Productivity and Pay in the United States 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 productivity has grown faster than pay. 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. In both countries there has been divergence: the pay of typical workers has grown substantially more slowly than average labour productivity over recent decades, driven by both rising labour income inequality and a declining labour share of income. Even as the levels of productivity and pay have grown further apart, however, we find evidence for a substantial degree of linkage between productivity growth and pay growth: in both countries, periods with faster productivity growth rates have been periods with faster rates of growth of the pay of average and typical workers, holding all else equal. This linkage appears somewhat 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 (i.e. statistically independent) 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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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 labour 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 United States, 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 United States? And what can this comparison tell us about the productivity-pay link in general? We tackle these questions in this article, 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: to the extent that productivity has grown faster than pay over time, the two series have diverged over the period.[2] As documented by Williams (2021) and Sharpe and Ashwell (2021) in Canada, and Bivens and Mishel (2015, 2021) among others in the United States, there has been divergence in both countries between labour productivity and the pay of both the average worker and typical workers. In this article 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

2 Labour 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 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.

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 United States, 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 article we update our analysis for the United States 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 technological change which increases productivity but leads to the substitution of labour 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 (i.e. statistically independent) 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 the hose is broken and is 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*). This has implications for what we expect to happen if we increase the water pressure at the faucet. If there is a hole in the hose, this may not make any difference: more water

3 For example, capital-augmenting technological change with an elasticity of substitution between labour and capital of greater than 1, or labour-augmenting technological change with an elasticity of substitution between labour and capital of less than 1 (Lawrence, 2015).

flowing into the hose will not affect the water level in the bucket. However, if there is instead a hole in the bottom of the bucket, increasing the rate of inflow of water into the bucket will indeed make a difference – it will slow the rate of draining of the bucket, and may even increase the water level on net.

As this metaphor illustrates, understanding the degree of linkage or delinkage between productivity and the pay of typical workers is therefore 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: an incrementally higher rate of productivity growth will not be expected to feed through into pay growth for typical workers, and the benefits instead will be reaped by others. 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 increased productivity growth should be expected to increase the pay of typical workers – an incrementally higher rate of productivity growth will exert upward pressure on typical workers' pay, and so 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).

Similarly, these conclusions can help us understand the dynamics of the past. Counterfactually, if there had been slower growth in productivity over recent decades, what would have happened to typical workers' pay? Under the delinkage hypothesis, it would have made little difference to the rate of growth of typical pay (which was relatively slow in real terms over recent decades in both Canada and the United States). Under the linkage hypothesis, typical workers' wage growth may have already been slow for other reasons (like declining worker bargaining power), and so slower productivity growth would have meant even slower (or perhaps even negative) real wage growth for typical workers over the period.

We begin our analysis in section 2, examining the degree of divergence between productivity and compensation in the United States 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?". We use two measures to proxy for the pay of typical workers in each country. For the United States, we use the average compensation of production and nonsupervisory workers, as well as median hourly compensation (available only since 1973). For Canada, we use a new measure we have constructed reflecting average hourly compensation of hourly-paid workers in five sectors for which historical time series data is available: manufacturing, mining, construction, laundries, and hotels and restaurants; since 1976, we also use an estimate of median hourly compensation.[4]

In both countries, the last four to five decades have seen substantial divergence in the growth paths of labour productivity and the pay of typical workers: labour productivity has grown much faster than real compensation for typical workers. This divergence can be thought of in terms of three wedges (as illustrated by Bivens and Mishel 2015): (i) a decline in the labour share of income (faster growth in labour productivity than average compensation, deflated by the same price deflator), (ii) a rise in inequality in (pre-tax and transfer) labour incomes caused by faster growth in average compensation than the compensation of typical workers, and (iii) a decline in labour's terms of trade (faster growth in consumer than producer price deflators).

These three trends have played out somewhat differently in the two countries. In both countries, a declining labour share of income has generated increasing divergence between labour productivity and average compensation. In both countries, market labour income inequality has also risen over the period we study, generating increasing divergence between average labour productivity and the real compensation of typical workers – but this trend has been much more pronounced in the United States. Trends in relative price deflators have differed across the two countries and time periods. On net, since labour productivity growth has been much faster in the United States than in Canada – particularly since 1976 – average compensation has also grown much faster in the United States than in Canada even though the US labour share has fallen. But since labour income inequality as measured by the mean-median ratio has risen so much faster in the United States 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 United States.

In section 3, we examine the degree of linkage or delinkage between hourly labour productivity and measures of average and typical worker compensation in the United States 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 United States, 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 United States 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 nonsupervi-

4 1976 is the first year for which median pay data for Canada are available.

sory 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 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 five 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 substantial caution.

Why does there seem to be a weaker link between pay and productivity in Canada than in the United States? In section 4, we explore possible explanations. One possibility is that Canada is a smaller, more internationally open economy than the United States. 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 United States 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 United States 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.

To What Extent Have Productivity and Pay Diverged?

Several studies have explored the divergence between productivity and pay in both Canada and the United States, 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

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.

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

papers on the United States 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

Data for the measures used in this analysis are carefully constructed from a variety of sources, which are provided in the appendix (available online at [http://www.csls.ca/IPM])

The main measure of labour productivity is total economy output per hour worked, where output is net of depreciation. This better reflects the production output available for labour 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 United States since the mid 1970s).[7] In both countries, this total economy productivity measure is a conservative estimate of productivity growth: 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, 2018). 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).

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

Average hourly compensation of all workers

This measure, used in our baseline analyses, reflects average hourly compensation of all employed persons in the total economy.[8] For Canada we construct this measure from total compensation divided by total hours worked (obtained from Statistics Canada). For the United States we use the average hourly compensation of all employed persons (obtained from the BLS total economy productivity data set). Note that since it is difficult to determine whether the income of self-employed workers is considered to be compensating labour or capital, our measure of average hourly compensation for both the United States and Canada includes an imputed measure of compensation for the self-employed based on wages of similar employee work-

7 Unlike in Williams (2021), our productivity measure does not exclude taxes less subsidies in order to be consistent with US data. In addition, 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).

8 The long-term total compensation and hours worked series were calculated from combining 1961-1997 data with 1997-2019 data (see on-line 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 (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).

ers.[9]

Average hourly compensation of employees only

This measure excludes the self-employed and therefore avoids challenges with imputing their labour income. For both Canada and the United States this is constructed as total compensation of employees divided by total hours worked by employees (in the total economy).

Median hourly compensation

Median compensation is a better reflection than average compensation of the experience of typical middle-income workers, as it is not skewed by large changes at the top or bottom of the income distribution. Median compensation measures are, however, not available over the entire period of our analysis for either country. For the United States, we use the Economic Policy Institute's estimates of median hourly compensation for each year since 1973. This is calculated by estimating median hourly wage and salary income from the Current Population Survey, and then multiplying this by the average ratio of total compensation to wage and salary income obtained from the Bureau of Economic Analysis. For Canada, we estimate a measure of median hourly compensation using Statistics Canada's data on median annual wage and salary income, divided by our estimate of median annual hours worked as estimated from the Labour Force Survey, and multiplied by the ratio of total compensation of employees to total wage/salary income of employees (obtained from Statistics Canada). Unfortunately, our measure of median hourly compensation in Canada must be approached with caution given substantial measurement concerns in our estimates of the number of hours worked. (A direct measure of median hourly compensation, which would be preferable to use, is only available from the Labour Force Survey from 1997 onwards).[10]

Typical compensation for hourly paid workers

Since median compensation measures are not available for the whole period, and given measurement error concerns for the Canadian median compensation series, we also provide an additional measure of 'Typical compensation' for each country.

Production/nonsupervisory compensation (US)

In the United States, we use average hourly compensation of production/nonsupervisory employees as another

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

10 Median compensation in Canada is calculated by 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).

proxy for the average compensation of typical workers. This is estimated from the average hourly earnings of production/nonsupervisory employees multiplied by the national average compensation-wage ratio (as described also in Stansbury and Summers (2019) and Bivens and Mishel (2015)). Production/nonsupervisory employees represent about 80-84 per cent of all employees in the US private sector.

Five-sector hourly compensation (Canada)

Unfortunately, for Canada an analogous measure of the compensation of production and nonsupervisory employees is only available from 1997 on (from the Statistics Canada Labour Force Survey). Instead, for our alternative proxy for typical workers' compensation, 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 – and then multiply this wage by the national average compensation-wage ratio.[11] We choose these five sectors since they are the only sectors with hourly wage data for hourly-paid workers for the entire period. They made up 34 per cent of total employment in 1961 and 24 per cent by 2011.[12] While this is not as comprehensive a measure as we would like, it is worth noting that 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 further in the appendix.

Note that in both the United States and Canada our typical compensation measures (median compensation, production/nonsupervisory compensation, and five-sector hourly compensation) are estimated from data on wage and salary income, and then adjusted to include an estimate of non-wage compensation using the national average ratio of total compensation to wages. This adjustment is important given the increase in non-wage compensation over recent decades (see for example Williams (2021) for Canada and Bivens and Mishel (2015) for the United States). 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

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

12 1961 and 2011 employment shares are from, respectively: the 1961 Census of Canada: Volume III, Part 2: Labour Force, Industries by Sex, Table 1; 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.

1.16 in the United States.[14]

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.[15] 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 Indices 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.[16]

Trends in Productivity and Pay, 1961-2019

Our primary period of analysis is 1961-2019, which is the longest period of analysis possible with Canadian data on average labour productivity and compensation.[17] Panel A in Chart 1 shows the productivity and compensation trends in Canada and the United States since 1961 (with growth rates by period in Table 1). There is a substantial divergence between productivity and typical compensation in both United States and Canada over the long-term period, regardless of choices about the price deflator. However, for both countries the size of the divergence between productivity and average compensation depends strongly on the price deflator used. In both countries, when productivity and compensation are deflated using the same price index – the NDP or GDP deflator respectively – there is a divergence between productivity and average compensation, which first emerges in the 1990s in Canada and around 2000 in the United States. In Canada average compensation outpaces labour productivity when deflated with either the CPI or HCE consumer price index.[18] For the United States the difference between series based on price deflators is even more stark: average compen-

14 However, this adjustment may introduce three issues of concern to our empirical analysis. First, to the extent that the share of compensation which comes from non-wage benefits is higher at the top of the income distribution, our adjustment will overstate the level of total compensation for typical workers. Second, to the extent that the share of compensation which comes from non-wage benefits may have grown by more for workers at the higher end of the distribution than those in the middle, our adjustment will also overstate the growth in compensation for typical workers. Third, as the share of non-wage compensation in total compensation grows over time, this imputation becomes more substantial in its impact on our estimated median/typical compensation estimates – and to the extent we are measuring true typical compensation with error as a result of imputing non-wage compensation using the average figure, this measurement error may grow over time.

15 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.

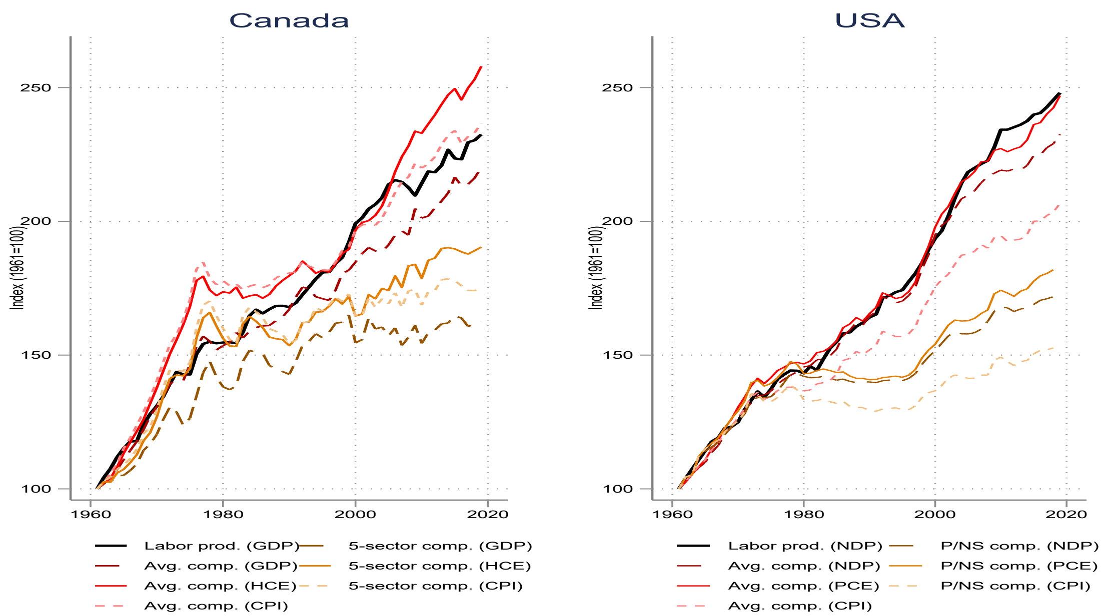
16 In general these price indexes differ because they are based on different underlying concepts, are constructed differently (a Fisher-type 'chain' price index vs. a Laspeyres-type price index), rely on different weights, cover some different items, and use different seasonal adjustment processes (McCully *et al.* 2007).

17 US data on average labour productivity and compensation extends back to 1948; we present results with this longer time period for the United States in the Appendix.

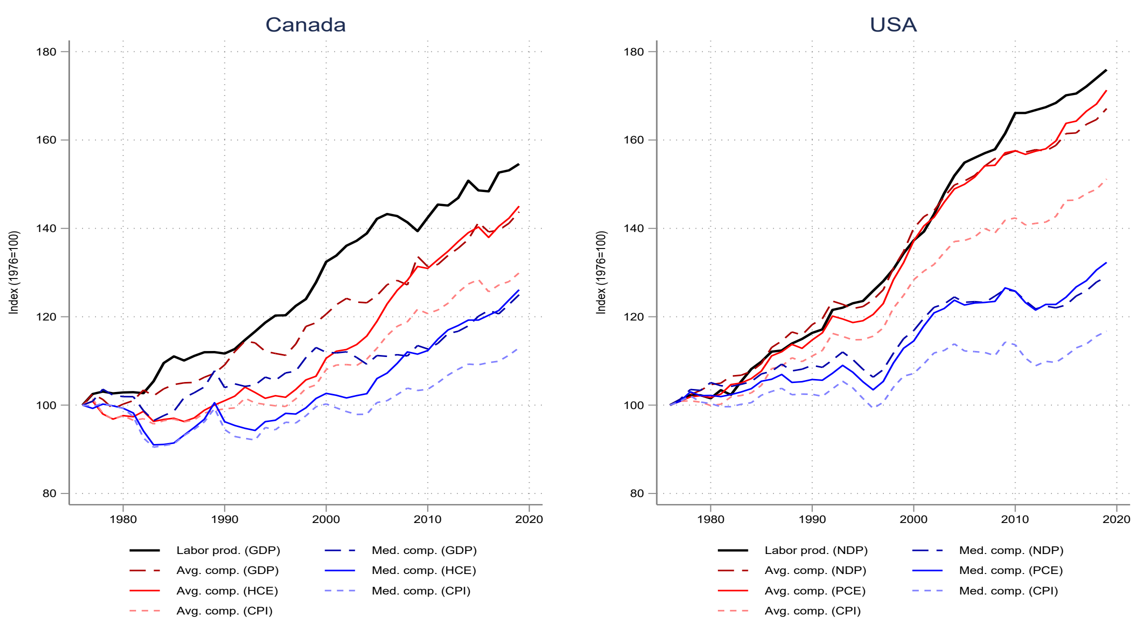
18 These results are largely in line with the analysis in Williams (2021), which finds over the same period for Canada that average real 'product wages' (deflated by output prices) tracked productivity measure while average real 'consumption wages' (deflated by CPI) outpaced both measures.

Chart 1: Productivity and Compensation, Canada and the United States

Panel A: Indexed 1961=100 for 1961-2019 period



Panel B: Indexed 1976=100 for 1976-2019 period



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 "five-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.

sation deflated by the PCE kept pace with labour productivity growth, while average compensation deflated by CPI grew about 41 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 Chart 1 charts these productivity and pay trends over the 1976-2019 period for which there is (imperfect) median hourly compensation data for Canada.[19] Over this slightly shorter period, average compensation grew slower than labour productivity for both countries, although the degree of divergence again depends on the deflator used to adjust compensation.

Bivens and Mishel (2015) discuss the divergence between net labour 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 labour's share of income decreases. In the United States, the decline in the labour share has been the subject of a great deal of research, and is attributed variously to technological changes, globalization and labour 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 labour 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 labour 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 compensation (as proxied by median compensation, or by production/nonsupervisory compensation in the US and five-sector hourly compensation in Canada). This wedge reflects rising labour income inequality (pretax and transfer) between the middle and top of the distribution. The increase in labour income inequality in both countries since the 1960s/1970s has been well documented in the United States (see overview in Stansbury and Summers, 2019) and in Canada (Green *et al.* 2017).[20] Similar to debates over the falling labour 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 techno-

19 Appendix Chart 1 illustrates the productivity-pay divergence in the United States for the full period for which we have data, 1948-2019.

20 The exact temporal dynamics of labour income inequality depend on the period chosen, particularly for Canada. The ratio between hourly mean and median compensation, or between hourly mean compensation and our "five-sector hourly" measure of typical compensation, has risen over most sub-periods from 1961-2019, as illustrated in Table 1 and Appendix Table 1. However, other measures of labour income inequality show a different picture. For example, the Gini coefficient of annual adjusted market income rose sharply in the 1980s and early 1990s and has gradually and incrementally declined a little over the following three decades (Table 11-10-0134-01 Statistics Canada).

Table 1: Productivity and Compensation Measures by Period (Per Cent Compound Annual Growth Rate

Panel A: Canada													
Measure	**Labour Productivity**	**Average compensation**			**Average compensation of employees**			**Median compensation**			**5-sector hourly compensation**		
Deflator	**GDP**	**GDP**	**HCE**	**CPI**	**GDP**	**HCE**	**CPI**	**GDP**	**HCE**	**CPI**	**GDP**	**HCE**	**CPI**
Sub-periods:													
1961-1976	2.80	2.90	3.90	4.10	2.50	3.60	3.70	-	-	-	2.00	3.00	3.20
1976-1997	1.00	0.60	0.20	0.10	0.70	0.20	0.10	0.40	-0.10	-0.20	0.90	0.40	0.30
1997-2019	1.10	1.10	1.50	1.10	1.00	1.40	1.00	0.70	1.20	0.70	0.00	0.50	0.10
Long periods:													
1961-2019	1.50	1.40	1.60	1.50	1.30	1.50	1.40	-	-	-	0.80	1.10	1.00
1976-2019	1.00	0.80	0.90	0.60	0.80	0.80	0.60	0.50	0.50	0.30	0.40	0.50	0.20

Panel B: United States													
Measure	**Labour Productivity**	**Average compensation**			**Average compensation of employees**			**Median compensation**			**5-sector hourly compensation**		
Deflator	**NDP**	**NDP**	**PCE**	**CPI**	**NDP**	**PCE**	**CPI**	**NDP**	**PCE**	**CPI**	**NDP**	**PCE**	**CPI**
Sub-periods:													
1961-1976	2.30	2.20	2.50	2.10	2.10	2.40	2.00	-	-	-	2.10	2.30	2.00
1976-1997	1.20	1.10	1.00	0.80	1.20	1.10	0.90	0.40	0.20	0.00	0.20	0.10	-0.10
1997-2019	1.50	1.30	1.50	1.20	1.30	1.50	1.10	0.80	1.00	0.70	0.90	1.10	0.70
Long periods:													
1961-2019	1.60	1.50	1.60	1.30	1.50	1.60	1.30	-	-	-	1.00	1.10	0.70
1976-2019	1.30	1.20	1.30	1.00	1.20	1.30	1.00	0.60	0.70	0.40	0.50	0.60	0.30

*Growth rates for production/ non-supervisory worker typical compensation calculated up to 2018 due to data availability
Note: Periods selected to correspond to periods used for regression analysis (which, in turn, correspond to the availability of different data series).

logical 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 United States.

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

These productivity and pay trends in Canada and the United States 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 United States, the labour 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 (Drummond, 2011).

The gap between Canadian and American productivity growth has also attracted attention. After Canada's stronger business sector labour productivity growth until the mid-1980s narrowed its levels gap with the United States to 5 percentage points, Canada experienced slower productivity growth for the following quarter-century, with its productivity level dropping to 72 per cent of the US level in 2010 (a 28 point gap), before closing to 26 points in 2016 (Sharpe and Tsang, 2018).[21]

Despite Canada's relatively poor productivity performance and worse average pay growth than in the United States since 1976, remarkably median pay growth has been about the same in these countries (as illustrated in Table 1 and Chart 1b). This is in line with a smaller recorded increase in income inequality over recent decades in Canada than the USA (Green *et al.* 2016).

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 United States 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 incremental 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 substantially faster growth in productivity than in median pay in the United States, there was still linkage between the growth rates of the series. This suggests that incremental 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 (i.e. statistically independent) to productivity growth (like, perhaps, globalization or the declining bargaining power of workers) are suppressing pay and therefore responsible for the rising productivity-pay gap. This section updates this analysis for the United States 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

21 Gu and Willcox (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.

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 (i.e. statistically independent) to productivity growth have been putting downward pressure on worker 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 in addition to productivity, these other factors will not affect estimation of β as long as they are orthogonal (i.e. statistically independent) to productivity growth. The parameter α is a constant.

$$\begin{aligned} &\mathit{Compensation\ growth}_t \\ &\quad = \alpha + \beta \mathit{productivity\ growth}_t \end{aligned} \tag{1}$$

We estimate this model by regressing the year-on-year change in hourly compensation on the change in labour productivity, controlling for the unemployment rate (see below). As described above, we use four separate measures of compensation in our regressions: two measures of average compensation (average compensation for all workers, average compensation for employees only), and two measures of typical compensation for each country (median compensation and production/nonsupervisory compensation for the United States; median compensation 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 United States, 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 labour productivity and the current and lagged three-year moving average of the unemployment rate.[22] We use moving 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 labour productivity. In the appendix, we also show results from a similar regression with five-

22 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.

year moving averages.

$$
\begin{aligned}
&\frac{1}{3}\sum_{0}^{2}\Delta log\ comp_{t-i} \\
&\quad = \alpha + \beta\frac{1}{3}\sum_{0}^{2}\Delta log\ prod_{t-i} \\
&\quad + \gamma\frac{1}{3}\sum_{0}^{2} unemp_{t-i} \\
&\quad + \delta\frac{1}{3}\sum_{0}^{2} unemp_{t-i-1} + \epsilon_t
\end{aligned}
\tag{2}
$$

In all specifications we control for the unemployment rate, for two reasons. First, as an indicator of labour market slack/tightness, the level of unemployment is likely to affect bargaining dynamics. In the context of a slack labour 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 more unemployed workers are searching for jobs at that time. Second, as a proxy measure of general labour 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

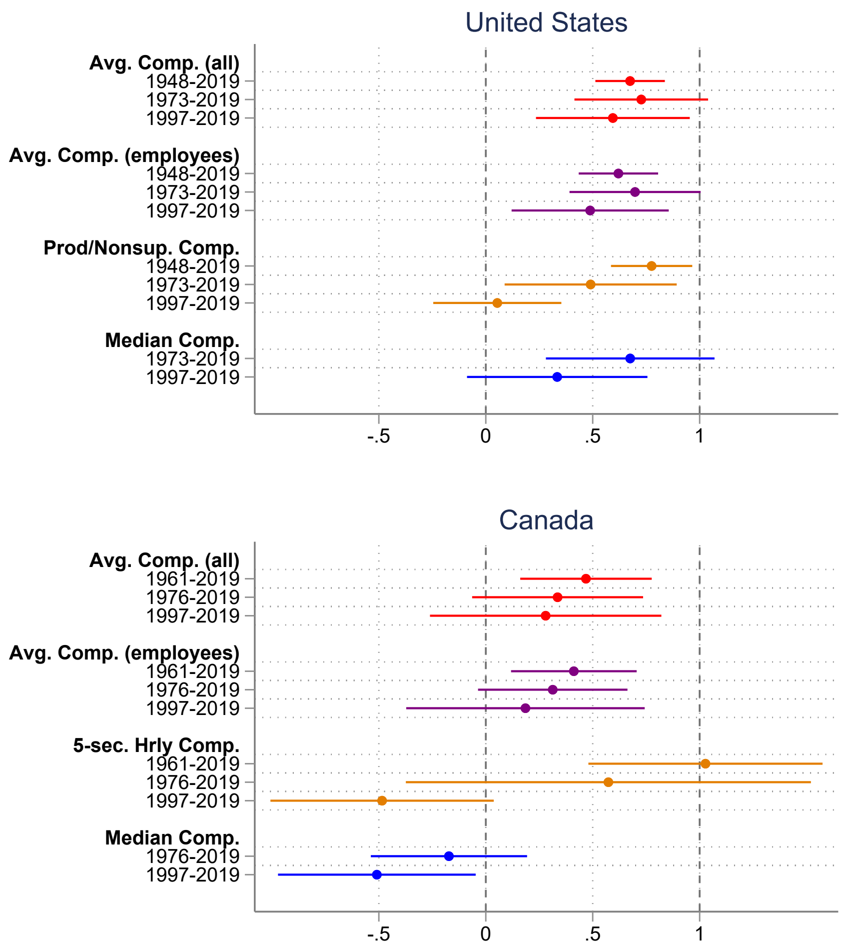
We run our baseline regression in equation (2) above for both the United States and Canada, over various time periods. Table 2 shows our regression results for the United States and Table 3 for Canada. Chart 2 charts the coefficients estimated for the compensation-pay relationship from these regressions (i.e.in equation (2) above), using the PCE or HCE chain-linked consumer price deflator. Each dot and line in the chart shows the point estimate and 95 per cent confidence interval (respectively) for this coefficient in the three-year moving average regression in equation (2). In addition, Chart 3 shows the cyclically-adjusted by residualizing these variables on the unemployment rate, the lagged unemployment rate (both three-year moving averages), and a constant. These results shed light on the degree of productivity-pay delinkage in the United States and Canada (discussed in turn below).[23]

United States

For the United States, these regression results suggest that average compensation 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), regardless of the price deflator used, the coefficient on

23 In the appendix, we present results with five-year rather than three-year moving averages.

Chart 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 labour productivity, the unemployment rate, and the lagged unemployment rate (with all variables taken as 3-year moving averages). Variables in US regressions are hourly net labour 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 (purple), 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 labour productivity for the entire economy (real NDP/hours worked) and hourly real compensation for all employed persons (red), hourly real average compensation for employees (purple), hourly real average compensation for hourly-paid workers in five 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.

Table 2: Coefficients From Regressions of Average Compensation on Productivity, United States, 3 Year Moving Averages

Period	1948-2019			1973-2019			1997-2019		
Specification	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Comp. deflator	NDP	PCE	CPI	NDP	PCE	CPI	NDP	PCE	CPI
Dep. Var.: Average Hourly Compensation, all employed persons, from national accounts, 3yma									
Labour Productivity	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									
Labour Productivity	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									
Labour productivity	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									
Labour Productivity	-	-	-	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

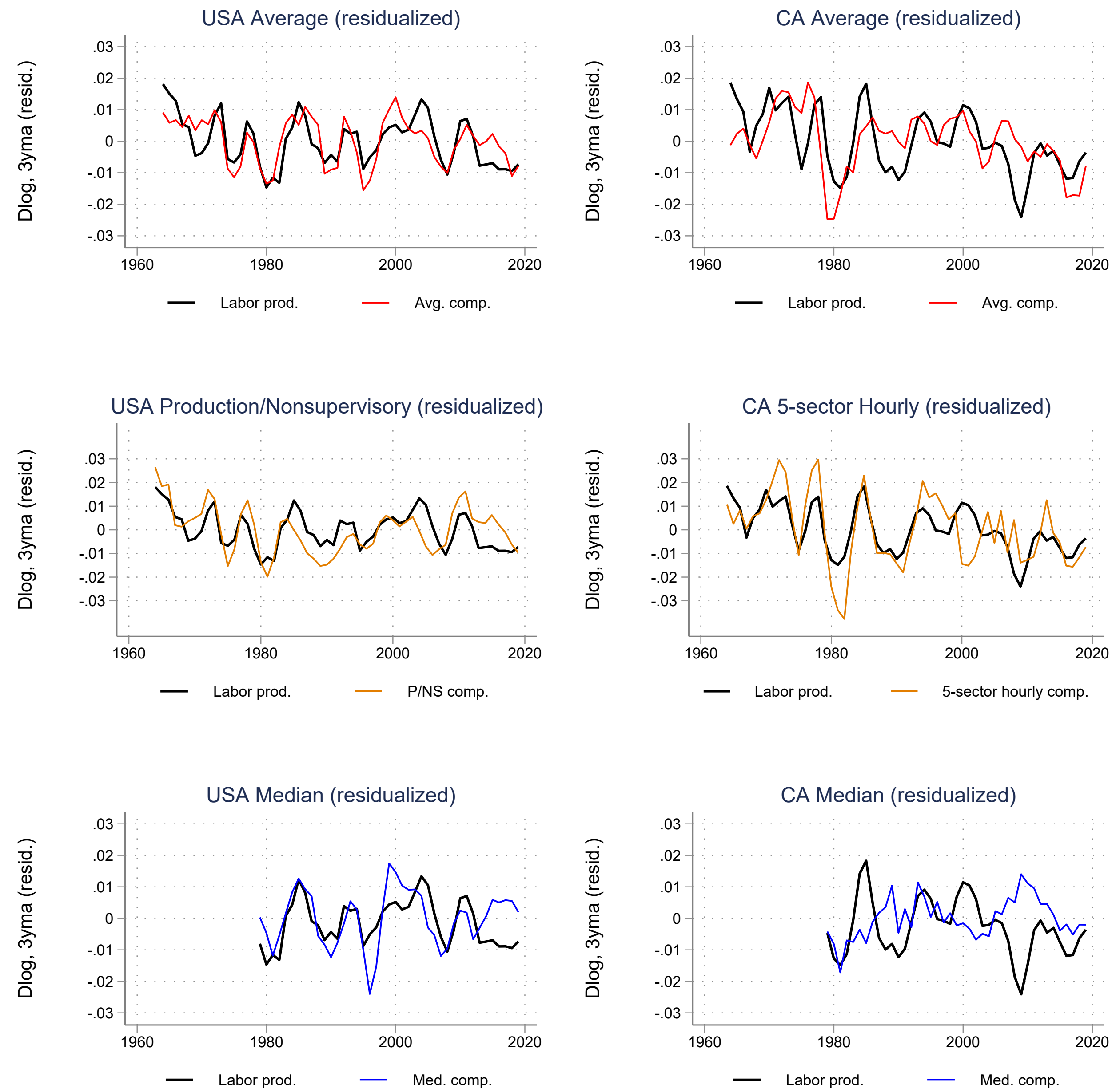
Note: Each cell contains the coefficient estimate on hourly labour productivity (change in log, 3y trailing moving average) from a regression of the change in log compensation (3yma) on the change in log net hourly labour productivity (3yma), controlling for the current and 1-year lagged unemployment rate (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.*

Table 3: Coefficients From Regressions of Average Compensation on Productivity, Canada, 3 Year Moving Averages

Period	1961-2019			1976-2019			1997-2019		
Specification	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Comp. deflator	GDP	HCE	CPI	GDP	HCE	CPI	GDP	HCE	CPI
Dep. Var.: Average Hourly Compensation, all employed persons, from national accounts, change in log, 3yma									
Labour productivity	0.50***	0.47***	0.69***	0.27	0.34*	0.39**	0.32***	0.28	0.24
(ch. log, 3yma)	(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, change in log, 3yma									
Labour productivity	0.44***	0.41***	0.64***	0.24	0.31*	0.37**	0.23**	0.19	0.15
(ch. log, 3yma)	(0.09)	(0.15)	(0.13)	(0.17)	(0.17)	(0.17)	(0.08)	(0.26)	(0.21)
Dep. Var.: Compensation of Hourly-Paid Workers in Five Sectors, change in log, 3yma									
Labour productivity	1.06***	1.03***	1.25***	0.50	0.57	0.63	-0.44*	-0.48*	-0.53**
(ch. log, 3yma)	(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, change in log, 3yma									
Labour productivity	-	-	-	-0.24*	(0.17)	(0.11)	-0.47***	-0.51**	-0.55***
(ch. log, 3yma)	-	-	-	(0.14)	(0.18)	(0.19)	(0.16)	(0.22)	(0.17)
Obs.	56	56	56	41	41	41	20	20	20

Note: Each cell contains the coefficient estimate on hourly labour 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 labour productivity (3yma), controlling for the current and 1-year lagged unemployment rate (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.* Observations refer to 3-year trailing moving average periods for annual change in log data. For example, the 56 observations in column (1) are for each year from 1964-2019, where the data point for 1964 incorporates data from 1961-2, 1962-3, and 1063-4.

Chart 3: Cyclically-adjusted Productivity and Compensation Growth, United States and Canada



Note: Each chart shows the 3-year trailing moving average of the change in log of labour productivity and of compensation, cyclically-adjusted by residualizing these variables on the unemployment rate, the lagged unemployment rate (both three-year moving averages), and a constant. 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 five 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.

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 United States is even more apparent when looking at the link between productivity and either the average compensation of production/nonsupervisory workers, or 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 1973-2019 sample for which median compensation data is available. Breakpoint tests in years 1997, 2000, and 2008 (Appendix Table 5) fail to reject the null hypothesis of no structural break for *average* compensation, but suggest structural breaks in the productivity-pay relationship for both of our typical worker measures: production/nonsupervisory compensation and median compensation. It is possible that this reflects a decline in the linkage between productivity and typical workers' pay in recent decades. It is also possible that, to the degree that there may be a growing bias in our estimates of median or production/nonsupervisory compensation over time (due to the growing influence of the non-wage compensation imputation), this may lead to attenuation of the estimated regression coefficients over time.

Chart 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 workers. 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 labour market of the late 1990s.

Canada

The regression results for Canada are shown in Table 3. For Canada, average compensation (all measures deflated using the HCE price index) is positively and significantly 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 5). Coefficients are relatively similar regardless of which price deflator is used to deflate compensation, as can be seen by comparing across columns (1)-(3) in Table 3.

Results for typical compensation are a little harder to interpret. One of our typical compensation measures, 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 this five-sector hourly compensation measure in Canada in 1997 (Appendix Table 5), and there is no evidence of this 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.[24]

Chart 3 illustrates the dynamics behind this: in the early 2000s, cyclically-adjusted productivity growth rose (and so did cyclically-adjusted average compensation growth), but cyclically-adjusted compensation growth in our five sectors of interest moved in the opposite direction, spiking sharply downwards. In contrast, in the Great Recession era there was a large decline in cyclically-adjusted productivity that was not matched by as large of a decline in cyclically-adjusted real compensation for typical workers in these five sectors.

Finally, there is no evidence of linkage for our other typical compensation measure – median compensation. Estimated coefficients are negative, with large standard errors, for both the 1976-2019 period and the more recent 1997-2019 period. Mechanically, this is driven by the 1997-2019 period featuring very few meaningful fluctuations in the growth rate of median compensation, with an exception during the Great Recession period, where the cyclically-adjusted rate of productivity growth fell but the cyclically-adjusted rate of median compensation growth rose.

We treat these results for median compensation 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. In addition, to the extent that our imputation of non-wage compensation is becoming more significant over time, and to the extent this may introduce measure-

24 Comparisons across the specifications with different deflators for compensation illustrate that a differential growth rate of different price indices is not the primary driving force behind this result: whether compensation is deflated with the GDP deflator, CPI, or HCE, estimated coefficients for the most recent period are negative, with large standard errors.

ment error and/or upward bias in our estimate of total compensation, the bias introduced by this imputation may also be increasing over time.

Exploring US-Canada Differences

In the previous section, we found that the relatively strong linkage found between productivity and pay in the United States in Stansbury and Summers (2019) held with updated data. This affirms the conclusion of that previous analysis that factors orthogonal (i.e. statistically independent) to productivity have been acting to suppress average and typical compensation in the United States even as productivity growth has been acting to raise it.[25]

We have found 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 United States 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.[26] As a result, it is reasonable that international factors are likely to be a relatively more important determinant of worker compensation in Canada than in the United States.[27]

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 United States as a whole. Comparing Canada to the eight regions of the continental US as defined by the Bureau of Economic Analysis, Canada sits somewhere in the middle in terms of GDP and population.[28] Canada's population in 2019 was 37.6 million and its GDP in 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, but smaller in both population and GDP terms than the South West, Great Lakes, Mideast, Far West, or South East regions of the United States.

It should be noted, of course, that the US regions are not perfect comparators:

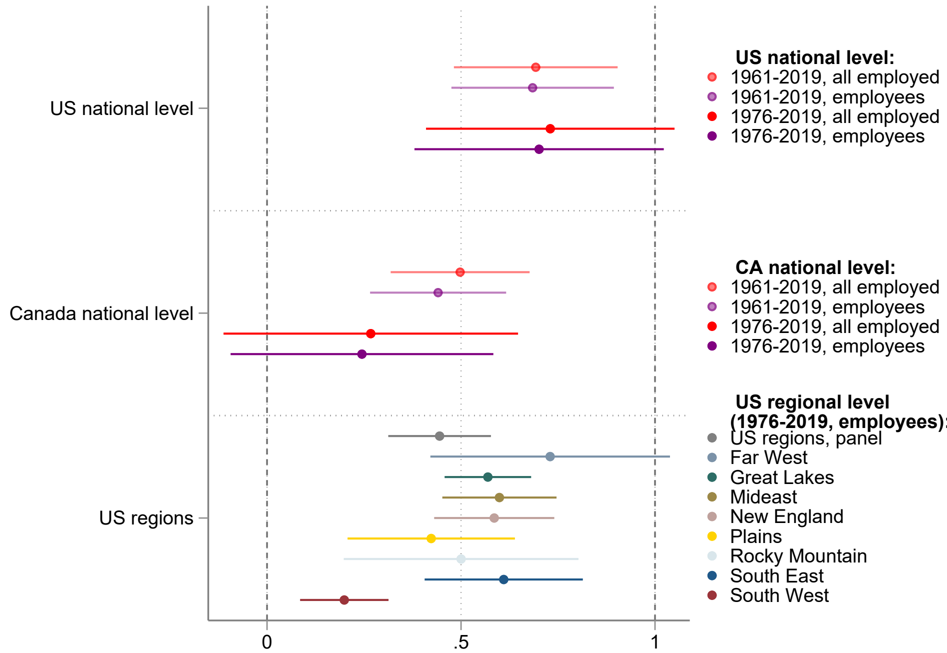
25 While the linkage between productivity and pay in the United States appears weaker for the first two decades of the 21st century than for the second half of the 20th century, this appears to be a result of extremely low cyclically-adjusted productivity growth in the post-Great Recession era not being matched by as large a decline in the cyclically-adjusted rate of compensation growth.

26 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.

27 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.

28 The eight regions and the states which comprise them are listed in Appendix Table 8.

Chart 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 labour 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 labour 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 labour 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 labour 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).

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 United States 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 labour 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 labour productivity and annual employee compensation from the BEA Regional Economic Accounts.[29] 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), the current and lagged regional unemployment rate (3-year moving average), and a constant. Coefficients from these regressions are shown in the bottom panel of Chart 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 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 US 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 labour productivity differentials between the United States 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 (United States minus Canada), controlling for the difference in unemployment. These regression results (in Appendix Table 4) suggest that a one percentage point faster productivity growth rate in the United States 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 United States? One notable feature of the Canadian economy

29 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 estimates of compensation per worker for the self-employed at the region level.

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 explain 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 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 compared to the transmission mechanism from productivity gains arising from, for example, new technologies.[30]

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 labour productivity. However, these divergences are attributed to slightly different forces. While the labour share of income has declined in both countries, and labour income inequality has also risen, the latter has been much more pronounced in the United States. As a result, despite much faster growth in both labour productivity and average compensation in the United States 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.

30 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 United States. 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 United States: the variance of the change in log productivity is the same or higher in Canada over the 1961-2019 period.

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 United States than in Canada.

In the United States there is also evidence for linkage between productivity and typical workers' pay, although the magnitude appears to attenuate somewhat over time. In Canada, the evidence on typical workers' pay is more mixed and depends on both the measure chosen and the time period: there is evidence of strong linkage of productivity with our measure of the compensation of hourly-rated workers in five sectors (although estimates in more recent periods become 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)), and there is no evidence of linkage of productivity with our measure of median compensation. Given the substantial concerns about measurement error in our measures of typical compensation in Canada, particularly median compensation, these estimates should be treated with caution however.

We explore possible explanations for the difference in the degree of estimated linkage between productivity and average compensation in the United States and Canada. In particular we emphasize the possibility that since Canada is a smaller, more internationally open economy than the United States, 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 United States 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 labour-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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