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Time series analysis of GDP, employment, and compensation in Canada controlling for nonlinear dynamics

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Abstract

This paper examines the relations between real GDP, real labour compensation per hour, and market hours worked in Canada over the period 1981Q1 to 2017Q4. We employ causality testing using the vector autoregression lag augmented approach based on possibly integrated or cointegrated processes. This approach avoids the pre-test bias associated with most other causality testing approaches. In addition, we control for the asymmetric impact of real GDP growth on the evolution of these variables. The first finding is that of unidirectional causality from hours worked to real GDP and bidirectional causality between real compensation per hour and market hours worked. Second, we find that the variables have a unique long-run cointegrating relationship. Third, controlling for the non-linear dynamics is important in analysing the causal relations among these variables.

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1. Introduction

We expound on the issues pertaining to the analysis of the relations between GDP, employment, and labour compensation; conduct a related statistical exercise using Canadian data; and present our findings. These variables play an important role in determining labour productivity and living standards. Accordingly, their analysis from different perspectives has continued to occupy the attention of both academicians and policymakers (Gu & Yan, 2017; Krugman, 1994; Sharpe, Arsenault, & Harrison, 2008). Despite this attention, however, neither the sign nor significance of the causal relations among these variables has been definitively settled empirically and theoretically.

In the basic short-run models of the interactions of labour and product markets, an increase in the compensation of workers can cause substitutions in the use inputs. Specifically, the increase in compensation can cause a decrease in the demand for labour, and an increase in the demand of complimentary inputs such as capital (e.g., machinery and equipment). At the same time, to the extent that substitution is not possible, limited, or costly, output may decrease concomitantly with the increase in labour compensation (Cahuc & Zylberberg, 2004). Similarly, within these basic models increases in GDP are generally associated with a non-negative change in the quantity of employment demanded. However, as these models are modified to incorporate more complexities to reflect real world frictions and imperfections, the interlinkages among compensation, employment, and GDP become less certain a priori.[1] In addition, whether employment is measured as hours worked or number of workers can impact the sign and significance (statistical and economic) of its correlation with GDP and compensation, as each measure could evolve differently over the business cycle (Abraham & Haltiwanger, 1995; Otani, 1978; Wilson, 1960). For these reasons, the dynamics of these variables over the business cycle has remained a puzzle (Hansen, 1985; Shimmer, 2005).

This puzzle is reflected in the results from the empirical literature. For example, several authors have found a positive relationship between real compensation per hour worked and employment (Bodkin 1969; Dunlop, 1938; Tarshis, 1939). On the other hand, others have found negative but mostly a non-contemporaneous relationship, no relationship at all, or a relationship that was time varying (Neftci, 1978; Sahin, Tansel, & Berument, 2014; Sheehan, Derody, & Rosendale, 1979). At the centre of the objective to disentangle causal relations among these variables is trying to determine which labour market policies should be implemented with a view to raise living standards and thus economic welfare.

Our paper seeks to establish causal relations between GDP, hours worked, and real labour compensation using Canadian business productivity data over the period 1981Q1 to 20174Q4 while controlling for the asymmetric growth in GDP by including the current depth regression (CDR) effect. The CDR effect captures the tendency of GDP to grow faster when recovering from recessions compared to when it grows during expansions. Our focus is on determining causal relations not to model the data per se from a theoretical perspective, although our results could form the basis for which benchmarks for calibration and simulated methods might be determined. There are three key findings. First, hours worked causes real GDP but not vice versa. At the same time, there is bidirectional causality between hours worked and real compensation

[1] These complexities and frictions are numerous. They include the impact of unions through wage bargaining, workforce composition, oligopolistic firm behaviour, efficiency wages, biased technical change, adjustment costs, informational asymmetries, complementarity and increased substitutability among the inputs of production, changes in labour supply, and long-run considerations (Cahuc & Zylberberg, 2004; Manning, 2010).

per hour. Second, we find that there is one cointegrating vector among the variables. This indicates the existence of a stable long-run equilibrium relationship and reinforces the causality findings. Third, in analysing the causal relations among these variables, controlling for the non-linear dynamics is important. Subordinately, we also find that the correlation of the growth rates in real GDP and compensation per hour is positive but not statistically significant at conventional levels. In addition, the contemporaneous correlation between the CDR effect and real compensation per hour is negative. At the same time, there is a noticeably strong countercyclical trend in labour's share in current dollar GDP over the business cycle. We situate the contribution of our paper in section 2 and describe the data and methods in section 3. The results are presented in section 4 and section 5 concludes.

2. Situating our contribution to the literature

Our paper can be contrasted most closely with the study by McFarlane, Das, and Chowdhury (2014), who made an important contribution in understanding the real wage, GDP, and employment (number of workers) relationship in Canada. They found one directional causation running from employment to real wages and bidirectional causation between employment and GDP. In contrast to the neoclassical expected result, they found that real wage growth could not explain the dynamics of employment. A point of commonality in the econometric approach with their paper and ours is that we account for the potential impact of the nonlinear growth in GDP on these variables over the business cycle by including the CDR effect. Omitting this effect from the causal testing could lead to biased inference (Bradley & Jansen, 1997; Jansen & Oh, 1999).

At the same time, McFarlane et al. (2014) serves as a point of departure for our study as we expand on their work in several ways. First, they use real wages as a measure of labour compensation. However, this measure does not include all the nonwage benefits that an employee receives. Consequently, they omit an important part of labour remuneration that has a role to play in an employee's work effort and accordingly the determination of output. In Canada, nonwage benefits include contributions an employer makes to employer-sponsored pension plans, employee dental, medical, and life insurance plans, leave entitlements for the employee, employee assistance programs, employment insurance program, payments to the Canada and Quebec pension plans, and so forth. These benefits vary across occupational groupings, educational attainment, firm's level of unionization, and other factors (Marshall, 2003). While the data we use does not separate out nonwage benefits from wages and salaries, some estimates put these benefits as high as 35% of an employee's salary despite attempts by employers to lower this in recent years (Smith, 2015; Stewart 2015).

Second, in McFarlane et al. (2014) the period of their analysis is 1994Q2 to 2012Q3 while ours is a much longer 1981Q1 to 20174Q4 and, therefore, our results can speak to the evolution of these variables over a longer time horizon. Third we use national accounts productivity data on the business sector rather than all sectors in Canada as was done in their study. The business sector excludes the government, non-profit institutions, private households (including imputed rent for owner occupied dwellings), the real estate, rental and leasing industry, and other non-commercial activities. By examining the business sector, we examine an economic sphere where activities are behaviourally less dissimilar and thus our estimates could potentially be subject to less noise. Third, we use the causality testing approach that follows the vector autoregression method based on possibly integrated processes developed by Toda and Yamamoto (1995) and Dolado and Lütkepohl (1996). This approach is different from the traditional Granger causality testing used by McFarlane et al. (2014). The method we use avoids the pre-test bias known to occur with the traditional approach. The pre-test bias occurs with the traditional approach because one proceeds with hypothesis testing about the coefficients after modelling the data on the basis of tests to determine the orders of integration or cointegration. Fourth, McFarlane et al. (2014) use employment rather than hours worked. Yet, it is the latter that is generally more responsive to changes in the business cycle. In addition, as noted by Ohanian and Raffo (2012), analysing hours worked is important for better cross country comparisons and the analysis of labour market policies. To our knowledge, no other study uses the Canadian productivity data to analyse GDP, employment in terms of hours worked, and real labour compensation as we do.

3. Data and Methods

3.1 Data

The period of our analysis is 1981Q1 to 2017Q4. We obtain the data from the website of Statistics Canada's Canadian socioeconomic (CANSIM) database of the indices of productivity (table 383-0008) and consumer prices (table 326-0020). Statistics Canada productivity measures are provided in the quarterly productivity accounts and covers only the business sector. The estimates from the productivity accounts are derived in part from administrative data files (e.g., Canada Revenue Agency Payroll Deduction), Statistics Canada surveys (e.g., Labour Force Survey, Survey of Employment and Payroll Hours, and Employment Insurance Statistics) and other sources. The data are consistent with the principles set forth in the Canadian System of National Accounts and thus with the estimates of national income and expenditure published quarterly and the industry accounts estimates published monthly by Statistics Canada.[2]

Hours worked is time allocated to market work and includes regular work, overtime work, moonlighting, time spent on breaks, travel, and training. It excludes time spent on vacation, parental or maternity leave, sick leave, and leave for personal reasons. Hours worked covers jobs that are employer based, in unincorporated businesses, own account self-employment, and family jobs that are not paid. In regard to the accuracy and reliability of the hours worked estimate, as it is based in part from the report of payroll hours that employees work it is subject to less heaping than if it were based solely on the self-reported hours worked by the employee (Lachowska, Mas, & Woodbury, 2018). Heaping occurs where hours work reported tends be constrained from above although the actual hours worked is greater. For example, employees may tend to report 40 hours worked irrespective of the fact the actual hours worked is greater as they exclude overtime work at their main job and the time working at a second or third job.[3]

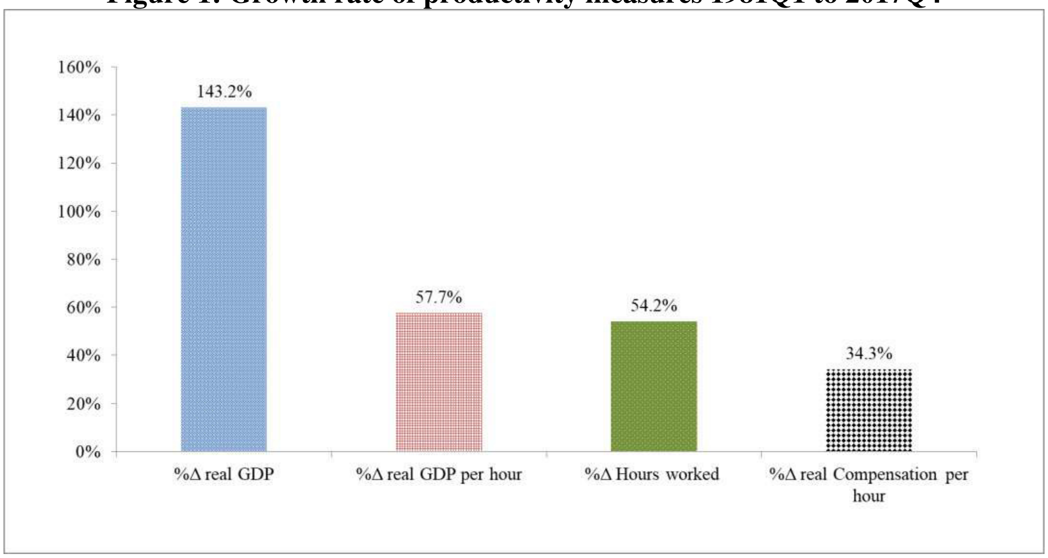
Compensation includes all remuneration in kind or cash for labour supply services provided to produce output. This measure includes an imputed labour income for those workers who are self-employed or work in unpaid family business (e.g., farms). The consumer price index (CPI) used to construct real measures of compensation is the *All-items CPI* (v41690973 in

[2] Further details on the sources and methods on these data are available from: http://www23.statcan.gc.ca/imdb/p2SV.pl?Function=getSurvey&SDDS=5042

[3] One data source that avoids the issue of heaping in hours worked is time use or budget surveys. These surveys require the respondent to account for their entire time over a 24-hour period. In so doing they tend to provide a more accurate measure of the time spent on various activities including the hours spent on market work. Unfortunately, this data source does not provide the link to the productivity measures we wish to examine nor is the time series of an appropriate frequency. Our results should be viewed in light of the limitations inherent in using hours worked from a combination of administrative and self-reported data sources.

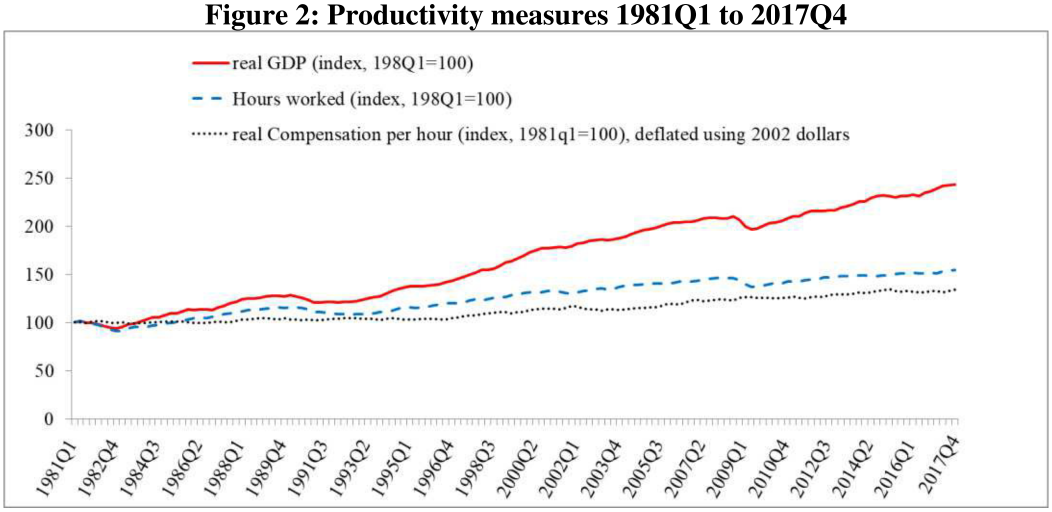
CANSIM), this CPI is based on a fixed-basket concept rather than a cost-of-living concept.[4] Nominal compensation was transformed to 2002 dollars using the All-items CPI. This transformed measure was then divided by hours worked to get real compensation per hour worked. The productivity data were rebased so that 1981Q1 equals 100. In the tables that display the results of our empirical analysis in section 4, real GDP is shown as GDP, hours worked as Hrs_wrk and real compensation per hour as $Comp\_hr$. Figure 1 and Figure 2 chart the growth rate in real GDP, real GDP per hour, real compensation per hour, and hours worked over the sample period.

Figure 1: Growth rate of productivity measures 1981Q1 to 2017Q4



Source: Authors' calculations based on Statistics Canada's CANSIM tables 383-0008 & 326-0020

Figure 2: Productivity measures 1981Q1 to 2017Q4



Source: Authors' calculations based on Statistics Canada's CANSIM tables 383-0008 & 326-0020

[4] A true cost-of-living index would take into consideration the ability of individuals to change their consumption patterns as prices change to keep their utility level constant. Since the CPI ignores this, it provides more of an upper bound in terms of the impact of price changes on cost-of-living.

From these figures we observe that real compensation growth, at 34.3%, lagged growth in real GDP per hour worked, at 57.7% over the period. In addition, hours worked co-moved more with real GDP per hour worked compared to real compensation per hours worked.
The CDR effect is included in our analysis to capture the nonlinear response of GDP growth to recessions and expansions (see Altissimo & Viloante, 2001; Beaudry & Koop 1993). It is operationally defined as $CDR_t = \max(GDP_t)_{s=0}^{t} - GDP_t$. Here $\max(GDP_t)_{s=0}^{t}$ is the maximum value of the natural logarithm of GDP between time 0 and t. The CDR is zero when GDP expands and positive when it contracts. The CDR effect is included as a share of real GDP.

3.2 Methods

We conduct the empirical analysis using the following steps. To start, we report the pairwise correlations among the variables and discuss any noteworthy features. We then proceed with the causality testing framework expounded by Toda and Yamamoto (1994, 1995) and Dolado and Lütkepohl (1996). This method employs a vector autoregression lag augmented approach based on possibly integrated processes wherein the exclusion tests for causality are valid irrespective of the order of integration or cointegration among the variables. In other words, their approach is robust to the order of integration of the variables and as such one can construct an augmented vector autoregression (VAR) in which the asymptotic chi-squared distribution of the Wald statistic for causality testing is valid. Ordinarily, causality testing is not valid in the presence of variables that are not all stationary, namely integrated of order zero. In addition, their approach circumvents the pre-test bias associated with modelling the data and then testing hypothesis about causation when the primary objective was assessing causation in the first place. This approach is suitable since the primary objective of this paper is causality testing.

In this causality testing framework, we determine the maximum order of integration among the variables, call this d. We use the Augmented Dickey Fuller (ADF) and Phillips-Perron (PP) unit root tests with intercept and trend. Unit root testing is important because in the presence of a unit root, inference based on empirical analysis may lead to incorrect inferences being drawn about the true nature of the relationship among the variables being examined. For these tests, there is always the question concerning the maximum number of lags on the differences that should be included. The lags to include is important to ensure that the data generating process of the series being examined is correctly captured so that the unit root tests can properly inform the order of integration of the series with as little bias as possible. This is less of a problem for the PP test because it corrects the test statistic for autocorrelations and heteroscedasticity. However, for the ADF test the number of lags must be chosen. It is generally agreed in the time series literature based on Monte Carlo experiments that is better to include too many lags than too few (Schwert, 1986; Ng & Perron, 2001). In light of this, we adopt the Schwert lag selection rule of thumb to select the maximum lags.

For the PP test we choose the same number of lags as that selected by the ADF test, although the results of the former are invariant to the number of lags chosen. The next step is to fit a well specified VAR in levels without regard to the order of integration or cointegration of the variables. To do this, we include the CDR term as an exogenous parameter and then use the reported final prediction error (FPE), Akaike's information criterion (AIC), Schwarz's Bayesian information criterion (SBIC), the Hannan and Quinn information criterion (HQIC) and the likelihood-ratio (LR) test statistics to select the initial starting lag for the VAR. Let the lag length for this be p. We then formulate the VAR with $p + d$ lags, where d represents the maximal order of integration among the variables from testing based on the PP and ADF unit root tests.

The d lags are treated as exogenous and the p lags are treated as endogenous. After this, the resulting VAR is checked for model adequacy, particularly whether it is stable wherein the moduli of the eigenvalues are strictly less than unity. If the stability condition is not satisfied additional lags are added until stability is achieved at a new p lag. The final VAR will have $p + d$ lags + exogenous CDR term as shown in equations (1) to (3) below.

$$ln(X_t) = k_1 + \sum_{i=1}^{p+d} \alpha_{1i} ln(X_{t-i}) + \sum_{i=1}^{p+d} \beta_{1i} ln(Y_{t-i}) + \sum_{i=1}^{p+d} \gamma_{1i} ln(Z_{t-i}) + \delta_1 CDR_t + e_1 \quad (1)$$

$$ln(Y_t) = k_2 + \sum_{i=1}^{p+d} \alpha_{2i} ln(X_{t-i}) + \sum_{i=1}^{p+d} \beta_{2i} ln(Y_{t-i}) + \sum_{i=1}^{p+d} \gamma_{2i} ln(Z_{t-i}) + \delta_2 CDR_t + e_2 \quad (2)$$

$$ln(Z_t) = k_3 + \sum_{i=1}^{p+d} \alpha_{3i} ln(X_{t-i}) + \sum_{i=1}^{p+d} \beta_{3i} ln(Y_{t-i}) + \sum_{i=1}^{p+d} \gamma_{3i} ln(Z_{t-i}) + \delta_3 CDR_t + e_3 \quad (3)$$

Here X_t, Y_t, and Z_t, are real GDP, real compensation per hour, and hours worked respectively; k_1, k_2, and k_3 are constants; p is the optimal order of the VAR, d is the maximal order of integration among the variables; and e_1, e_2, and e_3 are white noise error terms. As noted by Toda and Yamamoto (1995), for a VAR like ours with few variables and long lag length the inefficiency will generally be small. However, the pre-test biases on the basis of determining orders of integration or cointegration will be more pronounced. This is why as our interest is in causal relations we follow the lag augmented VAR approach.

We next conduct a Wald exclusion test for causality among the variables, which Toda and Yamamoto (1995) show to be asymmetrically valid for testing. In this test, the first p lags are treated as endogenous parameters to be excluded while lag d and the CDR term are treated as exogenous parameters. We also test for the significance of controlling for the nonlinear asymmetries in the growth of GDP. The final step is a cross validity check using the Johansen test for cointegration among the variables. If variables are cointegrated there exists a long run or equilibrium relationship among them. The Johansen test for cointegration is conducted if the variables were all integrated of the same order. The importance and relevance of this step follows from the fact that if a set of time series are cointegrated, there must be causality among them, either one way or two way, although the converse is not true (Clarke & Mirza , 2006; Toda & Phillips, 1994; Zapata & Rambaldi, 1997).

4. Results

4.1 Unconditional Pairwise Correlations

Before delving into our main causation findings, we report the unconditional pairwise correlations for the growth rates of the variables. While these correlations do not control for confounding factors, they provide a general perspective on the sign and significance of the contemporaneous relations among the variables. From Table I, we observe that the correlation between GDP and hours worked growth is positive. The correlation between hours worked and real compensation per hour is negative. This table also shows that the CDR effect term is negatively correlated with real GDP, hours worked, and real hourly compensation. As this variable is positive during contractionary periods of the business cycle, this result is consistent with the notion that such periods tend to, on average, exert downward pressure on the quantity of labour services demanded and the remuneration per hour paid.

We note that the correlation between the CDR and compensation per hour is weakest among the variables both in absolute value and statistical significance. Given this, it is not surprising that while real hourly compensation is positively related to GDP growth, this correlation is not significant at conventional levels. On this point, part of the reason could be with how labour share, nominal labour compensation divided by current dollar GDP, responds to changes in real GDP over the business cycle.

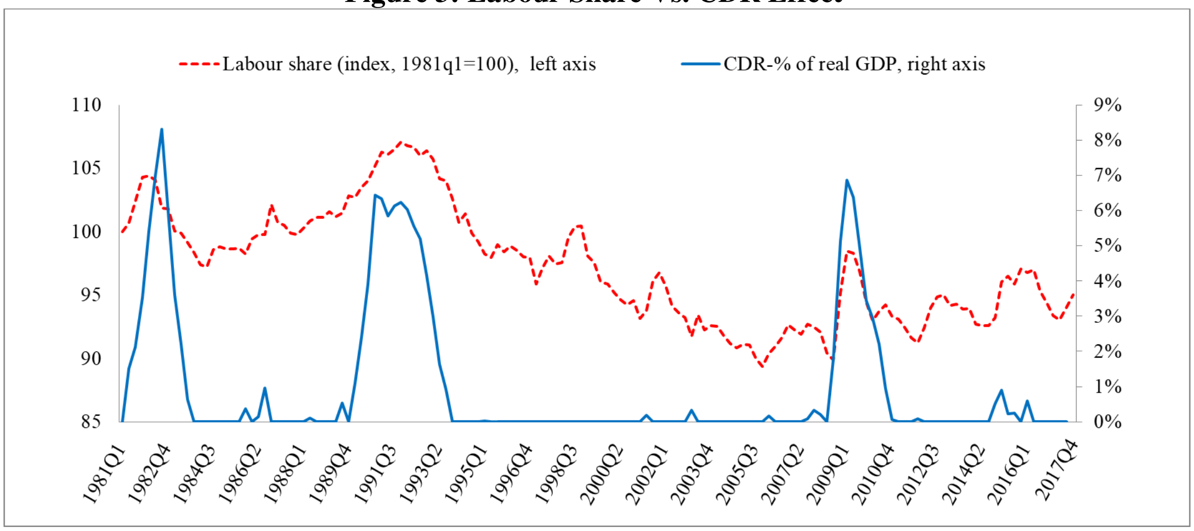
Table I: Pairwise Correlations

	$\Delta ln(GDP)$	$\Delta ln(Hrs\_wrk)$	$\Delta ln(Comp\_hr)$	CDR
$\Delta ln(GDP)$	1			
$\Delta ln(Hrs\_wrk)$	0.635***	1		
$\Delta ln(Comp\_hr)$	0.104	-0.231***	1	
CDR	-0.429***	-0.497***	-0.144*	1

Note: *** p<0.01, ** p<0.05, * p<0.1

Figure 3 plots labour share and the CDR effect. What we observe from this figure is that at times, labour share has been procyclical, countercyclical, and acyclical with changes in the business cycle.

Figure 3: Labour Share Vs. CDR Effect



Source: Authors' Calculation based on Statistics Canada's tables 383-0008 & 326-0020

While it can be generally said that labour share has been on a downward trajectory since 1981, of particular note is that during downturns labour share of GDP was markedly countercyclical. Of note also is that for long stretches from the mid-1990s up to the start of the Great Recession in 2008q4, labour share has trended downwards even though GDP growth was generally non-negative. This is consistent with the fact that real compensation per hours has largely not kept pace with real GDP growth per hour (productivity) as was discussed earlier on the basis of Figure 1 and Figure 2.

4.2 Unit Root, Causality, and Cointegration

Table II reports the PP and ADF unit root test results. The first half of the panel reports the test on the variables in levels. From this table, both the PP and ADF tests indicate that we fail to reject the presence of a unit root for the variables in levels. The second half of the panel reports the results on the first difference of the variables. In this case, both tests indicate that null-hypothesis is rejected at conventional levels of significance. Therefore, all our measures are integrated of order 1, non-stationary in levels but stationary in first difference. As the maximal order of integration is 1, this will inform the additional lag that we need to add to the VAR estimation in levels before proceeding to undertake causality testing.

Table II: Unit Root Tests

Variable	PP Test Statistic	ADF Test Statistic
$ln(GDP)$	-1.93	-1.74
$ln(Hrs\_wrk)$	-2.46	-2.62
$ln(Comp\_hr)$	-2.48	-2.34
$\Delta ln(GDP)$	-6.62***	-3.37*
$\Delta ln(Hrs\_wrk)$	-6.74***	-3.67**
$\Delta ln(Comp\_hr)$	-11.56***	-3.53**

Note: ***/** indicates that we reject the null hypothesis of a unit root at the less than 1% /5% level respectively

To construct the VAR in levels, we first get a starting number of lags based on the various information criteria with the CDR effect term included as an exogenous parameter. These are shown in Table III.

Table III: Lag Selection Criteria

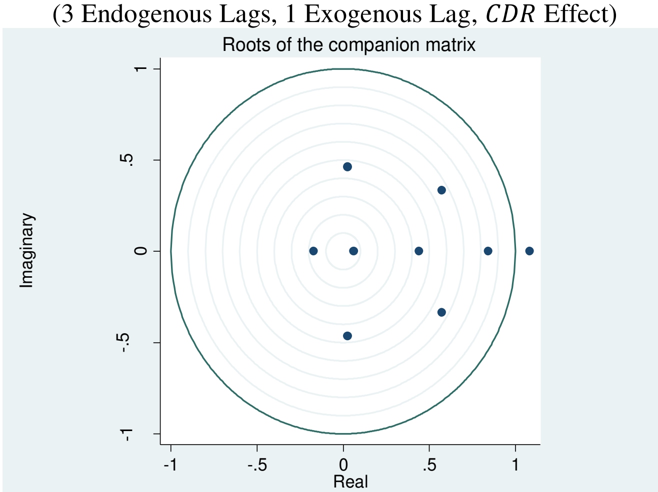
Lag	LR	FPE	AIC	HQIC	SBIC
0	-	0.0	-9.8	-9.8	-9.7
1	1632.4	0.0	-21.0	-20.9	**-20.7***
2	36.5	0.0	-21.1	**-20.9***	-20.7
3	**24.2***	**1.3e-13***	**-21.2***	-20.9	-20.5
4	13.8	0.0	-21.2	-20.8	-20.3

Note: * indicates lag selected by lag section criteria

The LR, FPE and AIC all suggest a lag of 3 on the levels. As such we proceed to estimate the VAR in levels with 3 endogenous lags, 1 exogenous lag, and the CDR effect term. The resulting regressions are omitted here because they are not of ultimate interest. However, we reject this specification on the basis that the resulting VAR is not stable as shown in Figure 4. Because of this, the lags on the endogenous variables are increased until the VAR stability conditions are satisfied. This occurred when we include 5 lags endogenous lags for the underlying VAR. As shown in Figure 5, in this case the VAR stability conditions are satisfied.

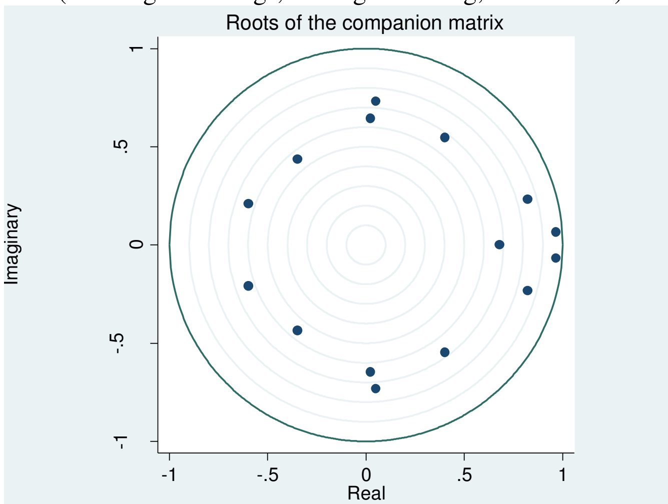
Figure 4: VAR Stability Test 1: Eigenvalue Roots

(3 Endogenous Lags, 1 Exogenous Lag, CDR Effect)



Note: One eigenvalue in moduli is ≥ 1, stability violated

Figure 5: VAR Stability Test 2: Eigenvalue Roots
(5 Endogenous Lags, 1 Exogenous Lag, CDR Effect)



Note: Eigenvalues in modulus are < 1, stability satisfied

We use this VAR to conduct the causality test on the basis of the Wald lag-exclusion statistics of the endogenous lagged variables 1 through 5. The test results are reported in Table IV.[5]

Table IV: Toda and Yamamoto Granger Causality test

		$ln(GDP_t)$	$ln(Hrs\_wrk_t)$	$ln(Comp\_hr_t)$
Variables excluded	Lags 1 to 5 of $ln(GDP_t)$	-	8.62	5.26
	Lags 1 to 5 of $ln(Hrs\_wrk_t)$	2.47***	-	14.92**
	Lags 1 to 5 of $ln(Comp\_hr_t)$	4.93	10.11**	-
	All endogenous except own	28.18***	24.83***	23.15***

Note: (1) ***,**, and * indicate 1%, 5%, and 10% level of statistical significance or less respectively that the variable should be included in the specified equation. χ^2 –Wald values are presented.

From the GDP equation, we observe that there is unidirectional causality from hours worked to real GDP ($\chi 2$ value of 22.47). Real compensation per hour by itself does not affect GDP. From the hours worked and real hours worked equation, we find that there is bi-directional causality between hours worked and real compensation per hours worked.

A part of our methodology was controlling for the nonlinearities of the growth of GDP over the business cycle on the evolution of these variables within the causality framework. In Table V, we report whether such a control was warranted by way of an exclusion test on the CDR effect term. The results show that for the GDP, hours worked and the VAR system as a whole the CDR effect term is statistically significant. For real compensation per hour the effect is not statistically significant.

Table V: Exclusion test for the CDR effect

	$ln(GDP_t)$	$ln(Hrs\_wrk_t)$	$ln(Comp\_hr_t)$	All
$CDR_t = 0$	26.57***	20.18***	1.09	38.68***

Note: (1) ***,**, and * indicate 1%,5%, and 10% level of statistical significance or less respectively that the variable should be included in the specified equation. χ^2 –Wald values are presented.

[5] The full VAR results are reported in Appendix Table AI for the interested reader.

As a cross check of the validity and robustness of the causality findings, we conduct the Johansen cointegration test on the variables. As noted earlier, if a set of variables are cointegrated it follows that there must be either unidirectional or bidirectional causality among them. However, causality does not imply that a set of variables will be cointegrated. The Johansen cointegration test is reported in Table VI and is based on the underlying 5 exogenous lags of the basic VAR that was used to conduct the causality test.

Table VI: Johansen Multivariate Cointegration Test Results

Variables	Cointegrating relationships (r)	Eigen-value	Trace Statistics	Maximum-Eigen Statistics
$ln(GDP), ln(Hrs\_wrk), ln(Comp\_hr)$	$r = 0$	0.138	30.159**	20.204**
	$r \leq 1$	0.062	9.545	9.112
	$r \leq 2$	0.006	0.843	0.843

Note: (1) ** indicates the statistical significance at the 5 percent level respectively to reject the null hypothesis on the number of cointegration equation.

From the trace and maximum statistics of the Johansen test, we reject the null of no cointegration among the variables in favour of the alternative of at most one cointegrating vector among real GDP, hours worked and real compensation per hour. There is a unique long run relationship among the variables. Therefore, the causality results have been cross validated.

5. Conclusion

In this paper, we examine the relations between real GDP, hours worked, and real labour compensation per hour worked in Canada using its national accounts business productivity data over the period 19981Q1 to 2017Q4. Our focus is on assessing causation among the variables, not to explain their dynamics. To that end, we employ the vector autoregression lag augmented approach based on possibly integrated processes. We also control for the impact of the non-linear growth in GDP over the business cycle. Regarding the findings, we have three that are central. First, there is evidence of bidirectional causality between real compensation per hour and hours worked. In addition, GDP is caused by hours worked, but we do not find evidence to support that the converse holds true. Second, the variables have a long-run cointegrating relationship, findings that reinforce the causality results. Third, controlling for the non-linear dynamics was important in analysing the causal relations among these variables. Subsidiary to these central findings, we also find that the correlation in the growth rates in compensation per hour and real GDP is positive but statistically insignificant at conventional levels. At the same time, the CDR effect and compensation per hour is negatively related and there is a countercyclical trend in labour's share of compensation in current dollar GDP over the business cycle.

While our results rest on several statistical assumptions, they can form the basis for future research in the analysis of the dynamics among these variables. In particular, one worthwhile extension of our paper would be to analyse labour compensation, real value added, and hours worked by industry. Another extension could be to consider a regional analysis across the various provinces in Canada. These analyses could be examined within a framework based on theoretic grounds and use methods different from or complimentary with that of causality testing.

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Appendix Table AI: Vector Autoregression Results
(5 Endogenous Lags, 1 Exogenous Lag, CDR Effect)

VARIABLES	$ln(GDP_t)$	$ln(HRS\_wrk_t)$	$ln(Comp\_hr_t)$
$ln(GDP_{t-1})$	1.185***	0.235***	0.087
	(0.099)	(0.081)	(0.100)
$ln(GDP_{t-2})$	-0.259*	-0.290**	0.011
	(0.148)	(0.121)	(0.149)
$ln(GDP_{t-3})$	0.167	0.059	0.042
	(0.150)	(-0.030)	(0.152)
$ln(GDP_{t-4})$	-0.124	-0.030	-0.087
	(0.149)	(0.122)	(0.151)
$ln(GDP_{t-5})$	0.025	0.062	-0.137
	(0.146)	(0.120)	(0.148)
$ln(HRS\_wrk_{t-1})$	0.137	1.026***	0.280**
	(0.126)	(0.103)	(0.127)
$ln(HRS\_wrk_{t-2})$	-0.534***	-0.206	-0.606***
	(0.183)	(0.150)	(0.184)
$ln(HRS\_wrk_{t-3})$	0.338*	-0.102	0.552***
	(0.196)	(0.161)	(0.198)
$ln(HRS\_wrk_{t-4})$	-0.258	0.189	-0.169
	(0.203)	(0.166)	(0.205)
$ln(HRS\_wrk_{t-5})$	0.107	-0.131	0.120
	(0.188)	(0.154)	(0.190)
$ln(Comp\_hr_{t-1})$	0.193*	0.118	1.094***
	(0.099)	(0.081)	(0.100)
$ln(Comp\_hr_{t-2})$	-0.194	0.065	-0.503***
	(0.147)	(0.121)	(0.149)
$ln(Comp\_hr_{t-3})$	0.079	-0.246**	0.414***
	(0.152)	(0.124)	(0.153)
$ln(Comp\_hr_{t-4})$	-0.026	0.172	0.037
	(0.149)	(0.122)	(0.150)
$ln(Comp\_hr_{t-5})$	-0.146	-0.214*	-0.070
	(0.141)	(0.116)	(0.116)
Current Depth Regression Effect(CDR)-%GDP	-0.345***	-0.285***	0.119
	(0.081)	(0.066)	(0.082)
$ln(GDP_{t-6})$	0.030	0.021	0.084
	(0.103)	(0.085)	(0.104)
$ln(HRS\_wrk_{t-6})$	0.149	0.108	-0.138
	(0.118)	(0.097)	(0.097)
$ln(Comp\_hr_{t-6})$	0.087	0.089	-0.014
	(0.093)	(0.076)	(0.094)
Constant	0.233	0.360**	-0.002
	(0.194)	(0.159)	(0.196)
N	142	142	142
$Adj-R^2$	0.998	0.998	0.998

Notes: (1) Standard errors are in parentheses (2) *** p<0.01, ** p<0.05, * p<0.1