Banc Ceannais na hÉireann
Central Bank of Ireland
Eurosystem

Economic Letter

Missing wage growth in the euro area: is the wage Phillips curve non-linear?

David Byrne & Zivile Zekaite

Vol. 2018, No. 9

Missing wage growth in the euro area: is the wage Phillips curve non-linear?

*David Byrne & Zivile Zekaite**

This *Letter* examines the relationship between wage growth and labour market tightness in the euro area, frequently represented by the Phillips curve. It predicts that falling unemployment should lead to greater wage growth. A key question for policymakers post-crisis is whether this relationship has changed or broken down. We show that the euro area wage Phillips curve is non-linear. When labour market slack is elevated, tightening does not lead to greater wage growth. The relationship only returns when slack is at lower levels. This finding explains why wage growth did not increase when the labour market tightened between 2013 and 2016, and why stronger wage growth has been evident since 2017.

Introduction

Until recently, the euro area had been experiencing a protracted period of disappointing wage growth despite a tightening labour market. Forecasts had systematically over-predicted wage growth and under-predicted employment growth in the post-crisis period (ECB, 2016). A similar pattern of low pay growth was also evident in other advanced economies (Yellen, 2015; Haldane, 2018). As a result, many have questioned whether the Phillips curve relationship between wages and unemployment has changed or broken down.

The contribution of this *Letter* is to show that the euro area wage Phillips curve is non-linear, in contrast to the commonly-used linear approach. We show that when labour market slack is elevated, wage growth does not respond to a tightening in slack. The relationship between slack and wages is only re-established at lower levels of slack. We show that non-linear representations of the Phillips curve fit the data better and perform better in forecasting exercises. This non-linear Phillips curve can help to explain why wage growth did not increase in the euro area between 2013 and 2016, despite a tightening labour market.

Understanding wage dynamics is highly important for monetary policy. Wage growth passes through to inflation and thus represents an important indicator of future price pressures for central banks (Haldane, 2018; Powell, 2018). Continued tightening in the euro area labour market is expected to lead to sustained upward pressure on underlying inflation (Draghi, 2018; Mersch, 2018). Wage growth is thus a key factor in achieving the ECB's inflation ob-

*Both Monetary Policy Division, Central Bank of Ireland. Email: david.byrne@centralbank.ie, zivile.zekaite@centralbank.ie. The views expressed in this paper are those of the authors and do not necessarily reflect the views of the Central Bank of Ireland or the ESCB. Helpful comments from Philip Lane, Gillian Phelan, Rebecca Stuart, Reamonn Lydon and Gerard O'Reilly are gratefully acknowledged.

jective and in understanding the future path of monetary policy.

A number of hypotheses could explain the period of "missing" wage growth in the euro area since 2013. First, the Phillips curve relationship may be time-varying or non-linear, i.e., dependent on the inflation environment or the business cycle (López-Villavicencio and Mignon, 2015; Kumar and Orrenius, 2016; Bonam et al., 2018). Theoretical models have suggested a number of causes of non-linearity, including capacity constraints (Dupasquier and Ricketts, 1998).

Phillips (1958) originally suggested that the relationship between wages and unemployment is "likely to be highly non-linear", due to downward nominal wage rigidity. Daly and Hobijn (2014) show that nominal wage rigidity led to a non-linear (convex) Phillips curve in the United States, based on the last three business cycles. Rigidities increase in recessions, whereby the labour market adjustment occurs through higher unemployment rather than lower wages. This leads to substantial pent-up wage deflation, and as a result, the rigidities do not decrease immediately when the economy starts to recover. Thus, the sensitivity of wage growth to labour market slack only increases after slack declines substantially. Bundesbank (2016) and Branten et al. (2018) provide evidence of the existence of nominal rigidities in many European countries. They also show that these tended to increase in the aftermath of the financial crisis.

Second, it may be the case that labour market slack is not measured accurately. Traditional indicators, such as unemployment rate, may not represent the true degree of slack. Cœuré (2017), among others, highlight that "broader" measures of unemployment may have increasingly mattered in recent years. These capture under-utilisation of labour and discouraged worker effects[1].

A number of papers have shown that underemployment has had a negative effect on wage growth (Bulligan et al., 2017; Bell and Blanchflower, 2018; Hong et al., 2018; Haldane, 2018). The share of workers who are involuntarily part-time has risen in many countries and has remained elevated even in countries where unemployment has returned to its pre-crisis levels (Bell and Blanchflower, 2018).

Third, changes in the structure of labour market and employment arrangements could increase job insecurity and weaken the bargaining power of employees (IMF, 2018). Fourth, low productivity growth as well as low past or expected inflation could have contributed to subdued wage growth (ECB, 2016). Finally, globalisation may affect labour supply and demand due to the flows of workers across borders and globalised production processes (IMF, 2018).

A vast literature exists on the euro area price Phillips curve, including a strand which focuses on whether it is linear. By contrast, few studies have analysed the shape of the euro area wage Phillips curve. These typically have done so by allowing regression coefficients to change over time. The evidence to date has shown a weaker response of wages to unem-

[1] For Ireland, Byrne and Conefrey (2017) construct a "Non-Employment Index" as a broader measure of slack.

ployment following the financial and sovereign debt crises. Bulligan and Viviano (2017) show that the slope has flattened through the recursive estimation of the wage Phillips curve. Similar findings are reported in IMF (2018) based on a rolling regression estimation of a panel of European countries. Bundesbank (2016) provide some evidence for a non-linear relationship between hourly wages and unemployment[2]. However, Ciccarelli and Osbat (2017) find no change in the slope of the wage Phillips curve since 2012.

Data

Our data cover the euro area and span the period from the inception of the euro to present: 1999Q1 - 2018Q2. Our dependent variable is wage growth, for which we use the quarterly annualised percentage change in compensation per employee[3]. We calculate productivity growth in a similar fashion, using output per employee to derive labour productivity per employee. To represent the role of inflation expectations in wage-setting, we take inflation expectations from the ECB's Survey of Professional Forecasters. We use the one year ahead forecast for euro area headline inflation. Table 1 fully describes our data, transformations and sources.

Our main measure of euro area labour market slack is the unemployment rate (ILO definition). We also complement this with the OECD's measure of involuntary part-time employment (IPT) to capture underemployment. This series is constructed as a GDP-weighted average of national data.

We split the unemployment rate into those unemployed on a long-term basis (for 12 or more months) and a short-term basis (fewer than 12 months). Kumar and Orrenius (2016) show that these unemployment rates may have differential effects on wage pressures. We define the unemployment gap as the difference between the unemployment rate and its equilibrium level. To represent this equilibrium level, we take the OECD's measure of the non-accelerating inflation rate of unemployment (the NAIRU). To represent "broad" unemployment, we use the measure known as "U6". This includes a measure of the underemployed and those who are marginally attached to the labour force, in addition to "narrow" unemployment. For the euro area this series is only available since 2005.

Methodology

To capture dynamics in wages in the euro area, we take a standard approach of estimating a wage Phillips curve which relates wage growth to productivity growth, labour market slack and inflation expectations[4]. In the previous literature, the wage Phillips curve has widely

[2] Bulligan et al. (2017) show that the intensive margin of labour utilisation matters, with the Phillips curve being flatter for lower levels of hours per worker.

[3] The results are robust to using the annual percentage change instead. Both methods are applied in the existing literature on Phillips curves. These results are available upon request.

[4] See, for instance, Blanchard and Katz (1997) for a discussion of supporting theoretical evidence.

been estimated as a linear model. An implication of this is that wage growth should respond in the same way to a tightening in the labour market no matter the position in the distribution of the slack variable.

By contrast, a non-linear specification of the wage Phillips curve would allow wages to respond differently to an identical tightening depending on how much slack there is in the labour market. This could particularly capture if "excess" slack weakens the relationship between tightening and wage growth. If a non-linear relationship were to hold, it could help to explain periods of "missing" wage growth. It also could have direct implications for the setting of monetary policy given the importance of wage growth for inflation, and consequently the importance of understanding wage dynamics.

We represent non-linearity in labour market slack variables using restricted cubic spline functions[5]. These apply transformations to a slack variable which create new variables, to be added to a regression, to capture any non-linearity. Kumar and Orrenius (2016) use a similar approach to examine non-linearity in the wage Phillips curve in the United States[6].

The linear and non-linear wage Phillips curves we estimate are given by:

$$\Delta w_t = \alpha + \beta_1 u_{t-1} + \gamma X_t + \epsilon_t \tag{1}$$

$$\Delta w_t = \alpha + \beta_1 u_{t-1} + \beta_2 u^S_{t-1} + \gamma X_t + \epsilon_t \tag{2}$$

where X_t contains inflation expectations at time t, the change in labour productivity and the lag of wage growth. In each equation, u_{t-1} represents labour market slack linearly using one of our measures of slack. We capture non-linearity in equation (2) by also including the spline term u^S_{t-1}, created from the corresponding slack measure using restricted cubic splines[7]. In this non-linear specification, the impact of labour market slack on wage growth is given by the sum of the coefficients β_1 and β_2.

While this method allows us to flexibly introduce non-linearity in labour market slack, we do not impose that the relationship should be non-linear. This methodology represents a test for non-linearity: if the spline term proves not to have significant explanatory power then we do not have evidence for non-linearity. We also include the share of employment consisting of those involuntarily part-time in our preferred specifications to capture underemployment effects (Bell and Blanchflower, 2018; Hong et al., 2018).

We estimate equations (1) and (2) by Ordinary Least Squares, using the slack variables as defined above. We also augment the unemployment rate and the unemployment gap models with the involuntary part-time employment rate. We estimate separately over two samples: the full sample since 1999Q1, and a shorter sample since 2005Q2, the point at which U6 becomes available. We also use a rolling regression, with ten-year windows, to show how the slope coefficient of the linear model has evolved through time.

[5] See Dupont and Plummer (2005) for a detailed discussion of restricted cubic splines and how they can be used to model complex non-linear relationships.

[6] Linehan et al. (2017) also show non-linearity in the Irish wage Phillips curve via cubic terms.

[7] We use three knots in the spline, but our results are robust to using four to seven knots.

To examine the evidence for non-linearity in the wage Phillips curve, we evaluate the linear and non-linear models based on how well they fit the data and on how they perform in out-of-sample forecasts. We estimate the models until the fourth quarter of 2015, and then recursively estimate adding 1 quarter to the sample each step. At each step, we then calculate the Root Mean Square errors (RMSEs) of 1- to 4-quarter ahead forecasts. We present the average of these RMSEs.

Results

To motivate the non-linear representation of the Phillips curve, we show how the relationship between slack and wage growth has developed over time in a linear model. We do this by means of ten-year rolling regressions over our sample. Figure 1 shows that the slope of the linear Phillips curve has approximately halved between 2009 and 2018, implying a much weaker relationship between slack and wage growth.

In Table 2 we provide evidence of how well linear and non-linear models fit the data. We include adjusted R-squared statistics from models estimated with selected slack measures on both the longer and shorter samples. We highlight in bold which of the linear and non-linear models has the better fit. In all but one case, the non-linear model fits the data better. The best-performing model in the full sample is the non-linear model using the unemployment rate and the IPT rate. We treat this hereafter as our main specification.

Accounting for underemployment in euro area wage dynamics appears to be important. This is underscored by the fact that models with the IPT share included fit the data better than their counterparts without this. This holds for both the unemployment rate and gap and for linear and non-linear specifications, with the non-linear specifications being the better.

Next, we evaluate the out-of-sample forecasting ability of the models. Table 3 shows the average RMSE for each model, with a lower value being better. As we found in Table 2, non-linear specifications perform better than their linear counterparts in all but one case. The best-performing model is again the non-linear specification with the unemployment rate as the slack variable and the underemployment measure included.

Table 4 shows the estimated coefficients of equations (1) and (2) with the unemployment rate as the slack variable. The third column adds the IPT rate to the non-linear specification. The coefficient on slack, β_1 is significant and negative, as is predicted by theory. In the better-fitting non-linear model, we find that the coefficient on the spline term, β_2, is significant and positive. The implies that the relationship between slack and wage growth is non-linear and convex[8].

Our best-performing model includes underemployment. The IPT share has a significant and negative effect on wage growth, with greater underemployment acting as a drag on wage growth. It is worth noting that this analysis is based on a relatively simple model. This model may not capture all the relevant factors in determining wage growth, such as the phase of

[8]We also find evidence for non-linearity in a country-by-country analysis.

the credit cycle or globalisation effects.

Figure 2 shows the non-linear wage Phillips curve from our preferred specification. We find that for unemployment rates between 12 per cent and approximately 9.5 per cent, the Phillips curve is flat. In this region, tightening in the labour market does not lead to an increase in wage growth. Between 2013 and 2016, the euro area unemployment rate lay in this region. Since 2017, however, the steeper portion of the curve has been reached. Additional tightening in the labour market has been consistent with an increase in wage growth since then.

Figure 3 compares the linear and non-linear Phillips curves. For much of the 2013-2016 period, the linear specification predicts increasing wage growth whereas the non-linear specification does not. This could help to explain the systematic overprediction of euro area wage growth in this period. At lower levels of slack, the linear and non-linear curves have different slopes, with the non-linear curve being steeper.

At the current point, as denoted by the vertical black line, the non-linear model predicts wage growth that is approximately 0.3 pp higher. There is an increasing difference between the models as slack tightens, with the non-linear model predicting increasingly higher wage growth for additional tightening.

Finally, we decompose wage growth in the euro area since 2011, using the preferred non-linear model and its linear counterpart. We calculate the contributions of each driver of wage growth based on the estimated parameters and the data. Figures 4 and 5 depict actual wage growth and the contributions of each variable based on the linear and non-linear models, respectively[9].

Based on the linear model, labour market slack exerted significant downward pressure on wage growth. After the peak in the unemployment rate in late 2013, the negative contributions from slack gradually diminished and became increasingly positive since the middle of 2017. Inflation expectations also had a significantly negative impact on wage pressures over the period 2013 - 2016. The negative contribution from underemployment become more important after 2013 and still holds wage growth back.

The better-fitting non-linear model gives different insights. Labour market slack had a longer-lasting negative effect on wage growth than is shown in the linear model. The effect was consistently negative until the end of 2016 when it started to decline gradually. It is only since the first quarter of 2018 that labour market slack led into an increase in pay growth. Underemployment also has a relatively stronger contribution in this model. This negative effect is still large at the end of the sample, acting to slow wage growth. Inflation expectations appear to play less of a role in this model.

[9] Expressed as deviations from means. The residual comprises the model residual and the contribution of lagged wage growth.

Conclusion

We find significant evidence for non-linearity in the euro area wage Phillips curve. We find that non-linear representations of the Phillips curve fit the data better and perform better in forecasting exercises. This holds across different measures of labour market slack. We also find significant evidence for negative effects of underemployment on wage growth, a topic which has increasingly come to the fore in a number of countries since the Global Financial Crisis.

The non-linear specification of the wage Phillips curve can help to explain the "missing" wage growth in the euro area between 2013 and 2016. Despite the fact that the labour market was tightening in this period, the Phillips curve was on a flat interval. This meant that wage growth did not respond to tightening. Linear models predict increasing wage growth in this period of elevated slack, which could help to explain systematic overprediction of euro area wage growth between 2013 and 2016. The non-linear Phillips curve can also help to explain why stronger wage growth has been evident since 2017.

There are a number of policy implications from this work. Given the centrality of wage growth in inflation dynamics, and in underpinning inflation forecasts, understanding the relationship between slack and wage growth is highly important. This works suggests that forecasting exercises could benefit from incorporating non-linearity in slack. The current levels of slack in the euro area labour market are consistent with the steeper portion of non-linear wage Phillips curve. This predicts greater wage growth, which should pass through to greater inflation, supporting the sustained adjustment in the path of inflation toward the inflation objective.

Furthermore, when the labour market is tight, the non-linear Phillips curve has a steeper slope than the linear Phillips curve has. This leads to increasingly large differences between the models in predicted wage growth from additional labour market tightening, and suggests upside risks to euro area wage growth should the labour market continue to tighten. This is of particular importance when looking forward to a period of monetary policy normalisation.

Appendix

Table 1: Data Description

Variables	Symbols	Description
Dependent variable	Δw_t	Growth in Compensation per Employee, quarterly annualised or year-on-year (Eurostat)
Explanatory variables	u_t	Unemployment Rate (Eurostat) Non-accelerating inflation rate of unemployment (OECD) Short-term and long-term unemployment rates (Eurostat) “U6” unemployment rate (Eurostat)
	u_t^S	Spline term constructed from slack measure (See Methodology section)
	IPT_t	Involuntary part-time employment as a share of total employment (OECD)
	Δx_t	Growth rate of labour productivity per employee, quarterly annualised or year-on-year (Eurostat)
	π_t^e	One year-ahead expectation of headline inflation rate (ECB Survey of Professional Forecasters)

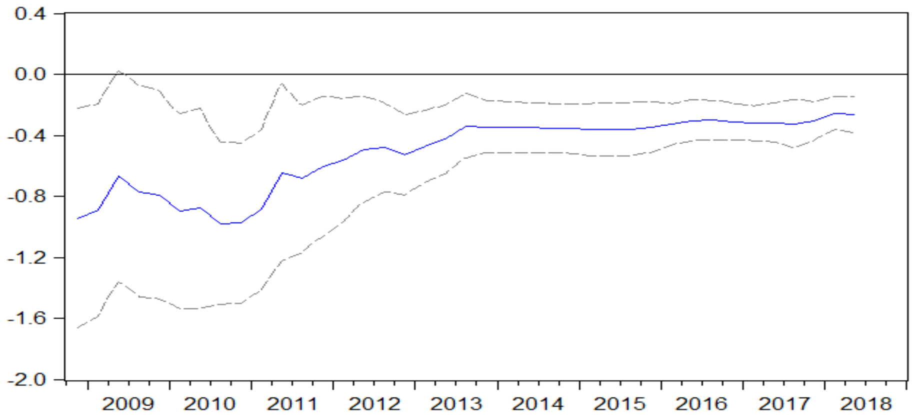

Figure 1: Coefficient on slack measure from rolling regression (10 years)

Table 2: Model fit

	Full sample		Since 2005Q2	
Slack measure	Linear	Non-linear	Linear	Non-linear
U. Rate	0.376	**0.391**	0.454	**0.498**
U. Gap	**0.350**	0.346	0.446	**0.463**
Broad U. Rate (U6)			0.428	**0.470**
ST & LT U. Rates	0.386	**0.421**	0.443	**0.488**
U. Rate & IPT	0.388	**0.442**	0.443	**0.497**
U. Gap & IPT	0.365	**0.383**	0.440	**0.468**

Note: Adjusted R-Squared statistics from estimations of equation (1) and (2).
Higher R-Squared of model-sample pair in bold.

Table 3: Root Mean Square errors of out-of-sample forecasts

	Full sample		Since 2005Q2	
Slack measure	Linear	Non-linear	Linear	Non-linear
U. Rate	0.582	**0.528**	0.531	**0.442**
U. Gap	0.494	**0.471**	0.466	**0.422**
Broad U. Rate (U6)			**0.423**	0.461
ST & LT U. Rates	0.623	**0.615**	0.578	**0.558**
U. Rate & IPT	0.506	**0.355**	0.518	**0.360**
U. Gap & IPT	0.427	**0.405**	0.484	**0.393**

Note: Models estimated to 2015Q4 and then recursively estimated adding 1 quarter to sample each step. RMSEs for each model are average of 1 to 4q-ahead forecasts from each step. Lower RMSE of model-sample pair in bold.

Table 4: Regression output from main specification

	(1)	(2)	(3)
Δw_{t-1}	-0.278**	-0.294**	-0.317**
	(0.121)	(0.117)	(0.134)
Δx_t	0.223***	0.258***	0.250***
	(0.033)	(0.039)	(0.042)
π^e_t	0.746***	0.567**	0.213
	(0.266)	(0.257)	(0.303)
u_{t-1}	-0.394***	-0.740***	-0.877***
	(0.072)	(0.224)	(0.243)
u^S_{t-1}		0.528*	0.886***
		(0.297)	(0.302)
IPT_{t-1}			-0.194**
			(0.076)
$Constant$	5.040***	8.337***	10.935***
	(1.061)	(2.211)	(2.588)
N	78	78	73
R-squared	0.376	0.391	0.442

Notes: HAC standard errors are in parentheses and signif. level displayed as *p<0.1; **p<0.05; ***p<0.01.

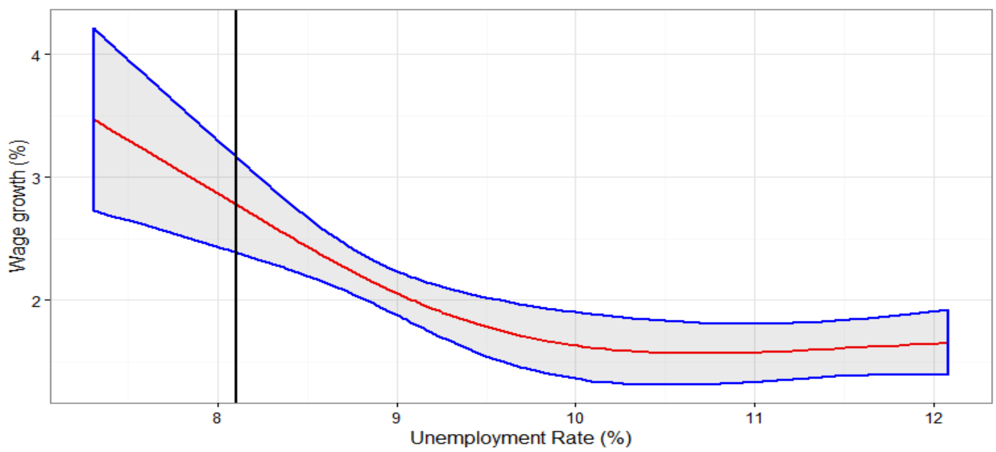

Figure 2: Non-linear euro area Phillips curve. Vertical line represents current U. Rate.

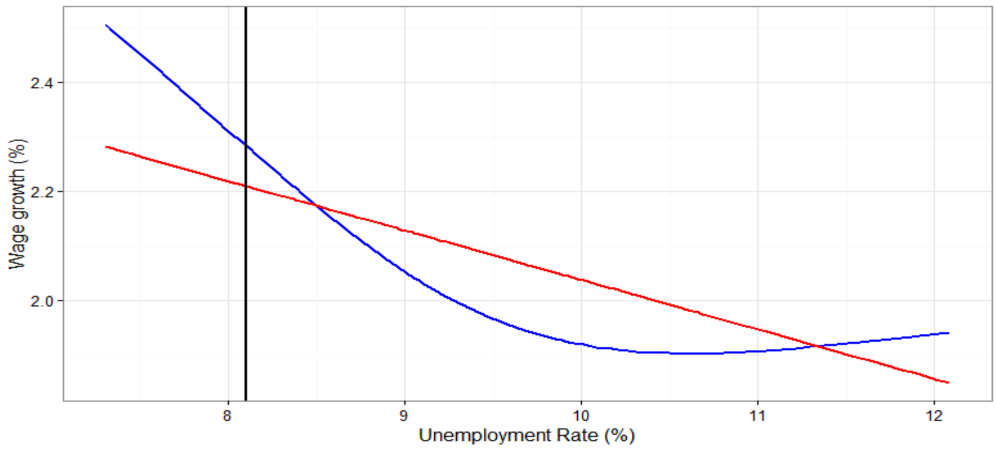

Figure 3: Linear (red) and non-linear (blue) Phillips curves. Vertical line represents current U. Rate.

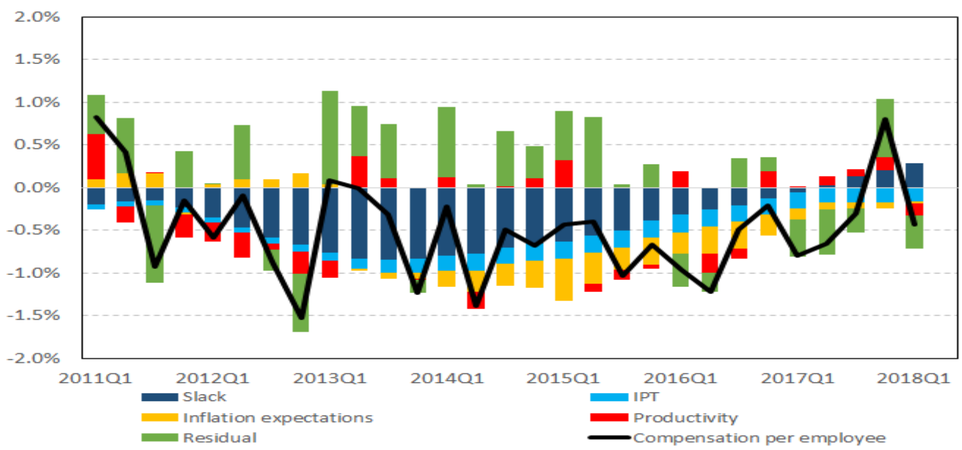

Figure 4: Wage growth decomposition: linear

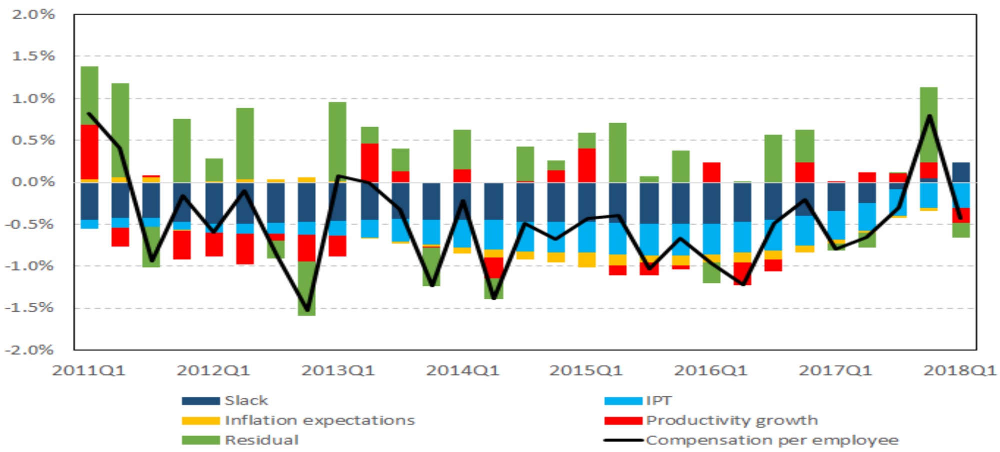

Figure 5: Wage growth decomposition: non-linear

References

Bell, David N.F. and David G. Blanchflower, "Underemployment in the US and Europe," NBER Working Paper 24927, National Bureau of Economic Research, 2018.

Blanchard, Olivier and Lawrence F. Katz, "What we know and do not know about the natural rate of unemployment," *Journal of Economic Perspectives*, Winter 1997, *11* (1), 51–72.

Bonam, Dennis, Jakob de Haan, and Duncan van Limbergen, "Time-varying wage Phillips curves in the euro area with a new measure for labor market slack," DNB Working Paper 587, Netherlands Central Bank, 2018.

Branten, Eva, Ana Lamo, and Tairi Rõõm, "Nominal wage rigidity in the EU countries before and after the Great Recession: evidence from the WDN surveys," Working Paper 2159, European Central Bank, 2018.

Bulligan, Guido and Eliana Viviano, "Has the wage Phillips curve changed in the euro area?," Occasional Paper 355, Bank of Italy, 2017.

_ **, Elisa Guglielminetti, and Eliana Viviano**, "Wage growth in the euro area: where do we stand?," Occasional Paper 413, Bank of Italy, 2017.

Bundesbank, "Wage dynamics amid high euro-area unemployment," Monthly Report, Deutsche Bundesbank, December, 2016.

Byrne, Stephen and Thomas Conefrey, "A Non-Employment Index for Ireland," Economic Letters 09/EL/17, Central Bank of Ireland August 2017.

Ciccarelli, Matteo and Chiara Osbat, "Low inflation in the euro area: Causes and consequences," Occasional Paper 181, European Central Bank, 2017.

Cœuré, Benoît, "Scars or scratches? Hysteresis in the euro area," 2017. Speech by Benoît Cœuré, Member of the Executive Board of the ECB, at the International Center for Monetary and Banking Studies, Geneva, 19 May 2017.

Daly, Mary C. and Bart Hobijn, "Downward nominal wage rigidities bend the Phillips curve," *Journal of Money, Credit and Banking*, 2014, *46* (S2), 51–93.

Draghi, Mario, "Hearing of the Committee on Economic and Monetary Affairs of the European Parliament," 2018. Introductory Statement by Mario Draghi, President of the European Central Bank, at the ECON committee of the European Parliament, Brussels, 24 September.

Dupasquier, Chantal and Nicholas Ricketts, "Non-Linearities in the Output-Inflation Relationship: Some Empirical Results for Canada," Staff Working Paper 98-14, Bank of Canada, 1998.

Dupont, William D. and Dale Plummer, "Using Stata v9 to model complex non-linear relationships with restricted cubic splines," North American Stata Users' Group Meetings 2005 4, Stata Users Group 2005.

ECB, "Recent wage trends in the euro area," Economic Bulletin Issue 3, European Central Bank, 2016.

Haldane, Andrew G, "Pay Power," 2018. Speech by Andrew Haldane, Chief Economist of the Bank of England, at the Acas "Future of Work" Conference Congress Centre, London, 10 October.

Hong, Gee Hee, Zsoka Koczan, Weicheng Lian, and Malhar S Nabar, "More Slack than Meets the Eye? Recent Wage Dynamics in Advanced Economies," IMF Working Paper 18/50, International Monetary Fund, 2018.

IMF, *Regional Economic Outlook: Europe, Managing the Upswing in Uncertain Times* World Economic and Financial Surveys Series, International Monetary Fund, 2018.

Kumar, Anil and Pia M. Orrenius, "A closer look at the Phillips curve using state-level data," *Journal of Macroeconomics*, 2016, *47* (Part A), 84–102.

Linehan, Suzanne, Reamonn Lydon, Tara McIndoe-Calder, Paul Reddan, and Diarmaid Smyth, "The Labour Market and Wage Growth after a Crisis," Quarterly Bulletin Signed Article, Central Bank of Ireland October 2017.

López-Villavicencio, Antonia and Valérie Mignon, "Instability of the Inflation–Output Trade-Off and Time-Varying Price Rigidity," *Oxford Bulletin of Economics and Statistics*, 2015, *77* (5), 634–654.

Mersch, Yves, "Monetary policy in the euro area - a brief assessment," 2018. Speaking points by Yves Mersch, Member of the Executive Board of the ECB, at the MNI Connect Roundtable, Singapore, 10 October.

Phillips, Alban W., "The relation between unemployment and the rate of change of money wage rates in the United Kingdom, 1861–1957," *Economica*, 1958, *25* (100), 283–299.

Powell, Jerome, "Monetary Policy and Risk Management at a Time of Low Inflation and Low Unemployment," 2018. Speech by Jerome Powell, Chairman of the Federal Reserve System, at the "Revolution or Evolution? Reexamining Economic Paradigms" 60th Annual Meeting of the National Association for Business Economics, Boston, Massachusetts, 2 October.

Yellen, Janet, "Inflation Dynamics and Monetary Policy," 2015. Speech by Chair Janet L. Yellen, at the Philip Gamble Memorial Lecture, University of Massachusetts, Amherst, Amherst, Massachusetts.

T: +353 (0)1 224 6000
www.centralbank.ie
publications@centralbank.ie

Bosca PO 559, Baile Átha Cliath 1, Éire
PO Box 559, Dublin 1, Ireland