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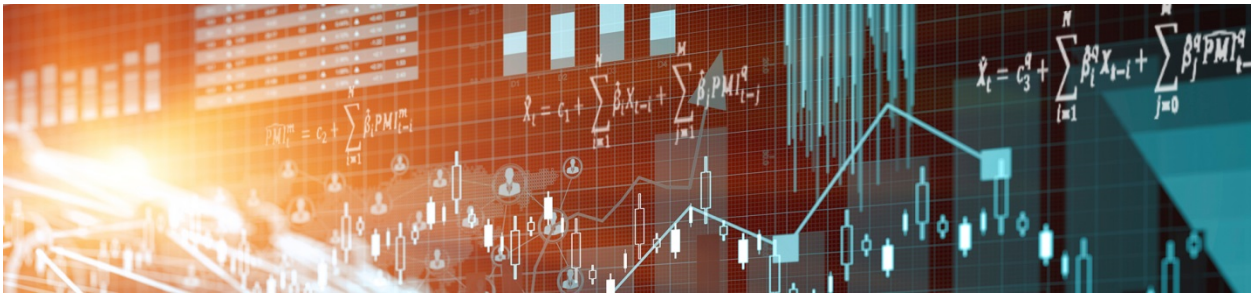
Exploring Wage Phillips Curves in Advanced Economies



by Rose Cunningham, Vikram Rai and Kristina Hess

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Abstract

We investigate the extent to which excess supply (demand) in labour markets contributes to a lower (higher) growth rate of average nominal wages for workers. Using panel methods on data from 10 advanced economies for 1992–2018, we produce reduced-form estimates of a wage Phillips curve specification that is consistent with a New Keynesian framework. We find comparable effects on nominal wage growth from several indicators of "slack" in the labour market: unemployment rates, unemployment rate gaps, the prime-age employment-to-population ratios, a composite labour market indicator constructed using a principal component for a wide range of labour force data, and unemployment rates separated by duration of unemployment. Our results provide evidence that while the slope of the wage Phillips curve seems to have become flatter following the global financial crisis in 2008, the relationship still appears to be highly significant. We find that the long-term unemployment rate (unemployment longer than six months) has had a larger effect on wage growth in the period since 2008. We also investigate the shape of the Phillips curve and find some evidence of a convex relationship between labour market slack and nominal wage growth, particularly for the pre-crisis period. Piecewise regressions suggest some mixed evidence on nominal rigidities in the aggregate data.

Bank topics: Labour markets; Inflation and prices; Monetary policy
JEL codes: C33, E31, E32

Résumé

Dans la présente étude, nous examinons la mesure dans laquelle l'offre (la demande) excédentaire sur les marchés du travail participe à une baisse (hausse) du taux de croissance des salaires nominaux moyens. En appliquant une méthode d'estimation à des données de panel provenant de dix économies avancées pour la période de 1992 à 2018, nous obtenons une spécification de la courbe de Phillips des salaires de forme réduite qui est compatible avec un cadre néo-keynésien. Nous constatons que plusieurs indicateurs du sous-emploi des ressources sur les marchés du travail ont des effets comparables sur la croissance des salaires nominaux. Ces indicateurs sont : les taux de chômage; les écarts de chômage; les ratios emploi-population des travailleurs dans la force de l'âge; un indicateur composite du marché du travail établi à partir d'une analyse en composantes principales d'un large ensemble de données sur la population active; et les taux de chômage par durée. Selon nos résultats, bien que la courbe de Phillips des salaires semble s'être aplatie depuis la crise financière mondiale de 2008, la relation entre le taux de chômage et la croissance des salaires apparaît encore très significative. Nous constatons que le taux de chômage de longue durée (plus de six mois) influe davantage sur la croissance des salaires depuis 2008. Nous étudions aussi la forme de la courbe de Phillips et nos résultats

semblent indiquer que la relation entre le sous-emploi des ressources sur le marché du travail et la croissance des salaires nominaux est convexe, surtout avant la crise. Enfin, par des régressions segmentées, nous tentons de déterminer la présence de rigidités nominales, mais les résultats obtenus à partir des données agrégées à l'étude sont peu concluants.

Sujets : Marchés du travail; Inflation et prix; Politique monétaire
Codes JEL : C33, E31, E32

1. Introduction

Labour market slack in advanced economies reached extraordinary levels following the global financial crisis in 2008. This included substantial increases in long-term unemployment rates in some countries, followed by a long period of elevated unemployment rates, though rates have since recovered to more ordinary levels. The low levels of unemployment in the United States partly motivated the recent normalization of monetary policy, despite relatively limited inflationary pressures.[1]

A decoupling of wages from economic slack is an important issue for macroeconomic policy-makers. This has led to renewed interest in estimates of wage Phillips curves (PCs). In this paper, we analyze labour market data for 10 major advanced economies and estimate reduced-form wage PCs based on Galí (2011). In particular, our analysis centres on three interrelated questions:

- How much do different types of labour market slack affect nominal wage growth?
- Has the relationship between wage growth and unemployment changed since the global financial crisis? That is, has the wage PC flattened?
- Is the wage PC nonlinear?

We explore these issues relating to the shape of the wage PC in advanced economies using different measures of labour market slack, time periods and functional forms. Estimating wage PCs in a multi-country panel setting allows us to exploit the considerable cross-country variation that exists in the labour markets of advanced economies.

We find economically and statistically significant negative effects on nominal wage growth from labour market slack. We also find that the sensitivity of nominal wage growth to measures of labour market slack appears to have diminished since the global financial crisis, suggesting a flattening of the wage PC. These findings are quite robust to different measures of labour market slack (unemployment rate gap, duration or alternative measures) and to different specifications and estimation approaches. Our findings are quite similar to those of several other recent papers on wage PCs discussed in the next section.

The paper is organized as follows. In Section 2, we provide a brief summary of the recent related literature on wage PCs. In Section 3, we present data from several different indicators of labour market slack as well as nominal and real wage growth. In section 4, we present the methodology to estimate wage Phillips curves and discuss the results. Finally, in Section 5, we offer some conclusions and policy implications.

2. Related literature

Our work relates to several recent papers that consider one or more of the three questions outlined above. Galí (2011), Galí and Gambetti (2019), Leduc and Wilson (2017) and Leduc, Marti and Wilson (2019) also estimate wage PCs. They focus on the United States and look for evidence of whether the shape of the wage PCs has changed in the post-crisis period. Using either aggregate or city-level data, they find that wage PC relationships remain statistically and economically significant, although the relationship has weakened in the post-crisis period. We extend this analysis to 10 advanced economies. Our findings are quite similar to theirs in that we find a significant wage PC relationship, with estimated wage PC coefficients that are quite similar to estimates for the United States by Galí and Gambetti (2019) and Galí (2011). We also find that the wage PCs for advanced economies have flattened in the post-crisis period.

[1] For example, when US policy rate normalization began on December 16, 2015, the Federal Open Market Committee stated, "A range of recent labor market indicators, including ongoing job gains and declining unemployment, shows further improvement and confirms that underutilization of labor resources has diminished appreciably since early this year" (Board of Governors of the Federal Reserve System 2015). Wilkins (2019) also emphasizes the importance of labour market developments for Canadian monetary policy.

Since the global financial crisis, researchers and policy-makers have been concerned that the unemployment rate may underestimate the degree of excess supply in the labour market. Several papers in the recent empirical literature examine the effect on wage growth of changes in labour market slack measured more broadly than only the total unemployment rate. These papers examine the influence on wages of changes in the age composition of the labour force, participation rates, underemployment and durations of unemployment (Mojon and Ragot 2019; Bell and Blanchflower 2018; Krueger, Cramer and Cho 2014; Blanchflower and Posen 2014). We add to this literature by examining how wages respond to different measures of slack, including the unemployment rate gap, unemployment rates, the working-age population ratio and a composite labour market indicator composed of seven individual measures. Ours is one of the first studies to consider alternative measures of labour market slack in a wage PC for a panel of advanced economies.

We also examine in more detail the effects on wages of long-term unemployment, since it rose dramatically in some countries after the global financial crisis and remained elevated for several years. While some recent studies by Blanchflower and Posen (2014) and Bell and Blanchflower (2018) considered this question for the United States and the United Kingdom, our paper is one of the first to consider this issue in a multi-country study. Earlier literature and some recent work, such as Krueger, Cramer and Cho (2014), argue that the long-term unemployed would not affect wage growth because they have different labour market characteristics (such as education and experience) than the recently unemployed, so they are less attached to the labour force. As such, they would not exert downward pressure on wages. The rise in long-term unemployment rates across advanced economies after the global financial crisis, however, revived interest in the issue. Yellen (2014) argues that the differences between the two groups were smaller than in the past. Blanchflower and Posen (2014) and Bell and Blanchflower (2018) find that the long-term unemployment rates do negatively affect wage growth in the United States and the United Kingdom. We also find some evidence that the long-term unemployed have had a significant negative effect on wage growth in the post-crisis period in our cross-country sample.

Our second question, whether wage PCs have flattened in recent years, stems from the well-known puzzle that inflation rates have remained quite stable despite large fluctuations in output and employment.[2] Reduced sensitivity of inflation to measures of slack may mean much more policy adjustment is required to address deviations of inflation from target. While inflation PCs have flattened, Galí (2011) finds that the wage PC relationships remained significant in the United States and were "alive and well." More recently, with a longer time series, Galí and Gambetti (2019) find evidence of flattening of the US wage PC during the post-crisis period. Our multi-country analysis allows us to examine whether this phenomenon extends to other advanced economies. We find that panel analysis also points to significant flattening of the wage PC in advanced economies since the global financial crisis.

Recent evidence of flatter wage or inflation PCs has renewed interest in possible nonlinearities in PCs, i.e., kinks (thresholds) or convexity, due to nominal rigidities. See Williams (2019) and the references therein for recent discussion of the debate on nonlinearity in inflation PCs. In the context of wage PCs, downward nominal wage rigidities could lead wages to become less sensitive to excess supply only after it reaches certain thresholds. For Canada, Brouillette et al. (2018) find some evidence of convexity in both wage and inflation PCs. In periods of high inflation, real wage adjustment may occur primarily through constant nominal wages. In periods of low inflation, however, nominal wage rigidities may lead to binding real wage rigidities. This could lead to more adjustment in the labour force occurring through employment rather than through wages. Jo (2019) and Daly and Hobijn (2014) test for such a phenomenon using US individual or state-level data and find some evidence of downward nominal rigidities binding in the global financial crisis and its aftermath. Leduc and Wilson (2017) and Leduc, Marti and Wilson (2019), who estimate a panel wage

[2] For recent discussion, see Bullard (2018) and Stock and Watson (2018).

PC using US city- and state-level data, do not find economically significant nonlinearities. We look at this issue briefly with our multi-country, aggregate data. Our panel regression analyses point to possible convexity, mostly in the pre-crisis period. In our tests for downward wage rigidities, we obtain somewhat mixed results. It appears that wages are more sensitive to unemployment gaps during periods of higher inflation, consistent with the downward nominal rigidity theory. However, we also see some evidence that wages have been relatively flexible in the post-crisis period.

3. Labour market slack and wage growth in advanced economies

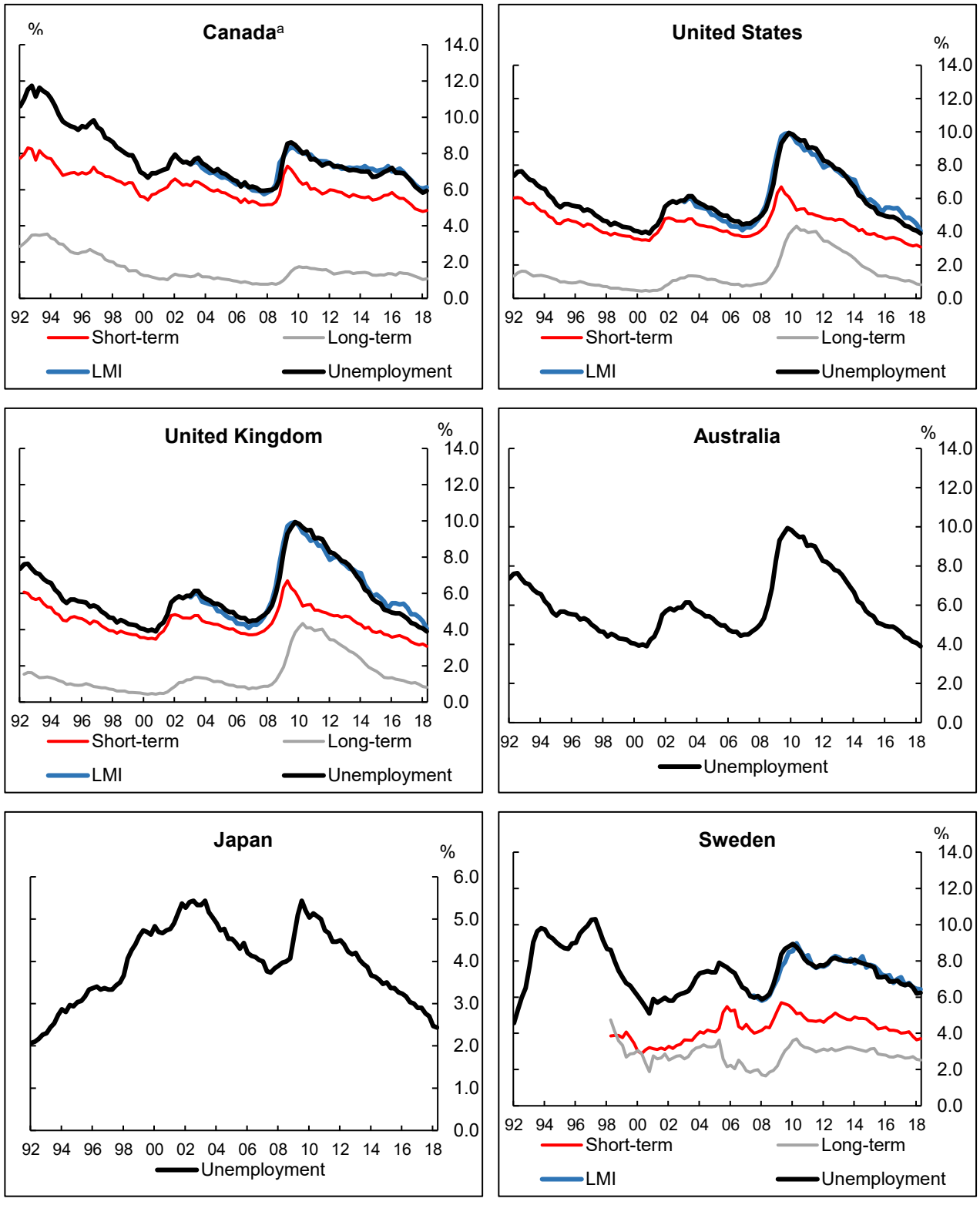
3.1. Unemployment rates and duration

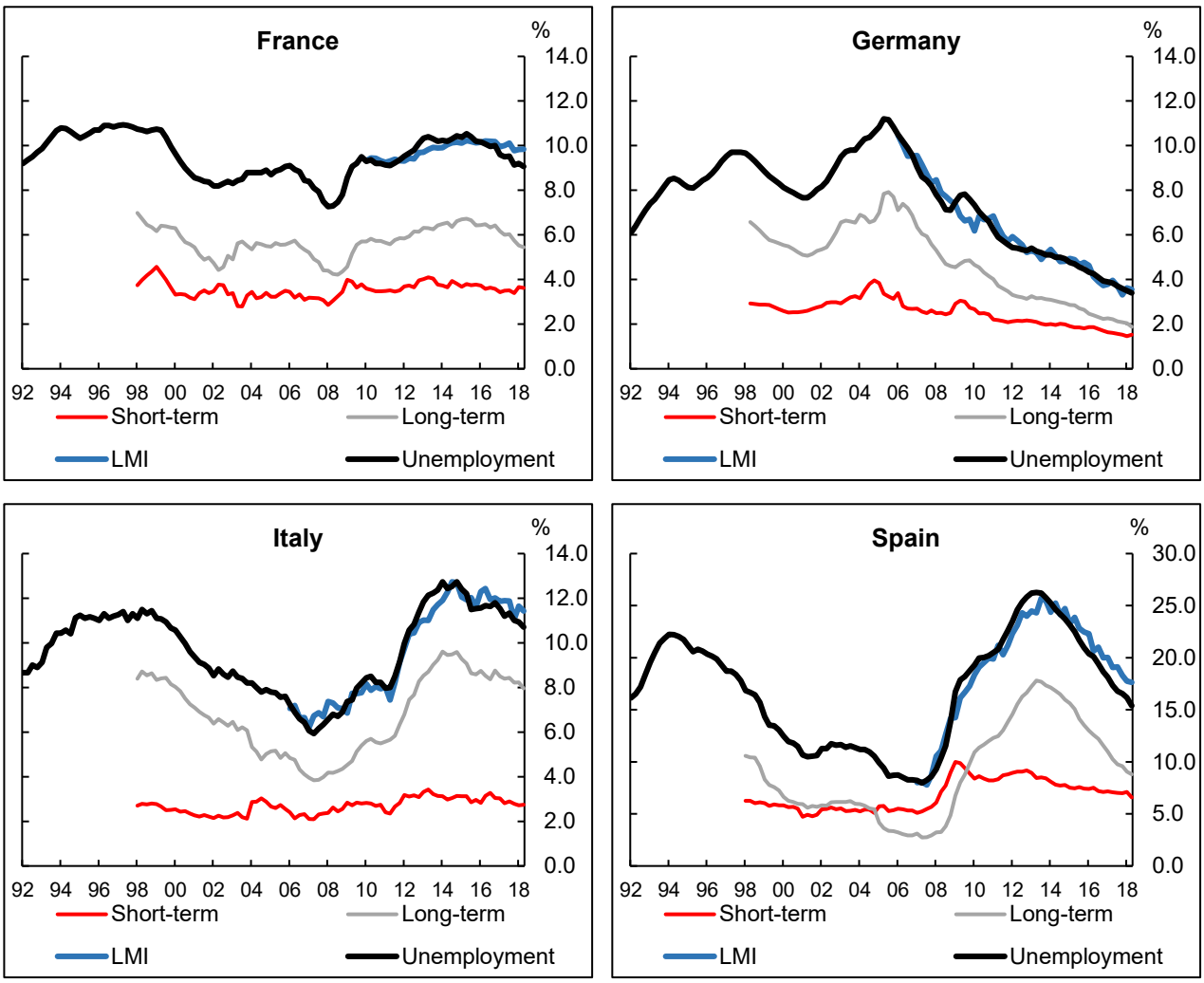
The unemployment rate is the most commonly cited business cycle indicator of excess supply in the labour market. The onset of recessions was highly synchronized in the global financial crisis, and total unemployment rates rose sharply in most advanced economies during 2008–09. Since then, however, economic recoveries have been more uneven, and unemployment rates and the duration of unemployment have varied considerably across the major advanced economies (**Chart 1**). Japan has the lowest unemployment rate of the major advanced economies. Total unemployment rates are in the low to moderate range in the United States, the United Kingdom, Canada and Sweden, and generally higher within the euro area. Germany, however, has had strong labour market performance since 2008 and now has a very low rate of unemployment of less than 3.5 percent. This may reflect the impacts of structural labour market reforms started in the previous decade and the relatively mild 2008–09 recession in Germany.

One of the key features of labour markets in advanced economies following the 2008 crisis was the rise in long-term unemployment rates (i.e., unemployment lasting longer than six months) and the substantial share of long-term unemployment in total unemployment for most advanced economies during the post-crisis period. The increase in long-term unemployment rates in the United States was particularly striking. Although short-term unemployment in the United States also rose sharply in the crisis, it did not surpass its previous peaks from the 1980s. However, the US long-term unemployment rate more than quadrupled following the global financial crisis to peak at 4.4 percent, the highest rate observed in the data available from 1950. Both long-term and short-term unemployment rates in the United States have since returned to pre-crisis levels. But the long-term unemployment rate remained elevated at more than 2 percent for more than six years after the onset of the crisis. By contrast, Canada experienced a small increase in long-term unemployment in 2008.

The euro area also experienced a large increase in long-term unemployment after 2008, driven by Spain, Italy and several smaller countries. Crises in several euro area countries from 2011 to 2012 contributed to weak labour market conditions in some of these countries. An important exception is Germany, where long-term unemployment rates have trended lower throughout the post-crisis period. Other euro area countries continue to have higher rates of long-term unemployment than the United States, as they have in previous decades. Galí (2015) finds evidence of strong hysteresis effects in Europe that contribute to increases in long-term unemployment after a recession and explain some of the upward trend in euro area unemployment. By contrast, the US unemployment rate has tended to revert back to its more constant non-accelerating inflation rate of unemployment (NAIRU).

Chart 1: **Unemployment rates in advanced economies**





Note: In Canada, the United States and the United Kingdom, short-term unemployment refers to unemployment of up to 6 months (26 weeks), and long-term unemployment is greater than 6 months. In the euro area countries (France, Germany, Italy and Spain), short-term unemployment is up to 5 months, and long-term unemployment refers to more than 5 months. In Sweden, long-term unemployment also includes persons under the age of 25 who have been unemployed for over 100 days. Unemployment by duration is not available for Japan or Australia. LMI means labour market indicators. Unemployment refers to total unemployment including both short-term and long-term unemployment rates.

[a] In a previous version of this paper Chart 1 had an incorrect series for the Canadian LMI line. This has now been corrected.

Source: National sources via Haver Analytics Last observation: 2018Q2

3.2. Other labour market activity indicators

Unemployment rates may not fully reflect the degree of labour market slack in the economy if firms or households also adjust their labour input on another margin, such as hours worked or labour force participation. We provide some exposition of labour force participation and hours worked in **Chart 2** and **Chart 3** to understand whether these may have been important margins of adjustment in recent data.

We find that participation rates have followed divergent paths in advanced economies. **Chart 2** shows that participation rates in many of the advanced economies in our sample declined after 2008. The reduction in participation rates is most pronounced in the United States, followed by Canada. Other economies, particularly in the left panel, have seen more stable participation rates, and Japan stands out among this group as having reversed the decline in its participation rate. The right panel of **Chart 2** shows generally modest increases in the participation rates in the euro area economies and Sweden after 2008.

Average hours worked have stayed the same or declined in most major advanced economies, even 10 years after the crisis. With the exception of Sweden, the major advanced economies all experienced declines in average hours worked since 2008. To some extent, the change in hours is a continuation of the secular downward trend that has been ongoing in many countries in the Organisation for Economic Co-operation and Development, other than the United States.

We again observe that the euro area economies and Sweden have followed similar paths, but they differ from other advanced economies. Spain and Italy stand out because their average weekly hours have fallen, in contrast with the trend of rising participation rates in these economies—suggesting an increase in part-time employment or underemployment. Among the other economies, Australia, like Spain and Italy, exhibits a decline in average weekly hours worked, while in Canada and the United States, hours appear more volatile and show no clear trend.

Chart 2: Participation rates across sample countries

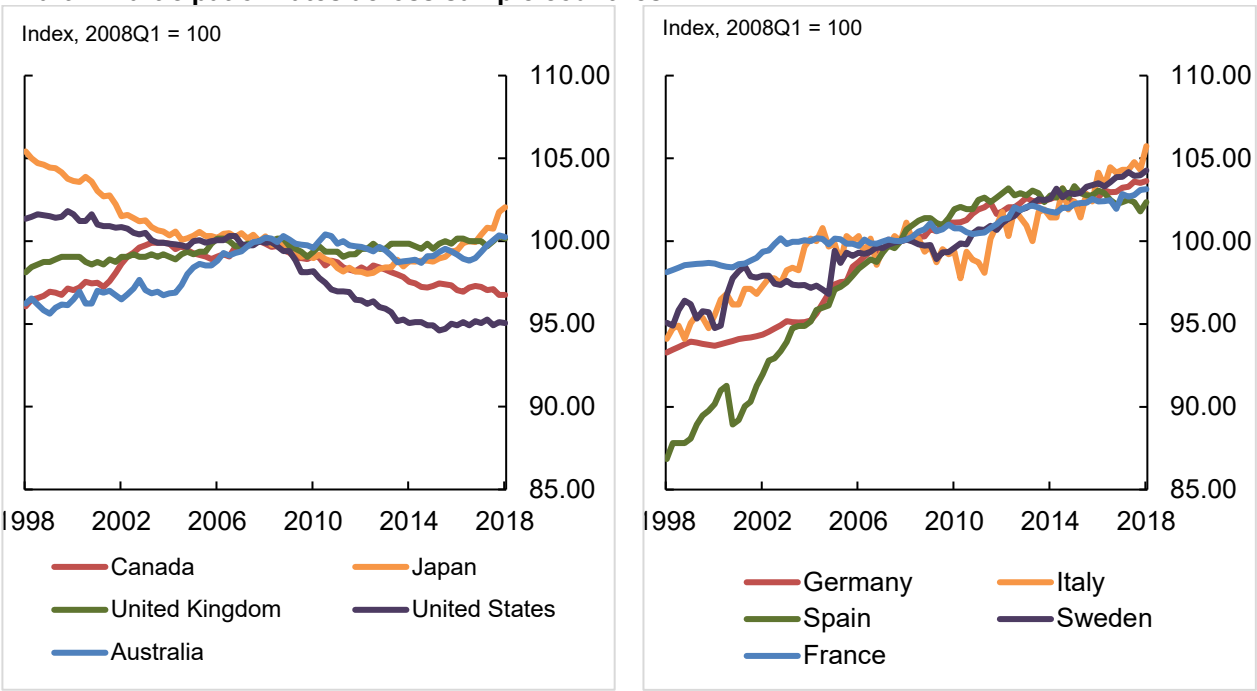


Chart 3: Average weekly hours worked across sample countries

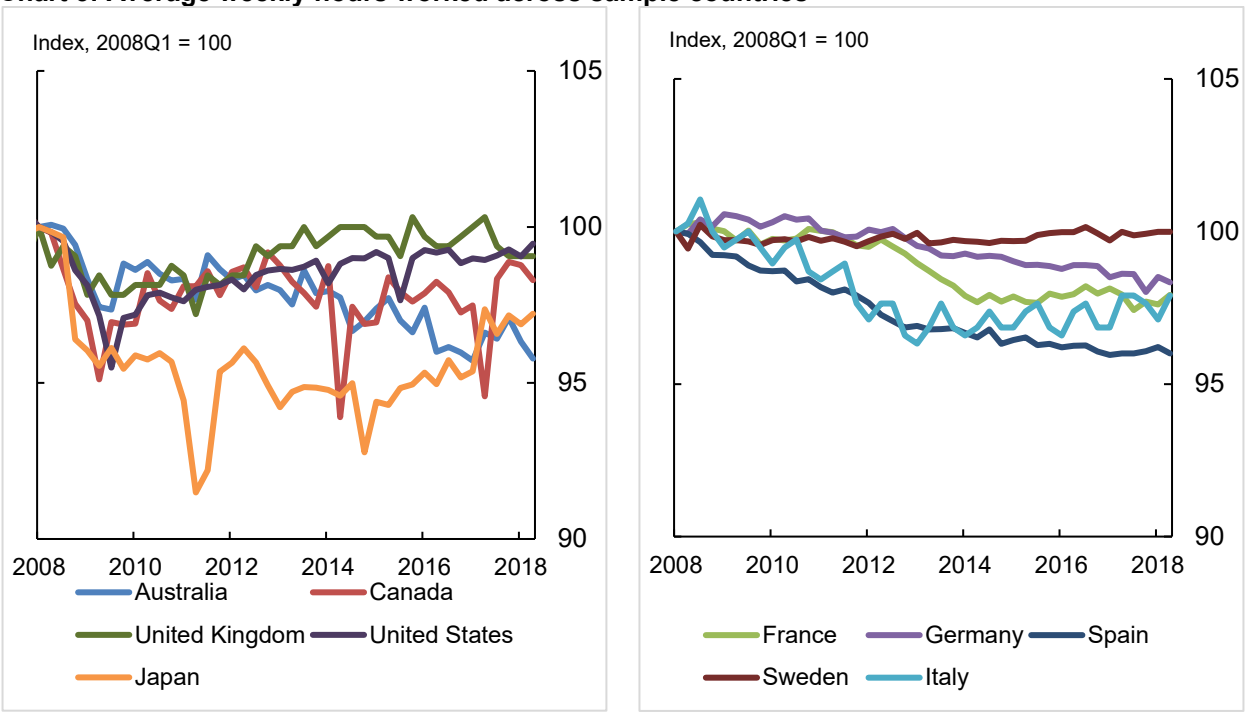


Chart 2 and **Chart 3** show that the unemployment rate on its own does not necessarily reflect all movements in the total amount of labour supplied and demanded in the economy. The adjustment of labour markets occurs on multiple margins and will ultimately be a combination of changes in the unemployment rate, the participation rate and average weekly hours. It is possible for a change in one of these indicators to offset the impact of a change in another on the total quantity of labour in the economy. We therefore also calculate a broader indicator of labour market supply slack than the single indicators discussed so far. We do so by constructing a principal component model, based on Zmitrowicz and Kahn (2014), which is included in **Chart 1** for comparison with the headline unemployment rate.[3]

We find that the principal component labour market indicator (LMI) for the United States is fairly similar to the unemployment rate. In Canada, the LMI we estimate is on average quite similar to the unemployment rate and tends to move with it. In the United States, the divergence between the LMI and the unemployment rate is relatively small in the most recent observations. Furthermore, by the end of our sample, the LMI is actually below the unemployment rate; the hiring, long-term unemployment and separation rates are all correlated with this gap, small though it is.

In the United Kingdom, Sweden and Germany, the LMI is quite consistent with the unemployment rate in most of the post-2008 period, suggesting it is a good indicator of cyclical labour market slack in those economies. In some of the euro area countries (France, Italy and Spain), the LMI indicates more labour market slack than the unemployment rate suggests in recent years. The divergence is mostly due to the participation rate and the underutilization rate.

[3] Zmitrowicz and Kahn (2014) estimate a common factor from eight different measures of labour market conditions and compare it with movements in the total unemployment rate. The eight indicators are unemployment rate, long-term unemployment rate, participation rate, growth in average hours worked, wage growth, underutilization rate, job-finding rate and separation rate. In this paper, we omit wage growth; because our aim is to use the indicator derived from analysis of the principal component model to try to explain wage growth, only the other seven indicators are included.

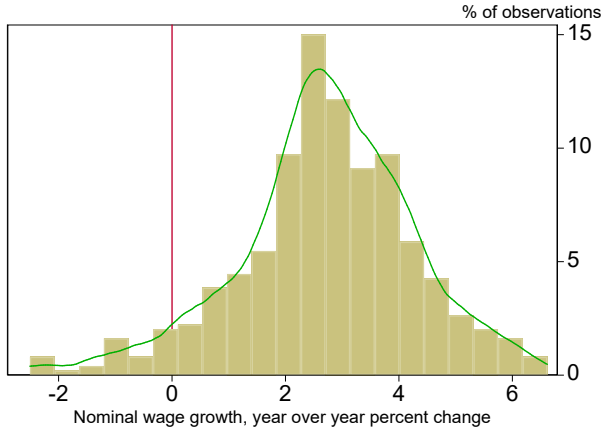
3.3. Wage growth

Before 2008, nominal wages rose consistently by 2.5 to 5 percent per year in the major advanced economies, except Japan, where wage growth was somewhat negative. A histogram (**Chart 5**) of our sample observations on nominal wage growth shows the mass of the distribution concentrated around 2.7 percent year over year in the pre-crisis period. After 2008, the whole distribution of wage growth shifts to the left, and the mean and median drop by about 1 percentage point (pp), a statistically significant difference (**Table 1** and **Chart 4**). We see that a considerably larger share of the observations are slightly negative, although negative observations are less than 7 percent of the total observations; in the post-crisis period, negative observations are only 10 percent. We also see that the observations near zero nominal wage growth are considerably more frequent in the post-crisis period. Persistently positive nominal wage increases, despite elevated labour market slack in the post-crisis years, may reflect nominal wage rigidities.

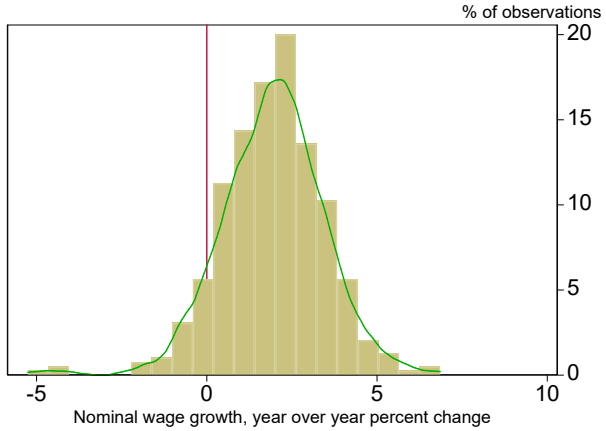
Table 1: Nominal wage growth (%), sample of 10 advanced economies

	1991Q1–2007Q4	2008Q1–2018Q2
95% confidence interval of mean	[2.56, 2.85].	[1.80, 2.09]
Mean	2.71	1.95
Median	2.70	1.93
5th percentile	-0.17	-0.53
25th percentile	1.83	0.91
75th percentile	3.74	2.89
95th percentile	5.32	4.38

Chart 4: Distributions of nominal wage growth

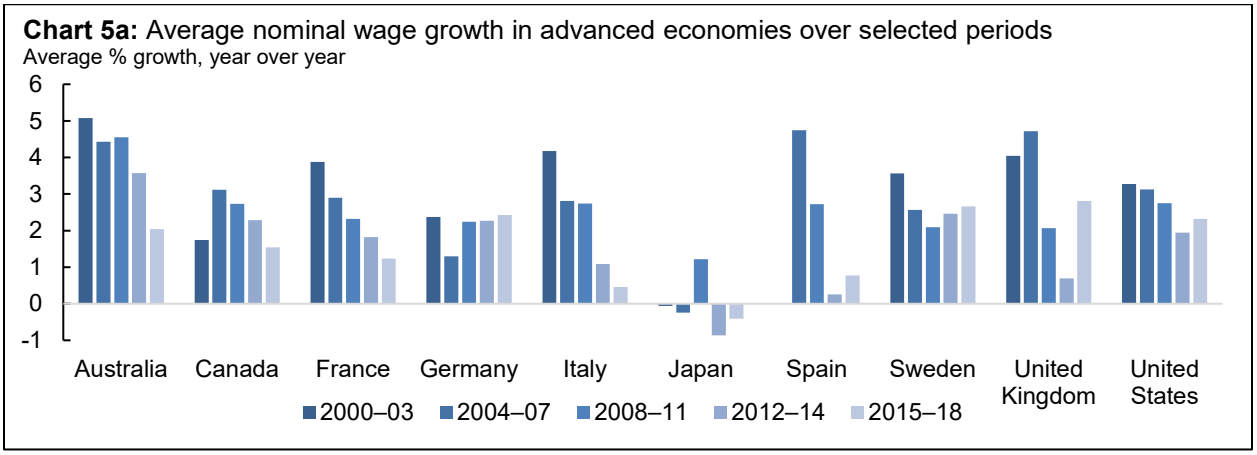


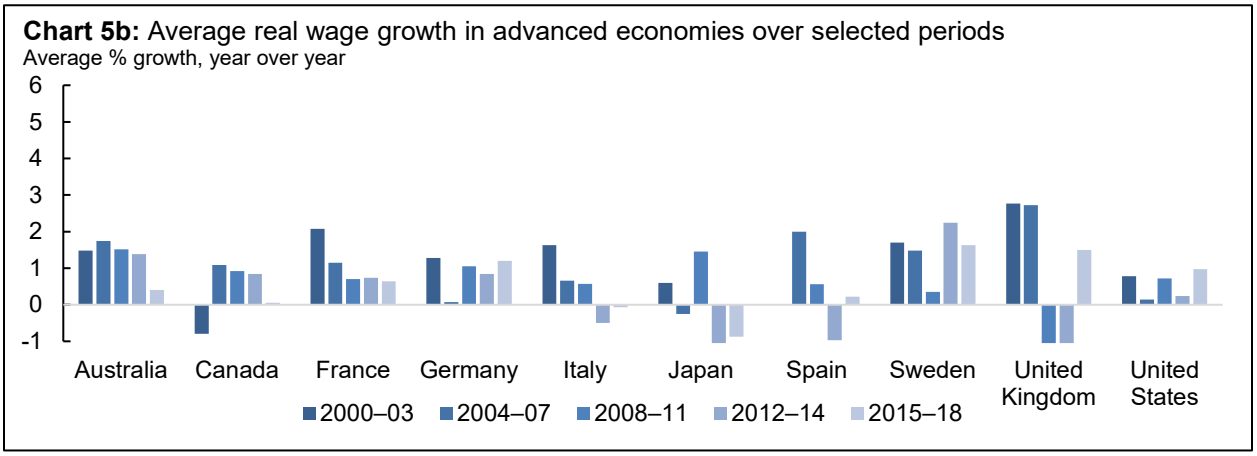
1992Q1–2007Q4



2008Q1–2018Q2

By country, near-zero nominal wage growth for one or two quarters occurs in the post-2008 period in Canada, the United States and the United Kingdom, but not in Sweden or the euro area. While nominal wage growth was usually positive in the post-2008 period, *real* wage growth was close to zero or even briefly negative in most countries in our sample (**Chart 5a** and **Chart 5b**). Even by 2014, near-zero real wage growth persisted. Sweden, however, was an exception, with consistently positive real wage growth in the post-2008 recovery period.





4. Estimating a wage Phillips curve for advanced economies

4.1. Methodology

Galí (2011) derives a reduced-form wage PC based on a standard New Keynesian dynamic stochastic general equilibrium model with staggered wage setting in Erceg, Henderson and Levin (2000). He then estimates a wage PC for the United States over the period from 1964 to 2009 and finds that labour market slack has a significant effect on nominal wage growth. Here, we estimate a Galí-type wage PC in a cross-country panel setting:

$$\pi_{it}^{w} = \alpha_i + \alpha_t + \beta uegap_{it} + \sum_{j=1}^{k} \gamma_j \pi_{it-j}^{p} + \varepsilon_{it}, \qquad (1)$$

where π_{it}^{w} denotes nominal average hourly wage inflation (year over year) in country *i* in quarter *t*; α_i denotes country fixed effects; α_t denotes time fixed effects; and $uegap_{it}$ is the unemployment rate gap $(u_{it} - u_{it}^{*})$, i.e., the difference between the natural rate of unemployment, or NAIRU (u_{it}^{*}), and the actual unemployment rate (u_{it}). Our estimate of the NAIRU is constructed using a Hodrick–Prescott (HP) filter of the current unemployment rate. This allows the natural rate to vary by country and over time. Finally, we include lags of the year-over-year consumer price inflation rate π_{it-j}^{p}, which controls for a possible cost-of-

living adjustment of wages to observed inflation or more general pass-through from lagged prices to wages, due to backward-looking expectations.[4]

Since a NAIRU estimate based on an HP filter may be sensitive to the end-of-sample values, or parameter settings, we also construct the natural rate of unemployment using two other alternatives. In the first alternative, we use a trailing 10-year average of the current unemployment rate as a proxy for the natural rate. For the second alternative, we estimate a linear trend of the unemployment rate for each country. The results are broadly consistent across different measures of the unemployment gap. In **Table 1** we report our estimates with the first two methods, but for the remaining results we report only the HP version for the sake of parsimony. Visual inspection of the unemployment gaps estimated by the HP filter suggests that this method produces an estimate of labour market slack that is narratively consistent with conventionally accepted dates of cyclical downturns.[5]

The model is estimated using fixed effects for a panel of 10 advanced economies using data from the first quarter of 1992 to the second quarter of 2018. Some countries have data for less than the full period, so the panel is unbalanced. The variables of interest (wage growth and labour market slack) are stationary for the countries in our sample.[6] The country fixed effects control for differences in monetary policy regimes and other sources of heterogeneity. Time fixed effects are also included to control for trends in output, productivity or inflation expectations (to the extent that they differ from observed lagged inflation). In robustness tests, we also include productivity and controls for possible correlation in the errors over time or space. All results are in tables in Appendix A. Appendix B provides details on data sources and variable construction.

4.2. Benchmark estimates of the effects of labour market slack on nominal wage growth

We estimate the wage PC using different measures of labour market slack over the full sample period and report the results in **Table A-1** in Appendix A. The specifications in columns 1 to 3 include the unemployment rate and its gap $(u_{it} - u_{it}^*)$ as the measure of labour market slack. The NAIRU, u_{it}^*, is estimated with an HP filter in column 2 and a 10-year, backward-looking moving average in column 3. As expected, we find that the coefficient estimates on these labour market slack terms are negative and significant for the 1992–2018 period. Ranging from -0.2 to -0.4, these estimates suggest an economically as well as statistically significant negative movement in nominal wage growth for an increase in labour market slack. The magnitudes of the coefficients are consistent with recent findings in Galí (2011) and Galí and Gambetti (2019).

[4] Abstracting from the time and country fixed effects, the model is quite similar to equation 19 in Galí (2011) and equation 1 in Galí and Gambetti (2019), which are based on standard empirical models, such as Blanchard and Katz (1999). Galí (2011) includes only one lag of quarterly inflation. We largely follow his specification and include one lag of annual inflation rates. Sensitivity tests with more than one lag of inflation did not materially change the results. It is also possible the lagged price inflation term is picking up lagged wage dynamics. We control for this possibility more explicitly in the robustness tests.

[5] For example, these estimates show large unemployment gaps during the financial crisis for all economies, which close at different paces. They also show large unemployment gaps for certain euro area economies following 2011, which close more slowly in Spain and Italy. The estimation is important for having a point estimate at each point in time for the unemployment gap, and we are comforted that the narrative implication of these gaps is plausible.

[6] Hausman tests also confirm that the fixed effects estimator is appropriate. The variables of interest (wage growth and the unemployment rate or gap variables) are stationary based on the Im–Pesaran–Shin panel unit root test, which permits unbalanced panels. The generalized least squares de-trended Dickey–Fuller and Elliott–Rothenberg–Stock tests, which have been shown to have more power, gave similar results.

When we use the more comprehensive LMI variable (described above) as the measure of labour market slack, the coefficient estimate remains quite similar to that of the unemployment rate variables (**Table A-1**, column 4).[7] This suggests that, for this full sample period, the unemployment rate or its gap is likely a sufficient proxy to assess the effects on wage growth of different labour market measures.[8]

To explore the effects on wage growth of changes in the duration of unemployment, we look at unemployment rates for short-term unemployment (less than six months) and long-term unemployment (six months or more) rather than total unemployment. We construct gaps for both these measures using an HP filter. Including both the short-term and long-term unemployment gap separately in the regression model (**Table A-1**, column 5), we find that only the long-term unemployment rate gap has a significant effect for this sample period. Its estimated coefficient is comparable in magnitude to the total unemployment and LMI indicators in the other specifications. The short-term unemployment rate variable was not found to be statistically significant. This finding is somewhat surprising; the only guess we would hazard to make is that this is due to the strong correlation between the rise in long-term unemployment and weaker wage growth following the financial crisis.

Finally, we estimate the model using the ratio of prime-working-age employment to population as the measure for labour market slack. Movements in this ratio capture the effect of changes in employment that occur due to unemployment, changes in participation and demographic effects. The final two columns of **Table A-1** show the effect of including this direction ratio and of including its deviation from trend using the HP filter to construct the gap term. When this ratio or gap is high, labour market conditions are tight. As such, it has the opposite sign to the other measures of labour market slack. Our wage PC coefficient estimates for these variables are of quite similar magnitudes as the other measures of labour market slack. Specifically, these coefficients suggest that a 1 pp increase in labour market tightness measured by this ratio or its gap would result in an increase in nominal wages of 0.25 to 0.45 percent. The 0.45 point estimate for the prime-age employment ratio in the second specification, where the ratio enters in deviation from trend, is close to the point estimate of -0.38 we obtain on the filtered unemployment rate.

Lagged CPI inflation is included in all the specifications in **Table A-1** and is generally found to be positive, as would be consistent with partial cost-of-living adjustment of wages, or less formal pass-through of past price increases into nominal wages. The estimated coefficient for inflation, however, changes considerably from specification to specification and is not always significant.

Since wage and price inflation may have been substantially higher in the 1990s in some countries, we also try limiting the sample to start in 2001 (**Table A-1**, column 6). This does not materially change the estimated coefficient on the unemployment rate gap. Similarly, when we incorporate a "crisis dummy" variable that takes a value of one for all periods starting in 2008 to the end of the sample, we do not find much change in the estimated wage PC (column 7) relationships. However, if we interact the crisis dummy variable with the unemployment gap variable, we can see more clear differences between the pre-crisis and post-crisis periods. Specifically, the interacted term is positive and significant, suggesting less sensitivity of wage growth to labour market slack in the post-crisis period. The dummy variable itself is not statistically different from zero, and the absolute value of the interaction term is about two-thirds the size of the estimated coefficient on the unemployment gap, suggesting triple the effect on wage growth of slack outside the crisis. In comparison with our baseline estimates of -0.38, then, here we find a baseline effect of the unemployment

[7] We can estimate this specification of the model for only eight of the countries in our sample because data are insufficient to construct the LMI for Australia and Japan.

[8] When we include the participation rate separately (it is a component of the LMI) in the regressions, we do not find that it had a significant effect on nominal wage growth. Furthermore, trends in the participation rate, hours worked and other margins of labour supply that influence the extent to which excess supply corresponds to a particular unemployment rate would be partly reflected in both methods we use to estimate the NAIRU.

gap on wage growth of -0.65 in our overall sample, conditional on allowing the coefficient to vary during the crisis. The point estimate for the slope of the wage PC in the crisis is significantly lower at -0.23.

Overall, the findings here show that different measures of slack have quite consistent and economically significant impacts on nominal wage inflation. Our estimates for the full 1992–2018 period suggest that nominal wage growth increases by about 0.3 pps for a 1 pp decrease in labour market slack. However, these initial estimates provide some evidence that the wage PC relationship may have changed since the global financial crisis. The next section explores this possibility further.

4.3. Has the wage Phillips curve flattened in recent years?

Several studies have documented that the inflation PC has flattened in recent years, with inflation seeming unresponsive to changes in the output gap. A natural question is whether the wage PC is heading in the same direction. Our results above suggest some changes in the wage PC coefficients in the post-crisis period. To explore the possible flattening of the wage PC, we estimate our specifications by limiting the sample, in turn, to before and after the global financial crisis, and also by conducting rolling regressions.

Table A-2 reports the results when we estimate our baseline specification in **Table A-1** for the pre- and post-crisis periods, splitting the sample in the first quarter of 2008.[9] We find that the coefficients on the total unemployment rate and unemployment gap are negative and significant in both subperiods. However, the coefficients associated with both variables are considerably smaller after 2008. The differences in these point estimates between the pre- and post-crisis periods are statistically significant only at the 10 percent level.[10] The lower point estimate in the post-2008 period suggests a flattening of the wage PC.

Columns 3 and 6 of **Table A-2** show estimates for a specification with short- and long-term unemployment gaps included separately. The coefficient on the long-term unemployment gap is statistically significant in both subperiods, and of similar magnitude, but has the wrong sign in the pre-2008 period. The gap of the short-term unemployment rate, however, is significant at the 10 percent level only in the post-2008 period.[11] These results suggest that the long-term unemployed contribute most to the wage PC relationship in the post-crisis period but that a relationship between wage growth and long-term unemployment is hard to establish in the pre-crisis period. The results in **Table A-2** also show that lagged inflation is generally significant only in the pre-crisis period.

We also perform rolling regressions, beginning in 1992 with a seven-year rolling window using the specifications in columns 1 and 2 of **Table A-1**. **Chart 6** shows that the estimated coefficients for the labour market slack variables were large and negative in the early years of the sample period but range from -0.2

[9] We do not have sufficient data to estimate our model with the LMI as a regressor for the pre-crisis period.

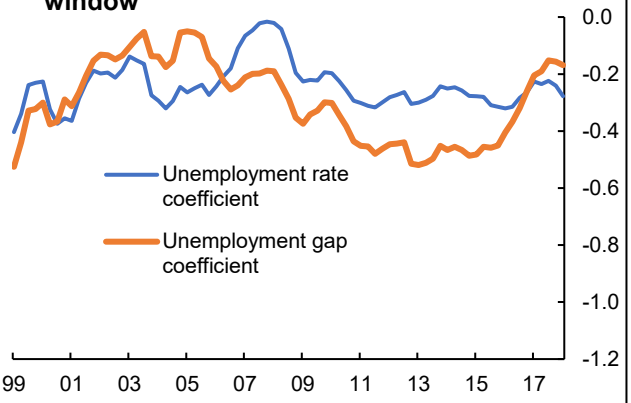
[10] Seemingly unrelated estimation is used to test the significance of linear hypotheses for coefficient estimates across sub-sample periods because these are cross-model hypotheses.

[11] To ensure the panel result is not being driven by the United States (where long-term unemployment rates increased markedly during the post-crisis period), we also confirmed that excluding the United States does not change the main finding that nominal wage growth has become more responsive to changes in long-term unemployment rates in the post-2008 period.

to -0.4 for most of the sample period. However, with the seven-year rolling window, the pre-crisis years drop out completely by 2014, at which time the coefficient estimates become about half as large. This is consistent with the split sample regression results in **Table A-2**. The rolling regression also suggests a steeper wage PC before the early 2000s.

Taken together, these findings provide evidence that the wage PC for advanced economies has flattened. While there remains a statistically and economically significant relationship between wages and the balance in labour markets, wage inflation seems to have become less sensitive to labour market slack since the global financial crisis.

Chart 6: **Rolling regression estimates for nominal wage Philips curve, 7-year window**



Note: Horizontal axis corresponds to the last date in the rolling window. Quarterly observations end in 2018Q2.

4.4. Is the wage Phillips curve convex?

The results above suggest the shape of the wage PC may be evolving in important ways. One hypothesis is that wages may become more sensitive to labour market slack only when it reaches more extreme values (i.e., the wage PC is convex). We conduct simple tests for convexity in the wage PC relationship by including both the linear and quadratic (i.e., squared) terms for the unemployment rate gap or unemployment rate in the regression model. We estimate the model over the full sample period and the pre- and post-2008 subperiods.

The results in **Table A-3** show that the linear terms for unemployment gap and unemployment rate continue to have the expected negative and significant relationship to wage inflation in all three periods. Using just the unemployment rate to measure labour market slack, we find its quadratic term is usually positive, suggesting some curvature, but the coefficients are small and not economically significant. Using our preferred measure of slack, the unemployment gap, we find that the square of the unemployment rate gap term is usually negative. In the pre-crisis period it is also quite large and statistically significant at the 5 percent level. This suggests that in the pre-crisis period, nominal wage growth was more sensitive to large deviations of unemployment from its natural rate; i.e., wages increased faster as labour markets became tighter. In the post-crisis period, the coefficient on the square of the unemployment rate gap is much smaller and not statistically or economically significant. These results corroborate the notion of some flattening of the wage PC that we have found in other specifications.

4.5. Could nominal wage rigidities account for the flattened wage Phillips curve?

The wage PC relationship may have flattened in the post-crisis period due to downward nominal wage rigidities, which cause wages to respond asymmetrically to labour market slack compared with labour market tightness. If employers and employees are reluctant to make or accept reductions in nominal wages following negative aggregate shocks that would otherwise reduce real wages, the growth of nominal wages may remain relatively stable, even in the presence of excess labour supply. Downward wage rigidities are likely to bind only in periods of excess supply or in the aftermath of recessions if there is pent-up demand for real wage cuts by firms. Both these outcomes could weaken the observed empirical relationship between

unemployment and nominal wage growth.[12] Jo (2019) notes some debate in the literature as to whether downward nominal wage rigidities can lead to larger adjustments to employment. Next, we estimate a series of piecewise regressions to test for the presence of nominal wage rigidities.

We first construct a positive unemployment rate gap dummy variable, which takes the value one when the unemployment rate gap is positive (i.e., excess labour supply), and interact it with the unemployment rate gap variable. The results are shown in columns 1 to 6 in **Table A-4a**. We find that the positive unemployment rate gap dummy term has the expected negative sign in both the full sample period and the subperiods, although it is not significant in the subsamples. The interaction term is negative and significant in the full sample estimates and the subperiods. This implies that the sensitivity of wages to the unemployment rate gap is significantly stronger in periods when the unemployment rate gap is positive (i.e., when there is excess labour demand) than in periods when the unemployment rate gap is negative (i.e., when labour market conditions are stronger). This difference is most pronounced during the pre-crisis period but is present in the post-crisis period as well.[13] Similarly, columns 7 and 8 of **Table A-4a** show the results of estimating the benchmark model separately for observations where the unemployment rate is rising or falling. We find the estimated coefficients on the unemployment rate gap are about three times larger for periods of rising unemployment compared with periods when the unemployment rate is declining. These results all seem to imply that nominal wage growth is considerably *more* responsive to changes in the unemployment rate gaps in periods of excess labour supply, contrary to the hypothesis of downward nominal rigidities.

In the nominal wage PC estimation results in **Table A-4a**, the coefficient on inflation usually has the expected, positive sign but seems to be larger during periods of declining unemployment rates and the pre-crisis subsample. In periods of high inflation, firms can "hide" real wage cuts by raising nominal wages by less than the full amount that consumer prices increase. The theory of downward nominal rigidities suggests that workers would be more willing to accept these real wage cuts than an equivalent but visible nominal wage reduction in a zero-inflation environment (Card and Hyslop 1997). Therefore, nominal wage rigidities are more likely to bind during periods of low inflation. We also estimate the baseline nominal wage PC model separately for observations with relatively high and low inflation, where "high" is defined as inflation that is 0.5 standard deviations above the sample mean and "low" is 0.5 standard deviations below it. We find that wage inflation is much more sensitive to the unemployment rate gap in periods of higher inflation, consistent with downward nominal rigidities. This potentially explains the flattening of the wage PC in more recent (low inflation) periods.

The results in **Table A-4b** are mixed on the question of downward nominal rigidities. We repeat our specifications using the dummy variable approach, specifying it such that a binding nominal rigidity prevents wages from responding to positive unemployment gaps. We do so by including a dummy variable for positive unemployment gaps and interacting it with the unemployment gap. However, we find here that the dummy variable for a positive gap has a statistically significant negative coefficient, suggesting that real wages decline significantly as the unemployment rate gap increases. Although the coefficient estimates are somewhat smaller than in the nominal wage PC estimates above, these estimates do not appear to provide much evidence of downward rigidities. Other specifications show the negative relationship between real wages and the unemployment rate gap is more negative when the unemployment rate gap is positive, and

[12] Schmitt-Grohé and Uribe (2013, 2016) show that nominal wage rigidities can increase unemployment and did so in the peripheral euro area and in the United States during the global financial crisis.

[13] As an alternative to the dummy variable approach described above, we conduct separate regressions on observations with positive unemployment rate gaps or negative unemployment rate gaps, across the full sample and subperiods. We find the same result that nominal wages seem more sensitive to unemployment rate gaps during periods of excess labour supply (positive unemployment rate gaps) compared with tight labour markets. (To avoid repetition we do not present these results here, but they are available upon request.)

this effect is stronger in the post-crisis period. Similarly, periods of rising unemployment correspond to a stronger real wage PC relationship.

We also attempt in **Table A-4b** to examine the downward nominal rigidity hypothesis following Card and Hyslop (1997), who argue that this form of nominal rigidity implies that real wage cuts will occur only when inflation is high. If this hypothesis holds, then we should see a steeper real wage PC in periods of higher inflation. This is indeed what we find in columns 15 and 16 in **Table A-4b.** This is the strongest support for downward nominal rigidity we can find among our estimates, although it is far from conclusive.

Overall our findings provide only limited support for the idea that wage rigidities have been generating the flattening in the wage PC in recent years. They may even suggest that wages were relatively flexible and responsive to labour market weakness in the post-crisis period. However, this finding is only suggestive. We use only aggregate data on average wages for all our analyses. If the composition of the employed workforce changes significantly, e.g., less experienced workers are laid off, the average wage may change even if there are no changes to employed workers' wages. Therefore, the extent of wage rigidity or flexibility in response to aggregate shocks would be more clearly identified with microdata that tracks changes to individual employees' wages.

4.6. Robustness tests

Table A-5 presents the results of several robustness tests where we estimate the nominal wage PC model over the full sample period. First, we add labour productivity growth to the regression, since that is a potential determinant of real wage growth rates and therefore could be an important omitted variable. These results indicate that productivity growth has the expected positive relationship with nominal wage growth. The lagged inflation term also remains positive but is statistically significant only at the 10 percent level. Including productivity growth does not weaken the estimated relationship between labour market slack and wage growth since the coefficients on the unemployment rate gap terms remain negative and significant. Indeed, the coefficient on the unemployment rate gap based on the HP-filter version of NAIRU is considerably more negative than we find in the benchmark results shown in **Table A-1**. The estimated coefficient on the unemployment rate gap variable with a NAIRU based on a moving average, however, is very similar to the estimate in **Table A-1**.

We also include a European Central Bank (ECB) dummy variable, which takes the value one for all euro area countries, to control for common monetary policy in euro area countries, which may not be adequately captured by fixed time or country effects. The ECB dummy itself has a negative sign, suggesting that these countries have a lower rate of wage growth over the full sample period than non-ECB countries. Its inclusion does not result in any material change in our coefficient estimates on the unemployment rate gap or inflation variables. Next, to control for possible spatial or serial correlation in the errors, columns 5 and 6 present the results of the benchmark model estimated with clustered errors. The coefficient estimates for the unemployment gap and inflation variables remain quite similar to our benchmark results in **Table A-1**.

Finally, we estimate a dynamic panel version of our wage PC relationship by including a lag of nominal wage growth in the regression model (columns 7 and 8). To ensure no endogeneity effects from the lagged dependent variable in this panel estimation, we use the Arellano–Bond generalized method of moments estimator. The lagged wage growth variable has a large, positive coefficient of about 0.65, indicating wage growth is quite smooth, with a strong autoregressive component. The coefficient on the unemployment rate gap remains negative and significant; but, not surprisingly, it is much smaller in the presence of a lagged wage growth term. This is reassuring because even when we control for lagged wage growth, we still find a significant relationship between the unemployment rate gap and nominal wage growth.

5. Conclusion: The wage Phillips curve is alive but not necessarily well

We examine data on several measures of labour market activity and their evolution in major advanced economies since the global financial crisis of 2008–09. While the indicators can be somewhat mixed, broader measures of excess supply in the labour market currently suggest more slack in some advanced economies than headline unemployment rates are picking up.

Galí (2011) concluded his study of wage PC analysis for the United States by noting that, unlike the inflation PC relationship, the wage PC was "alive and well." Mojon and Ragot (2019) echo this comment. More recently, however, Galí and Gambetti (2019) found a marked flattening of the wage PC in the United States. Our findings here indicate that nominal wage growth is significantly affected economically and statistically by excess supply in the labour market, so the wage PC relationship is alive. We also find that rates of long-term unemployment and broader measures of labour market slack than the total unemployment rate or unemployment rate gap are significant, particularly in the post-2008 period. This suggests that underemployed or long-term unemployed persons can exert downward pressure on wages. This is consistent with other studies that find that the composition of the workforce can likely explain some of the wage puzzles in the post-crisis period.

While we find that the wage PC is still alive, it is not clear that it is well. Our rolling regressions, split sample and some of the piecewise regression results provide considerable evidence that the wage PC has flattened in the post-crisis period in advanced economies. This finding is consistent with the sluggish wage growth that we have seen in recent years, even as labour markets have become quite tight in many advanced economies. Moreover, some of our piecewise regressions suggest that the wage PC relationship could be quite asymmetric, with most of the responsiveness in wages occurring in periods of excess labour supply rather than in periods of labour market tightness.

Appendix A

Table A-1: Nominal wage Phillips curve baseline estimates, full sample period

	(1)	(2)	(3) >2001	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Unemployment rate (UR)	-0.33***									
	(0.03)									
UR gap (HP)		-0.36***	-0.36***						-0.36***	-0.55***
		(0.06)	(0.07)						(0.06)	(0.08)
Crisis dummy x UR gap (HP)										0.31***
										(0.12)
Crisis dummy									-0.20	-0.18
									(0.80)	(0.74)
UR gap (MA)				-0.23***						
				(0.03)						
Inflation, %y/y = L,	-0.00	0.14**	0.03	0.13**	-0.34***	-0.04	0.12**	0.14***	0.14**	0.11**
	(0.05)	(0.05)	(0.07)	(0.05)	(0.08)	(0.07)	(0.06)	(0.05)	(0.05)	(0.05)
LMI					-0.29***					
					(0.03)					
Short-term UR (HP)						-0.06				
						(0.14)				
Long-term UR (HP)						-0.26***				
						(0.08)				
Prime-wage E/POP ratio							0.24***			
							(0.02)			
Prime-wage E/POP ratio (HP)								0.45***		
								(0.06)		
Observations	879	879	640	860	411	636	879	879	879	879
R-squared	0.41	0.31	0.34	0.33	0.49	0.34	0.85	0.84	0.31	0.32
Constant	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
FE	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
TE	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES

Table A-2: Nominal wage Phillips curve estimates, pre- and post-crisis subperiods

	(1) <2008	(2) <2008	(3) <2008	(4) >=2008	(5) >=2008	(6) >=2008
Unemployment rate (UR)	-0.41***			-0.29***		
	(0.06)			(0.04)		
UR gap (HP)		-0.31***			-0.25***	
		(0.10)			(0.08)	
Short-term UR (HP)			-0.61***			0.42*
			(0.19)			(0.23)
Long-term UR (HP)			0.45***			-0.32***
			(0.15)			(0.09)
Inflation %y/y (t-1)	0.20***	0.35***	0.11	-0.14*	-0.03	-0.14
	(0.07)	(0.07)	(0.12)	(0.08)	(0.08)	(0.08)
Observations	459	459	300	420	420	336
R-squared	0.32	0.24	0.25	0.37	0.29	0.35
Constant	NO	NO	NO	NO	NO	NO
Fixed Country Effects	YES	YES	YES	YES	YES	YES
Fixed Time Effects	YES	YES	YES	YES	YES	YES

Robust standard errors in parentheses
**** p<0.01, ** p<0.05, * p<0.1*

Table A-3: **Nominal wage Phillips curve estimates, tests for convexity**

	(1) >1991	(2) >1991	(3) <2008	(4) <2008	(5) >=2008	(6) >=2008
Unemployment rate (UR)	-0.54***		-1.18***		-0.51***	
	(0.06)		(0.16)		(0.08)	
Unemployment rate ^2	0.01***		0.05***		0.01**	
	(0.00)		(0.01)		(0.00)	
UR gap (HP)		-0.36***		-0.30***		-0.21***
		(0.06)		(0.10)		(0.07)
UR gap (HP) ^2		-0.05**		-0.11		-0.06*
		(0.02)		(0.08)		(0.03)
Inflation %y/y (t-1)	-0.03	0.15***	0.20***	0.32***	-0.17**	0.00
	(0.05)	(0.05)	(0.07)	(0.07)	(0.08)	(0.08)
Observations	879	879	459	459	420	420
R-squared	0.42	0.32	0.34	0.24	0.38	0.30
Constant	NO	NO	NO	NO	NO	NO
FE	YES	YES	YES	YES	YES	YES
TE	YES	YES	YES	YES	YES	YES

Table A-4a : Nominal wage Phillips curve estimates, tests for rigidities

	(1) >1991	(2) >1991	(3) <2008	(4) <2008	(5) >=2008	(6) >=2008	(9) High inflation periods	(10) Low inflation periods
UR gap (HP)	-0.28***	0.12	-0.11	0.22	-0.22**	0.14	-0.75***	-0.22**
	(0.08)	(0.11)	(0.15)	(0.21)	(0.10)	(0.14)	(0.15)	(0.10)
Positive UR gap dummy	-0.34***	-0.30**	-0.39**	-0.37*	-0.17	-0.16		
	(0.13)	(0.13)	(0.20)	(0.20)	(0.18)	(0.18)		
		-0.74***		-0.65**		-0.62**		
		(0.18)		(0.29)		(0.24)		
Positive UR gap dummy x UR gap	0.13**	0.12**	0.34***	0.31***	-0.03	-0.01		
	(0.05)	(0.05)	(0.07)	(0.07)	(0.08)	(0.08)		
Inflation %y/y (t-1)	-0.28***	0.12	-0.11	0.22	-0.22**	0.14		
	(0.08)	(0.11)	(0.15)	(0.21)	(0.10)	(0.14)	0.05	-0.07
	-0.34***	-0.30**	-0.39**	-0.37*	-0.17	-0.16	(0.20)	(0.15)
Observations	879	879	459	459	420	420	204	297
R-squared	0.34	0.36	0.26	0.28	0.33	0.34	0.34	0.36
Constant	NO	NO	NO	NO	NO	NO	NO	NO
FE	YES	YES	YES	YES	YES	YES	YES	YES
TE	YES	YES	YES	YES	YES	YES	YES	YES

Table A-4b: Real wage Phillips curve estimates, tests for rigidities

	(1) >1991	(2) >1991	(3) >1991	(4) >1991	(5) <2008	(6) <2008	(7) <2008	(8) <2008	(9) >=2008	(10) >=2008	(11) >=2008	(12) >=2008	(13) Falling UR	(14) Rising UR	(15) High inflation periods	(16) Low inflation periods
UR gap (HP)	-0.24***	-0.19*	0.19	0.14	-0.03	0.08	0.26	-0.06	-0.24**	-0.21*	0.29*	0.25**	-0.70***	-0.16	-0.07	-0.32**
	(0.07)	(0.10)	(0.12)	(0.10)	(0.10)	(0.16)	(0.24)	(0.16)	(0.10)	(0.12)	(0.16)	(0.12)	(0.15)	(0.13)	(0.09)	(0.13)
UR gap x Inflation				-0.21***				0.02				-0.27***				
				(0.05)				(0.08)				(0.07)				
Positive UR gap Dummy		-0.19	-0.16			-0.21	-0.20			-0.16	-0.16					
		(0.15)	(0.15)			(0.21)	(0.22)			(0.23)	(0.22)					
			-0.70***				-0.33				-0.84***					
			(0.22)				(0.31)				(0.30)					
Positive UR gap Dummy x UR gap	-0.24***	-0.19*	0.19	0.14	-0.03	0.08	0.26	-0.06	-0.24**	-0.21*	0.29*	0.25**	-0.70***	-0.16	-0.07	-0.32**
	(0.07)	(0.10)	(0.12)	(0.10)	(0.10)	(0.16)	(0.24)	(0.16)	(0.10)	(0.12)	(0.16)	(0.12)	(0.15)	(0.13)	(0.09)	(0.13)
Observations	884	884	884	884	464	464	464	464	420	420	420	420	207	298	540	344
R-squared	0.25	0.26	0.27	0.28	0.17	0.17	0.17	0.17	0.30	0.30	0.32	0.36	0.59	0.46	0.29	0.48
Constant	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
FE	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
TE	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES

Table A-5: Robustness tests of the nominal wage Phillips curve estimates

	(1) w. Productivity growth	(2) Arellano–Bond	(3) Arellano–Bond	(4) Country-clustered SEs	(5) Year+country-clustered SEs	(6)	(7) w. ECB dummy	(8)
UR gap (HP)	-0.63***		-0.13***		-0.36***	-0.36***	-0.37***	
	(0.08)		(0.04)		(0.09)	(0.09)	(0.06)	
UR gap (MA)		-0.30***		-0.08***				-0.23***
		(0.04)		(0.02)				(0.03)
Productivity growth, %y/y	0.13*	0.14**						
	(0.07)	(0.07)						
Inflation, %y/y = L,	0.10	0.11*	0.06	0.06	0.14	0.12	0.14**	0.12**
	(0.06)	(0.06)	(0.04)	(0.04)	(0.15)	(0.13)	(0.05)	(0.05)
Nominal wages = L,			0.65***	0.64***				
			(0.02)	(0.03)				
ECB dummy							-0.19	-0.45**
							(0.18)	(0.21)
Observations	664	645	864	846	879	879	879	860
R-squared	0.30	0.31			0.31	0.47	0.31	0.34
Constant	NO	NO	NO	NO	NO	NO	NO	NO
FE	YES	YES	YES	YES	YES	YES	YES	YES
TE	YES	YES	YES	YES	YES	YES	YES	YES
Number of id			10	10				

Appendix B: Data sources and variable construction

This appendix describes the data sources and construction of variables used in the panel and country-level regressions.

Nominal wages: Nominal wages is an index of average hourly wages, where available, and total weekly or monthly wages of all workers scaled by average hours worked, including overtime (where available), from national sources via Haver Analytics. Data are monthly from Australia, Canada, Sweden, Japan, the United Kingdom and the United States, converted to quarterly. Data from source are quarterly for the euro area countries.

Hours: Hours are average weekly hours of all workers, where available. For Japan and the United States, agricultural workers are excluded. For the euro area, construction is excluded. Data are from national sources via Haver Analytics.

Average nominal hourly wages: This is constructed using the difference in the growth rates of the series for nominal wages and nominal hours for Australia, the United Kingdom and Japan, and taken from national sources via Haver Analytics for other economies.

Real wages: Real wages are calculated as the difference between year-over-year nominal wage growth and year-over-year growth in nominal consumer prices, as indicated by the consumer price index, in the same period.

CPI: CPI is the consumer price index, or the HCIP in the case of the euro area, from national sources via Haver Analytics.

Unemployment: Unemployment is the headline unemployment rate reported by national labour force surveys, via Haver Analytics. It is defined as the share of the labour force that is not employed and has searched for employment within the four weeks before the survey.

Short-term unemployment: This is calculated as the difference between long-term unemployment and unemployment.

Long-term unemployment: This is defined as the share of the labour force that has been unemployed for a duration of greater than 27 weeks or six months.

Participation rate: We use national sources via Haver Analytics, defined as the share of the population aged 15 and older in the labour force, except in the United Kingdom, which uses the working age population of those aged 15 to 64. Data are from national sources via Haver Analytics, with the exception of Australia, where data are from the Australian Bureau of Statistics.

Productivity: Productivity is defined as quarterly real output per hour worked by all workers, from national sources via Haver Analytics.

References

Bell, D. N. F. and D. G. Blanchflower. 2018. "The Lack of Wage Growth and the Falling NAIRU." NBER Working Paper No. 24502.

Blanchard, O. and L. F. Katz. 1999. "Wage Dynamics: Reconciling Theory and Evidence." *American Economic Review Papers and Proceedings* 89 (2): 69–74.

Blanchflower, D. G. and A. S. Posen. 2014. "Wages and Labor Market Slack: Making the Dual Mandate Operational." Peterson Institute for International Economics Working Paper No. 14-6.

Board of Governors of the Federal Reserve System. 2015. "Federal Reserve Issues FOMC Statement." Press release, May 1.

Brouillette, D., M. Dockrill, H. Lao and L. Savoie-Chabot. 2018. "Bending the Curves: Wages and Inflation." Bank of Canada Staff Analytical Note No. 2018-15.

Bullard, J. 2018. "The Case of the Disappearing Phillips Curve." Speech at the 2018 ECB Forum on Central Banking Macroeconomics of Price- and Wage-Setting, Sintra, Portugal, June 19.

Card, D. and D. Hyslop. 1997. Does Inflation "Grease the Wheels of the Labor Market?" In *Reducing Inflation: Motivation and Strategy*, edited by C. D. Romer and D. H. Romer, 71–122. Chicago: University of Chicago Press.

Daly, M. C., and B. Hobijn. 2014. "Downward Nominal Wage Rigidities Bend the Phillips Curve." Federal Reserve Bank of San Francisco Working Paper No. 2013-08.

Erceg, C., D. Henderson and A. Levin. 2000. "Optimal Monetary Policy with Staggered Wage and Price Contracts." *Journal of Monetary Economics* 46 (2): 281–314.

Galí, J. 2011. "The Return of the Wage Phillips Curve." *Journal of the European Economic Association* 9 (3): 436–461.

Galí, J. 2015. "Hysteresis and the European Unemployment Problem Revisited." NBER Working Paper No. 21430.

Galí, J. and L. Gambetti. 2019. "Has the U.S. Wage Phillips Curve Flattened? A Semi-structural Exploration." NBER Working Paper No. 25476.

Jo, Y. J. 2019. "Downward Nominal Wage Rigidity in the United States." Job Market Paper.

Krueger, A. B., J. Cramer and D. Cho. 2014. "Are the Long-Term Unemployed on the Margins of the Labor Market?" *Brookings Papers on Economic Activity* (Spring): 229–280.

Leduc, S., C. Marti, and D. J. Wilson. 2019. "Does Ultra-Low Unemployment Spur Rapid Wage Growth?" Federal Reserve Bank of San Francisco Economic Letter No. 2019-02.

Leduc, S. and D. J. Wilson. 2017. "Has the Wage Phillips Curve Gone Dormant?" Federal Reserve Bank of San Francisco Economic Letter No. 2017-30.

Mojon, B. and X. Ragot. 2019. "Can an Ageing Workforce Explain Low Inflation?" BIS Working Papers No. 776.

Schmitt-Grohé, S. and M. Uribe. 2013. "Downward Nominal Wage Rigidity and the Case for Temporary Inflation in the Eurozone." *Journal of Economic Perspectives* 27 (3): 193-212.

Schmitt-Grohé, S. and M. Uribe. 2016. “Downward Nominal Wage Rigidity, Currency Pegs, and Involuntary Unemployment.” *Journal of Political Economy* 124 (5): 1466–1514.

Stock, J. and M. Watson. 2018. “Slack and Cyclically Sensitive Inflation.” Presentation to the European Central Bank Forum on Central Banking, Sintra, Portugal, June 18–20.

Wilkins, C. A. 2019. “A Look Under the Hood of Canada’s Job Market.” Speech at the Toronto Region Board of Trade, Toronto, Ontario, January 31.

Williams, J. 2019. “Discussion of 'Prospects for Inflation in a High Pressure Economy: Is the Phillips Curve Dead or Is It Just Hibernating?' by Peter Hooper, Frederic S. Mishkin, and Amir Sufi.” Remarks at the US Monetary Policy Forum, New York City, February 22.

Yellen, J. L. 2014. “What the Federal Reserve Is Doing to Promote a Stronger Job Market.” Speech at the 2014 National Interagency Community Reinvestment Conference, Chicago, Illinois, March 31.

Zmitrowicz, K. and M. Khan. “Beyond the Unemployment Rate: Assessing Canadian and U.S. Labour Markets Since the Great Recession.” *Bank of Canada Review* (Spring): 42–53.