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PRODUCTIVITY AND PAY IN THE US AND CANADA

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ABSTRACT

We study the productivity-pay relationship in the United States and Canada along two dimensions. The first is divergence: the degree to which the levels of productivity and pay have diverged. The second is delinkage: the degree to which incremental increases in the rate of productivity growth translate into incremental increases in the rate of growth of pay, holding all else equal. We show that in both countries the pay of typical workers has diverged substantially from average labor productivity over recent decades, driven by both rising labor income inequality and a declining labor share of income. Even as the levels of productivity and pay have grown further apart, we find evidence for some linkage between productivity and pay in both countries: a one percentage point increase in the rate of productivity growth is associated with a positive increase in the rate of pay growth, holding all else equal. This linkage appears stronger in the US than in Canada. Overall, our findings lead us to tentatively conclude that policies or trends which lead to incremental increases in productivity growth, particularly in large relatively closed economies like the USA, will tend to raise middle class incomes. At the same time, other factors orthogonal to productivity growth have been driving productivity and typical pay further apart, emphasizing that much of the evolution in middle class living standards will depend on measures bearing on relative incomes.

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1. Introduction and conceptual framework: divergence and delinkage

Economic theory predicts that workers in aggregate should receive higher compensation as the value of what they are able to produce increases (assuming their supply is not perfectly elastic). The growing gap between productivity and the pay of typical workers in the United States since the early 1970s has therefore been the subject of much attention. In Canada there has been similar focus on a growing gap between productivity and pay in recent decades. If productivity has been growing fast, yet pay of typical workers has been growing slowly, this raises the question: does productivity growth benefit typical workers by raising their pay? Stansbury and Summers (2019) approached this question for the US, finding that despite the growing gap between productivity and typical pay over 1948-2016, incremental increases in the rate of productivity growth appeared to translate close to one-for-one into incremental increases in the rate of growth of pay of typical workers. This result suggests that there is still transmission from productivity growth to pay growth – implying that faster productivity growth would all else equal benefit typical workers by raising their pay – but that other factors not related to productivity growth have been suppressing pay over recent decades even as productivity has been acting to raise it.

Has this relationship held for Canada as well? How does Canada's productivity-pay relationship compare to that of the US? And what can this comparison tell us about the productivity-pay link in general? We tackle these questions in this paper, emphasizing **two dimensions of the relationship between productivity and pay, which we call divergence and delinkage**.

We use *divergence* to refer to a growing gap between productivity and pay in levels:[2] to the extent that productivity has grown faster than pay over time, the two series have diverged over the period. As

[2] Labor productivity will always be higher than pay if returns to other factors of production are non-zero. By divergence, we refer to an increase in the gap between productivity and pay over time. The degree of divergence

documented by Williams (2021) and Sharpe and Ashwell (2021) in Canada, and Bivens and Mishel (2013, 2021) among others in the US, there has been divergence in both countries between labor productivity and the pay of both the average worker and typical workers. In this paper we compare the degree of divergence across the two countries along different metrics and time periods.

We use *delinkage* to refer to the relationship between the growth rates of productivity and pay, holding all else equal. At one extreme, if a one percentage point higher growth rate in productivity is associated with a one percentage point higher growth rate in pay, all else equal, we consider the two series to be linked: it suggests that an incrementally higher rate of productivity growth will lead to an incrementally higher rate of pay growth. At the other extreme, if a one percentage point lower growth rate in productivity is associated with no change in pay all else equal, we consider the two series to be delinked: it suggests that an incrementally higher or lower rate of productivity growth will have no effect on the rate of growth of pay. In Stansbury and Summers (2019), we showed that despite divergence in levels between productivity and median pay in the US, there was still substantial linkage in the growth rates of the series. This suggested that incremental increases in aggregate productivity growth could be expected to translate close to one-for-one into increases in typical pay, holding all else equal. In this paper we update our analysis for the US and examine the degree of linkage or delinkage in Canada.

Why does the degree of linkage or delinkage, as measured through annual changes, matter? If two series – like productivity and pay – have diverged, studying the degree of linkage or delinkage helps us diagnose why this has happened. On one extreme is *complete delinkage*: something may be blocking the transmission mechanism from productivity to pay, so that an incremental increase in productivity growth does not translate into an incremental increase in pay growth. Indeed, the factor causing increased productivity growth may itself be acting to suppress workers' pay – for example, a

can be visualized by indexing both productivity and pay to 100 in a given year, and charting the extent to which the two series diverge over time.

technological change which increases productivity but leads to the substitution of labor for capital.[3] On the other extreme is *complete linkage*: an incremental increase in productivity growth translates one-for-one into a boost to workers' pay growth, all else equal – suggesting that the transmission mechanism from productivity to pay is functioning, but that at the same time other factors orthogonal to productivity growth are suppressing pay and therefore responsible for the rising productivity-pay gap. Understanding the degree of linkage in the productivity-pay relationship can therefore shed light on the degree to which incremental productivity growth helps boost workers' pay.

The concept can be illustrated by a simple metaphor: water in a bucket. Think of pay as the level of water in a bucket. Think of water running into the bucket from a hose as productivity growth. Over the last forty years, the faucet has been running – productivity has been growing – but the level of water in the bucket has barely risen. Why might this be? It is possible that there is a hole in the hose leaking water somewhere between the faucet to the bucket: the transmission mechanism from productivity to pay is broken (*delinkage*). Or, it is possible that there is a hole in the bucket: even as the water flowing from the hose is increasing the water level in the bucket, water is draining from the hole at the bottom of the bucket, meaning that on net the water level does not rise (*linkage*).

Understanding the degree of linkage or delinkage between productivity and the pay of typical workers is of considerable policy significance. Much of traditional economic policy discussion is directed at accelerating productivity growth, whether through promoting investment, technological progress or better functioning markets. If the delinkage hypothesis holds, then success or failure on these dimensions will have little impact on middle class well being. Instead, success in raising middle class incomes will depend *entirely* on distributional measures. In contrast if, despite divergence between productivity and middle-class pay, there is still linkage between the two, then it is still the case that

[3] For example, labor-augmenting technological change with an elasticity of substitution between labor and capital of greater than 1 (or capital-augmenting technological change with an elasticity of substitution between labor and capital of less than 1).

increased productivity growth should be expected to increase the pay of typical workers – a rising tide can be expected to lifts all boats to some extent – even as there may at the same time be other variables reducing the relative growth in incomes of the lower or middle parts of the distribution (like the declining bargaining power of workers, or the increase in globalization).

We begin our analysis in section 2, examining the degree of divergence between productivity and compensation in the US and Canada since 1961. We ask the question "To what extent has productivity grown faster than average pay, or than the pay of typical workers?", proxying for the pay of typical workers in the US with the average compensation of production and nonsupervisory workers, and in Canada with a new measure we have constructed reflecting average hourly compensation of hourly-paid workers in five large sectors for which historical time series data is available: manufacturing, mining, construction, laundries, and hotels and restaurants. Since 1976, we also examine a more common proxy for typical workers – median compensation – in both countries.[4]

In both countries, the pay of typical workers has diverged substantially in real terms from average labor productivity. This divergence can be thought of in terms of three wedges (as illustrated by Bivens and Mishel 2015): (i) a decline in the labor share of income (divergence between labor productivity and average compensation, deflated by the same price deflator), (ii) a rise in labor income inequality (divergence between average compensation and the compensation of typical workers), and (iii) a decline in labor's terms of trade (divergence between consumer and producer price deflators).

These three trends have played out somewhat differently in the two countries. In both countries, a declining labor share of income has generated increasing divergence between labor productivity and average compensation. In both countries, labor income inequality has also risen, generating increasing divergence between average labor productivity and the real compensation of typical workers (since

[4] 1976 is the first year for which Canadian median pay data is available.

1961) or median workers (since 1976) – but this trend has been much more pronounced in the US. Trends in relative price deflators have differed across the two countries and time periods. On net, since labor productivity growth has been much faster in the US than in Canada – particularly since 1976 – average compensation has also grown much faster in the US than in Canada even though the US labor share has fallen. But since labor income inequality has risen so much faster in the US than in Canada, the growth in real median compensation has been about the same in both countries despite the much faster growth in productivity in the US.

In section 3, we examine the degree of linkage or delinkage between hourly labor productivity and measures of average and typical worker compensation in the US and Canada since 1961 – asking the question "To what extent does an incremental increase in productivity growth translate into an incremental increase in compensation growth, all else equal?".

In the US, we find relatively strong linkage between productivity and pay, both for average compensation and our measures of typical workers' compensation (updating the evidence in Stansbury and Summers 2019). In regressions of the three-year moving average of the change in log compensation on the change in log productivity, controlling for unemployment, we find that over recent decades a one percentage point increase in the rate of productivity growth in the US has been associated with 0.6-0.8 percentage points faster average compensation growth, 0.5-0.7 percentage points faster median compensation growth, and 0.3-0.9 percentage points faster growth in the compensation of production and nonsupervisory workers[5]

In Canada, we find moderate linkage between productivity and average compensation: a one percentage point increase in productivity growth has been associated all else equal with 0.3-0.7

[5] Coefficients depend on the time period considered (1948-2019 or 1973-2019), the price deflator used for the compensation series, and the moving average length. All coefficients were strongly significantly different from zero and many coefficients were not significantly different from one.

percentage points higher average compensation growth (with coefficients in later decades not statistically significantly different from zero). We find strong evidence of linkage between productivity and typical compensation as proxied by hourly-rated workers in 5 sectors over 1961-2019, but estimates for more recent periods are too noisy to rule out either of our extreme cases of strong linkage (one-for -one translation from productivity to pay) or strong delinkage (no translation of productivity to pay).[6] We find no evidence of linkage between productivity and median compensation, but large standard errors and measurement error concerns in the median hourly compensation series suggest that this result should be interpreted with some caution.

Why does there seem to be a weaker link between pay and productivity in Canada than in the US? In section 4, we explore possible explanations. One possibility is that Canada is a smaller, more internationally open economy than the US. The smaller and more open the economy, the greater the degree to which productivity and real compensation may be determined abroad rather than domestically – and the less, therefore, one might expect researchers to be able to detect a process where productivity increases translate into increases in real compensation. We present evidence consistent with this hypothesis: coefficient estimates on regressions of average compensation on productivity in US regions – which are similar in GDP and population to Canada, and could be considered small open economies – are substantially lower than for the US as a nation, and similar in magnitude to the estimates for Canada. A second possibility is that there is more meaningful high frequency variation in productivity in the US than in Canada, but we do not find substantial evidence to support this.

Finally, in section 5 we conclude, discussing other possible drivers of the US-Canada differences and implications for policy.

[6] In addition, breakpoint tests indicate a structural break in the relationship between productivity and this 5-sector measure of typical pay around 1997 or 2000.

2. To what extent have productivity and pay *diverged*?

Several studies have explored the divergence between productivity and pay in both Canada and the US, with conclusions dependent in large part on measurement choices, especially regarding the output measure used for productivity. Williams (2021) provides an overview for Canada of measures and data sources, the recent literature, and an analysis of trends. Bivens and Mishel (2015, 2021) and Stansbury and Summers (2019) are among the papers on the US which document the divergence between productivity and pay, and examine the role of measurement choices for depreciation, price deflators, and productivity and compensation series. In this section we describe the measures used in our analysis and compare key trends in the US and Canada in light of previous research.

Data for the measures used in this analysis are carefully constructed from a variety of sources, which are provided in the appendix.

The main measure of **labor productivity** is total economy output per hour worked, where output is net of depreciation. This better reflects the production output available for labor compensation than a productivity measure based on gross domestic product, especially when the capital depreciation rate is increasing (as it has in both Canada and the US since the mid 1970s).[7] In both countries, this total economy productivity measure is a conservative estimate of productivity growth over time: changes in output in the government and non-profit sectors are generally calculated from changes in inputs, due to challenges quantifying public sector output that is not priced, which implicitly assumes zero productivity growth (BEA Handbook of Methods, Baldwin and Rylska 2007). If we assumed instead that there was positive productivity growth in the government and non-profit sectors, we would find an even larger divergence between productivity and pay (due to a faster growth rate for the former).

[7] Unlike in Williams (2021), our productivity measure does not exclude taxes less subsidies in order to be consistent with US data and because otherwise a decrease in tax rates leads to an apparent increase in productivity (which can significantly affect the year-to-year changes which are the focus of our study).

We explore the divergence of productivity from compensation by looking at four measures of compensation for each country:

- **Average hourly compensation of all workers**, including the self-employed.[8] This measure, used in our baseline analyses, includes an imputed measure of compensation for the self-employed based on wages of similar employee workers. (This imputation reflects the difficulty of determining whether income of the self-employed is considered as compensating labor or capital inputs).[9]
- **Average hourly compensation of employees only**. This measure excludes the self-employed and therefore avoids challenges with imputing their labor income.
- **Median hourly compensation**. Median compensation is a better reflection than average compensation of the experience of middle-income workers, as it is not skewed by large changes at the top or bottom of the income distribution. Unfortunately, however, median compensation measures are not available over the entire period of the analysis: they are only available since 1973 for the US and 1976 for Canada. Moreover, our measure of median hourly compensation in Canada must be approached with some caution given substantial measurement concerns in the number of hours worked (a direct measure of median hourly compensation is only available since 1997).[10]

[8] The long-term total compensation and hours worked series were calculated from combining 1961-1997 data with 1997-2019 data (see appendix for details). One caveat is that the publicly-available 1961-1997 data (from Statistics Canada Table 36-10-0303-01, the same table that Uguccioni et al. (2016) use to construct 1976-1997 data) was last revised in 2007 and is no longer in use. Williams (2021) instead uses historical data provided by Statistics Canada on special request that differs slightly (comparison available upon request).

[9] The imputation is carried out by the respective statistical agencies of the US and Canada. Williams (2021) reports that in Canada self-employment as a share of total labor compensation peaked in the 1990s and is now approximately 4%. Average compensation including the self-employed has grown faster than average compensation of employees in Canada over 1961-2019, as illustrated in Appendix Figure 4. There is much less difference between the growth rates of compensation including or excluding the self-employed in the US.

[10] Median compensation in Canada is calculated from dividing median annual wage/salary income by a median annual hours worked measure constructed from the Labour Force Survey. However, both the numerator and denominator contain possible measurement error. The income measure includes wages/salaries of anyone that has worked at all in a year (even for one week), so the median may be skewed by, for example, changing numbers of seasonal workers. The denominator calculates annual hours worked as 52 multiplied by median weekly hours worked, which ignores changes over time in weeks worked per year (for example, due to parental leave).

- **'Typical compensation'** measures provide another view on worker pay that extend the period of analysis for typical workers, avoid potential measurement issues for Canada, and themselves provide an interesting measure of compensation for a large share of the US and Canadian workforce respectively. For the USA we use average hourly compensation of production/nonsupervisory employees, as in Stansbury and Summers (2019) and Bivens and Mishel (2015). Production/nonsupervisory employees represent about 80-84% of all employees in the US private sector. Unfortunately for Canada the analogous measure from the Statistics Canada Labour Force Survey (LFS) is only available from 1997 on. Instead, we use historical data from the Survey of Employment, Payrolls and Hours (and precursors) to construct a measure of the (weighted) average hourly wage of workers paid by the hour across five sectors of the economy: Manufacturing; Mining (including oil/gas); Construction; Laundries and cleaners; and Hotels and restaurants.[11] These sectors made up 44% of total employment in 1951 although this share decreased to 24% by 2011.[12] Nonetheless, the hourly-rated jobs in these sectors are generally among those with lowest barriers to entry for workers (e.g. credential requirements) and thus represent some of the sectors that are most likely to provide employment opportunities during times of growth.[13] The construction of this measure is detailed in the appendix.

All our compensation measures are adjusted to include non-wage compensation. We do this by multiplying hourly wages by the ratio of average real total compensation to average wage/salary compensation in the US or Canada (as appropriate). This adjustment is important given the increase in non-wage compensation and supplementary labor income (also called employer social contributions)

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[11] Note the Survey of Employment, Payrolls and Hours and precursors only survey businesses with 20+ employees.

[12] 1951 and 2011 employment shares are from, respectively: the Report of the Ninth Census of Canada: Volume IV: Labour Force, Occupations and Industries, Table 19; and 2011 National Household Survey Data tables: Industry - (NAICS) 2007 (425), Class of Worker (5), Age Groups (13B) and Sex (3) for the Employed Labour Force Aged 15 Years and Over, in Private Households of Canada

[13] For example, Beach (2016) notes that "The rapid growth of Canada's resource and energy sectors out West and in Atlantic Canada and the strong housing construction boom…have provided distinctly strong employment opportunities for relatively lower-educated, largely male workers." The major omission is retail trade, for which there is no publicly available hourly-rated workers average wage data from the SEPH until 1983.

over recent decades (see for example Williams (2021) for Canada and Bivens and Mishel (2015) for the US). Indeed, over the 1961-2019 period the ratio of total compensation to average wage/salary compensation increased from 1.13 to 1.25 in Canada and from 1.05 to 1.16 in the USA. To the extent that the share of compensation which comes from non-wage benefits is higher at the top of the income distribution, this adjustment will overstate compensation for median or typical workers.

Before examining trends in productivity and compensation, it is helpful to summarize the **price deflators** used in this analysis to bring these series into real terms by adjusting for inflation. Productivity series are adjusted for changes in producer prices using the GDP deflator in Canada and the NDP deflator in the US.[14] There are then three choices of deflators to adjust the compensation series for inflation. Real 'product wages' use these producer price indexes to adjust for output price inflation. Real 'consumer wages' are calculated using either the Consumer Price Index (CPI) or a chain-type price index of goods and services purchased by consumers, called the Personal Consumption Expenditures (PCE) in the USA and the Household final consumption expenditure deflator (HCE) in Canada.[15]

Our primary period of analysis is 1961-2019, which is the longest period of analysis possible with Canadian data on average labor productivity and compensation.[16]

Figure 1 charts the productivity and compensation trends in Canada and the US over recent decades. Panel A shows these trends over 1961 to 2019. There is a substantial divergence between productivity and *typical* compensation in both USA and Canada over the long-term period, regardless of choices about the price deflator. However, for both countries the size of the divergence between

[14] As Williams (2021) notes, Statistics Canada does not produce a price deflator for NDP at basic prices and the best alternative measure is to use the GDP deflator as the price index for NDP.
[15] In general these price indexes differ because they are based on different underlying concepts, are constructed differently (a Fisher-type 'chain' price index vs. a Laspeyres-type price index), rely on different weights, cover some different items, and use different seasonal adjustment processes (McCully et al., 2007).
[16] US data on average labor productivity and compensation extends back to 1948; we present results with this longer time period for the US in the Appendix.

productivity and *average* compensation depends strongly on the price deflator used. In both Canada and the US, when productivity and compensation are deflated using the same price index – the GDP or NDP deflator respectively – there is a divergence between productivity and average compensation, which first emergences in the 1990s in Canada and around 2000 in the US. In Canada average compensation outpaces labor productivity when deflated with either the CPI or HCE consumer price index.[17] For the US the difference between series based on price deflators is even more stark: average compensation deflated by the PCE kept pace with labor productivity growth, while average compensation deflated by CPI grew about 45 percentage points less than productivity.

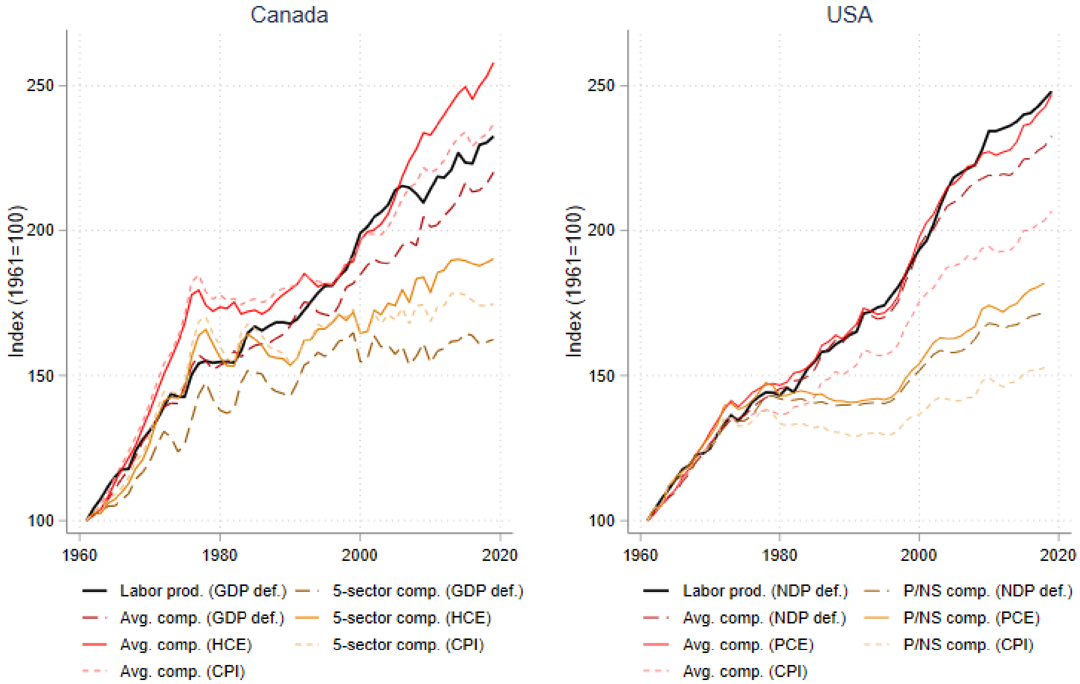
The starting point of the analysis is also important for our conclusion on the degree of divergence between productivity and average pay. Panel B of **Figure 1** charts these productivity and pay trends over the 1976-2019 period for which there is (imperfect) median hourly compensation data for Canada.[18] Over this slightly shorter period, average compensation grew slower than labor productivity for both countries, although the degree of divergence again depends on the deflator used to adjust compensation.

[17] These results are largely in line with the analysis in Williams (2021), which finds over the same period for Canada that average real 'product wages' (deflated by output prices) tracked productivity measure while average real 'consumption wages' (deflated by CPI) outpaced both measures.

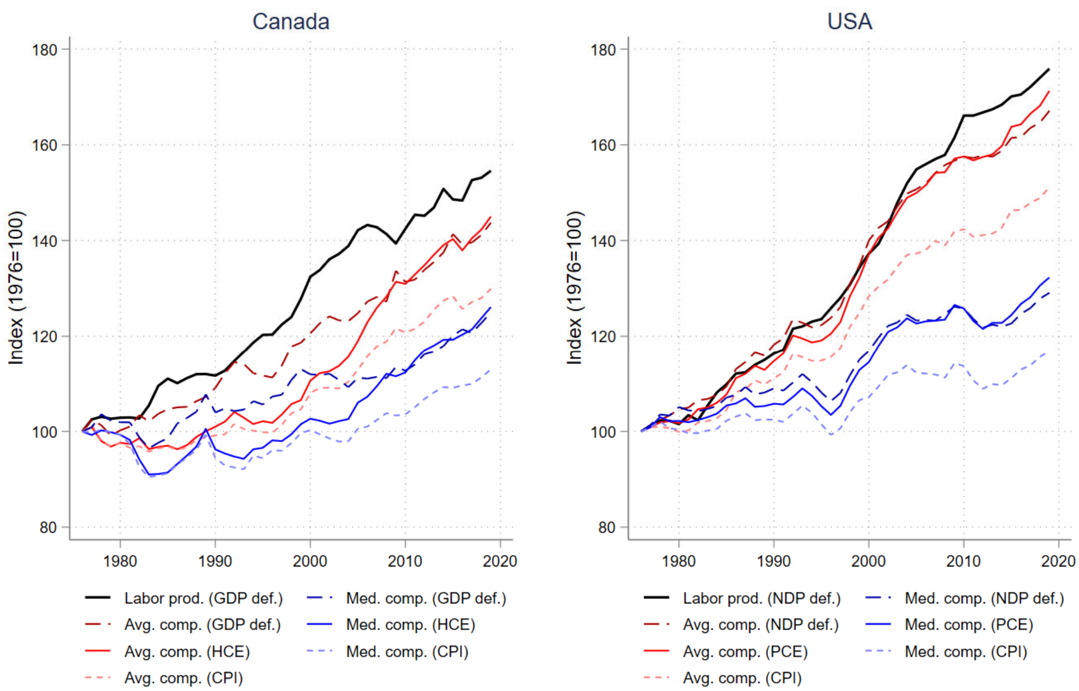
[18] Appendix Figure 1 illustrates the productivity-pay divergence in the US for the full period for which we have data, 1948-2019.

Figure 1: Productivity and compensation, Canada and the US

Panel A: indexed 1961=100



Panel B: indexed 1976=100



Note: "Avg. comp" refers to average compensation, "Med. comp." to median compensation, "P/NS comp." to the average hourly compensation of production and nonsupervisory workers (US only) and "5-sector comp." to our constructed measure of pay for "typical workers" in Canada, the average hourly compensation of hourly-rated workers in five sectors. Parentheses refer to the deflator used to adjust the series to real terms. Series are indexed to 1961=100 in Panel A and 1976=100 in Panel B.

Bivens and Mishel (2015) discuss the divergence between net labor productivity and median real compensation in terms of three separate ‘wedges’. First is the divergence between average productivity and average compensation (measured with the product price deflator) as labor’s share of income decreases. In the US, the decline in the labor share has been the subject of a great deal of research, and is attributed variously to technological changes, globalization and labor offshoring, reductions in worker bargaining power, higher firm concentration, increased markups, and housing market dynamics (see overview in Stansbury and Summers, 2020). In Canada, Sharpe et al. (2008) argue for three key drivers of the decline in the labor share: the declining bargaining power of workers, rising commodity prices, and an increasing share of GDP going to capital consumption allowances; Williams (2021) notes that the net labor share (compensation divided by net domestic product, which excludes the impact of changes in the share of GDP going to capital consumption allowances) has declined very little over 1961-2019.

Another wedge is the divergence between average and typical or median compensation. This reflects rising labor income inequality between the middle and top of the distribution. This increase in labor income inequality has been well documented in the US (see overview in Stansbury and Summers, 2019) and in Canada (Green et al., 2017). Similar to debates over the falling labor share, the increase has been attributed variously to purely technological explanations or institutional factors (such as declining unionization rates and increased trade with China) as well as slower growth in educational attainment in the face of skill-biased technological change (Goldin and Katz, 2009).

A final wedge relates to the ‘terms of trade’ divergence between consumer prices used to deflate compensation and the producer prices used to deflate output. Bivens and Mishel (2015) describe this wedge as “the faster price growth of things workers buy relative to the price of what they produce” and report that output prices have been outpaced by consumer price growth in the US.

Using a gross output per hour worked measure of labor productivity, Uguccioni et al. (2016) decompose this gap between productivity and median pay in Canada from 1976 to 2014 and find that increased average-median earnings inequality accounts for 51% of the gap while 30% is accounted for by a decrease in labor's share of income and the final 19% by a deterioration in labor's terms of trade. However, a longer-term analysis by Williams (2021) finds that labor’s terms of trade improved by 0.3% per year on average from 1961-2019 in Canada.

These productivity and pay trends in Canada and the USA are interesting to consider alongside each other. In both countries there has been concern over slow productivity growth during the 21st century amidst a global productivity slowdown. In the US, the productivity slowdown has been attributed to a mix of mismeasurement, an industrial shift from high to low productivity sectors, slow TFP growth, population aging, and other factors (Moss et al., 2020). Canada’s particularly poor productivity performance has confounded policymakers (see for example Drummond, 2011). The gap between Canadian and American productivity growth has also attracted attention. After Canada’s stronger business sector labor productivity growth until the mid-1980s narrowed its levels gap with the USA to 5 percentage points, Canada experienced slower productivity growth than the USA for the following quarter-century, with its productivity level dropping to 72% of the USA level in 2010 (a 28 point gap), before closing to 26 points in 2016 (Sharpe and Tsang, 2018). Gu and Wilcox (2018) suggest this recent catch-up by Canada is due to its higher total factor productivity growth, larger capital deepening effect, and more gradual realization of the benefits of ICT investment.

Despite Canada’s relatively poor productivity performance and worse average pay growth than in the USA since 1976, remarkably median pay growth has been about the same in these countries (as illustrated in Figure 1b). This is in line with a smaller recorded increase in income inequality over recent decades in Canada than the USA (Green et al., 2017).

3. To what extent have productivity and pay *delinked?*

The analysis in the previous section illustrates that the pay of typical workers has grown more slowly than productivity in both the US and Canada. Studying the degree of linkage or delinkage helps diagnose why this disconnection has happened, and what this might imply in terms of whether increases (or decreases) in the rate of productivity growth in the future will benefit (or reduce) typical workers' pay. As outlined in the introduction, if a one percentage point growth rate in productivity is associated with a one percentage point growth rate in pay, all else equal, we consider the two series to be linked, and if it is associated with no change in pay all else equal, we consider the two series to be delinked. Stansbury and Summers (2019) showed that despite substantial divergence in levels between productivity and median pay in the US, there was still substantial linkage in the growth rates of the series. This suggests that increases in US productivity growth still translated close to one-for-one into increases in typical pay, holding all else equal, which implies that the transmission mechanism from productivity to pay is functioning, but that at the same time other factors orthogonal to productivity growth are suppressing pay and therefore responsible for the rising productivity-pay gap. This section updates this analysis for the US and examines the degree of linkage or delinkage between productivity and pay in Canada.

Empirical estimation

We use a simple linear model as in equation (1) below in order to understand the degree of productivity-pay linkage, following Stansbury and Summers (2019). They describe a spectrum of possible interpretations of the productivity-pay divergence: at one end, 'strong delinkage' where an incremental increase productivity growth does not systematically translate into any incremental growth in workers' compensation, holding all else equal; and at the other end of the spectrum 'strong linkage' where an incremental increase in productivity growth can be expected to translate one-for-one into an incremental increase in compensation growth. Strong linkage could be compatible with a situation where the *levels* of productivity and pay have diverged if factors orthogonal to productivity growth have been putting downward pressure on workers' compensation at the same time as rising productivity has been putting upward pressure on pay.

Under the ‘strong linkage’ view $\beta = 1$ and under the ‘strong delinkage’ view $\beta = 0$. A value of β between 0 and 1 suggests some point on the spectrum between productivity-pay linkage and delinkage. While this is a partial model and other factors may affect compensation growth besides productivity, these other factors will not affect estimation of β as long as they are orthogonal to productivity growth.

$$Compensation\ growth_t = \alpha + \beta\ productivity\ growth_t \quad (1)$$

We estimate this model by regressing the year-on-year change in hourly compensation on the change in labor productivity, controlling for the level of unemployment (see below). As described above, we use four separate measures of compensation in our regressions: average compensation for all workers, average compensation for employees only, median compensation, and typical worker compensation (production/nonsupervisory compensation for the US, and our constructed measure of compensation for hourly-rated workers in five sectors in Canada). Since we run the same analyses on all measures, for brevity all four measures are referred to as ‘compensation’ below. In our baseline specifications, all compensation measures are deflated with the chain-linked consumer price deflator (PCE for USA, HCE for Canada).

In our baseline regression, in equation (2) below, we regress the three-year moving average of the change in log compensation on the three-year moving average of the change in log labor productivity and the current and lagged three-year moving average of the unemployment rate.[19] We use moving

[19] We account for autocorrelation introduced by the moving average specification by using Newey-West heteroskedasticity and autocorrelation robust standard errors, with a lag length of 6 years.

averages rather than annual changes in our baseline specification to account for a potentially longer time horizon for the productivity-pay relationship, for example because firms change pay and benefits infrequently or because it takes firms and workers some time to discern that increased output is due to higher labor productivity. In the appendix, we also show results from a similar regression with five-year moving averages.

$$\frac{1}{3}\sum_{0}^{2}\Delta\log comp_{t-i} = \alpha + \beta\frac{1}{3}\sum_{0}^{2}\Delta\log\ prod_{t-i} + \gamma\frac{1}{3}\sum_{0}^{2}\ unemp_{t-i} + \delta\frac{1}{3}\sum_{0}^{2}\ unemp_{t-i-1} + \varepsilon_t \quad (2)$$

In all specifications we control for the level of unemployment, for two reasons. First, as an indicator of labor market slack/tightness, the level of unemployment is likely to affect bargaining dynamics. In the context of a slack labor market with a high unemployment rate, employers would be able to raise compensation by less than they otherwise would have for a given productivity growth rate, as a more unemployed workers are searching for jobs at that time. Second, as a proxy measure of general labor market conditions, unemployment is likely to reflect broader cyclical economic fluctuations that could impact compensation in the short term. For example, higher unemployment may reflect a downturn, which could mean lower pay rises for a given rate of productivity growth. If unemployment is also related to changes in productivity growth – for example, if the least productive workers are likely to be laid off first in a downturn– then excluding unemployment would bias the results. By controlling for the current and one-year lagged moving average of the unemployment rate we allow for both the level and the change in unemployment to affect compensation growth.

Regression results

We run our baseline regression in equation (2) above for both the United States and Canada, over various time periods. **Figure 2** charts the coefficients estimated for the compensation-pay relationship from these regression (i.e. β in equation (1) above). Each dot and line in the chart shows the point estimate and 95% confidence interval (respectively) for this coefficient in the three-year moving average regression in equation (2). In addition, **Figure 3** shows the cyclically adjusted trends in compensation growth and productivity growth by charting the 3-year trailing moving average of the change in log of labor productivity and of compensation, cyclically-adjusted by residualizing these variables on unemployment and lagged unemployment (both also three-year moving averages). These results shed light on the degree of productivity-pay delinkage in the USA and Canada (discussed in turn below).[20]

USA: For the USA, these regression results suggest that average compensation (deflated in our baseline specifications using the PCE) is for the most part still strongly linked to net productivity, as found in Stansbury and Summers (2019). For both average compensation measures (i.e. including and excluding the self-employed), the coefficient on productivity is close to 1. The confidence intervals illustrate that these coefficients are strongly significantly different from 0 and, for the 1973-2019 regressions with the largest estimated coefficients, not significantly different from 1. Interestingly, the coefficients are smallest for the more recent 1997-2019 period, suggesting that the linkage may be getting weaker over time (though there is still a somewhat strong link and the confidence interval of the point estimate does not contain zero).

This weaker relationship in recent decades in the US is even more apparent when looking at the link between productivity and measures of *typical* compensation: the average compensation of production/nonsupervisory workers, and median compensation. With production/nonsupervisory compensation as the dependent variable, the coefficient on productivity is very large for the sample over the entire postwar period but very small (and not significantly different from zero) for the subsample over the last two decades. The coefficient on productivity in the regression with median compensation is also very small for the 1997-2019 period, although it is larger for the longer-term 1973-

[20] In the appendix, we present results with alternate price deflators for compensation, and with five-year rather than three-year moving averages.

2019 sample for which median compensation data is available. Breakpoint tests in years 1997, 2000, and 2008 (Appendix Table 6) fail to reject the null hypothesis of no structural break for *average* compensation, but suggest structural breaks in the productivity-pay relationship for our measures of *typical* compensation (production/nonsupervisory compensation and median compensation).

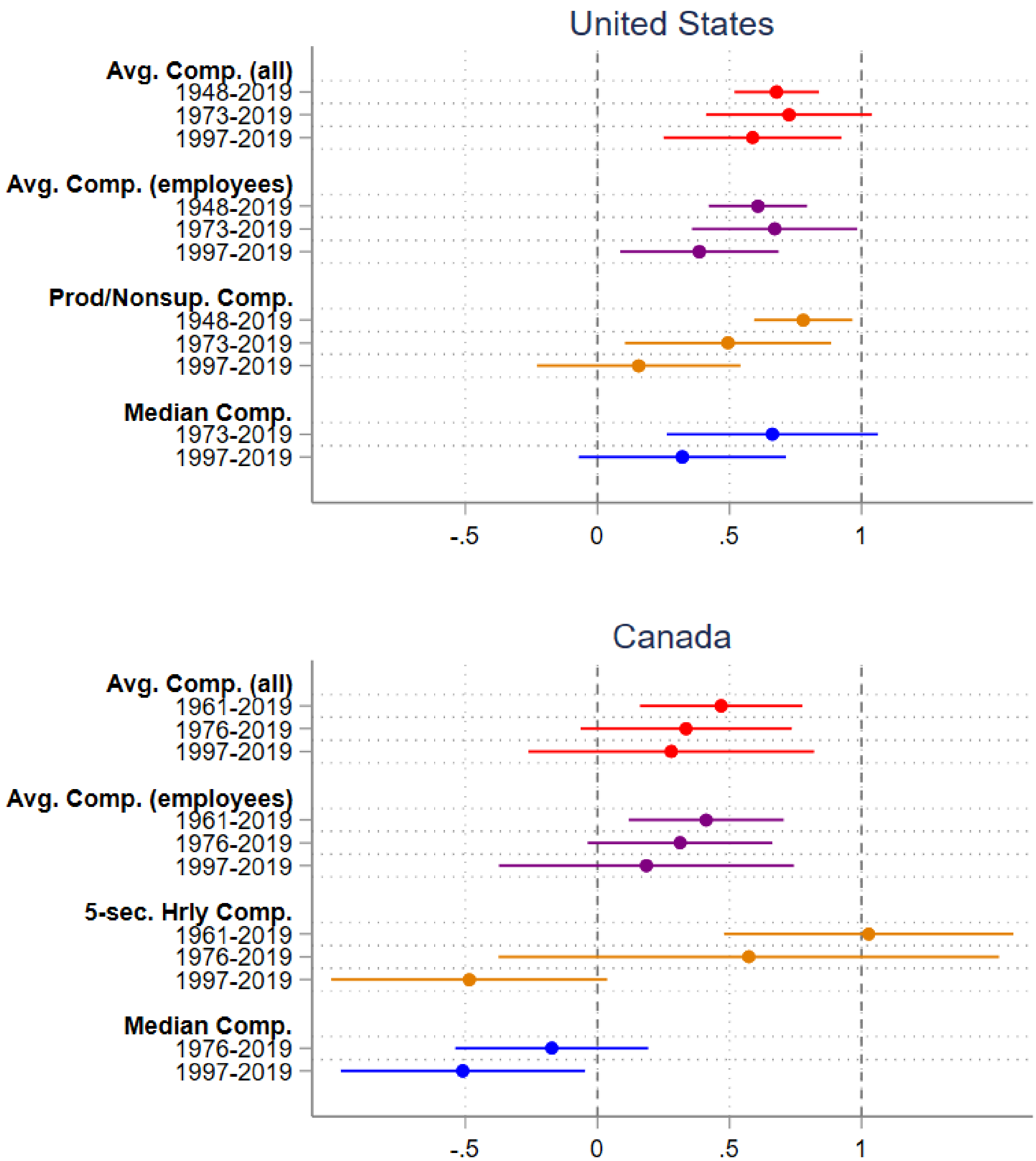
Figure 3 illustrates the temporal dynamics of the relationship, showing that in the US compensation growth generally co-moved with productivity growth until the 2000s. In the early 2000s, cyclically-adjusted productivity grew faster than compensation, while the decline in productivity growth in the 2010s was not matched by as substantial a decline in real compensation growth. This pattern held for both average compensation and the compensation of production and nonsupervisory wokrers. For median compensation, the picture is a little more nuanced: the spikes in the blue line from 1995-2005 illustrate that median compensation grew more slowly than would have been predicted by the level of unemployment in the mid 1990s and more quickly in the tight labor market of the late 1990s.

Canada: The regression results for Canada are somewhat more difficult to interpret. For Canada, average compensation (all measures deflated using the HCE price index) appears to be only somewhat linked to productivity over the longer-term 1961-2019 sample (whether or not the self-employed are included). The point estimates on these regressions are somewhat smaller than those for the US – between 0.4 and 0.5, with confidence intervals ruling out both 0 (strong delinkage) and 1 (strong linkage). Estimated coefficients are smaller, and not significantly different from zero, for the more recent 1976-2019 period and especially the 1997-2019 period (although structural break tests fail to reject the null hypothesis that there is no change in the productivity-average compensation relationship in 1997, 2000, or 2008 – see Appendix Table 6).

In contrast, the baseline typical compensation measure, average wages for hourly-rated workers in five sectors, is strongly linked to productivity over the whole period with the coefficient very close to one and strongly significantly different from zero. Yet breakpoint tests indicate a structural break for typical compensation in Canada in 1997 (Appendix Table 6), and there is no evidence of this typical compensation measure being linked to productivity in the past two decades: the point estimate, in fact, is negative, although the standard errors are so large that a coefficient of zero is also within the estimated confidence interval. **Figure 3** illustrates the dynamics behind this delinkage: in the early 2000s, cyclically-adjusted productivity and compensation moved in opposite directions, and in the Great Recession era there was a large decline in cyclically-adjusted productivity that was not matched by a large decline in real compensation.

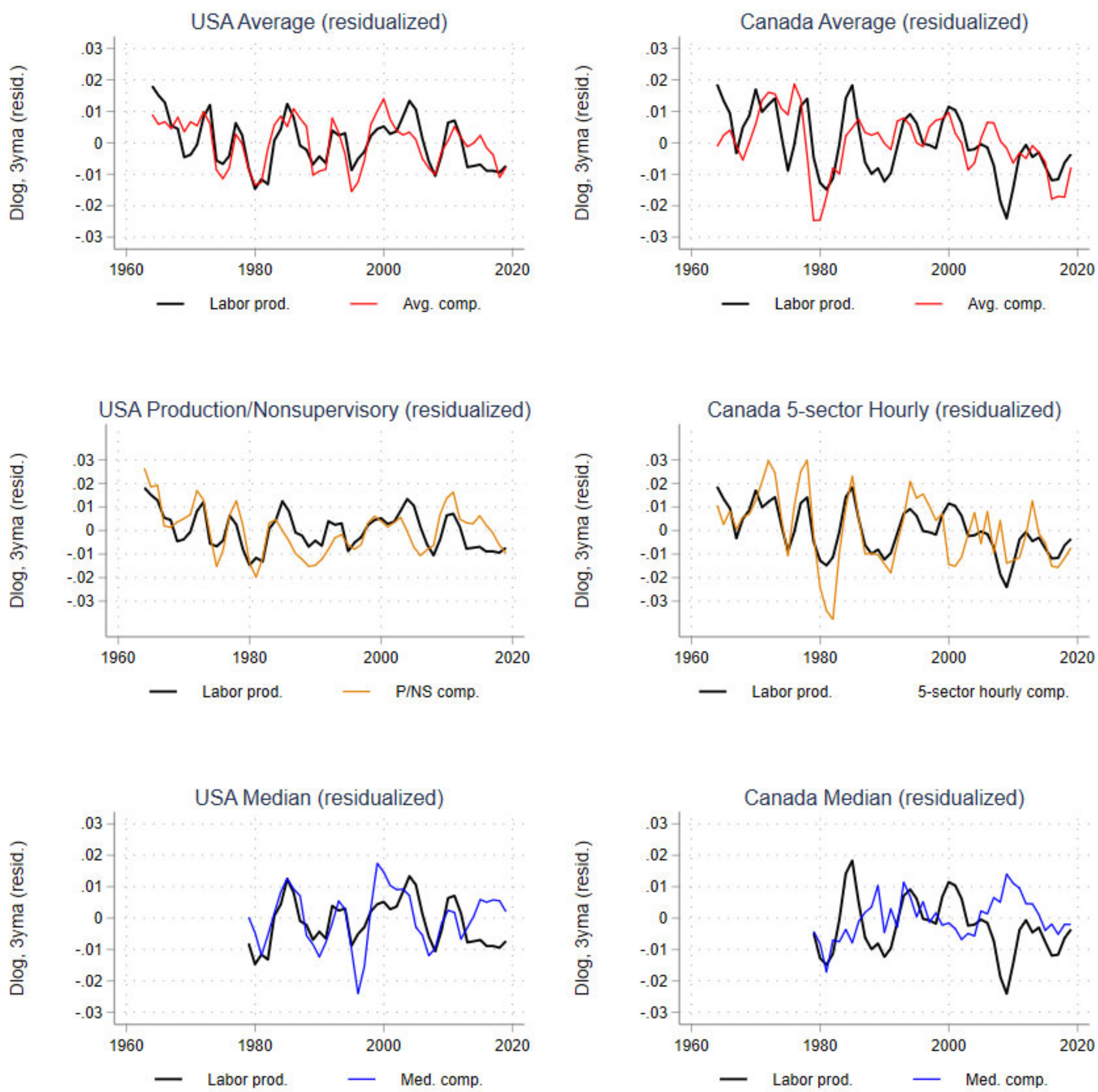
Finally, there is no evidence of linkage for the median compensation measure for Canada – point estimates are negative, with large standard errors, for both the 1976-2019 period and the more recent 1997-2019 period. We treat this result with caution, however, given the large potential measurement error for this measure of median hourly compensation (discussed above): to the extent that we are measuring total hours worked per year with noise, and to the extent that year-to-year fluctuations in true median hourly compensation are relatively small, the noise in the hours worked measure could swamp the "signal" of true median hourly compensation.

Figure 2: Coefficient on compensation-productivity regressions



Note: Each dot and line shows the point estimate and 95% confidence interval for the coefficient on productivity, from an annual regression of the change in log of compensation on the change in log of labor productivity, the level of unemployment, and the lagged level of unemployment (with all variables taken as 3-year moving averages). Variables in US regressions are hourly net labor productivity for the entire economy (real NDP/hours worked) and hourly real average compensation for all employed persons including the self-employed (red), hourly real average compensation for employees (blue), hourly real average compensation for production and nonsupervisory employees (orange), and hourly real median compensation for all employees (blue). Compensation is inflation-adjusted using the PCE price index. Variables in Canada regressions are hourly net labor productivity for the entire economy (real NDP/hours worked) and hourly real compensation for all employed persons (red), hourly real average compensation for employees (blue), hourly real average compensation for hourly-paid workers in 5 large sectors (orange), and hourly real median compensation for all employees (blue). Compensation is inflation-adjusted using the HCE price index. All regressions have Newey-West heteroskedasticity and autocorrelation consistent standard errors with a lag length of six.

Figure 3: Cyclically-adjusted productivity and compensation growth, US and Canada



Note: Each chart shows the 3-year trailing moving average of the change in log of labor productivity and of compensation, cyclically-adjusted by residualizing these variables on unemployment and lagged unemployment (both also three-year moving averages). The first row of charts shows average compensation for all employed workers, the second row shows our two measures of compensation for typical workers (production/nonsupervisory workers in the US, and hourly-paid workers in 5 large sectors in Canada), and the third row shows median hourly compensation. All US compensation measures are deflated using the PCE; all Canadian compensation measures are deflated using the HCE price index.

4. Exploring US-Canada differences

In the previous section, we found that the relatively strong linkage found between productivity and pay in the USA in Stansbury and Summers (2019) held with updated data. This affirms the conclusion of that previous analysis that factors orthogonal to productivity have been acting to suppress average and typical compensation in the USA even as productivity growth has been acting to raise it.[21]

We have found far less conclusive evidence for strong linkage between year-to-year fluctuations in productivity growth and compensation growth in Canada. It is possible that the relatively small size of these regression coefficients on productivity growth, and large standard errors, may be related to explanations specific to the Canadian context: there may, for example, be a weaker productivity-pay link in Canada than the USA because the former is a smaller, more open economy. The Canadian economy is less than one-eleventh the size of the USA economy and has more than twice the share of trade as a percentage of GDP.[22] As a result, it is reasonable that international factors are likely to be a relatively more important determinant of Canadian workers' compensation than in the USA.[23]

To evaluate this argument, we analyze the productivity-pay relationship at the level of other similar small open economies: US regions. The economies of some US regions may be better analogs for the Canadian economy than the economy of the US as a whole. Comparing Canada to the eight regions of the continental US as defined by the Bureau of Economic Analysis,[24] Canada sits somewhere in the middle in terms of GDP and population. Canada's population in 2019 was 37.6 million and its GDP in

[21] While the linkage between productivity and pay in the US appears weaker for the first two decades of the 21st century than for the second half of the 20th century, this appears to be a result of extremely low cyclically-adjusted productivity growth in the post-Great Recession era not being matched by as large a decline in the cyclically-adjusted rate of compensation growth.
[22] Economy size in terms of PPP-adjusted GDP. Trade is sum of exports and imports of goods and services as a share of GDP. Data from World Development Indicators database, World Bank. Over 2010-2019, Canada's trade share of GDP ranged between 60 and 67 percent; the US' trade share of GDP ranged between 26 and 30 percent.
[23] To the extent that these international factors are correlated with both productivity and compensation growth in Canada, these may be expected to reduce the strength of the linkage we can estimate between productivity growth and compensation growth in Canadian data.
[24] The eight regions and the states which comprise them are listed in Appendix Table 8.

2019 (in current USD) was $1.74 trillion: this made it larger in both population and GDP terms than the Rocky Mountain, New England, or Plains regions of the US, but smaller in both population and GDP terms than the South West, Great Lakes, Mideast, Far West, or South East regions of the US.

It should be noted, of course, that the US regions are not perfect comparators: their economies are more open (to each other) than Canada's economy is to the rest of the world, since trade frictions between US regions are lower than between Canada and the US or other countries, and migration is substantially easier between US regions than across an international border into or out of Canada. If migration across US regions fully arbitrages wage differences between US regions, one would have no reason to expect a productivity-pay linkage at the US region level. This comparison therefore relies to some extent on the assumption that US regions represent distinct labor markets, with less-than-perfect arbitrage of wages through migration between regions.

To analyze the productivity-pay relationship for the eight US regions, we construct worker-level measures of annual labor productivity and annual employee compensation from the BEA Regional Economic Accounts.[25] We use these to run our baseline regressions at the region level, regressing the change in log of compensation on the change in log of productivity (3-year moving average), controlling for the current and lagged level of regional unemployment. Coefficients from these regressions are shown in the bottom panel of Figure 4, where the first coefficient estimate shows the estimate from a panel regression across all regions (including region and year fixed effects), and the other coefficient estimates show the estimates from separate time series regressions for each region. Across most

[25] To estimate annual productivity per worker for each region, we start with region-level GDP, adjust it for depreciation by the national GDP-NDP ratio, deflate it with the national NDP price index, and then divide by the number of employed persons in the state (employees and self-employed). To estimate annual real compensation per worker for each region, we divide total employee compensation by the number of employees (from the BEA Regional Economic Accounts), and deflate compensation by the national PCE price index. Note that our compensation measure is for employees, not all employed persons, because of difficulties in obtaining good estimates of compensation per worker for the self-employed at the region level.

regions, the point estimates are close to and not significantly different from 0.5, but are significantly different from 0 for all US regions and significantly different from 1 for seven of the eight US regions.

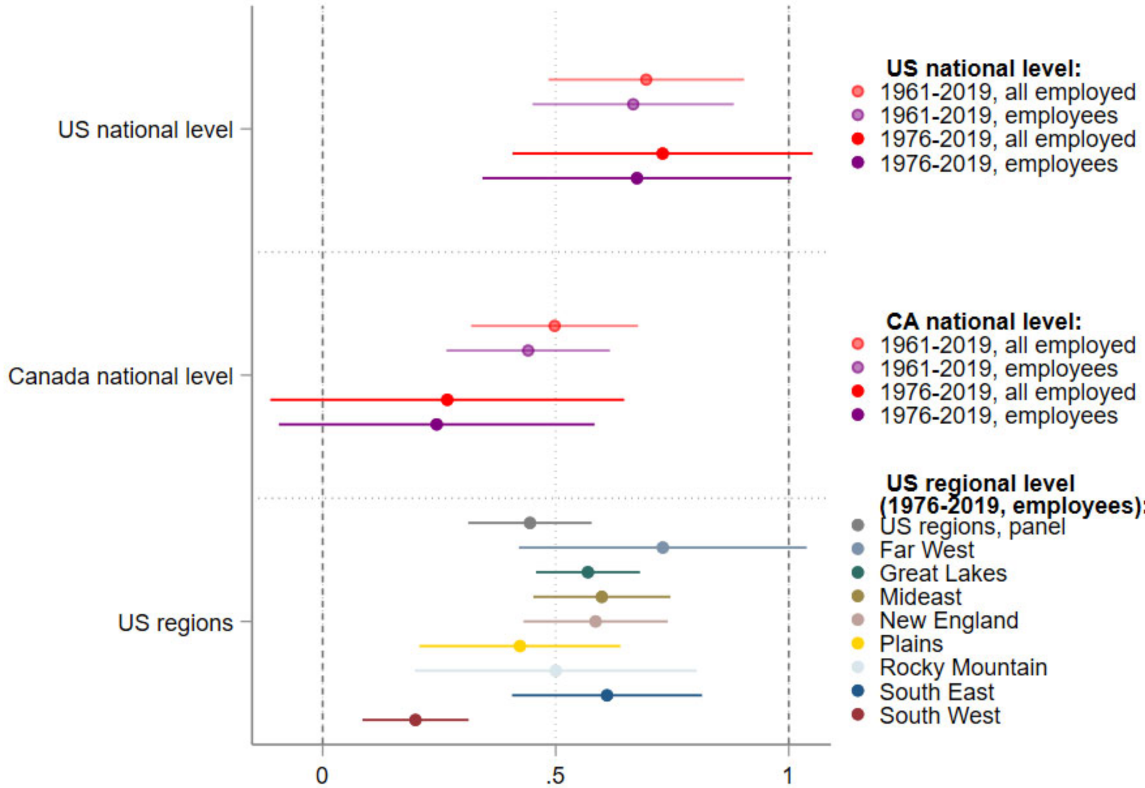
Notably, the coefficients from these region-level regressions are much smaller than those for the US national level regressions for average compensation. Indeed, the magnitude of the coefficients for US regions are quite close to those for average compensation for Canada – especially for the USA regions most geographically proximate and similar to Canada: the Plains, Great Lakes, and Rocky Mountain regions. This evidence is consistent with the idea that the more open an economy is, the less tightly linked are year-to-year changes in domestic productivity and domestic compensation. A further point of comparison is whether labor productivity differentials between the US and Canada translate into differences in pay. To test this, we regressed the difference in the change in log compensation on the difference in the change in log productivity (US minus Canada), controlling for the difference in unemployment. These regression results (in Appendix Table 5) suggest that a one percentage point faster productivity growth rate in the USA than in Canada translates into a 0.2-0.5 percentage point faster average compensation growth rate, holding all else constant. This fits with the finding noted above that the US experienced faster productivity growth and average compensation growth than Canada between 1976 and 2019. On the other hand, we find no evidence that a one percentage point faster productivity growth rate in the US than in Canada translates into a faster median compensation growth rate in the former. This is consistent with the fact that despite much faster productivity growth in the US than in Canada, real median compensation grew at about the same rate over the period.

Why might the Canadian economy, as a more open economy, have a smaller measured linkage between productivity and pay than the US? One notable feature of the Canadian economy is its dependence on commodities which are subject to international price fluctuations. For example, international commodity price 'supercycles' are an important influence on Canada's terms of trade, exchange rate, employment, income and inflation (Buyuksahin et al., 2016), and Green et al. (2019) find that the most recent Canadian resource boom in the 2000s substantially boosted real average wages in Canada broadly—that is, not only in the resource sector nor only in resource regions—which may have also hurt firms in non-resource regions by raising wage costs without the increase in demand enjoyed by firms in resource regions. It is possible that the influence of international commodity price fluctuations may affect the weakness of the measured productivity-pay relationship – though, it does not provide a completely obvious account of why the productivity-wage relationship would be affected if both series were deflated by a (correctly measured) product price index. To us this appears to be an avenue worth of further exploration.

Another avenue worthy of further exploration would be the degree to which productivity fluctuations which occur for different reasons may be expected to translate into pay growth. For example, a larger share of the fluctuations in measured productivity growth rates in Canada are l driven by natural resource prices, as compared to changes in technology or other drivers of economy-wide productivity., It is possible that the transmission mechanism from measured productivity gains as a result of export price increases differs as opposed to productivity gains arising from, for example, new technologies.[26]

[26] The timing of the transmission process may also differ according to the source of productivity growth, and the extent to which it is perceived as transitory or permanent. In a study of the US oil and gas field services industry, Kline (2008) finds that wage increases lag price increases in the oil extraction sector. A further possible explanation for the smaller degree of linkage between productivity and pay in Canada as compared to the US might have been a smaller degree of meaningful high frequency fluctuations in Canadian productivity growth compared to the USA. If this were the case, we would expect attenuated coefficients on the productivity-pay relationship due to classical measurement error. We do not, however, find evidence that productivity fluctuations are smaller in Canada than in the USA: the variance of the change in log productivity is the same or higher in Canada over the 1961-2019 period.

Figure 4: Coefficient on compensation-productivity regressions: comparison to US regions



Note: Each dot and line shows the point estimate and 95% confidence interval for the coefficient on productivity, from an annual regression of the change in log of compensation on the change in log of labor productivity, the level of unemployment, and the lagged level of unemployment (with all variables taken as 3-year moving averages). Variables in US national level regressions are hourly net labor productivity for the entire economy (real NDP/hours worked) and hourly real compensation for all employed persons including the self-employed (shown in red), and for employees only (shown in purple). Compensation is inflation-adjusted using the PCE price index. Variables in Canada national level regressions are hourly net labor productivity for the entire economy (feal NDP/hours worked) and hourly real compensation for all employed persons including the self-employed (shown in red), and for employees only (shown in purple). Compensation is inflation-adjusted using the HCE price index. Variables in US regional level regressions are labor productivity per worker (real NDP/employed persons) and annual real compensation for employees (employee compensation/employees), inflation-adjusted using the PCE price index. The “US regions, panel” regression is a panel regression which includes region and year fixed effects and has robust standard errors clustered at region level. All other regressions are time series regressions with Newey-West heteroskedasticity and autocorrelation consistent standard errors (using a six year lag).

5. Concluding Remarks

The analysis above sheds light on the productivity-pay relationship in the United States and Canada. First, we studied the *divergence* in levels between productivity and pay. In both countries the pay of typical workers has diverged substantially in real terms from average labor productivity. However, these divergences are attributed to slightly different forces. While the labor share of income has declined in both countries, and labor income inequality has also risen, the latter has been much more pronounced in the US. As a result, despite much faster growth in both labor productivity and average compensation in the US than in Canada – particularly since 1976 – the growth in real median compensation has been about the same in both countries.

Second, we studied whether this divergence has come alongside a *delinkage* in the growth rates of productivity and pay. We find evidence for some linkage between productivity and pay in both countries: a one percentage point higher productivity growth rate is associated with significant increases in the rate of compensation growth in both countries. However, our evidence suggests that this linkage between productivity and *average* pay growth may be stronger in the US than in Canada. In contrast, there is evidence of strong linkage of productivity with measures of typical workers' compensation in both countries, although in Canada estimates for more recent periods are too noisy to rule out either strong linkage (one-for-one translation from productivity to pay) or strong delinkage (no translation of productivity to pay).

We explore possible explanations for these findings. In particular we emphasize the possibility that since Canada is a smaller, more internationally open economy than the US, there may be a greater role for international factors (such as global commodity prices) that affect both productivity and compensation growth to reduce the strength of the linkage between domestic productivity growth and domestic compensation growth in Canada. This is supported by a comparison of our productivity-pay regression results from Canada with estimates of regressions of average compensation on productivity in US regions, which are similar in GDP and population to Canada, and could also be considered small open economies. These estimates suggest that linkage in US regions is substantially lower than for the US as a nation, and is similar in magnitude to the estimates for Canada.

The argument that the productivity-pay linkage is weaker in small open economies merits further study. Combined analysis of multiple countries may shed light on the importance for the size and trade-dependence of a country on its degree of productivity-pay linkage. Another focus of further research should be the degree to which productivity fluctuations which occur for different reasons may be expected to translate into pay growth. For example, productivity growth arising from a new labor-substituting technology may be expected to have substantially different implications for the pay of typical workers, than would productivity growth arising from different types of technological change – or, indeed, from productivity growth arising from a change in export demand or export prices. Understanding the role of these factors in the productivity-pay relationship will enable policymakers to respond appropriately. In particular, as policymakers in Canada continue to express concern over its slow productivity growth rate, it is important to understand the extent to which slower productivity growth may impact workers at different points in the income distribution.

Further research will illuminate the extent to which increases in productivity growth raise living standards across the board and which sources of increased growth impact most strongly on different parts of the income distribution. We think it is unlikely that the view that growth augments the incomes of most workers will be overturned. In addition to its direct impact on middle class incomes we expect that by augmenting government revenue collections increased growth will lead to at least some extent to augmented public spending. Finally, we emphasize that to suggest that productivity growth influences middle class living standards is not of course to imply that fluctuations in growth are primary determinants of middle class living standards – other distributional factors are also important.

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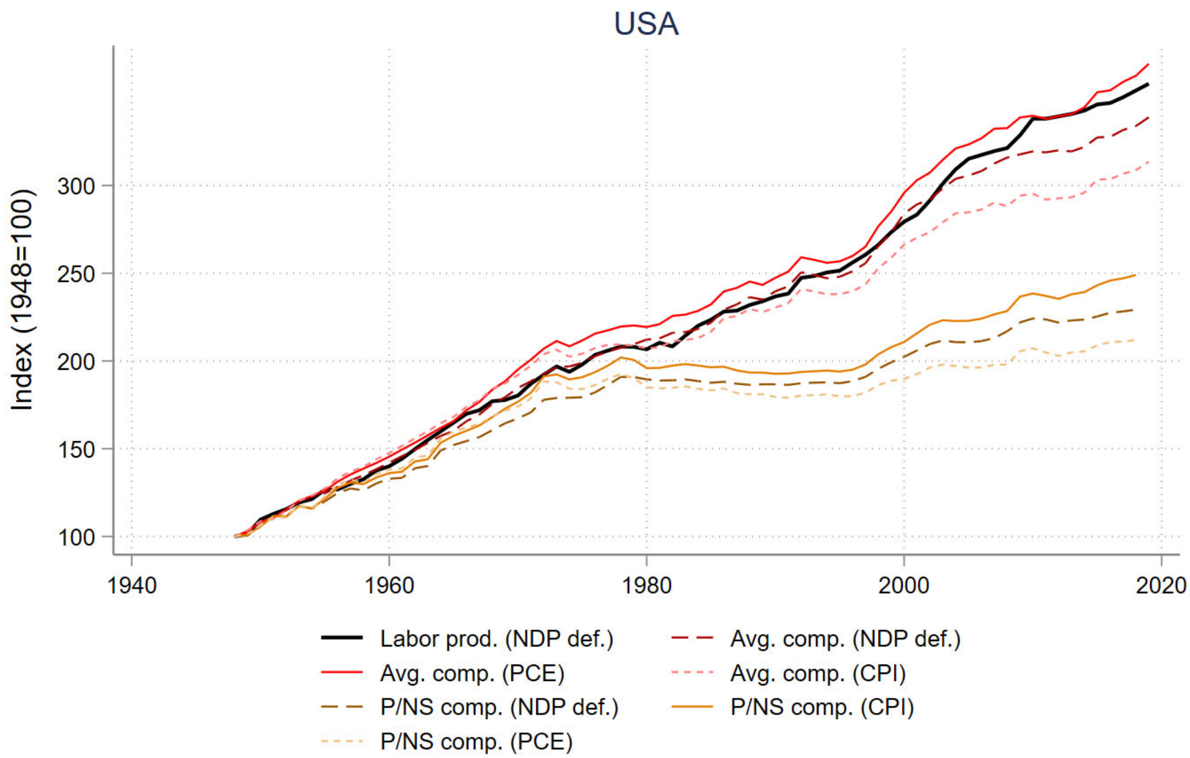
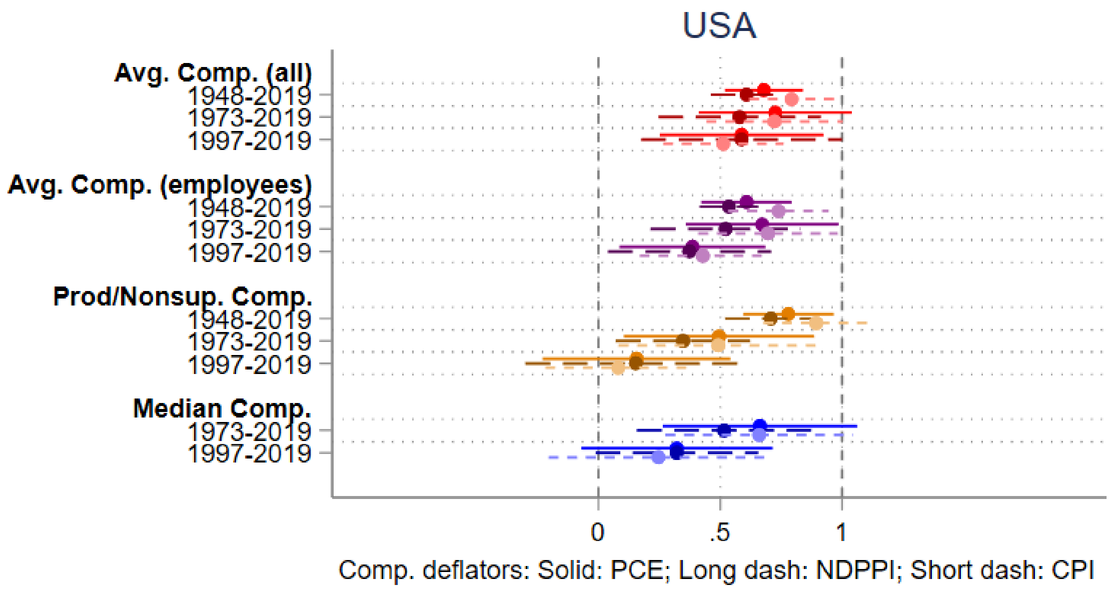
Appendix: Additional Figures and Tables

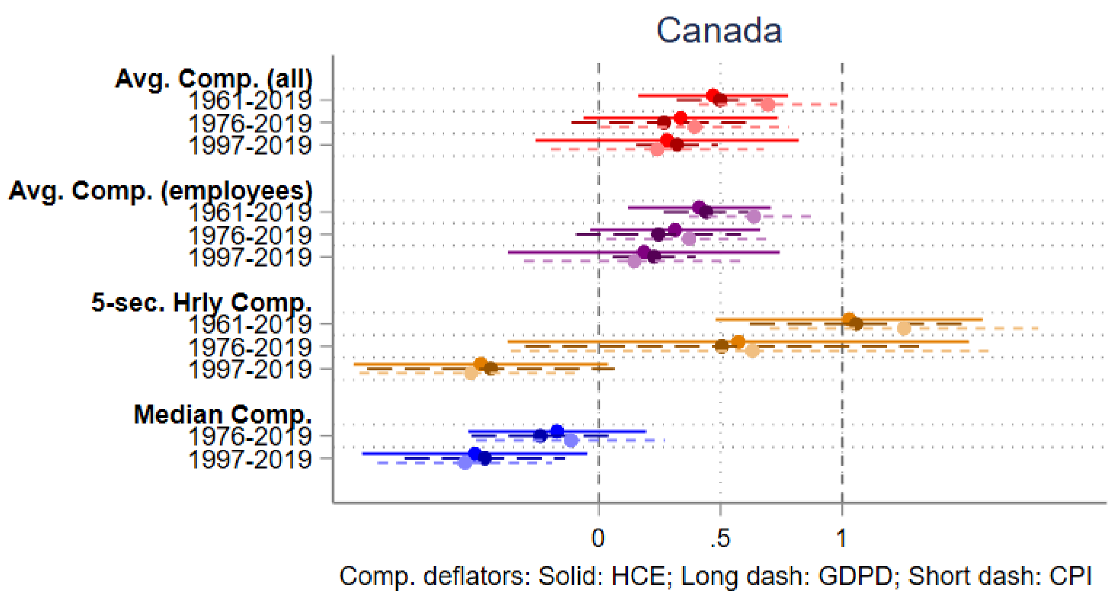
Appendix Figure 1: Productivity and compensation in the US, 1948-2019



Notes: this figure replicates Figure 1 in the main paper, but indexes the US series for productivity, average compensation of all employed persons, and for average compensation of production/nonsupervisory workers, to 1948. Canadian data is not presented here because it extends back only to 1961.

Appendix Figure 2: Coefficient on compensation-productivity regressions, including compensation series with different price deflators

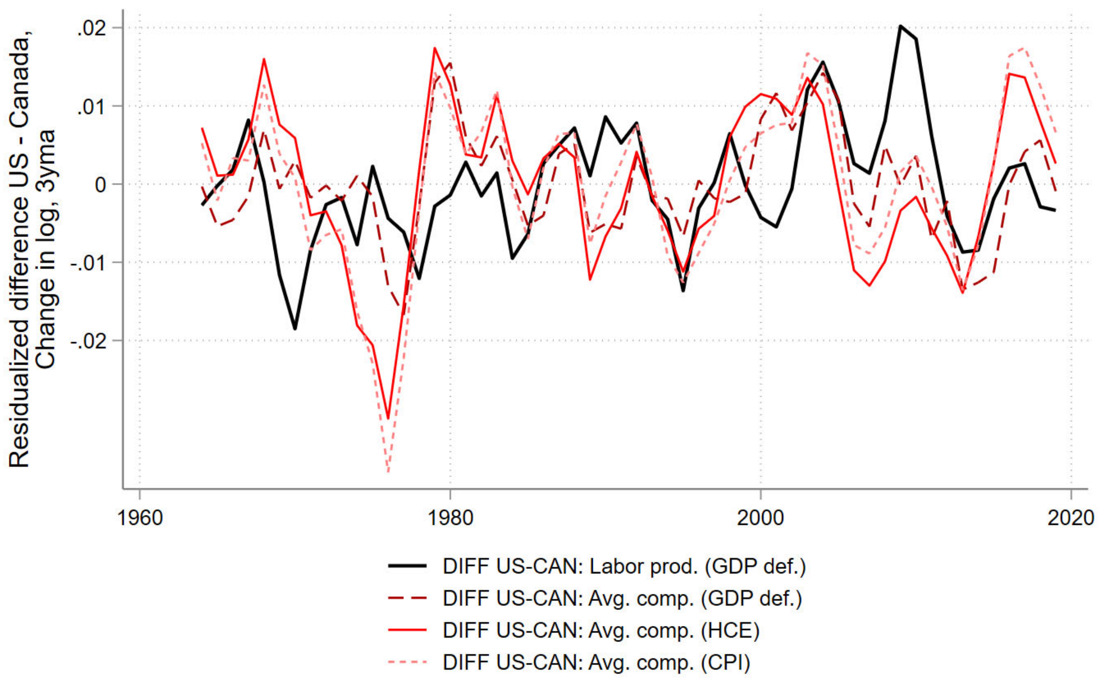




Notes: this figure replicates Figure 2 in the main paper, but includes coefficient estimates and confidence intervals for compensation deflated by the NDP/GDP price deflator (for US/Canada respectively), illustrated with long dashes, and by the CPI, illustrated with short dashes.

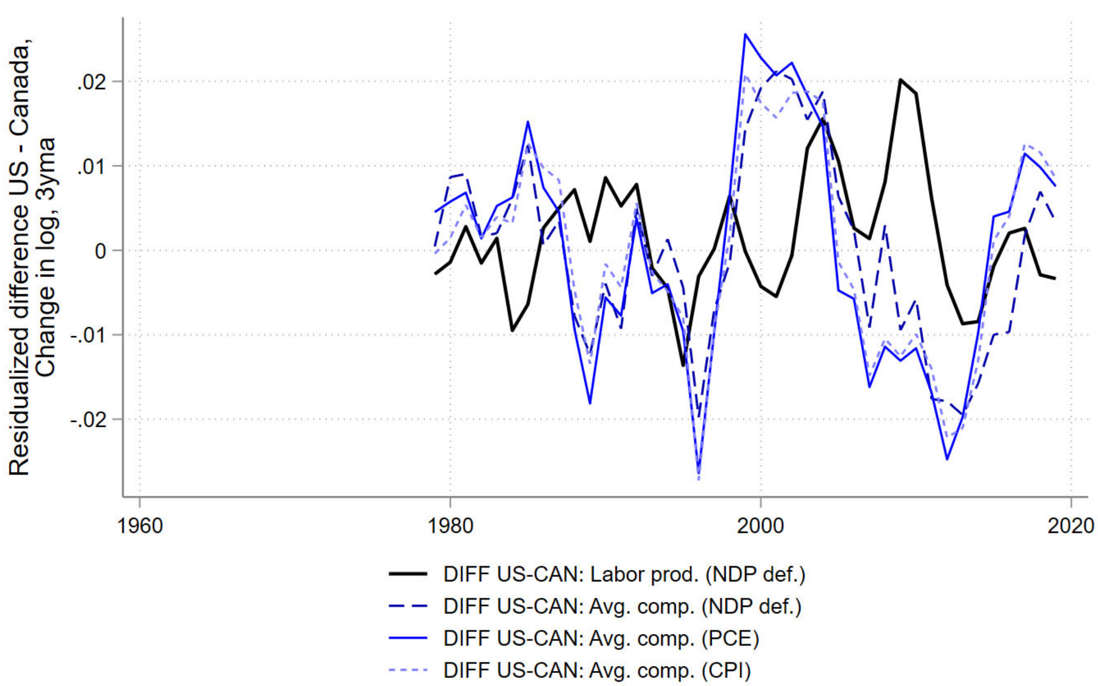
Appendix Figure 3: US Canada differentials: cyclically-adjusted productivity growth and compensation growth

Panel A: Average compensation



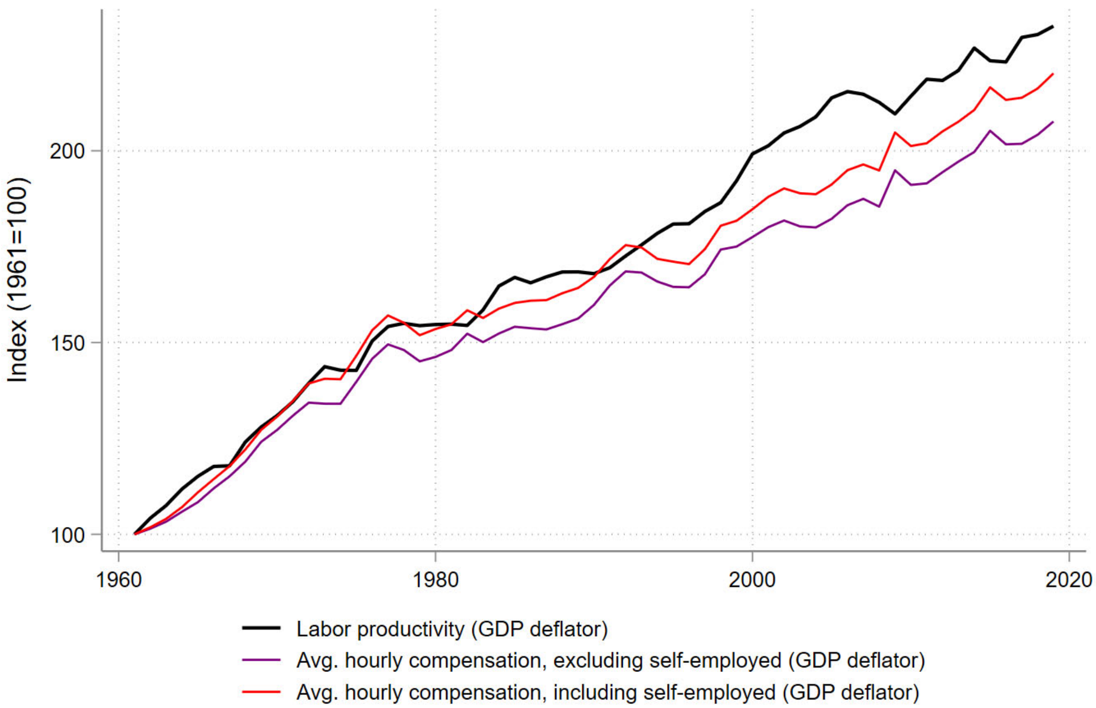
All variables residualized on unemployment difference, lagged unemployment difference, and a constant.

Panel B: Median compensation

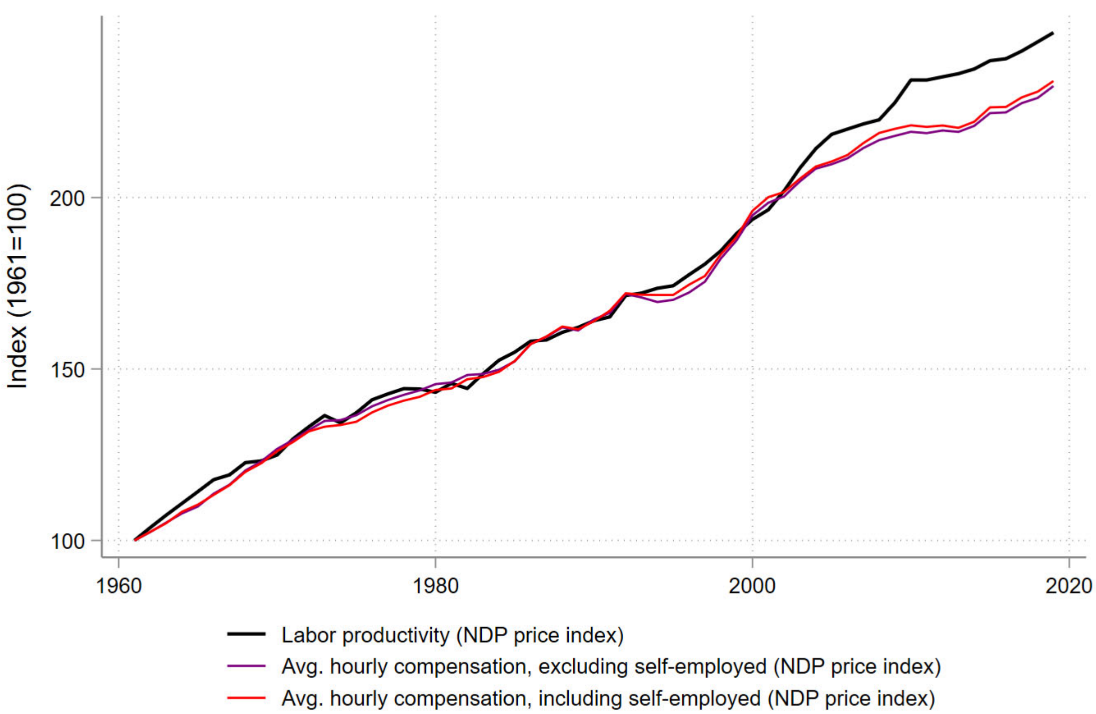


All variables residualized on unemployment difference, lagged unemployment difference, and a constant.

Appendix Figure 4: Average hourly compensation with and without the self-employed, 1961-2019
Panel A: Canada



Panel B: USA



Appendix Table 1: Canada

Coefficients from regressions of average compensation on productivity, 3 year moving averages

	1961-2019			1976-2019			1997-2019		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	GDP	HCE	CPI	GDP	HCE	CPI	GDP	HCE	CPI
Dep. Var.: Average Hourly Compensation, all employed persons, from national accounts, 3yma									
	0.50***	0.47***	0.69***	0.27	0.34*	0.39**	0.32***	0.28	0.24
	(0.09)	(0.15)	(0.14)	(0.19)	(0.20)	(0.19)	(0.08)	(0.26)	(0.21)
Dep. Var.: Average Hourly Compensation, employees, from national accounts, 3yma									
	0.44***	0.41***	0.64***	0.24	0.31*	0.37**	0.23**	0.19	0.15
	(0.09)	(0.15)	(0.13)	(0.17)	(0.17)	(0.17)	(0.08)	(0.26)	(0.21)
Dep. Var.: Average Hourly Compensation, employees, survey-based, 3yma									
	-	-	-	-0.05	0.01	0.07	-0.22	-0.26	-0.30
	-	-	-	(0.16)	(0.19)	(0.20)	(0.16)	(0.22)	(0.19)
Dep. Var.: Average Hourly Compensation, employees, from Labour Force Survey, 3yma									
	-	-	-	-	-	-	-0.20	-0.25**	-0.29***
	-	-	-	-	-	-	(0.17)	(0.11)	(0.08)
Dep. Var.: Compensation of Hourly-Paid Workers in Five Sectors, 3yma									
	1.06***	1.03***	1.25***	0.50	0.57	0.63	-0.44*	-0.48*	-0.53**
	(0.22)	(0.27)	(0.27)	(0.40)	(0.47)	(0.49)	(0.24)	(0.25)	(0.22)
Dep. Var.: Median Hourly Compensation, employees, survey-based, 3yma									
	-	-	-	-0.24*	-0.17	-0.11	-0.47***	-0.51**	-0.55***
	-	-	-	(0.14)	(0.18)	(0.19)	(0.16)	(0.22)	(0.17)
Dep. Var.: Median Hourly Compensation, employees, from Labour Force Survey, 3yma									
	-	-	-	-	-	-	-0.19	-0.23	-0.27**
	-	-	-	-	-	-	(0.22)	(0.14)	(0.12)
Obs.	56	56	56	41	41	41	20	20	20

Note: Each cell contains the coefficient estimate on hourly labor productivity (change in log, 3y trailing moving average) from a regression of the change in log compensation (3yma) on the change in log net hourly labor productivity (3yma), controlling for the current and 1-year lagged value of unemployment (3yma) and a constant, using annual data. Newey-West (HAC) standard errors (6-year lag) are listed below each coefficient estimate in parentheses, *** p<0.01, ** p<0.05, * p<0.1. The 56 observations in columns (1) and (2) are for each year from 1964-2019, where the data point for 1964 incorporates data from 1961-1964 inclusive, and so on.

Appendix Table 2: USA

Coefficients from regressions of average compensation on productivity, 3 year moving averages

	1948-2019			1973-2019			1997-2019		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	GDP	PCE	CPI	GDP	PCE	CPI	GDP	PCE	CPI
Dep. Var.: Average Hourly Compensation, all employed persons, from national accounts, 3yma									
	0.60***	0.67***	0.79***	0.57***	0.73***	0.73***	0.58**	0.59***	0.53***
	(0.07)	(0.08)	(0.09)	(0.16)	(0.15)	(0.14)	(0.20)	(0.17)	(0.12)
Dep. Var.: Average Hourly Compensation, employees, from national accounts, 3yma									
	0.55***	0.62***	0.74***	0.54***	0.70***	0.70***	0.47**	0.49**	0.42***
	(0.06)	(0.09)	(0.11)	(0.16)	(0.15)	(0.14)	(0.21)	(0.17)	(0.12)
Dep. Var.: Compensation of Production and Nonsupervisory Workers, hourly, 3yma									
	0.70***	0.78***	0.89***	0.33**	0.49**	0.49**	0.03	0.05	-0.01
	(0.10)	(0.10)	(0.11)	(0.14)	(0.20)	(0.21)	(0.15)	(0.14)	(0.13)
Dep. Var.: Median Hourly Compensation, 3yma									
	-	-	-	0.52***	0.68***	0.68***	0.32*	0.33	0.27
	-	-	-	(0.18)	(0.20)	(0.18)	(0.17)	(0.20)	(0.23)
Obs.	69	69	69	44	44	44	20	20	20

Note: Each cell contains the coefficient estimate on hourly labor productivity (change in log, 3y trailing moving average) from a regression of the change in log compensation (3yma) on the change in log net hourly labor productivity (3yma), controlling for the current and 1-year lagged value of unemployment (3yma) and a constant, using annual data. Newey-West (HAC) standard errors (6-year lag) are listed below each coefficient estimate in parentheses, *** p<0.01, ** p<0.05, * p<0.1.

Appendix Table 3: Canada

Coefficients from regressions of average compensation on productivity, 5 year moving averages

	1961-2019			1976-2019			1997-2019		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	GDP	HCE	CPI	GDP	HCE	CPI	GDP	HCE	CPI
Dep. Var.: Average Hourly Compensation, all employed persons, from national accounts, 5yma									
	0.55***	0.56***	0.81***	0.23	0.28	0.33	-0.08	0.37**	0.10
	(0.09)	(0.21)	(0.18)	(0.19)	(0.20)	(0.19)	(0.21)	(0.16)	(0.14)
Dep. Var.: Average Hourly Compensation, employees, from national accounts, 5yma									
	0.48***	0.49**	0.74***	0.19	0.24	0.29	-0.20	0.25	-0.02
	(0.08)	(0.20)	(0.17)	(0.18)	(0.19)	(0.18)	(0.21)	(0.18)	(0.16)
Dep. Var.: Average Hourly Compensation, employees, survey-based, 5yma									
	-	-	-	0.05	0.10	0.14	-0.58**	-0.13	-0.40***
	-	-	-	(0.17)	(0.18)	(0.19)	(0.20)	(0.16)	(0.13)
Dep. Var.: Average Hourly Compensation, employees, from Labour Force Survey, 5yma									
	-	-	-	-	-	-	-0.64**	-0.19**	-0.46***
	-	-	-	-	-	-	(0.23)	(0.07)	(0.06)
Dep. Var.: Compensation of Hourly-Paid Workers in Five Sectors, 5yma									
	0.96***	0.96***	1.21***	0.39	0.44	0.49	-0.73*	-0.28	-0.55**
	(0.15)	(0.22)	(0.21)	(0.33)	(0.39)	(0.42)	(0.39)	(0.19)	(0.23)
Dep. Var.: Median Hourly Compensation, employees, survey-based, 5yma									
	-	-	-	-0.42***	-0.37**	-0.32*	-1.10***	-0.65***	-0.92***
	-	-	-	(0.12)	(0.16)	(0.18)	(0.18)	(0.18)	(0.14)
Dep. Var.: Median Hourly Compensation, employees, from Labour Force Survey, 5yma									
	-	-	-	-	-	-	-0.56***	-0.11	-0.37***
	-	-	-	-	-	-	(0.17)	(0.14)	(0.10)
Obs.	54	54	54	39	39	39	18	18	18

Note: Each cell contains the coefficient estimate on hourly labor productivity (change in log, 5y trailing moving average) from a regression of the change in log compensation (5yma) on the change in log net hourly labor productivity (5yma), controlling for the current and 1-year lagged value of unemployment (5yma) and a constant, using annual data. Newey-West (HAC) standard errors (6-year lag) are listed below each coefficient estimate in parentheses, *** p<0.01, ** p<0.05, * p<0.1.

Appendix Table 4: USA

Coefficients from regressions of average compensation on productivity, 5 year moving averages

	1948-2019			1973-2019			1997-2019		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	GDP	HCE	CPI	GDP	HCE	CPI	GDP	HCE	CPI
Dep. Var.: Average Hourly Compensation, all employed persons, from national accounts, 5yma									
	0.65***	0.69***	0.86***	0.59***	0.75***	0.73***	0.59***	0.60***	0.47***
	(0.08)	(0.09)	(0.09)	(0.15)	(0.12)	(0.11)	(0.11)	(0.11)	(0.09)
Dep. Var.: Average Hourly Compensation, employees, from national accounts, 5yma									
	0.60***	0.65***	0.82***	0.58***	0.73***	0.72***	0.47***	0.48***	0.35***
	(0.07)	(0.09)	(0.09)	(0.16)	(0.13)	(0.14)	(0.12)	(0.10)	(0.09)
Dep. Var.: Compensation of Production and Nonsupervisory Workers, hourly, 5yma									
	0.67***	0.71***	0.88***	0.16	0.31*	0.30	0.06	0.07	-0.07
	(0.13)	(0.12)	(0.13)	(0.11)	(0.18)	(0.19)	(0.10)	(0.11)	(0.12)
Dep. Var.: Median Hourly Compensation, 5yma									
	-	-	-	0.38*	0.54**	0.53**	0.34*	0.35	0.22
	-	-	-	(0.20)	(0.22)	(0.21)	(0.18)	(0.21)	(0.24)
Obs.	67	67	67	42	42	42	18	18	18

Note: Each cell contains the coefficient estimate on hourly labor productivity (change in log, 5y trailing moving average) from a regression of the change in log compensation (3yma) on the change in log net hourly labor productivity (5yma), controlling for the current and 1-year lagged value of unemployment (5yma) and a constant, using annual data. Newey-West (HAC) standard errors (6-year lag) are listed below each coefficient estimate in parentheses, *** p<0.01, ** p<0.05, * p<0.1.

Appendix Table 5: USA-Canada differential

Coefficients from regressions of the US-Canada difference in compensation growth on the US-Canada difference in productivity growth, 3 year moving averages

Dep. Var.:	1961-2019			1976-2019								
Hourly Compensation	(1)	(2) Average	(3)	(4)	(5) Average	(6)	(7)	(8) Average	(9)	(10)	(11) Median	(12)
Deflator	GDP def	PCE	CPI	GDP def	PCE	CPI	GDP def	PCE	CPI	GDP def	PCE	CPI
Source	NA	NA	NA	NA	NA	NA	Svy	Svy	Svy	Svy	Svy	Svy
Net labor productivity	0.27**	0.17	0.48***	0.28	0.08	0.28*	0.11	-0.09	0.12	0.10	-0.10	0.11
	(0.12)	(0.15)	(0.15)	(0.19)	(0.16)	(0.16)	(0.25)	(0.20)	(0.22)	(0.28)	(0.23)	(0.23)
Unemployment	0.01***	0.00	0.00	0.01***	-0.00	-0.00	0.00	-0.00**	-0.00***	-0.01***	-0.02***	-0.02***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Lagged unemployment	-0.01***	-0.00**	-0.01*	-0.01***	-0.00*	-0.00	-0.00	0.00	0.00	0.01***	0.01***	0.02***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Constant	-0.01***	-0.03***	-0.04***	-0.01	-0.03**	-0.02*	0.01	-0.01	-0.00	0.01	-0.01	-0.01
	(0.00)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.02)	(0.02)	(0.02)
Observations	56	56	56	41	41	41	41	41	41	41	41	41

Newey-West (HAC) standard errors (6-year lag) in parentheses, *** p<0.01, ** p<0.05, * p<0.1

Note: Each column regresses the 3-year trailing moving average of the US-Canada difference between the change in log of real hourly compensation in each country on the 3-year trailing moving average of the US-Canada difference between the change in log of net hourly labor productivity in each country, 3-year trailing moving average of the US-Canada difference in unemployment and its 1-year lag, and a constant. The 56 observations in columns (1) and (2) are for each year from 1964-2019, where the data point for 1964 incorporates data from 1961-1964 inclusive, and so on.

Appendix Table 6: P-values from Wald tests for structural breaks

Compensation measure		1997	2000	2008
Canada	Average compensation, all employed persons (1961-2019)	.705	.905	.360
	Average compensation, employees (1961-2019)	.479	.800	.360
	Typical compensation (5 sector hourly wage) (1961-2019)	.000	.000	.195
	Median compensation (1976-2019)	.048	.033	.012
USA	Average compensation, all employed persons (1961-2019)	.105	.103	.060
	Average compensation, employees (1961-2019)	.330	.310	.403
	Typical compensation (production/nonsupervisory employees) (1961-2019)	.000	.000	.000
	Median compensation (1973-2019)	.062	.074	.036

All deflated by HCE (Canada) or PCE (USA). P-values reported to 3 decimal places. Structural break tests are run using our baseline regression specification, as laid out in expression (2) and with regression coefficients reported in Figure 2 and Appendix Tables 1 and 2. Years 1997, 2000, 2008, represent years for which a structural break is tested.

Appendix Table 7: US states in BEA regions

Region	States
New England	Connecticut, Rhode Island, Massachusetts, Vermont, New Hampshire, Maine
Mideast	Pennsylvania, Maryland, Delaware, New Jersey, New York, District of Columbia
Great Lakes	Wisconsin, Illinois, Indiana, Ohio, Michigan
Plains	North Dakota, South Dakota, Minnesota, Nebraska, Kansas, Missouri, Iowa
Rocky Mountain	Montana, Idaho, Wyoming, Colorado, Utah
Far West	Washington, Oregon, California, Nevada
Southwest	Arizona, New Mexico, Texas, Oklahoma
Southeast	Arkansas, Louisiana, Mississippi, Alabama, Florida, Georgia, Tennessee, Kentucky, West Virginia, Virginia, North Carolina, South Carolina

Appendix: Data

USA data

- **Net labor productivity per hour, total economy**:
  - Net Domestic Product (BEA NIPA Table 1.7.5), divided by Total Hours, Total Economy (from total economy productivity data set available on request from BLS).
- **Average compensation per hour, total economy:**
  - Average Hourly Compensation, Total Economy (from total economy productivity data set available on request from BLS).
- **Average employee compensation per hour:**
  - Total compensation of employees (BEA NIPA Table 6.2) divided by total hours worked by employees (BEA NIPA Table 6.9).
- **Median compensation per hour, total economy:**
  - Data obtained from EPI who calculated it as follows: Nominal median hourly wages, estimated using microdata from the CPS-ORG, multiplied by ratio of real compensation to wages. Real compensation/wage ratio was calculated by obtaining nominal compensation/wage ratio from BEA NIPA data and deflating the insurance component by the PCE medical care index and the rest of the series by the PCE. Further details in Bivens and Mishel (2015).
- **Average compensation per hour, production and non-supervisory workers:**
  - Data obtained from EPI who calculated it as follows: Average hourly earnings for production/nonsupervisory workers from BLS CES since 1964, estimated pre-1964 using average hourly earnings for production workers, multiplied by real compensation/wage ratio calculated as described for the median compensation series. Further details in Bivens and Mishel (2015).
- **Unemployment rate:**
  - Unemployment rate ages 25-54, Bureau of Labor Statistics.

Canada data

- **Net labor productivity per hour, total economy (since 1961)**
  - Constructed as total economy net domestic product divided by total hours worked for all jobs (from the productivity accounts), where total economy net domestic product is measured as income-based GDP minus consumption of fixed capital, deflated by the GDP deflator.[27]
  - Calculated from annual averages of quarterly data in Statistics Canada Table: 36-10-0103-01

[27] We use the GDP deflator because Statistics Canada does not produce a price deflator for Net Domestic Product (Williams 2021).

- **Average compensation per hour, total economy (since 1961)**
  - Constructed as total compensation divided by total hours worked, combined from two series:
    - 1997-2019 compensation and hours worked data for all workers (including self-employed) is from Statistics Canada Productivity Accounts (Table 36-10-0480-01)
    - 1961-1996 compensation and hours worked data for all workers (including self-employed) is from Statistics Canada Productivity Accounts (Table 36-10-0303-01). The annual growth rates from this data are used to backcast levels for 1961-1996 from the 1997 level in the more recent dataset from 1997-2019.
- **Average employee compensation per hour, total economy (since 1961)**
  - 1961-2019 Total compensation: Annual averages of Compensation of employees series from the quarterly income-based GDP data tables in National Accounts, Statistics Canada Table 36-10-0103-01.
  - Total compensation for employees is then divided by total hours worked for employees from the Productivity Accounts, which is combined from two series:
    - 1997-2019 total hours worked data for employees series is from Statistics Canada Productivity Accounts (Table 36-10-0489-01)
    - 1961-1996 total hours worked data for employees series is from Statistics Canada Productivity Accounts (Table 36-10-0303-01). As above, the annual growth rates from this data are used to backcast levels for 1961-1996 from the 1997 level in the more recent dataset from 1997-2019.
- **Typical compensation: Hourly workers in 5 sectors (since 1961)**
  - This composite wage is constructed as a weighted average of the average hourly compensation of workers paid by the hour in each of 5 industries: manufacturing, mining (including oil/gas), construction, laundries, and hotels and restaurants. The weights for each industry in each year are its share of the total number of hourly wage-earners in the 5 industries multiplied by the ratio of average weekly hours worked in the industry to (unweighted) average weekly hours across all 5 industries.[28]

$$CompositeWage_t = \sum_{i=1}^{5} \overline{Wage}_{it} \left(\frac{\overline{Hours}_{it}}{AvgHours_t}\right)\left(\frac{Emp_{it}}{TotEmp_t}\right)$$

    Where $\overline{Wage}_{it}$ is the average hourly wage and $\overline{Hours}_{it}$ is the average weekly working hours in sector i in year t, as reported in the SEPH (and precursors) data

  - The hourly compensation of hourly-rated workers in each of these 5 industries is taken from the average hourly wage in each industry, from the Statistics Canada Survey of

[28] Note also: the 1961-71 annual data for these three measures (hourly wage, number of wage earners, average hours) for each industry i in each year t were actually calculated as the average of 4 monthly observations per year, the 'middle month' of each quarter (i.e. February, May, August, and November)

Employment, Payrolls and Hours (and precursors),[29] multiplied by the average ratio of total compensation to wages and salaries in the entire economy (calculated from the income-based GDP accounts).

    - This measure is then adjusted for non-wage compensation through multiplying the wage/salary compensation measure by the average real compensation/wage ratio. For Canada, this is calculated as total compensation of employees divided by wages and salaries compensation as reported in Statcan Table 36-10-0103-01. This is deflated by the HCE.

- **Median compensation (since 1976)**
    - This is constructed using Median annual wage and salary income as reported in Statistics Canada Table 11-10-0239-01. This is calculated by Statistics Canada from three surveys).[30] It is then multiplied by average ratio of total compensation to wages and salaries (calculated from the income-based GDP accounts) and divided by our estimate of annual average hours worked, which is 52 x median hours worked weekly.[31]
    - This measure is also adjusted for non-wage compensation, through the same method as described above for typical compensation in Canada.
    - An alternative measure available since 1997 is the median hourly wage rate from the Labour Force Survey, as tabulated in Statistics Canada Table 14-10-0340-01.
- **Unemployment rate**
    - For 1976 on, the unemployment rate is for ages 15 and over and from Statistics Canada Table 14-10-0327-01
    - For 1961-1975, the unemployment rate is for ages 14 and over and from Historical Statistics of Canada, Series D223-235.

Deflators

For Canada, three different price indices are used to deflate nominal measures:

- Consumer Price Index (CPI), from Statistics Canada Table 18-10-0005-01
- Household final consumption expenditure deflator (HCE), from Statistics Canada Table 36-10-0130-01
- GDP deflator, from Statistics Canada Table 36-10-0130-01

[29] Specifically: we use the Survey of Employment, Payrolls and Man-hours for 1961-1982. The data from this survey and from the Statistics Canada Survey of Employment, Payrolls and Hours were supplemented with information on employment counts from the monthly publications *Employment earnings and hours* (for 1970-1971) *and Man-Hours and Hourly Earnings* (for 1961-1970). We do not use the data provided in these surveys for hourly-rated earnings in transportation, because the industry is not consistently defined over the whole period. Dataset with detailed sources is available upon request.

[30] These three surveys are the Survey of Consumer Finances (SCF) from 1976 to 1992, a combination of the SCF and the Survey of Labour and Income Dynamics (SLID) from 1993 to 1997, the SLID from 1998 to 2011 and the Canadian Income Survey (CIS) beginning in 2012 (according to footnote 3 on StatCan Table 11-10-0239-01)

[31] Median weekly hours worked is defined as the median value of 'usual hours worked in all jobs' as calculated from the Labour Force Survey microdata.

Similarly, for the US three different price indices are used to deflate nominal measures:

- NDP deflator: Net Domestic Product price index (BEA NIPA Table 1.7.4).
- CPI deflator: BLS CPI-U series before 1978 (CPI for All Urban Consumers); BLS CPI-U-RS since 1978 (CPI Research Series Using Current Methods).
- PCE deflator: Personal consumption expenditures price index (BEA NIPA Table 2.3.4).