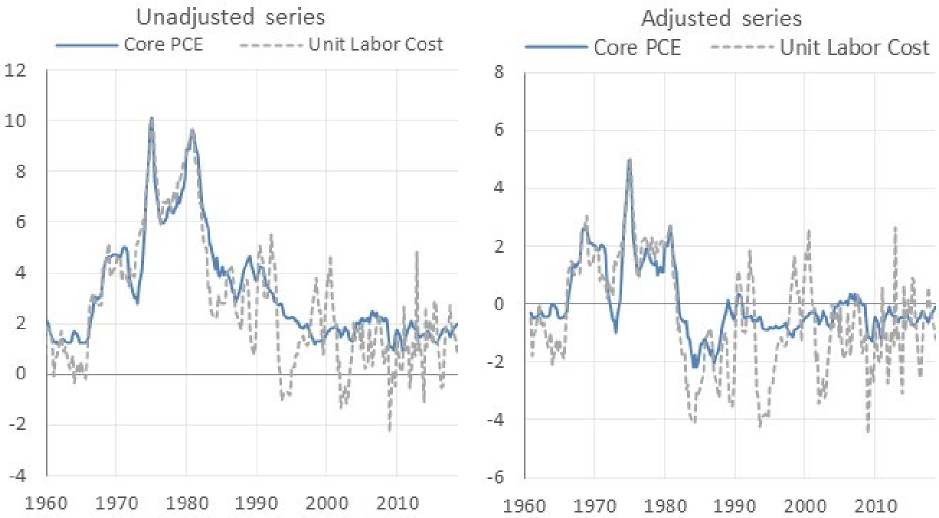
[7] An expansionary shock increases nominal marginal costs and due to nominal rigidities, labor becomes more attractive and employment rises. The more dampened the increase in prices, the stronger the employment effect.

[8] We have also conducted, as a robustness check, in this paper our analysis using the PCE, instead of the core PCE, price index. We found that our results are broadly robust to this alternative specification.

[9] We focus in our analysis on compensation series. These differ from wages in that they include employer contributions for social insurance, pension contributions, and employer payments for health insurance and other fringe benefits.

[10] We use a measure of labor productivity for the nonfarm business sector; in the case of the euro area, for the comparison exercise shown in Section 4.4 we use a measure for the economy as a whole.

Figure 1: Unit Labor Cost and Core PCE inflation, year on year % change



Sources: Authors' calculations. Sample: 1960Q1-2018Q3.

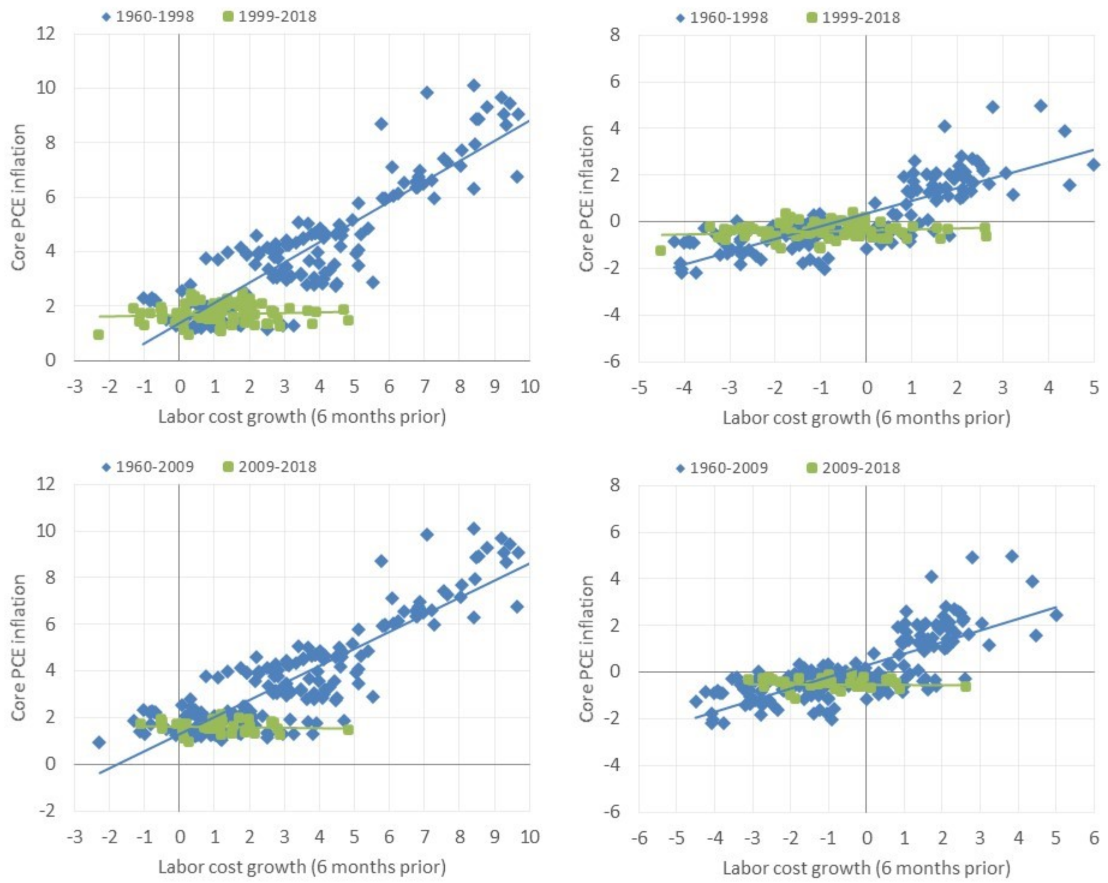
frequency.[11]

Figure 1, left hand panel, plots the year-on-year growth rate of our measures of labor cost and price inflation over the period 1960Q1-2018Q3. The high correlation between price and labor cost inflation (0.82) demonstrates why policy makers pay close attention to labor costs when assessing price inflation. In part the high co-movement between the two data series can be explained by a strong common (downward) trend over an important part of the sample (i.e. the 1980s and early 1990s) which can be attributed to the improvements in the anchoring of inflation expectations towards lower levels. In view of this, we decided to adjust the labor cost and price inflation series for such a common trend. To do so, we follow Knotek and Zaman (2014) who were in turn inspired by the forecasting literature that has found gains in inflation forecasting accuracy by specifying inflation 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 by subtracting inflation expectations from the year-on-year growth rates of these series. There exist a large number of inflation expectations measures for the United States.[12] In our analysis, we use the long term inflation expectations used in the FRB-US. The series are defined in PCE terms and combine three estimates: (1) an econometric estimates of inflation expectations from Kozicki and Tinsley (2001) early in the sample, (2) 5- to 10-year ahead survey measures compiled by Richard Hoey and (3) 1- to 10-year ahead expectations from the Survey of Professional Forecasters.

[11] We compute the trend series in a similar manner as Peneva and Rudd (2017). We compute a low pass filter on trend productivity growth in the same way as Staiger et al. (2001), namely as the low-frequency component obtained from a band-pass filter of the annualized log difference of nonfarm business output per hour. We use an ARIMA(4,1,0) model to pad the actual productivity growth series prior to its 1947Q2 starting point; to pad the series after its 2018Q3 endpoint, we set the series equal to the CBOs January 2018 forecast of average trend labor productivity growth from 2018Q4 to 2029 and to the 2029 value of the CBO forecast thereafter. The padded series is only used in the trend extraction routine, not to construct any of the labor cost series that we use in our VAR models.)

[12] For more details on the range of measures available, see Appendix A.

Figure 2: Scatter plot of unadjusted (left panel) and adjusted (right panel) labor cost growth (6 months prior) and price inflation



Sources: Authors' calculations. Sample: 1960Q3-2018Q3.

By combining these approaches, the FRB-US series provide the longest available long term inflation expectations series for PCE inflation.[13] The adjusted series are shown in Figure 1, right hand panel. This adjustment also implies that the series are stationary, according to a standard ADF unit root test.

The common trend is important to understand the link between labor cost and price inflation. As shown in Figure 2, the correlation between the two series appears to have changed more recently when looking at unadjusted data, while the difference is notably smaller when considering the adjusted series. For the remainder of the paper, we base our analysis on the adjusted series of labor cost and price inflation.

[13]Note that some of the estimates used to construct the series are CPI based. In those cases, Federal Reserve Board staff adjusted the source data so as to make it PCE consistent.

3 The baseline VAR analysis

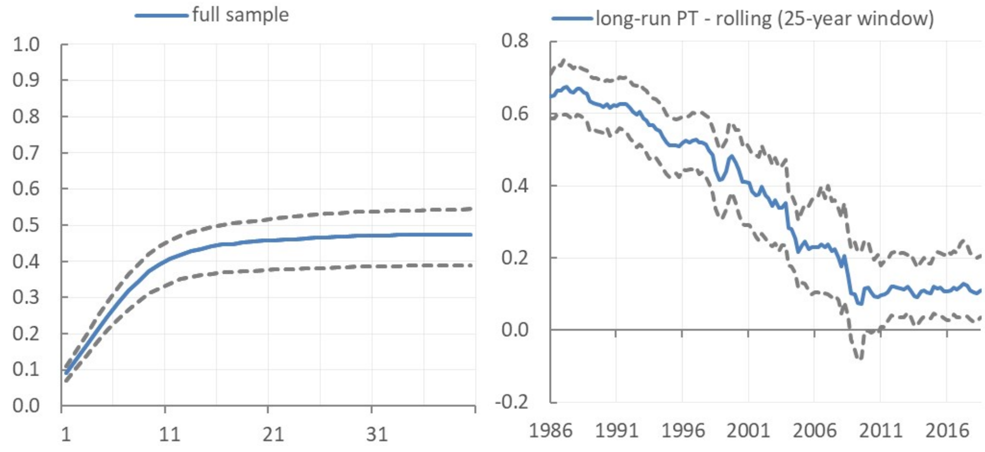
To examine in a dynamic and more conditional manner the link between labor cost and price inflation we estimate the relationship in a VAR setup. Our baseline VAR system contains three variables: the growth rates of (i) real GDP, (ii) our labor cost measure and (iii) core PCE price index. The latter two variables have been adjusted as explained in Section 2 to remove a common trend. The baseline estimation period ranges from 1960Q4 to 2018Q3. The VAR system is 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)).[14]

In this simple set-up we can evaluate the impulse response function of price inflation to a labor cost inflation shock 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 price inflation rise when labor cost inflation increases 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 40 quarters.[15]

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.

Figure 3, left panel, plots the impulse response functions of price inflation to a shock to labor cost inflation, standardized as explained above. The estimates can be interpreted as pass-through multipliers from labor cost to price inflation.

Figure 3: US: Choleski decomposition-based pass-through from labor cost to price inflation



Sources: Authors' calculations. The dashed lines show the 16 and 84 percentiles.

The Chart shows that over the full sample there is indeed a pass-through from labor cost to price inflation of almost 0.5. Nevertheless, we find that the response of price inflation to a labor cost inflation

[14] We also conduct a robustness check of our results by adding the spread between a long- and a short-term interest rate to the VAR system. The included variable is intended to proxy for monetary policy. Our findings are largely unaffected by this extension. The results are available from the authors upon request.

[15] With such standardization, the multipliers are comparable across sectors and countries

shock has been steadily declining over time. We conduct rolling estimations and show the results in the right panel of Figure 3. The pass-through is estimated to be particularly low towards the end of the sample (i.e. for the 25-year rolling window estimates that started in the mid-1980s and thereafter). The latest estimate would suggest that this pass-through is only 0.1. This finding is consistent with other studies, such as for instance Peneva and Rudd (2017). It can also explain why for instance Powell (2020) has indicated that movements in labor costs no longer appear to be a good guide to future price movements.

4 What explains the declining pass-through from labor cost to price inflation?

Which factors have driven the decline in the pass-through from labour cost to price inflation in the United States? To this end we consider and verify four possible hypotheses with some ex-ante plausibility: (i) a change in the inflation environment, echoing improved anchoring of inflation expectations; (ii) the changing nature of the shocks prevailing in the economy; (iii) increased trade openness; (iv) changes in firm market power.

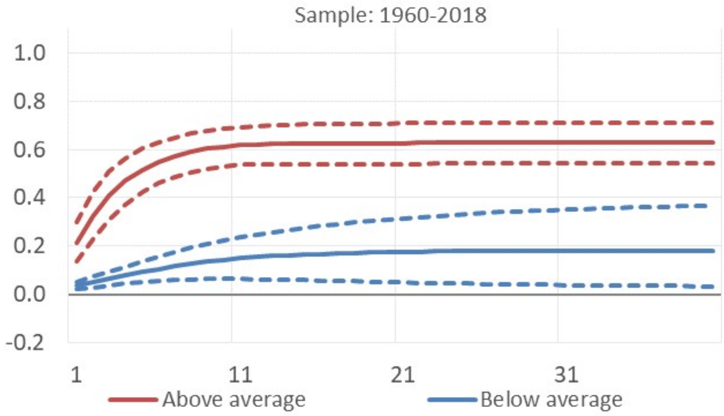
4.1 Changes in the inflation environment

Peneva and Rudd (2017) conjecture that the decline in the pass-through of labor cost to price inflation can be explained by an improved anchoring of the public's expectations of longer term inflation. A number of other studies have also argued that the inflation environment matters for the pass-through, via a variety of channels. In particular, the pass-through could be lower when inflation is low. Taylor (2000) for instance attributes a lower pass-through in a low inflation environment to the low expected inflation persistence, while Daly and Hobijn (2014) stress the role of downward wage rigidities. Another argument that has been put forward 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 more responsive to shocks at higher levels of inflation (see Head et al. (2010)). The latter finding was also confirmed by Nakamura and Steinsson (2013) who present evidence that firms adjust their prices more frequently in periods of high inflation.

To check the importance of this proposition, we estimate our baseline VAR (detailed in Section 3) with a Markov-switching specification and two regimes for the switching parameters depending on whether the level and volatility of inflation are above or below their historical averages. Results are reported in Figure 4.

Our results are consistent with the theoretical literature: the pass-through from labor cost to price inflation is higher and faster if estimated over samples where the adjusted inflation rate and its volatility are above the historical averages. Concretely, we find, over our full sample period a pass-through of 0.62 when adjusted inflation is above the sample average, and of almost 0.2 when adjusted inflation is

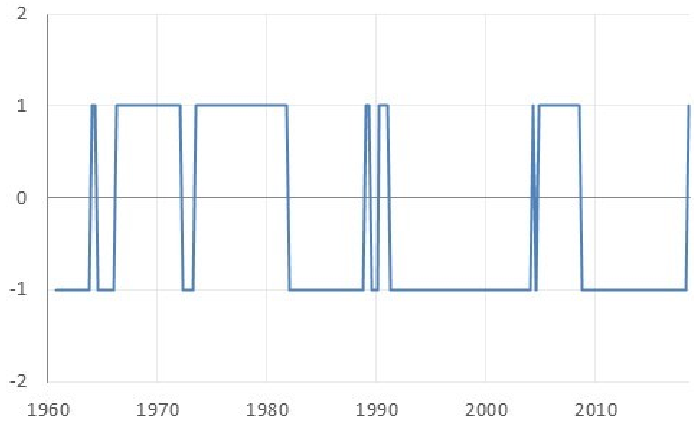
Figure 4: Pass-through from labor cost to price inflation under low versus high level and volatility of price inflation



Sources: Authors' calculations.

below. In the former case, the response is also more rapid, reaching a peak after 9 quarters. Instead, when inflation is below the sample average, the response is sluggish. This would suggest prima facie that a low inflation environment could indeed, at least in part, explain the declining pass-through. However, it should be noted that such an analogy is not straightforward. Indeed, our results show that the pass-through is low when inflation, adjusted for long term inflation expectations, is low relative to its historical average. Figure 5 shows the time periods when the adjusted inflation series in the US was below the sample average.

Figure 5: Evolution of adjusted PCE inflation minus sample period average



Sources: Authors' calculations. Note: series show a positive (negative) value when adjusted inflation is above (below) the sample average.

Overall, Figure 5 confirms that there have been more incidences of a low inflation environment in the most recent period (i.e. since 1990), but not exclusively so. Moreover, it should be noted that the low inflation regime pass-through estimates from our Markov-switching model still indicate a slightly higher pass-through coefficient for the most recent period compared to what is reported in Figure 3. These results would therefore suggest that the low inflation environment is likely to have played an important role in the declining pass-through from labor cost to price inflation. At the same time, it does not fully account for recent developments.

4.2 The changing composition of the shocks hitting the economy

A number of recent studies have argued that the link between labor cost and price inflation is shock-dependent (see for instance Hahn (2021), Bobeica et al. (2020) and Gumiel and Hahn (2018)).[16] As a result, the pass-through from labor cost to price inflation could change over time as the shocks that prevail in the economy evolve. From a theoretical perspective, this argument is grounded in the new Keynesian models where the correlation and lead-lag relationship between labor cost inflation and price inflation depend on the relative degree of the prevailing price and wage rigidities. The latter are time varying, depending on the type of shock that hits the economy.[17] Empirically, such findings are also supported by Nekarda and Ramey (2019) who show that the cyclicality of the price-cost markup is shock dependent.

In order to form a view on the shocks hitting the economy - in particular those regarding the labor market - we augment the baseline VAR model and consider the following 6 variables (the first four expressed in growth rates): real value added, core PCE price index, nominal compensation per hour, labor productivity, the unemployment rate and a proxy for the shadow rate (as computed by Wu and Xia (2016)).[18] We identify, using sign restrictions as detailed in Table 1, five types of shocks in our model: (i) aggregate demand, (ii) aggregate supply (technology), (iii) labor supply, (iv) wage markup and (v) monetary policy shocks.[19]

The identifying restrictions build on previous findings in the literature which we adapt for the purpose of this study by including explicitly the two variables which are indicative for the inflationary pressures stemming from labor costs, i.e. wages and productivity. Besides the *classical* demand, supply and monetary policy shocks, this system allows us to identify two types of labour market shocks: a labor supply and a wage markup shock. In case of a positive labor supply shock, labor force participation increases. This translates into a positive impact on output and on the unemployment rate. Wage growth falls and so does inflation. The negative impact on wage growth distinguishes this labor supply shocks from technology shocks (see for instance Peersman and Straub (2009)). The second labor market shock, i.e. the wage markup or wage bargaining shock, captures an increase in firm wage bargaining power. This shock leads to lower marginal costs, wage growth and inflation, while output increases and

[16] A similar argument has been put forward to understanding the Phillips curve relationship (see Gali and Gambetti (2019)).

[17] In this context, Gumiel and Hahn (2018) using the New Area Wide Model, a DSGE model for the euro area, find that the response of the GDP deflator under demand shocks is qualitatively and quantitatively distinct from the response under supply shocks. The pass-through is stronger for demand than for supply shocks, with the key difference given by the behaviour of profit margins, which increase after a positive demand shocks (amplifying the pass-through from labor costs to prices).

[18] All variables except the unemployment rate and the shadow rate are expressed in annual growth rates, with inflation and nominal compensation adjusted by long term expectations, as previously discussed.

[19] The restrictions are imposed on impact and suffice to uniquely disentangle all five shocks.

Table 1: The five shock VAR: identification scheme

Variables	*Shocks*					
	Demand	Supply	Labor supply	Wage markup	Monetary pol	Other
Real value added	+	+	+	+	+	•
Prices	+	-	-	-	+	•
Wages	+	+	-	-	+	•
Productivity	+	+	•	•	•	•
Unemployment rate	-	•	+	-	-	•
Shadow rate	+	•	•	•	-	•

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

the unemployment rate decreases, as detailed in Foroni et al. (2018). Finally, this model also includes a shadow rate to identify a monetary policy shock. This is relevant given the extended period where the policy rate was at the zero lower bound.[20]

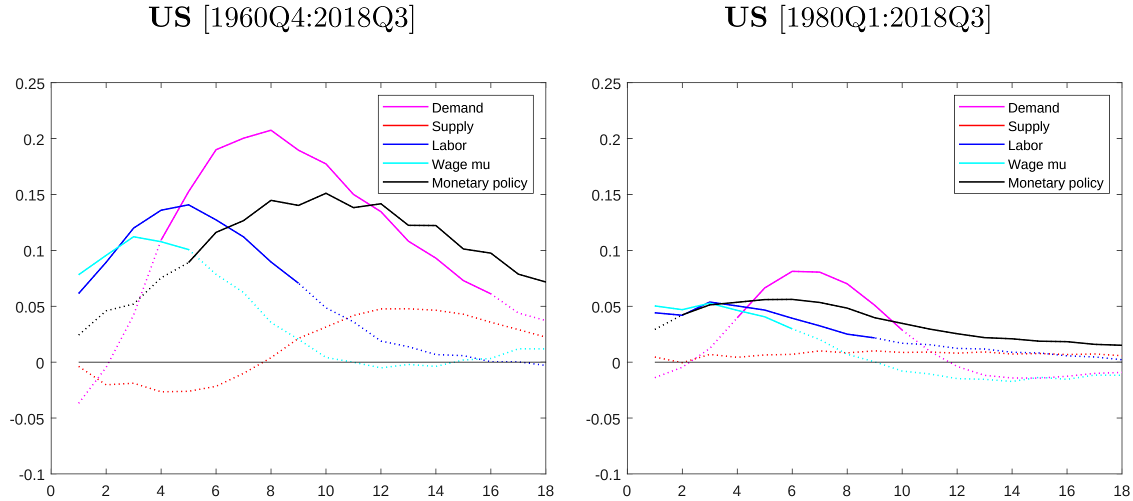
To analyze whether the link between labor cost and price inflation is shock dependent, we apply the methodology proposed in Bobeica et al. (2020). Concretely, we compare the response of price inflation to a shock (e.g. demand shock) to its response to the same shock in a counterfactual scenario in which labor costs do not react. We repeat this exercise for each shock. The difference between the unrestricted inflation response and the counterfactual inflation response (in which we assume that labor cost inflation does not change) can then be interpreted as an indication for the importance of the labor cost channel as an amplifier for the response of price inflation.

The idea of building a counterfactual scenario in which a particular variable does not react to a certain shock in order to study amplification mechanisms in a VAR has been previously explored for other purposes. The literature studying the impact of oil price shocks has assessed their role via the reaction of inflation expectations (see Aastveit et al. (2020), Wong (2015)) or via the reaction of monetary policy (see Kilian and Lewis (2011) or Bernanke et al. (1997), who followed an early version of Sims and Zha (2006)). Using the same methodology, Bachmann and Sims (2012) isolate the role of confidence in the transmission of government spending shocks, while Ciccarelli et al. (2015) use counterfactual scenarios within a VAR to identify the effects of monetary policy shocks via the credit channel. These papers (except Aastveit et al. (2020)) operate with a VAR framework identified with contemporaneous zero restrictions. In a Choleski framework each variable has a corresponding shock, so it is straightforward to shut down the impulse response function (IRF) of a variable by constructing a sequence of hypothetical shocks in that variable in a recursive manner, such that its IRF is zero at all times. When the identification scheme is based on sign restrictions and not a Choleski ordering, as we propose in this paper, things get more complicated. Let's say we want labor costs not to react to supply shocks; in this case there is no *labor cost shock* to offset the response of labor costs to supply shocks. One has to instead make assumptions on which other shocks are doing the offsetting (i.e. is it the demand, other shock or, our preferred version, a combination of all shocks hitting the economy).

[20]The estimation has been performed using the BEAR toolbox, see Dieppe et al. (2016).

Appendix N in Bobeica et al. (2020) shows the details behind the derivation of the counterfactual $IRFs$.

Figure 6: Amplification of price inflation response due to the labor cost channel



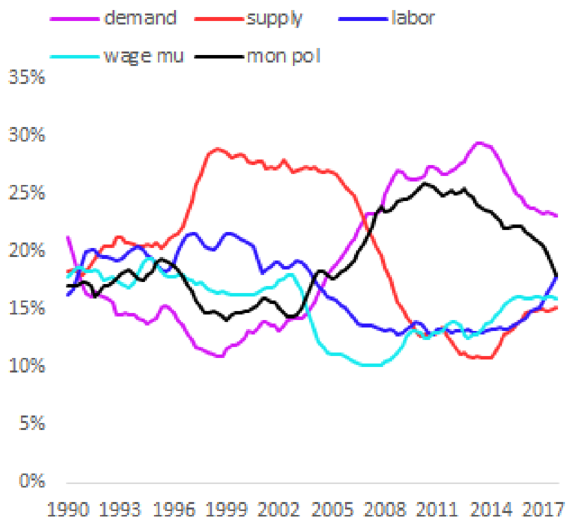
Note: The solid lines show a significant impact, i.e. the cases where the median counterfactual IRF lies outside the 68 percent posterior uncertainty band of the unrestricted IRF; borderline cases were left out. *Wage mu* stands for wage markup shocks.

Results are reported in Figure 6. They confirm the theoretical model predictions and those of Bobeica et al. (2020) for the euro area, i.e. the link between labor cost and price inflation is shock dependent. We find that the link between labor cost and price inflation is strongest and fastest for demand, monetary policy and labour market shocks, whereas aggregate supply shocks only generate a weak link between labor cost and price inflation.

The key question of interest to our analysis is whether the US economy has over time been increasingly hit by shocks that are associated with a weaker link between labor cost and price inflation. To this end, we consider the historical shock decomposition from the model. Figure 7 shows that especially between the mid-1990s and mid-2000s, the relative contribution of supply shocks increased notably. These findings, combined with the results shown in Figure 6, suggest that over this period, the changing composition of shocks has likely contributed to a declining pass-through.

However, at the same time, the constellation of shocks does not appear to be a dominant factor for the observed decline in pass-through. First, in particular in the mid 2000s, the contribution of supply shocks receded, while the pass-through continued to decline. Second, when we compare the price inflation response due to the labor cost channel across shocks over the sample period 1960Q1-2018Q3 with the shorter sample period 1980Q1-2018Q3 (Figure 6) we find that the amplification of price inflation due to the labor cost channel is notably smaller across all shocks in the more recent period. This would suggest that while the types of shocks hitting the economy could have lowered the pass-through to some degree, other factors above and beyond this channel are at play.

Figure 7: The relative contribution of shocks to price inflation in absolute terms (10-year moving average)



Sources: Authors' calculations. Note: 10 year moving average of the relative contributions in absolute terms presented in Figure 17. *Wage mu* stands for wage markup shocks.

4.3 Trade openness

Increased trade integration and trade openness has been frequently mentioned as a key factor altering labor cost and inflation dynamics in the United States. Economic theory would suggest that increased exposure to foreign competition alters the competitive dynamics among firms and among workers in both exporting and importing countries. This is expected to affect product prices and the sensitivity of inflation to positive domestic resource utilization and labor cost dynamics.

A number of studies have empirically analyzed the impact of global factors on the relationship between inflation and economic activity. Forbes (2018) finds that global factors have played a more prominent role in determining US inflation outcomes since the 1990s. Borio and Filardo (2007), Auer et al. (2017), Zhang (2017) and Gilchrist and Zakrajsek (2019) document that globalization has reduced the sensitivity of inflation to domestic factors. They argue that the integration of China and other lower-cost producers in world production networks has increased competition, thereby inducing downward pressure on wages and import prices in the United States and other industrial countries.[21]

Along similar lines, increased exposure to foreign competition and markets could also have altered the link between labor cost and price inflation. Using micro European data from the Wage Dynamics Network, Bertola et al. (2012) find that in a highly competitive environment, a positive wage shock makes firms more likely to reduce other costs and less likely to increase prices. Also, firms with a

[21] Note that there is no full consensus in the literature on these conclusions. Several authors, see for instance among others Ball and Mazumder (2019), find instead that the apparent weakened link between inflation and economic activity can be attributed to a lower frequency of price adjustments at the firm level.

higher exposure to foreign competitors are more likely to respond to domestic cost shocks by lowering other costs. The explanation put forward is that foreign competitors are unlikely to be hit by the same domestic cost shock - e.g. wage shock - which makes it difficult for the firm to pass-through this cost shock to prices in a competitive environment.

4.3.1 Industry-level estimates: data sources

To understand whether increased trade openness has had an impact on the link between wage and price inflation, we compare the evolution of the labor cost-price inflation pass-through - based on our baseline VAR - with that of trade openness at the most disaggregated level possible. To do so, we construct a data set of industry-level data on trade openness, inflation, real value added and unit labor costs from various sources. We collect data for the manufacturing sectors with NAICS codes 31 to 33 at the 4- and in some cases 5-digit level. We found this is the most disaggregated level for which data is available for a large number of industries (around 100) over an extended period of time (in many cases starting from 1973).

To construct our inflation series, we utilize industry-level PPIs as published by the Bureau of Labor Statistics. Figure 8 left panel shows the time series evolution of the unweighted cross-sectional median of the year-on-year percentage change in the PPI series of the 100 industries we collected. The shaded area shows the 25-75 percentile interquartile range, while the dashed line shows the evolution of the year-on-year percentage change in the aggregate core PPI series. The evolution of the median closely matches the dynamics of the core PPI series, suggesting that the constructed industry-level data are representative of the economy as a whole.[22]

We merge our constructed inflation series with the corresponding industry-level real value added data. Value added data at industry level is available from the Census bureau's Annual Survey of Manufacturers over the period 2008-2018. We combine it with the value added data from the NBER CES manufacturing sector database which covers the period 1958-2011.[23] To create quarterly data, we interpolated the annual series using industrial production data constructed by the Federal Reserve. We do so using the dynamic Chow-Lin method proposed by Santos Silva and Cardoso (2001).[24]

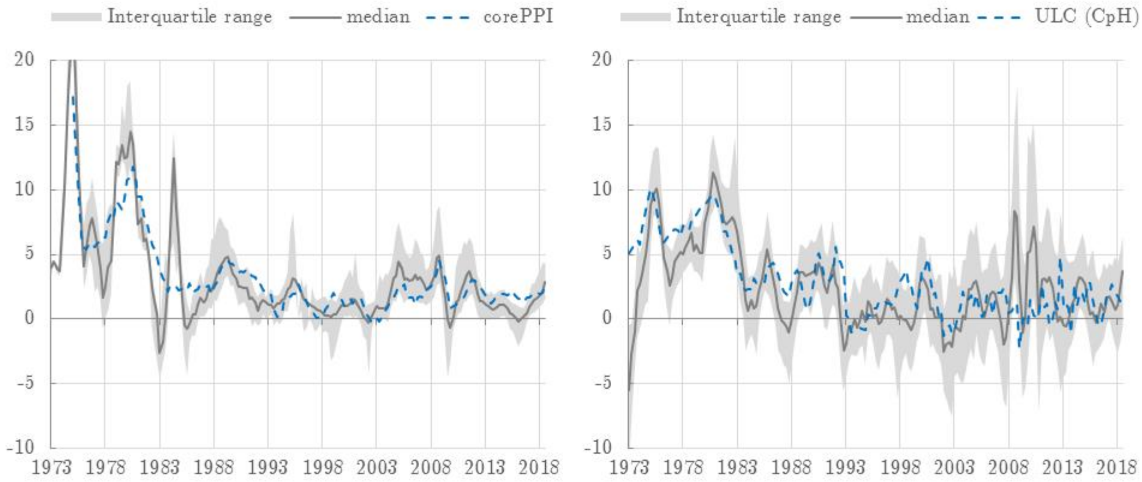
We complement these series on output activity and prices with data on labor costs. Labor costs are calculated as the ratio of wages to labor productivity. Labor productivity in turn is computed as the ratio of real value added to employment. Our wage and employment data stem from the same source as our real value added series. To create quarterly series, we interpolate them using the data on wages and employment from the Quarterly Census of Employment and Wages (QCEW), a data collection program that publishes a quarterly account of employment, total wages, and average weekly

[22] We use PPI series as these are available at the industry-level. At the aggregate level, we find that our PPI series is closely related to the PCE deflator. Specifically, over the period 1973-2018 the contemporaneous correlation between the median PPI series and the PCE deflator, both expressed in year-on-year percentage changes, is 0.81.

[23] NBER CES data is available on the following website: http://data.nber.org/nberces/

[24] The industry-level price and industrial production data are available at monthly frequency, and we convert them to quarterly frequency by simply averaging the values of each index over the three months of each quarter. Industrial production indexes are in some cases not available for the all 4 or 5-digit NAICS industries. In case the data was not available at such disaggregated level, we assigned the industrial production series from the more aggregate level.

Figure 8: Median and Interquartile range of core PPI and ULC inflation series at industry level versus aggregate Core PPI and aggregate ULC series



Sources: Authors' calculations. Sample: 1973Q1-2018Q3.

wages per employee, reported by companies covering more than 95 percent of US jobs. The QCEW data, however, are available only starting in 1990Q1. Prior to that we interpolate the series using sectoral level employment and wage data from the OECD STAN database.[25] Figure 8, right panel shows the resulting time-series evolution of the unweighted cross-sectional median of the year-on-year percentage change in the labor cost series of the 100 industries we collected. The shaded area shows the 25-75 percentile interquartile range while the dashed line shows the evolution of the year-on-year percentage change in the aggregate labor cost series (as described in section 2). As evidenced by the shaded bands, labor cost inflation rates vary significantly across industries. At the same time, the time series fluctuations in the median closely matches dynamics of the corresponding aggregate, an indication that our industry-level data are representative of the economy as a whole.

To measure trade exposure at the industry level, we combined the quarterly (nominal) import and export data from the Census trade online database (available since 2002) with the historical annual (nominal) import and export data made available by Peter Schott.[26] The historical data covers the period 1972 to 2005. The data provided are disaggregated by country (source for imports and destination for exports). These data were first aggregated to the total annual imports and exports at the industry level. For the period 1972 to 1989 the data were classified under the 4 and 5-digit Standard Industrial Classification (SIC) codes. These series had to be first mapped into industries at the NAICS level. To do so, we relied on the approach used by the Federal Reserve Board of Governors to map industrial production data at SIC level into NAICS level data. To compute trade exposure, the export and import

[25] The industry-level QCEW data exhibit significant seasonal fluctuations. Accordingly, we filtered all industry-level variables using the Census Bureaus X12 seasonal adjustment procedure, hence all of our growth rates (i.e., log differences) are constructed using seasonally adjusted level series. To ensure that our results were not influenced by a small number of extreme observations, all quarterly growth rates were in addition winsorized at the 0.5th and 99.5th percentiles.

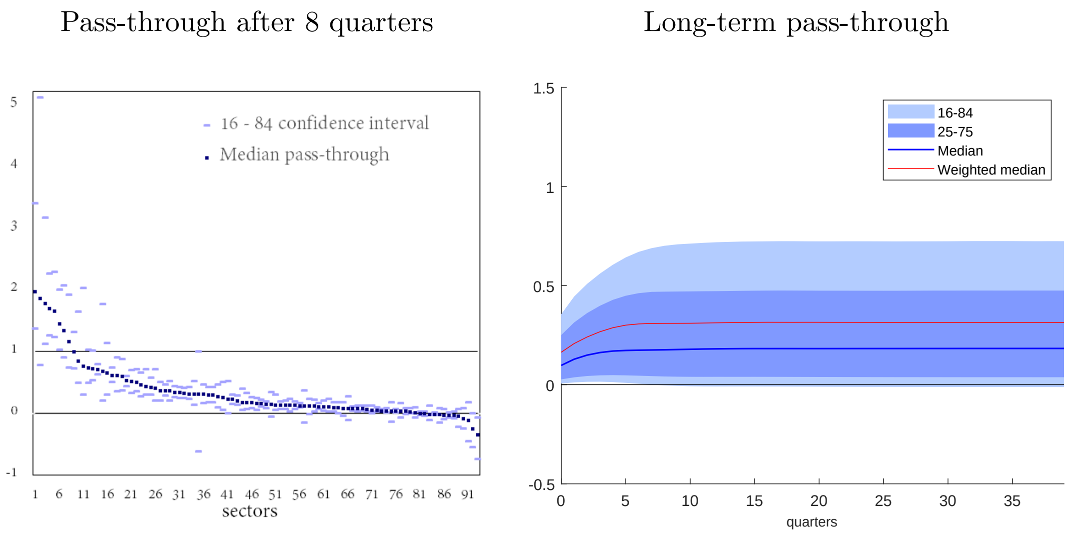
[26] Data available at: https://faculty.som.yale.edu/peterschott/international-trade-data/

annual series were then merged with the value added output series described above[27].

4.3.2 Industry-level estimates: pass-through and trade exposure

To analyze whether there is a link between trade openness and the pass-through from labour cost to price inflation at the industry level, we estimate our 3-variable baseline VAR as described in Section 3 on an industry-by-industry basis.[28] The left-hand panel of Figure 9 shows the medium-term pass-through (after two years) for all the 93 sectors, estimated for the entire available sample for each sector. For most industries, the pass-through of labor cost to price inflation is statistically significant, albeit low. The same message can be derived when looking at the long-term pass-through (right hand panel), where the unweighted median pass-through across sectors is around 0.2 and around 0.3 when aggregating the industry-level results using their weight in the total real value added. The results go in the direction of those in Heise et al. (2020), who highlight a very small or insignificant (depending on the sample) pass-through in manufacturing. Contrary to Heise et al. (2020) we however do not find that the pass-through is statistically insignificant at most horizons or even negative from quarter 10 onwards.

Figure 9: Pass-through estimates across economic sectors



Note: The long-term pass-through refers to the long-run (40 quarter) value; the median of the long-term pass-through is derived based on all the draws for all 93 manufacturing sectors.

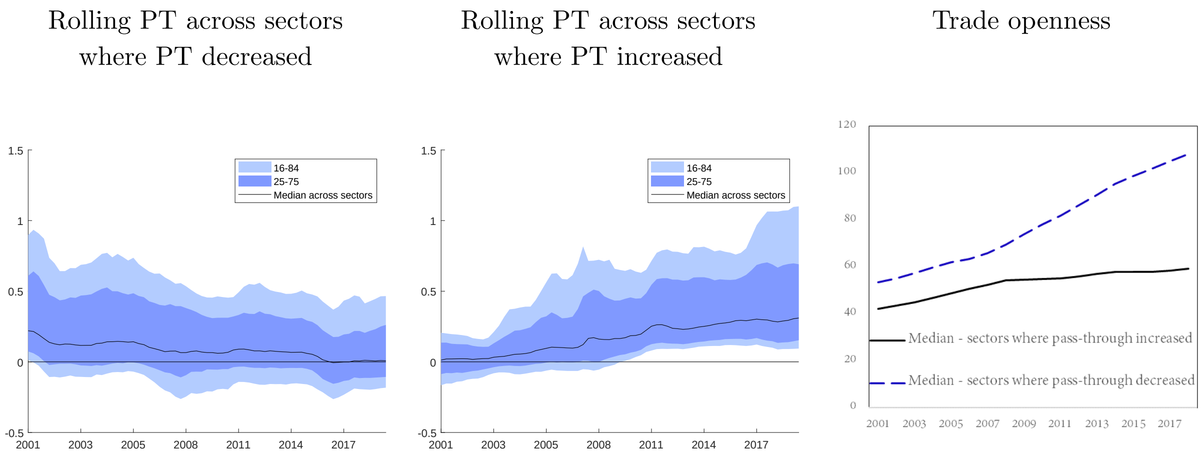
The sectoral information allows us to investigate at industry level the link between labor cost to

[27]Concretely, trade openness is computed as the ratio between the sum of import and export on the one hand and value added on the other hand

[28]We estimate the pass-through at the sector level using the baseline VAR shown in Section 3 within the 3-variable set-up: year on-year growth in real value added, labor cost and producer price inflation (the latter two adjusted for the common trend given by long-run expectations), with this ordering. The available sample is sector specific - for about 40 sectors the data starts in 1987 at the latest, whereas for 56 sectors the data starts in 2005. The pass-through is proxied by the ratio of the cumulative responses of price and labor cost inflation to a shock in unit labor costs.

price inflation pass-through on the one hand and trade openness on the other hand. For around a third of the industries we have data starting late 1980s. This allows us to conduct rolling estimations over 60 quarters.[29] We find that for 17 sectors the pass-through has decreased, for 16 sectors the pass-through has increased and for 5 it is broadly unchanged. Figure 10 shows in the left and middle panel the estimates for the first two categories respectively. It is interesting to check how these two industry groups differ in terms of trade openness. The right-hand panel of Figure 10 shows the evolution of trade openness for industries with decreasing versus increasing pass-through over the same rolling window. The chart shows the well-documented finding that trade openness has generally increased across manufacturing industries. However, it also shows that in industries where pass-through decreased over time, trade openness increased faster. Moreover, the figure also suggest that it is not only the change in trade openness that could have a bearing on the pass-through, but also its level. The pass-through of labor cost to price inflation namely fell in sectors where the level of trade openness was higher.

Figure 10: Pass-through PT and trade openness



The pass-through refers to the long-run (40 quarter) value; the median of the long-term pass-through is derived based on all the draws for the considered sectors; x-axis shows the end of the 60 quarter rolling window. Trade openness is defined as the ratio of imports plus exports over value added.

These results are confirmed when we compare the pass-through in industries with above versus below median trade openness over the period 2005-2018. Figure 11 shows that above median trade openness is associated with a lower pass-through value, although the difference is small.[30] Concretely, the median pass-through for sectors with a relatively high degree of trade openness is close to 0.1, whereas the median pass-through of sectors with lower trade openness is around 0.3. This offers some support, albeit not wholeheartedly, to the theories claiming that trade openness has diminished the

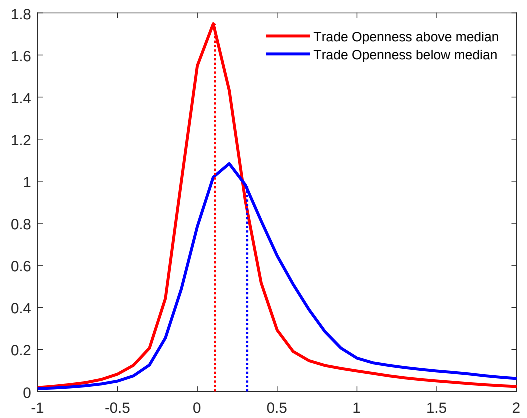
[29]The window for the rolling estimation is smaller than in section 3, where a window of 100 quarters was used, as our industry-level data sample starts later.

[30]The result holds also when looking at estimates starting 2005 for all the sectors or when narrowing down the selection of the sectors only to those for which the sample starts at least in '86. It also holds when looking at mean trade openness.

pass-through of labor costs to inflation.

In order to ensure that our results are not driven by the set of industries considered, by the reference period for the trade openness indicator, or by the way we interpolated annual data, we performed a robustness check using annual data. Due to the short sample for a number of sectors, we only consider the 37 sectors for which the sample starts at least as early as 1987. Figure 18 in Appendix C shows the estimates of the pass-through across all the sectors when the trade openness at the sector level is above versus below the average computed over a common sample, namely 1987 - 2018. The figure conveys the same message: pass-through is somewhat smaller when the degree of trade integration is higher. As a caveat, the implications of these results for the economy-wide pass-through are limited by the fact that our industry level data set covers only the manufacturing sector.

Figure 11: Long-term pass-through estimates across sectors according to the level of trade openness



Note: The pass-through refers to the long-run (40 quarter) value. The pass-through estimates pool the draws for all available sectors; the vertical lines indicate the median.

4.4 Changes in the pricing power of firms

In the industrial organisation literature, the ability and willingness of firms to pass-through cost push shocks depends crucially on the degree of competition a firm faces. While the pass-through of an industry-wide cost push shock is complete under perfect competition, lesser competition will lead to a lower degree of pass-through, provided that demand is not too convex.[31] Melitz (2018) discusses how certain assumptions on the shape of demand (originally advocated by Alfred Marshall as his second law of demand) imply a negative relationship between markups and pass-through: in response to a given cost shock, a low-cost/high-productivity firm adjusts its markups by more than a high-cost/low-productivity firm. In other words, better performing firms with higher markups exhibit lower pass-through rates.

[31] When demand is very convex and there is imperfect competition in the market, pass-through could even exceed one.

Empirically, the relation between cost pass-through and competition has been extensively studied in the industrial organisation literature. However, the focus has been on specific narrowly defined sectors and often extends beyond labor cost shocks (i.e. for instance by considering changes in the tax regime). At a more aggregate level, most empirical studies that have analyzed the relation between the degree of market competition and cost pass-through come from the international economics literature, where there is a long tradition of estimating the impact that competition may have on the pass-through of changes in the exchange rate onto goods prices.

Existing studies on the link between cost pass-through and market power in the industrial organisation and international macroeconomics literature have so far been inconclusive. A number of studies (see for instance Kim and Cotterill (2008) and Amiti et al. (2019)) find that increases in market power are associated with a reduction in the aggregate (industry-wide) pass-through. Instead, Gopinath and Itskhoki (2011) found no clear link between the level of market concentration and the exchange rate pass-through elasticity. And finally, some other studies stress that the relationship is non-linear: using data for US firms, Auer and Schoenle (2016) show that the relation between the estimated exchange rate pass-through and market share is U-shaped, similar to previous findings by Feenstra et al. (1996).

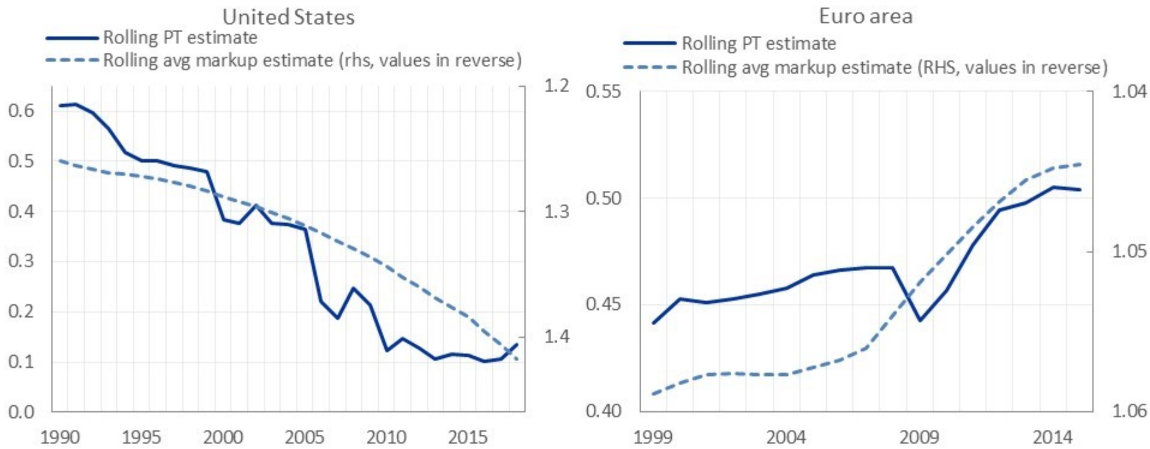
Such inconclusive findings may however at least in part relate to the difficulty to empirically capture the degree of market competition. A number of measures, such as the degree of market concentration or a firm's market share, are often used as proxies for the degree of firm market power in such studies. However, such proxies are at best imperfect and at worst can even be wrong (see also the discussion in Syverson (2019)). For instance, the correlation between market concentration and market power is only true under very specific market structures, such as the Cournot quantity competition. When relaxing some of the assumptions in the Cournot quantity competition model, such as assuming that products are differentiated, there is no longer a relation between market concentration and market power. As a result, it is unsurprising that mixed evidence has emerged from the empirical literature as to how cost pass-through is linked to market concentration measures.

While the industrial organisation and international macro literature has extensively studied the degree of market competition and its potential implications, it traditionally has attracted far less attention among macroeconomists. At the macro level, the traditional prevailing assumption has namely been that the degree of market competition is imperfect but stable. Only recently, the analysis of the trend developments in market power has entered the field of macroeconomics in response to a number of studies which found that there may be a potential rise in market power in the United States which would put into question the standard macro model assumption of unchanged firm market power.

The topic was most prominently brought to the fore by DeLoecker and Eeckhout (2017). The authors show that the average markup for US firms has risen sharply over the past three decades. More specifically, they find that the increase occurred across industries but was mostly concentrated among high markup firms (i.e. those firms that had a high markup at the beginning of the sample witnessed the biggest rise in markups). A number of other studies, using different approaches and methodologies, have confirmed the DeLoecker and Eeckhout (2017) finding that market power of US firms has risen. For instance, Hall (2018) and Nekarda and Ramey (2013) also find, in this case using macro data, support for the conclusion that the markup has risen for US firms in recent decades. Moreover, a number of studies also show that concentration ratios have been rising (see for instance Peltzman (2014), Gutierrez and Philippon (2017) and Autor et al. (2017)).

The developments in firm market power at the aggregate level have already been linked to a number of secular macro trends in the United States, such as the decrease in labor and capital share, the decline in low skilled wages, the decline in labor flows, labour force participation and migration rates and the slowdown in aggregate output (see for instance DeLoecker and Eeckhout (2017) and Eggertsson et al. (2018)). Haldane et al. (2018) also conjectures that these developments can, at the aggregate level, change the the slope of the Phillips curve and the degree of cost pass-through although not testing it empirically.

Figure 12: The link between market power and labor cost pass-through



Sources: Authors' calculations. Note: the solid series show the rolling pass-through estimate (at 40 quarter horizon) of a labour cost shock to price inflation based on a Choleski VAR estimation as described in Section 3. For the United States the results are shown for a 30 year rolling window, for the euro area for a 20-year rolling window. A detailed description of the data used for the euro area estimations can be found in Appendix A and McAdam et al. (2019) in the case of markups. The markup estimates are shown in reverse scale.

To analyze whether there is a possible link between the labor cost- price inflation pass-through and the degree of market power, we compare the developments in our estimated labor cost pass-through (as described above in Section 3 and shown in the right panel of figure 3) with the developments of a measure of firm market power from DeLoecker and Eeckhout (2017), which we also compute on a rolling basis over the same time period.[32]

The results are shown in Figure 12 left panel. Overall there is a very strong link between the decline in the pass-through from labor cost to price inflation and the evolution of the aggregate markup (in reverse scale) with the correlation coefficient being 0.93. We use estimates for the euro area as a cross-check for this observation. For the euro area, in contrast to the United States, the pass-through from labor cost to price inflation has remained stable over time, possibly even increasing somewhat. Cross checking these movements against the estimates of the aggregate markup (in reverse scale) also

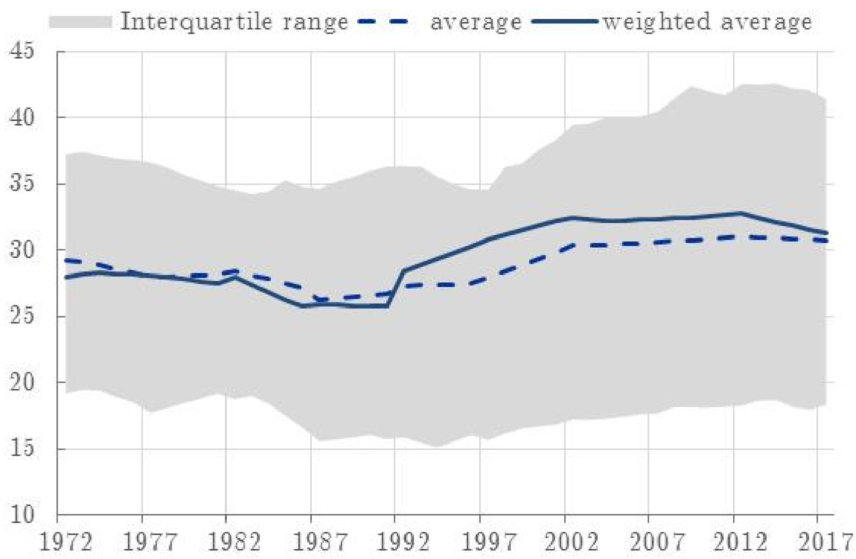
[32] The markups made available by DeLoecker and Eeckhout (2017) are based on accounting data from Compustat. Following Hall (1988), the authors compute the markup for any variable input as the ratio between the elasticity of output to that variable input, and the share of revenues the input is paid. The elasticity is obtained by means of estimating a production function (where the variable input used is approximated by the firms' cost of goods sold), whereas the revenues paid to the input are directly observed in the data.

confirms a strong link, with the aggregate markup in the euro area having even declined somewhat over time, while the pass-through has increased.

4.4.1 Industry-level estimates: pass-through and market concentration

The US result is validated when we look at a more disaggregated level and compare at industry level the pass-through with the CR4 concentration ratio (as a proxy for market power). It is true that theoretically, and as already indicated above, markups are the most direct measure of market power among the possible empirical proxies. Estimated indicators of markups come however with some measurement uncertainty (see Traina (2018)). So it is also worth looking at an alternative proxy, and concentration indices are a popular choice. For the purpose of our analysis we obtain the CR4 ratios from the US Economic Census Concentration accounts, which are published every five years (2017 is the latest available vintage.) The series (linearly interpolated) are shown in Figure 13.

Figure 13: CR4 across US manufacturing industries

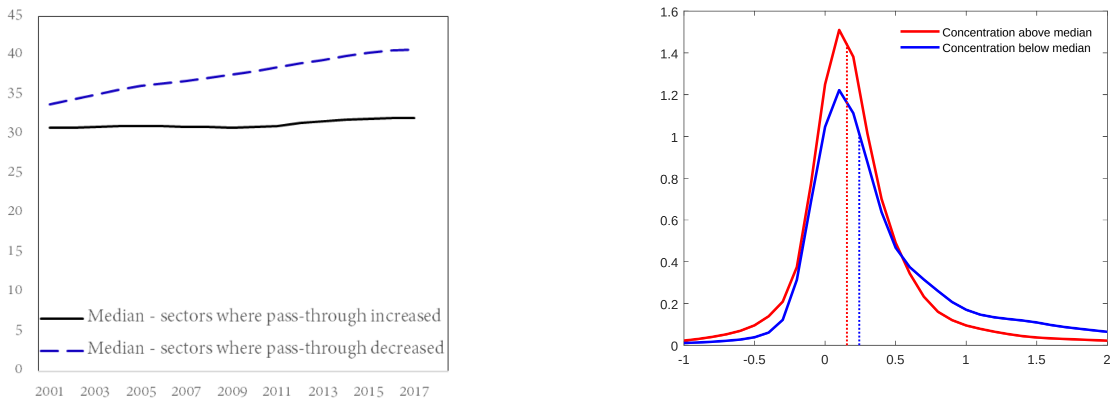


Sources: Authors' calculations. Note: the solid series shows the sales weighted average CR4 across industries, while the dashed line shows the unweighted average for the same industries. The grey range shows the 25-75% interquartile range. Data is published every five years, the chart shows the series using a linear interpolation.

We apply the same methodology as discussed in Section 4.4.1. First, for the fraction of industries for which we have data starting late 1980s (38 sectors out of 93) we conduct rolling estimation of the pass-through. We split the sectors into a set for which the pass-through has decreased and a set for which the pass-through has increased and check how these two industry groups differ in terms of concentration. Figure 14, left-hand panel, shows that market concentration increased for the industries with decreasing pass-through, whereas for industries with increasing pass-through market concentration stagnated. As in the case of the link with trade openness, we uncover a level effect. Not only that market concentration increased for the industries with decreasing pass-through, but market concentration was also higher than for the other sectors. The fact that the level of market concentration might matter is shown in Figure 14, right-hand panel. The chart shows that above median market concentration is associated with a lower pass-through value, although the difference is small.[33] Concretely, the median pass-through for sectors with a relatively high degree of market concentration is close to 0.1, whereas the median pass-through for sectors with lower market concentration is close to 0.3.

Figure 14: Pass-through and sectoral market concentration

Market concentration | Pass-through and the level of CR4



Note: (a) Market concentration is a rolling average over 15 years; (b) The pass-through refers to the long-run (40 quarter) value. The pass-through estimates pool the draws for all available sectors; the vertical lines indicate the median.

5 Conclusions

We document and confirm in this paper that the pass-through from labor cost to price inflation in the US has significantly weakened over the past three decades.

We have analyzed in this paper four key hypotheses that could account for the observed decline in pass-through: (i) the change in the inflation environment towards lower levels echoing improved anchoring of inflation expectations; (ii) the changing constellation of shocks hitting the economy; (iii) the increase in the degree of trade integration and (iv) the secular rise in firm market power.

Overall we find that all factors have contributed to the declining pass-through from labor cost to price inflation in the United States. Importantly, we find that the pass-through tends to be lower when inflation - after adjusting it for long term inflation expectations - is below its historical average. Second, we find that the pass-through is strongest when co-movements are triggered by demand shocks, and weakest when they are triggered by supply shocks. Between the mid-1990s until mid-2000s, supply

[33]The result holds also when looking at estimates starting 2005 for all the sectors.

shocks became more prominent, thereby likely contributing to the decline in pass-through. However, we also find that across all types of shocks, the pass-through has declined in recent years, suggesting that factors above and beyond the type of shock have led to a declining pass-through. We also find some evidence that our third hypothesis, namely increased trade integration, is associated with a lower pass-through. Indeed, our results show that in the manufacturing sector, pass-through has decreased most in those industries where trade openness increased most. Moreover, we unveil a level effect: the pass-through appears to be smaller in more open industries. However, while all these results would support our hypothesis, none of them provides the full explanation. Finally when testing our last hypothesis - namely that changing firms' market power has reduced the aggregate pass-through in the United States - we unveil a striking correlation between the dynamics of the economy-wide estimated pass-through to that of a measure of aggregate firms' markup. We also make use of the level of concentration in each sector, as proxied by CR4 ratios from the US Economic Census Concentration account. We find that the sectors in which pass-through has decreased are the ones where concentration was on the rise, whereas concentration has remained flat for the rest of the sectors. However also here, while the results are supporting our hypothesis, the overall effects are too small to explain the observed aggregated developments.

The fact that the decline in pass-through appears at least in part to be linked to structural trends also implies it is unlikely to revert in the near future. As such, our results bring supportive evidence to the view taken by the FED in the context of its monetary policy strategy review (see Powell (2020)) that a robust job market can be sustained without causing an outbreak of inflation.

Appendix A Data documentation

Inflation, labor cost and unemployment rate series were all obtained from the Bureau of Labor Statistics. Compensation per hour series are available since 1947Q1, whereas the Employment Cost Index is available since 1980Q3. Real GDP series are obtained from the Bureau of Economic Analysis (series in seasonally adjusted annual rates in 2012 billion chained dollars).

To proxy for the monetary policy stance, we use the effective Federal Funds rate. However, we use the shadow rate, as estimated by Wu and Xia (2016) over the period where the effective Federal Funds rate was at the *zero lower bound*[34] .

Inflation expectations are difficult to measure. For the US, there exist a wide variety of approaches. As we wish to subtract from our inflation and labor cost series a slow moving low-pass trend from our series, we focus on long term inflation expectations. Ex ante it is unclear which long term inflation expectations measure would be preferable. A number of measures are available:

- Survey based inflation expectations Michigan survey: Consumer survey for 5 year ahead inflation expectations. The series exist on a continuous basis since 1990Q4. (one year expectations available since 1978).

  Additional information: http://www.sca.isr.umich.edu/

- Survey based inflation expectations Philadelphia Fed: 10-year ahead inflation expectations from survey among professional forecasters, available since 1991Q4.

  Additional information: https://www.philadelphiafed.org/research-and-data/real-time-center/survey-of-professional-forecasters/

- Survey based inflation expectations Philadelphia Fed combined with historical data from other series: From 1991Q4 the 10-year ahead SPF inflation expectations are used. Prior to that, a combined series based on the Philadelphia Fed's Livingston Survey and from the Blue Chip Economic Indicators are used (information available back to 1979Q4). The gaps in the quarterly series are filled by means of a linear interpolation.

  Additional information: https://www.philadelphiafed.org/-/media/research-and-data/real-time-center/survey-of-professional-forecasters/historical-data/additional-cpie10.xlsx?la=en

- Market based inflation expectations computations by Groen and Middeldorp (2013): Breakeven backcast estimated 10 year inflation expectations as computed by Groen and Middeldorp.

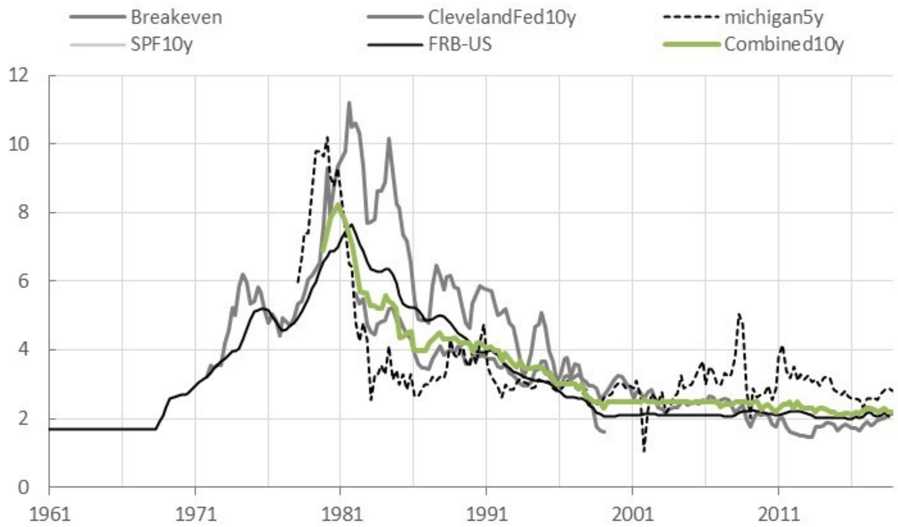
  Additional information: https://libertystreeteconomics.newyorkfed.org/2013/08/creating-a-history-of-us-inflation-expectations.html

- Combined approach computations by Haubrich et al. (2012): Methodology combines market and survey based inflation expectations. Inflation expectations are available for 1 to 30 years ahead. We chose the 10 year ahead series.

  Additional information: https://www.clevelandfed.org/our-research/indicators-and-data/inflation-expectations.aspx

[34] Note that we define the period where the Federal Funds rate is at the zero lower bound any time in which the effective Federal Funds rate is in the 0 to 0.25 percent range targeted by the Federal Open Market Committee. Over our sample this was the case between end 2008 and end 2018.

Figure 15: Measures of long-term inflation expectations % change



Sources: Authors' calculations. Sample: 1960Q1-2018Q3.

- Long term inflation expectations as used in FRB-US: The series are defined in PCE terms and combine three estimates: (1) an econometric estimates of inflation expectations from Kozicki and Tinsley (2001) early in the sample, (2) 5- to 10-year ahead survey measures compiled by Richard Hoey and (3) 1- to 10-year ahead expectations from the Survey of Professional Forecasters. By combining these approaches, the FRB-US series provide the longest available long term inflation expectations series for PCE inflation.

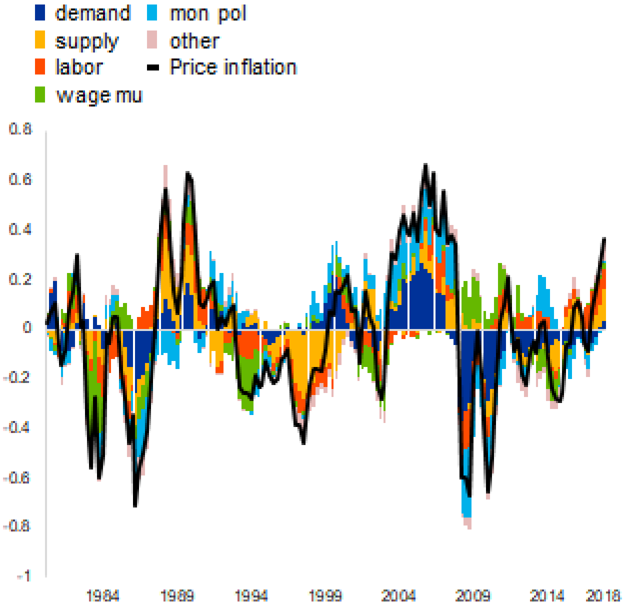
Additional information: http://joshuachan.org/code/code$_{t}rend_{I}E.html$

The various measures are shown in Figure 15. In our analysis, we use the long term inflation expectations used in the FRB-US, which is the the longest available long term inflation expectations series for PCE inflation.

For the *euro area* exercise presented in Figure 12, right hand panel, we employ data for the aggregate economy as follows: real GDP, compensation of employees, GDP deflator. The series were obtained as seasonally and working day adjusted series from Eurostat over the period 1980Q1-2018Q3. The nominal variables were adjusted for a common trend given by long-term expectations from Consensus Economics, which is available starting 1989Q4, on a semi-annual basis for most of the period. We interpolated it to quarterly frequency and also back-casted it till 1980 using a slow moving inflation trend (based on a Hodrick-Prescott filter).

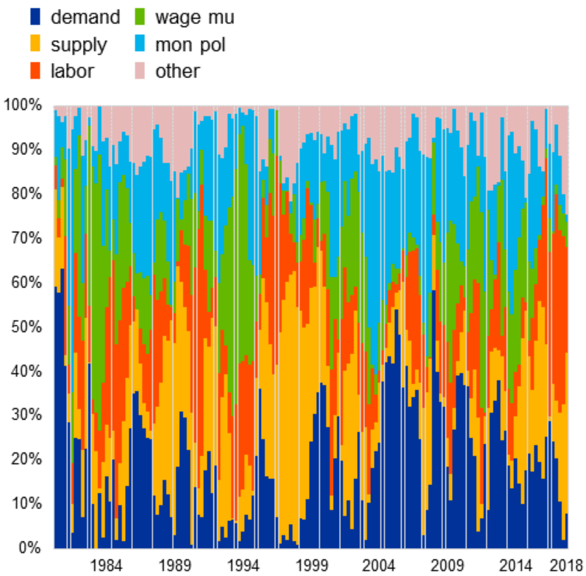
Appendix B The changing relative importance of shocks

Figure 16: Shock decomposition of price inflation



Sources: Authors' calculations.

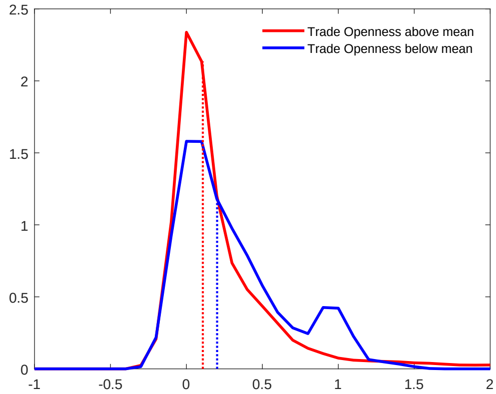
Figure 17: The relative contribution of shocks in absolute terms to the dynamics of price inflation)



Sources: Authors' calculations. Note: contributions of the various shocks presented in Figure 16 in absolute values and in relative terms.

Appendix C Increased trade openness

Figure 18: The link between pass-through and trade openness. Estimates based on annual data



Note: The pass-through refers to the long-run (40 quarter) value. The pass-through estimates pool the draws for all available sectors; the vertical lines indicate the median.

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