Drivers of Weak Wage Growth in Advanced Economies

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Acknowledgements

Abstract

Since the global financial crisis, advanced-economy wage growth has been generally low relative to past recoveries, especially after accounting for the evolution of labour market conditions over this period. This paper investigates a variety of potential explanations for this weakness, drawing on findings from the literature as well as analysis of recent labour market data in advanced economies. Overall, we find that much of the unexplained weakness is likely explained by alternative measures of labour market slack—particularly the rise of involuntary part-time work. In addition, changing inflation dynamics and a number of structural factors may also be contributing to the weakness. These factors include weaker bargaining power of workers due to lower unionization rates, increased firm concentration, restrictive labour mobility practices, greater labour market reform and changing demographic factors. Other factors, such as migration and technological change, may also be affecting advanced-economy wage growth, but the direction and magnitude of these impacts are more ambiguous. Identifying and quantifying the causal effects that the factors examined in this note may have on advanced-economy wage growth is beyond the scope of our analysis. However, our review of international evidence does help to recognize likely drivers of the observed weakness in wage growth and lays the foundation for future work examining certain factors in more detail.

Bank topics: International topics; Labour markets
JEL codes: E31, F0, J3

Résumé

Depuis la crise financière mondiale, la croissance des salaires dans les économies avancées a été généralement plus faible que lors de reprises précédentes, surtout après la prise en compte de l'évolution des conditions sur le marché du travail pendant cette période. Dans cette étude, nous envisageons diverses raisons qui pourraient expliquer cette faiblesse. Pour ce faire, nous effectuons un survol de la littérature pertinente et analysons les données récentes sur le marché du travail des économies avancées. Dans l'ensemble, nous en concluons qu'une grande partie de la faiblesse inexpliquée se justifie probablement par différentes mesures des capacités excédentaires sur le marché du travail, en particulier l'augmentation du travail à temps partiel involontaire. De plus, la dynamique changeante de l'inflation et un certain nombre de facteurs structurels pourraient aussi contribuer à la faiblesse. Parmi ces facteurs, citons le pouvoir de négociation réduit des travailleurs en raison de la baisse du taux de syndicalisation, la concentration accrue des entreprises, les pratiques restrictives en matière de mobilité de la main-d'œuvre, les réformes du marché du travail et des changements démographiques. D'autres éléments, comme la migration et les progrès technologiques, peuvent également avoir une incidence sur la croissance des salaires dans les économies avancées, mais le sens et l'ampleur de cette incidence sont plus incertains. L'identification et la quantification des effets de causalité des facteurs examinés dans cette note sur la croissance des salaires dans les économies avancées dépassent la portée de notre analyse. Notre examen des données

internationales aide toutefois à déterminer les causes probables de la faiblesse observée de la progression des salaires et jette les bases d'éventuelles études plus poussées de certains facteurs dans l'avenir.

Sujets : Questions internationales; Marchés du travail
Codes JEL : E31, F0, J3

Summary

Since the global financial crisis, advanced-economy wage growth has been generally low relative to past recoveries (**Chart 1**), especially after accounting for the evolution of labour market conditions over this period. This note investigates a variety of explanations for this weakness using labour market data for several advanced economies as well as a review of the literature. Overall, much of the unexplained weakness can be captured by alternative measures of slack, though structural factors may also be at play:

1. Following the global financial crisis, labour market slack increased by more than suggested by unemployment rates alone and is still exerting downward pressure on wages in some advanced economies.
   - The sharp rise of involuntary part-time (IPT) work during and following the global financial crisis disguised the extent of labour market slack.
   - Although unemployment rates have been falling, the incidence of IPT work has adjusted slowly and remains high in some economies. This may still be restraining wage growth.
2. Structural changes may have dampened the relationship between wage growth and labour market slack or tightness**.**
   - Over the past 30 years or so, unionization rates have declined, monopsony power in labour markets appears to have increased, populations have aged, trade has been liberalized and technology has changed.
   - Some of these structural changes seem to have contributed to a steady decline in wage growth that may not have been captured in standard wage Phillips curve (WPC) analyses.
   - As such, rules of thumb based on past WPC estimates may not give reliable indications of how wage inflation will adjust as labour markets tighten.

**Chart 1: Hourly wage rates in advanced economies**
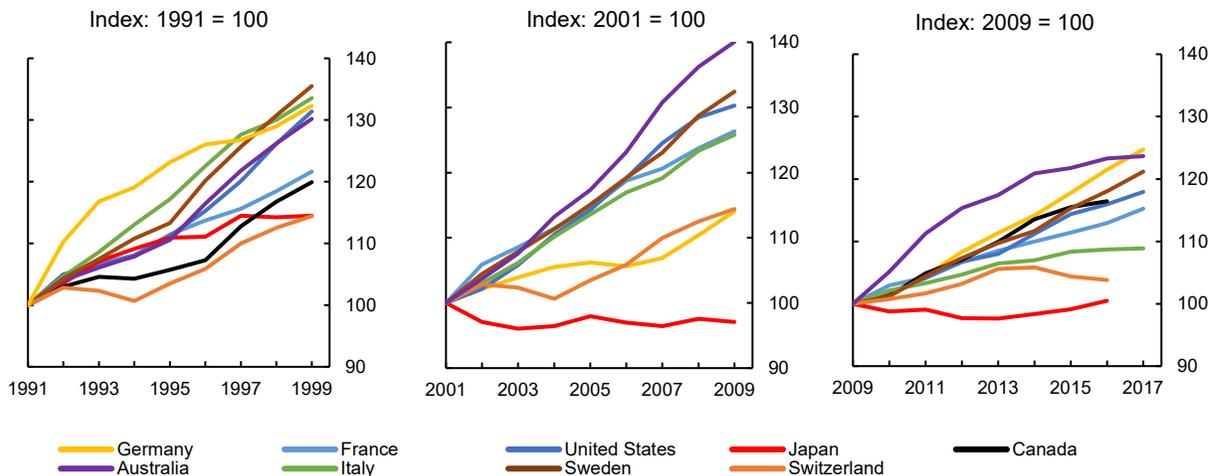
Note: This figure shows the evolution of nominal wages (hourly wages per employee) in selected advanced economies relative to their levels during the last three US recessions. Years 1991–99, 2001–09 and 2009–17 are displayed; each panel covers the same time span.
Sources: Organisation for Economic Co-operation and Development and Bank of Canada calculations

1. How do wages compare with wage Phillips curve predictions?

Over the past three to five years, wage growth has been lower than what might have been expected at this stage of the cycle in several economies (**Chart 2**).[1] Apart from unemployment, weak inflation (**Chart 3**) and somewhat soft growth in labour productivity may also be contributing to keeping wages low. Although the pace of growth of trend labour productivity picked up around 2016, it remains below its pre-crisis average (**Chart 4**).

Nevertheless, even after we control for unemployment, inflation and labour productivity, advanced-economy wage inflation has been weaker than would be expected since 2013. To show this, we estimate country-specific and panel wage Phillips curve (WPC) regressions covering 14 advanced economies (see **Appendix A** for details on the data used and **Appendix B** for details on the regressions). The residuals from both approaches (averaged across countries) are plotted in **Chart 5**. They indicate that wage inflation has increasingly weakened relative to the model predictions since 2013. Moreover, the results also suggest that this recent weakness has been broad-based across the countries in our sample (**Chart 6**). In the euro area and the United States, the residuals from our analysis seem small, but this partly reflects some positive residuals in late 2014 and early 2015. For the United States, the average unexplained wage growth during 2016 and 2017 is -0.65 percentage points (indeed, most countries have residuals that are more negative during the past two years).[2, 3]

Many reasons have been put forward to explain the missing wage growth. In the next section, we investigate four broad sets of possible explanations: cyclical underemployment (we consider the roles played by involuntary part-time and discouraged workers); changing inflation dynamics; structural labour market changes (we consider declining

Chart 2: Wage growth and unemployment
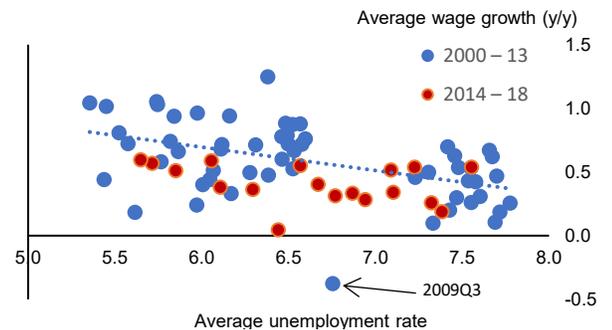
Note: The unemployment rate and wage growth data are simple averages of data for the United States, United Kingdom, Austria, France, Germany, Italy, the Netherlands, Sweden, Switzerland, Canada, Japan, Finland, Ireland and Australia. y/y is year-over-year.
Sources: Organisation for Economic Co-operation and Development and Bank of Canada calculations

**Chart 3: Average core inflation in selected economies**
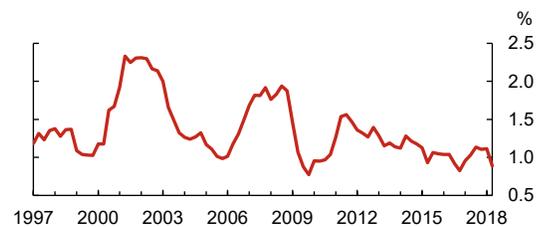
Last observation: 2017Q1

Note: Country selection follows that noted in Chart 2. All countries have equal weights.
Sources: Organisation for Economic Co-operation and Development and Bank of Canada calculations

Chart 4: Average trend labour productivity growth
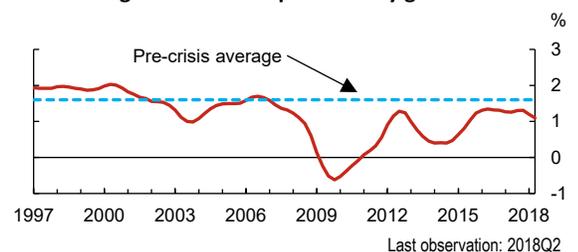
Last observation: 2018Q2

Note: Country selection follows that noted in Chart 2. Data are three-year moving averages of year-over-year growth rates.
Sources: Organisation for Economic Co-operation and Development and Bank of Canada calculations

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[1] Wage Phillips curve residuals are larger after 2013, though the exact date for the sample break is arbitrary.
[2] Our country-specific regressions include lagged wage growth as an explanatory variable. Thus, we may be explaining wage growth weakness with past weakness. This is standard in time series regressions.
[3] Our residuals for the euro area are small. This likely reflects the fact that the wage inflation data for the euro area are very smooth compared with other countries. For the euro area, between 2016 and 2017, the average unexplained wage growth is about 0.2 percentage points.

unionization rates, the rise of monopsony power, labour market reforms, population aging and migration); and other structural factors (we consider technological change and trade). Where possible, we apply available data to our WPC analysis to see whether (a) there is a correlation between the recent country-specific residuals noted in **Chart 6** and (b) the data are statistically significant in our panel estimates.

Chart 5: Unexplained wage inflation: residuals from panel and country-specific estimation
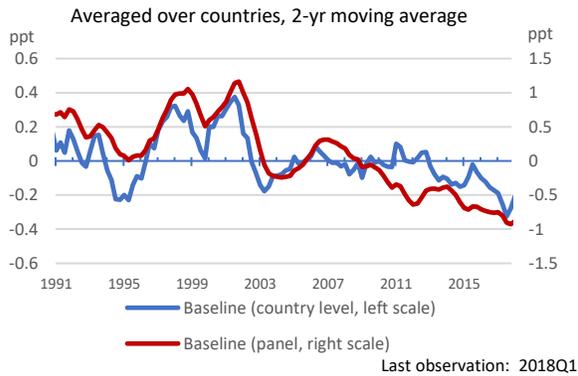
Averaged over countries, 2-yr moving average

Baseline (country level, left scale)

Baseline (panel, right scale)

Last observation: 2018Q1

Note: ppt is percentage points.
Sources: Organisation for Economic Co-operation and Development and Bank of Canada calculations

Chart 6: Unexplained wage inflation: residuals from country-specific estimation
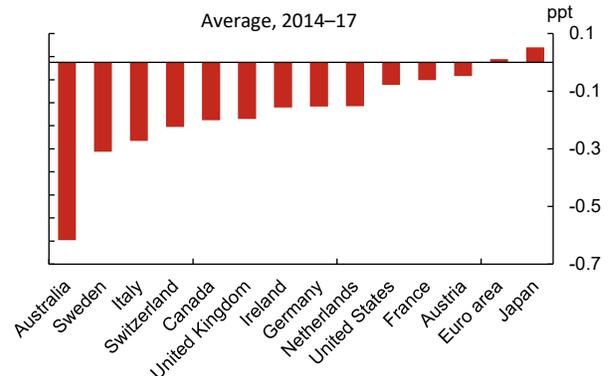
Average, 2014–17

Note: ppt is percentage points.
Sources: Organisation for Economic Co-operation and Development and Bank of Canada calculations

2. What can explain weak wage inflation beyond conventional wage Phillips curves?

2.1 Cyclical underemployment

One possibility for the unexplained wage weakness in recent years is that the unemployment rate has not properly captured the full extent of post-crisis labour market slack. IPT and marginally attached workers are both possible sources of labour market slack, though they could affect wages differently. IPT workers are those who are active in the labour market and willing to work more, while marginally attached workers are those who would be willing to work but are not actively looking, perhaps because they find the prospects of finding a suitable job too poor. A rise in IPT workers should therefore put downward pressure on wages, while an increase in marginally attached workers could put either upward or downward pressure on wages, depending on whether the effect of withdrawing from the labour market dominates the effect of being willing to work but not employed.

When IPT and marginally attached workers are included in our panel WPC analysis, we find that an increase in IPT workers puts downward pressure on wage growth while an increase in the incidence of marginally attached workers tends to increase wage growth (see Appendix B, Table B-2, columns 2 and 3). In **Chart 7,** we also find that the relatively high levels of IPT workers may have contributed to some of the recent unexplained country-specific wage weakness (as measured by the residuals from our WPC analysis noted in **Chart 6**). This seems particularly so for some European countries such as Italy, Ireland,

the Netherlands, Switzerland and the United Kingdom.[4] To the extent that involuntary unemployment remains high in many countries (e.g., Australia, Italy, France, Ireland and the United Kingdom; **Chart 8**), it could still be a factor contributing to weak wage growth in these economies.

Chart 7: **Involuntary part-time workers as a share of the labour force (2014–16 relative to pre-2014 average) vs. unexplained wage inflation**
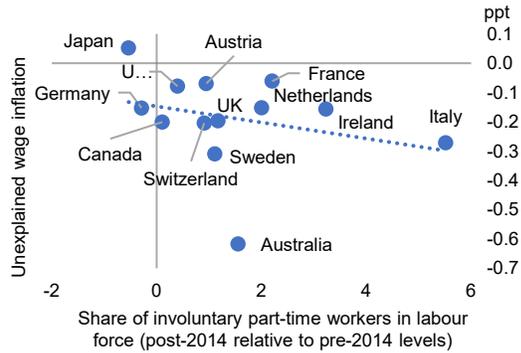

Chart 8: **Involuntary part-time workers as a share of the labour force**


Note: ppt is percentage points.
Sources: Organisation for Economic Co-operation and Development and Bank of Canada calculations
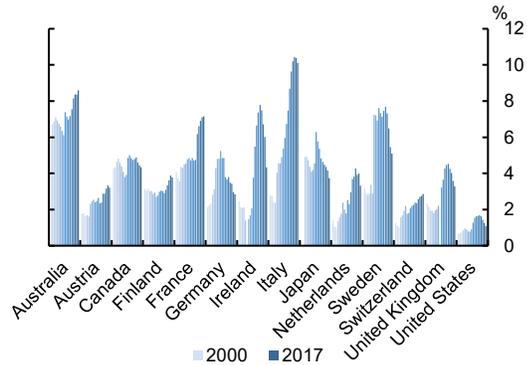
2.2 Inflation dynamics

Inflation dynamics are important determinants of wage dynamics.[5] Wages are typically set for fixed periods of time through contracts or laws and therefore respond to past inflation (to bring real wages back in line with their equilibrium value) and expected inflation (to prevent them from becoming misaligned in the future). The weight put on each type of inflation likely depends on a variety of factors, including the confidence that firms and workers have in their forecasts.

To investigate the role of inflation expectations and how the assigned weight has shifted over time relative to that placed on past inflation, we estimate a separate inflation-expectations augmented Phillips curve using only the euro area member countries as a panel with weighted fixed

Chart 9: **Core inflation and core inflation expectations**
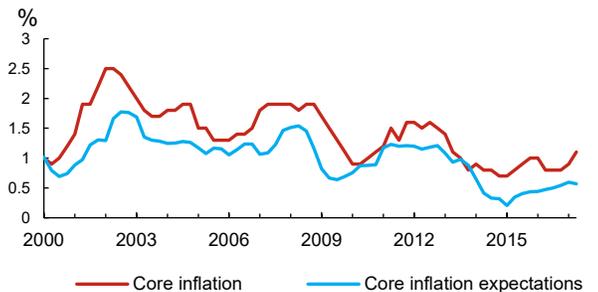
Source: Bank of Canada calculations   Last observation: 2017Q2

Chart 10: **Coefficients from rolling wage Phillips curve regressions**
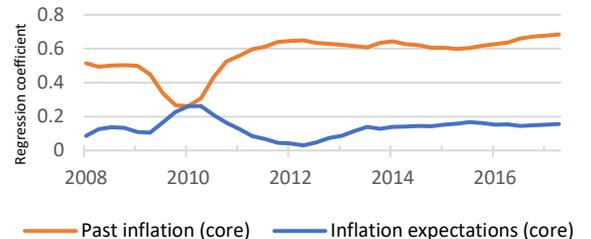
Source: Bank of Canada calculations   Last observation: 2017Q2

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[4] Though the chart is not shown, we also examine the role that marginally attached workers play in explaining the residuals from **Chart 6.** We find that there is a positive correlation mostly due to Australia, which is an outlier.
[5] See **Appendix C** for information on the methodology and data used in this section.

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effects.[6, 7] To calculate inflation expectations, we follow Buchmann (2009) and use the European Commission's consumer surveys about perceptions of current and expected prices to compute inflation-expectations series from survey responses from 2000 to 2017.[8] To estimate how the coefficients on the expected inflation and past inflation variables differ over time, we run 38 recursive regressions in which the end of the sample period is extended from 2008Q1 in the initial estimate to 2017Q2 in the final estimate.

The results suggest inflation dynamics have worked to keep wage inflation low in the euro area, as past inflation and inflation expectations have been weak (**Chart 9**). In addition, we find that the weight put on past inflation rose between 2015 and mid-2017, suggesting that the wage-setting process has become more backward-looking (**Chart 10**).[9] To the extent that core inflation has been stubbornly low, the results suggest that wage inflation in the euro area has likely lagged price inflation more than in the past.

2.3 Structural shifts in labour markets
2.3.1 Declining unionization rates

Union membership has been decreasing in most advanced economies for the last 30 years (**Chart 11**), potentially contributing to weak wage growth. This trend could be driven by various factors, such as structural shifts that have favoured non-unionized industries or trades; labour market reforms designed to increase labour market flexibility and competitiveness; or other factors.

When included in our panel regression, the unionization rate measure has the expected positive sign and is significant, a finding that is consistent with other empirical work (see Appendix B, Table B-2, columns 2 and 3, as well as IMF 2017 and Hong et al. 2018).[10] However, we find only weak evidence that unionization rates

Chart 11: Union density in advanced economies
Percentage of wage and salary earners

Last observation: 2017
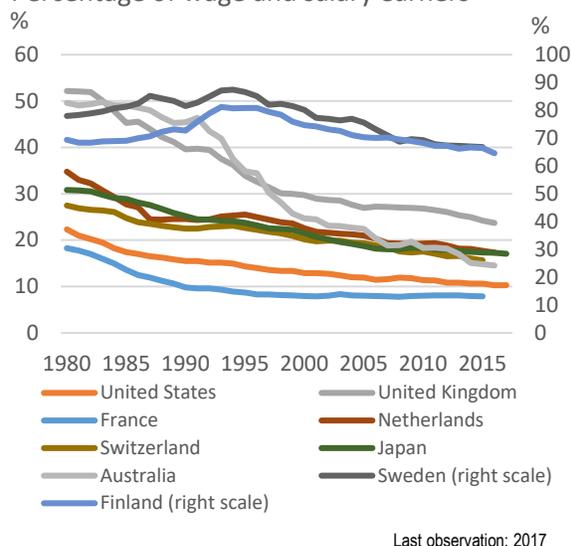
Note: Union density corresponds to the ratio of wage and salary earners who are trade union members divided by the total number of wage and salary earners.
Source: Organisation for Economic Co-operation and Development

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[6] The euro area countries were selected to investigate the role of inflation expectations because there is a consistent set of survey and inflation data for individual countries that is not available across other advanced economies.

[7] Weighted fixed effects estimation is preferred over unweighted fixed effects because we are ultimately interested in aggregate euro area inflation, and euro area countries vary greatly in size. This method reduces the importance of countries such as Malta or Cyprus in the estimation and increases the relative importance of larger countries such as Germany and France.

[8] These inflation-expectations data were used because they come from a consistent set of country-level data for a large number of countries. No information is available for Luxembourg, so it was dropped from the sample.

[9] This finding is consistent with observations made by Drahgi 2017.

[10] That said, the data for union membership are annual and incomplete. Because of this, we had to interpolate to be able to include the data in our regressions, and as such, we are somewhat cautious about putting too much emphasis on the estimation results, which may simply be evidence of a correlation.

explain the recent softness in wage growth (as measured by our country-specific residuals). Our results suggest that declining unionization rates could be a factor leading to slow wage growth over the longer term, but not so much in recent years.

2.3.2 Increased monopsony power

Practices by large firms that reduce worker job mobility could be hindering wage growth. In the United States, job-to-job changes are an important driver of wage fluctuations (Karahan et al. 2017) and correlate better with wage inflation than the unemployment rate (Hahn et al. 2017; Moscarini and Postel-Vinay 2017). In the wake of the crisis, US job-to-job transitions fell to historic lows, particularly for younger workers (Bosler and Petrosky-Nadeau 2016). Krueger (2018) argues that the use of non-compete and no-poaching clauses is on the rise, which might explain this phenomenon. Thus, such restrictions on job mobility, which are often touted as a means to safeguard firm-specific intellectual property, may also be reducing wage growth (US Department of the Treasury 2015).[11] That said, US job-to-job transitions have recently returned to more normal levels and wage growth has started to pick up, although it remains somewhat weaker than expected, everything else considered.

Changes in firm concentration can also affect the ability of workers to increase their wages. Benmelech, Bergman and Kim (2018) find that employer concentration has increased significantly in the United States since 1977 and that high employer concentration correlates with lower wages. Using data on public companies from 74 countries, Diez, Leigh and Tambunlertchai (2018) find that markups are negatively correlated with the share of income going to workers and that markups have been rising in advanced economies since the 1980s. In addition, markups in these economies increased significantly since the global financial crisis. If the Benmelech, Bergman and Kim (2018) finding (that high employer concentration correlates with lower wages) extends to other advanced economies, then the post-crisis rise in firm concentration might also account for some of the weakness in advanced-economy wage growth in recent years.

Overall, Krueger (2018) argues that, while other factors help explain why wage growth is weaker than expected by conventional relationships, policy-makers should pay close attention to weakening worker bargaining power.

2.3.3 Aging

Because older workers are typically paid more than younger workers, the composition and dynamics of labour market demographics can affect wage growth. On one hand, for an aging labour force, average wages should increase because older workers are paid more than younger workers (the *transition effect*). On the other hand, all things being equal, an economy that has a large share of younger workers could experience higher (or lower) wage growth compared with economies with a low share if wages of the younger workers tend to rise faster (or slower) than those of the older employees (perhaps due to differences in productivity or changes to labour laws during the sample period) (the *share effect*). To some extent, certain effects associated with aging (such as the process of human capital accumulation) should be captured by the labour productivity variable, but it is possible that some elements of the aging process could reflect other factors not well captured in a standard Phillips curve specification. Thus, we include data on aging in our Phillips curve analysis to try to capture the two effects (the rate of growth

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[11] Because data are limited on job-to-job changes and restrictive mobility practices for other countries, it is unclear how widespread these phenomena are.

of younger cohort minus the that of the older cohort and the share of younger workers in the labour force).

**Chart 12: Labour force growth differential (older minus younger)**
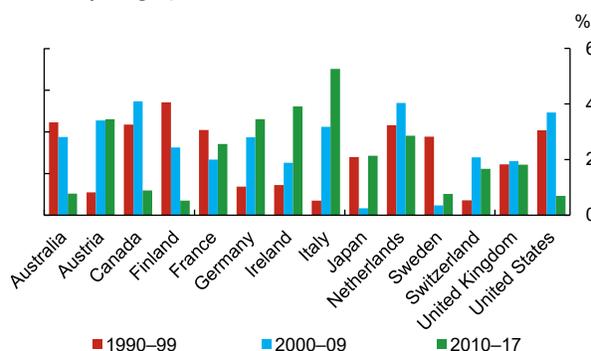
Chart 13: Share of younger cohort
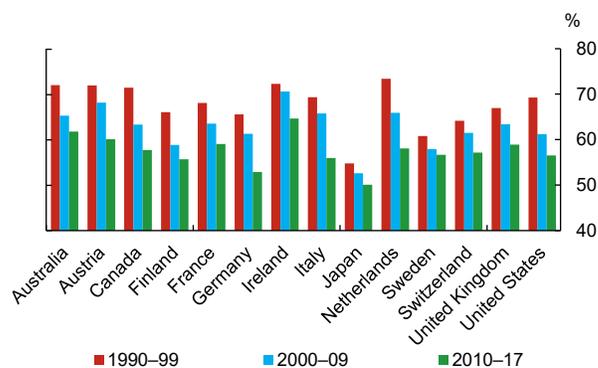
Note: Share of younger cohort is the number of 15- to 44-year-olds in the labour force as a share of the total. The growth differential is the year-over-year percentage change of those aged 45+ minus the year-over-year percentage change of the those aged 15–44.
Sources: Organisation for Economic Co-operation and Development Labour Force Statistics and Bank of Canada calculations

We find some empirical support for both the transition and share effects when they are included in our panel regressions (**Appendix B**, **Table B-2**).[12] Specifically, we find the following:

a) Faster growth in the size of the older cohort relative to the younger cohort is associated with higher wage growth. This suggests that labour productivity may not be fully capturing the impact of the transition effect. In some economies (Australia, Canada, Finland, Sweden and the United States), the difference between the rates of labour force growth of the two cohorts is much smaller now than in the 1990s, which suggests that wage growth should be slower in these economies, all else being equal. For other economies like Germany, Ireland and Italy, we should expect the opposite (**Chart 12**).

b) The share of younger workers in the labour force is positively correlated with wage growth, which could be evidence that younger workers have been enjoying faster rates of wage growth than older workers. It is not clear why this is, but one possibility is that older workers tend to be employed in older, less dynamic industries (e.g., manufacturing), while the opposite might be true for younger workers (who may be more predisposed to find employment in more nascent sectors such as information technology). Thus, given that the share of younger people in advanced-economy labour markets is generally at its lowest level in over 40 years (**Chart 13**), the share effect implies that the rate of growth in average wages should be relatively low compared with the past.[13]

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[12] In principle, one might expect the experience-wage profile to reflect experience-related productivity (human capital accumulation). As such, the impact of aging should be captured in the empirical analysis by the labour productivity variable. However, wages may also reflect cultural norms or other factors that are not fully captured in labour productivity statistics. Hence, aging could help to provide additional insight into the evolution of wage growth in economies where the share effect dominates the transition effect.

[13] For the United States, Krueger (2018) estimates that labour force aging reduces wage growth by about 0.25 percentage points.

When we compare data on these demographic variables with our country-specific residuals from **Chart 6**, we find little evidence that demographic changes contributed to the unexplained weakness in wage growth since 2013. Thus, demographics may not be playing a major role in explaining wage weakness in recent years.

2.3.4 Labour market reforms

For some advanced economies, particularly in the euro area, labour market rigidities have been an important feature of the economic landscape. The past decade or so has seen some economies introduce reforms that might explain some of the post-crisis weakness in wage growth. Indeed, data from the European Central Bank's Wage Dynamics Network survey show that firms in non-reformer countries found it harder to lower wages, lay off employees temporarily and adjust working hours than firms in reformer countries (**Chart 14**).[14]

Wages have become more responsive to labour market slack in the period during which labour market reforms were implemented. **Chart 15** plots the coefficient on the unemployment rate from rolling WPC regressions using panel data for the 19 euro area countries and illustrates that in the aftermath of the global financial crisis the coefficient fell from -0.15 before the crisis to stabilize at around -0.23 in the post-crisis period. This increase in the responsiveness of wages to labour market slack may be due in part to the impact of reform measures.

Chart 14: Changes in firm perceptions about the ease of making labour market adjustments (in countries that have tended undertake reforms versus other countries)

Chart 15: Coefficients on the unemployment rate from rolling wage Phillips curve regressions
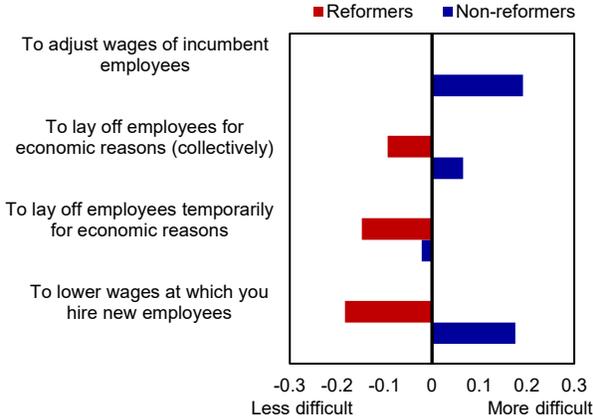
Note: Scores are the difference between the survey response and survey average, based on scores from 1 to 5, with 1 being much less difficult and 5 being much more difficult.
Source: European Central Bank Wage Dynamics Network survey
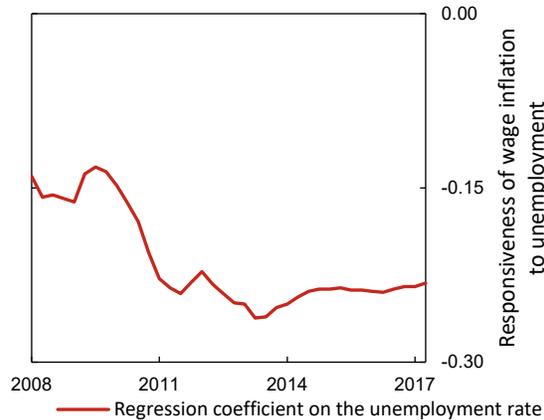
Source: Bank of Canada calculations   Last observation: 2017Q2

2.3.5 Migration

Immigration affects labour market slack and may also play a role in explaining the recent dynamics of nominal wages in major migrant-accepting countries, particularly in Europe. Standard economic models

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[14] We identify reformer countries based on an evaluation of changes to euro area countries' labour market regulations since 2010.

predict that immigration pushes wages down because of an increase in labour supply. However, two schools of thought emerge from the empirical literature: On one hand, Card (1990) finds no effect of immigration on employment and wages of locals. On the other hand, Borjas (2003) argues that immigrants compete for labour with natives of similar skill and experience on a national level, hurting the job market outcomes of natives with similar skills and experience. Overall, one might expect that the arrival of new migrants would add to labour market slack and therefore contribute to downward pressure on wages as they enter the labour force. Eventually, however, immigration may trigger new investment and consumption, which should eventually eliminate the slack.[15] Consequently, immigration could play a role in explaining weak wage growth in major migration destinations. For example, in the European Union, workers can move freely from countries with high unemployment rates such as Spain to fill positions in countries such as Germany, alleviating German wage pressures.[16] In addition, Europe (and particularly Germany) has received a large influx of refugees over the past few years, increasing the labour supply as some of them integrate into the labour force. Indeed, German employment growth has been solid since 2015, pushed up by flows into the labour force that are likely fuelled by strong immigration.

2.4 Other structural factors

2.4.1 Trade

Although trade liberalization may have been a factor in reducing wage pressure over the past 25 years in certain sectors, it is unlikely to explain the recent weakness. Through trade and the expansion of global value chains, workers now compete for jobs on an international scale. Autor, Dorn and Hanson (2013) find that rising trade with China decreased industrial employment and wages in multiple sectors in the United States. While we would expect that the most skill-intensive sectors in advanced economies benefit from increased trade, creating upward pressure on wages for skilled employees, low-skilled workers may be negatively affected. In recent years, however, China's real export growth has decelerated considerably while the country's exports have shifted to more sophisticated goods (Kruger, Steingress and Thanabalasingam 2017). Moreover, since the global financial crisis, global trade has slowed relative to gross domestic product as the impacts of past trade liberalization episodes have been exhausted (see Francis and Morel 2015). Therefore, trade is less likely to explain the recent weakness in wage growth. Moreover, as Krugman (2016) argues, trade cannot explain the overall economy-wide weakness in wage growth, unless monetary policies are prevented from achieving full employment due to the zero lower bound constraint.

2.4.2 Technological change

Technological change and automation is often thought to have reduced the demand for labour, particularly unskilled workers, which could be putting downward pressure on wages. In an empirical analysis of the effect of robot densification on labour market outcomes, Graetz and Michaels (2018)

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[15] In principle, the near-term impact on nominal wages will depend on whether the negative effect on wages of an increase in labour supply outstrips the positive effect of an increase in labour demand that may be created by the arrival of new migrants (for example, the arrival of asylum claimants in Germany created an initial increase in demand for housing, which may have boosted labour demand in construction).

[16] However, this can't explain excess weakness at the aggregate EU level.

show that while automation has no significant effect on overall employment and a positive effect on aggregate wages, it reduces the employment and wages of low-skilled labour. This is consistent with Acemoglu and Restrepo (2017), who find that automation reduces employment and wages in local markets where robots are implemented. In addition, the successful adoption of digital technology is concentrated among a handful of superstar firms (Charbonneau et al. 2017), a phenomenon consistent with a decoupling of wages and productivity in technologically leading firms (OECD 2018) and strongly associated with a decline in the labour share (Autor et al. 2017). However, these markups are likely to be temporary because they reflect innovation rents rather than a lack of barriers to entry (OECD 2018). Consequently, if the technology market remains competitive, increased productivity should flow through to wages, albeit unevenly.

3. Conclusion

Based on our analysis, we consider that much of the unexplained recent weakness can be captured by alternative measures of slack (in particular, the rise of involuntary part-time work). In addition, inflation dynamics and a number of structural factors may have also been contributing to the weakness, although a lack of solid data and empirical evidence makes it difficult to assess. Weaker bargaining power of workers due to lower unionization rates, increased firm concentration, restrictive labour mobility practices and greater labour market reform may have combined with changing demographic factors to weaken potential wage growth in the post-crisis era. Other factors such as migration and technological change may also be at play, but their impact on wages is more ambiguous.

Appendix A: Data

Quarterly data used in the wage Phillips curve regression analysis (see Appendix B) are as follows:

Data from OECD Economic Outlook Database via Haver Analytics

 a. Total economy wage per employee
 b. Total economy average number of hours worked per employee
 c. Unemployment rate
 d. Labour productivity (total economy)
 e. Working-age population (total)

Data from Haver Analytics G10 database (based on data from national statistical agencies)

 f. Core inflation (year-over-year percentage change)

Data from OECD Labour Force Survey Database via Haver Analytics

 g. Marginally attached workers (annual data, interpolated to convert to a quarterly series)
 h. Involuntary part-time workers (total)
 i. Labour force aged 15–24
 j. Labour force aged 25–34
 k. Labour force aged 35–44
 l. Labour force total
 m. Union density (the ratio of wage and salary earners who are members of a union divided by the total number of wage and salary earners; based on surveys or administrative data where survey data are not available)

Other

Wage Dynamics Network Survey, European Central Bank

Calculations (based on series as noted above)

- Indexed nominal hourly wage per employee = $100*(a_t / b_t)/ (a_{\text{index date}} / b_{\text{index date}})$
- Year-over-year percentage increase in hourly wage per employee = $(a_t / b_t) /(a_{t-4} / b_{t-4}) -1$
- Marginally attached workers' share of working-age population (marginally attached workers as a share of working-age population) = g_t / e_t
- Involuntary part-time workers as share of the labour force: h_t / l_t
- Share of younger workers in labour force: $(i_t + j_t + k_t)/l_t$
- Growth rate of older workforce minus growth rate of younger: $[l_t - (i_t + j_t + k_t)]/ [l_{t-4} - (i_{t-4} + j_{t-4} + k_{t-4})] - (i_t + j_t + k_t)/(i_{t-4} + j_{t-4} + k_{t-4})$

Appendix B: Regression details

Using data for 14 advanced economies[17] from 1981 to 2017, we estimate the following simple wage Phillips curve (WPC) equation for each country and as a panel:

$$\dot{w}_t = \alpha_i + \beta \dot{p}_{t-1} + \gamma u_t + \omega \pi_t + e_t,$$

where $\dot{w}_t$ is the year-over-year percentage change in average hourly wages, u_t is the unemployment rate, $\dot{p}_{t-1}$ is the lagged inflation rate (we use core, averaged over the last four quarters), and π_t is a measure of trend labour productivity growth (we use a 12-quarter average). For the country-specific regressions, a lagged dependent variable was added.

Data are quarterly from the OECD Economic Outlook, Main Economic Indicators, and Labour Force Statistics databases from 1981Q1 to 2017Q4 (where available) and cover the economies noted in **Chart 2**.

WPC models often include measures of the unemployment gap (i.e., deviations of the unemployment rate from its natural rate). Given that the natural rate is unobservable, we prefer the raw unemployment rate. This can be unsatisfactory if the natural rate of unemployment changes when the economy moves into and out of recession (i.e., if there is hysteresis in the labour market). To control for this possibility, we try specifications that include the change in unemployment but find that the change variable is statistically insignificant.

As discussed in the text, we also include various other explanatory variables in our panel estimation.

The results from the country-specific regressions are reported in **Table B-1**; the panel results are reported in **Table B-2**.

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[17] The panel included the United States, the United Kingdom, Austria, France, Germany, Italy, the Netherlands, Switzerland, Canada, Japan, Sweden, Ireland, Australia and the euro area.

Table B-1: Country-specific regressions

VARIABLES	(1) Australia	(2) Austria	(3) Canada	(4) Euro area	(5) France	(6) Germany	(7) Ireland	(8) Italy	(9) Japan	(10) Nether-lands	(11) Sweden	(12) Switzer-land	(13) United Kingdom	(14) United States
Core inflation[1]	0.302***	-0.035	-0.002	0.281**	-0.109	0.131	0.229**	0.294***	-0.198	0.239	0.114	0.043	-0.559	0.204**
	[0.006]	[0.704]	[0.988]	[0.016]	[0.153]	[0.522]	[0.023]	[0.007]	[0.262]	[0.128]	[0.149]	[0.814]	[0.116]	[0.019]
Trend labour productivity[2]	0.075	0.013	0.008	0.065	0.185	0.103	0.051	0.169	-0.006	0.306	0.332***	0.010	0.265	0.308**
	[0.638]	[0.342]	[0.919]	[0.463]	[0.110]	[0.275]	[0.392]	[0.184]	[0.968]	[0.110]	[0.002]	[0.552]	[0.282]	[0.026]
Unemployment	-0.121*	-0.030	-0.209**	-0.143***	-0.107*	-0.115***	-0.091*	-0.118*	-0.575***	-0.144*	-0.111	-0.372*	0.155	-0.153**
	[0.078]	[0.752]	[0.019]	[0.000]	[0.099]	[0.004]	[0.091]	[0.066]	[0.010]	[0.086]	[0.127]	[0.091]	[0.362]	[0.016]
Lagged wage inflation	0.696***	0.895***	0.772***	0.524***	0.826***	0.715***	0.730***	0.480***	0.482***	0.676***	0.363***	0.858***	0.678***	0.570***
	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]
Constant	0.944*	0.425	2.105***	1.996***	1.408**	1.272***	1.210	1.732**	2.356**	0.894	2.238***	1.785*	0.709	1.370***
	[0.058]	[0.379]	[0.004]	[0.000]	[0.042]	[0.007]	[0.128]	[0.020]	[0.014]	[0.142]	[0.001]	[0.069]	[0.526]	[0.007]
Observations	118	105	77	68	105	85	97	105	74	106	105	87	82	138
R-squared	0.715	0.825	0.686	0.863	0.796	0.749	0.836	0.626	0.441	0.627	0.298	0.810	0.674	0.565

Note: p-values are in brackets; *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

[1] Core inflation is the average rate of core inflation over the past four quarters.

[2] Trend labour productivity is the average rate of labour productivity over the past three years.

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)
Core inflation (average of past four quarters)	0.586***	0.258**	0.316***	0.453***	0.569***	0.261***
	[0.000]	[0.019]	[0.000]	[0.000]	[0.000]	[0.000]
Trend labour productivity (average of past three years)	0.228***	0.126*	0.099**	0.170***	0.261***	0.057
	[0.000]	[0.058]	[0.019]	[0.000]	[0.000]	[0.256]
Unemployment rate	-0.340***	-0.404***	-0.414***	-0.396***	-0.381***	-0.551***
	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]
Discouraged workers' share of working-age population		0.727***				
		[0.007]				
Involuntary part-time			-0.192***			
			[0.000]			
Share of young in labour force				0.085***		
				[0.000]		
Growth rate of older workforce minus growth rate of younger					0.092***	
					[0.000]	
Unionization rates						0.162***
						[0.000]
Constant	3.827***	2.876***	5.442***	-0.882	3.844***	1.723**
	[0.000]	[0.000]	[0.000]	[0.233]	[0.000]	[0.030]
Observations	1,355	325	832	1,141	1,201	488
R-squared	0.316	0.173	0.431	0.336	0.32	0.547
Number of countries	14	13	14	13	14	8

Note: p-values are in brackets; *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Appendix C: Details on euro area regression analysis (for Charts 10 and 15)

For the results illustrated in **Chart 10** and **Chart 15**, we estimate a separate inflation-expectation augmented Phillips curve using only the euro area member countries as a panel, with weighted fixed effects. To calculate inflation expectations, we follow Buchmann (2009) and use the European Commission's consumer surveys about perceptions of current and expected prices to compute the inflation-expectations series from survey responses over the period from 2000 to 2017 (no information is available for Luxembourg, so it was dropped from the sample). Other data sources are listed in **Table C-1**. To estimate how the coefficients on the inflation-expectations and past inflation variables fluctuate over time, we run 38 recursive regressions where the end of the sample period is extended from 2008Q1 in the initial estimate to 2017Q2 in the final estimate. **Chart 10** plots the estimated coefficients on past core inflation (one-period lag) and expected future inflation. **Chart 15** plots the estimated coefficients for the unemployment rate.

Table C-1: Data sources for the inflation-expectations augmented Phillips curve analysis

Series	Sources
Core inflation	Harmonised Index of Consumer Prices measure excluding energy, food, alcohol and tobacco for the euro area (19 countries) from Eurostat (via Haver Analytics)
Wages	Index of total labour cost (NACE revision 2), seasonally and working-day adjusted, Eurostat (via Haver Analytics)
Inflation expectation	European Commission Consumer Survey (via Haver Analytics)
Labour productivity	Real labour productivity per hour worked (national accounts measure), Eurostat (via Haver Analytics)
Unemployment rate	Harmonized unemployment rate, Eurostat (via Haver Analytics)

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