

Regional Differences in Canadian Labour Dynamics: A Broad Macroeconometric Investigation

by

Alisha Chicoine

BSc. (Honours), University of Victoria, 2012

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In the Department of Economics

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University of Victoria

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## **Supervisory Committee**

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#### **Supervisory Committee**

Dr. Judith A. Clarke, Supervisor  
(Department of Economics)

Dr. Kenneth G. Stewart, Member  
(Department of Economics)

## **Abstract**

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Dr. Judith A. Clarke, Supervisor  
(Department of Economics)

Dr. Kenneth G. Stewart, Member  
(Department of Economics)

We examine the dynamics of Canadian labour markets using data from the Survey of Employment, Payroll, and Hours and the Labour Force Survey from Statistics Canada from 1961-2014. Using univariate, and multivariate Vector Autoregressive methodology, we estimate Impulse Response Functions and perform Granger non-causal tests to explore the relationships between wages, employment, and unemployment. We demonstrate the difference in analysis gained from regional definitions and assumptions regarding the heterogeneity of provinces within the Canadian regional context. Transitory labour supply shocks propagate different directions and magnitudes in wage growth in Quebec and unemployment growth in Manitoba, New Brunswick, and Nova Scotia when estimating Impulse Response Functions in the provincial trivariate VAR framework. We also find that there are statistically significant differences in the estimated parameters of regional multivariate VAR model specifications and corresponding restricted models, though these tests are not exhaustive.

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## 1. Introduction

In 1984, the unemployment rate averaged 15.2% in British Columbia compared to the national average of 11.3% over the period 1976 to 2014. Meanwhile in the Atlantic region, the unemployment rate reached a nationwide maximum of 21.9% in Prince Edward Island in 1993. Within five years the unemployment rate declined to 15.8% in PEI and 10.3% in BC, whereas the national average stood at 7.8%. A similar regional story can be told for other variables describing innovations in the labour market. What could best describe evolutions in employment, unemployment, and wages, and do these evolutions differ with respect to how the regions are defined? This paper aims to consider such questions.

While many relationships in the labour market can be explained largely by basic economic theory of labour dynamics and exogenous forces on market wages, the data suggests that there are causal relationships within the labour market that motivate some heterogeneity of effects between provinces. For example, unexplained market forces that can be captured by the residuals in one province may impact the dynamic responses of labour market shocks in another province. Furthermore, these economic relationships are likely heavily influenced by time and the memory of past values. It is not sufficient to consider these time-series as purely random samples, but rather of having heterogeneity and autocorrelation. This paper aims to extend the body of research on this issue in Canada, as well as introduce and motivate another avenue of methodology in exploring the dynamics of labour market evolutions.

To undertake this study, we use Canadian data that is aggregated by industry, but disaggregated by province. Wage data was obtained from 1961-2014, while unemployment rates and employment levels data were obtained from 1976-2014. We collect monthly data, splice wage data where appropriate, and convert to quarterly data. Use of quarterly data, over annual data, allows for greater

degrees of freedom as well as a unique perspective on some highly seasonal labour markets in the Atlantic region. A univariate analysis for each variable by province sets the stage for the trivariate Vector Autoregressive (VAR) model. We then estimate a multivariate VAR model by region, and allow for contemporaneous covariance and cross-provincial influences via the parameters as well as the error term structure.

The work presented here expands upon the literature by relaxing the assumption of homoskedasticity and homogeneity in the parameters in a regional model estimation that pool across provinces or states. This regional multivariate VAR framework, while complex, lends itself to explore cross-provincial effects amongst the autoregressive terms as well as unexplained variations in the error terms. The evidence found suggests that Granger causal relationships are sensitive when accounting for heterogeneity in the parameters and contemporaneous covariance structures.

Section 2 reviews the broad literature that has explored regional evolutions and labour dynamics in several countries since the early 1990's. Section 3 examines the data first from a graphical standpoint to glean any possible correlations in the data across provinces, and then in a formalized univariate way after testing for unit roots. Section 4 introduces and estimates the trivariate VAR model, and explores Impulse Response Functions. Within section 4, we also introduce the multivariate regional VAR model. Section 5 provides concluding remarks, and suggestions for the direction of future research.

## **2. Literature Review**

Much research has investigated regional evolutions in labour dynamics, including for Canada and the United States (US). For instance, using data from 1961-1982, Altonji and Ham (1990) investigated the sources of fluctuations in Canadian employment growth via a VAR (Vector AutoRegression) factor

model. They model exogenous aggregate and disaggregate shocks to unveil consequential shocks and variation in employment growth at a national, regional, and disaggregated industrial level. Altonji and Ham found that in using the United States' GDP as a proxy to account for shocks from the US or international markets, US shocks accounted for much of the fluctuations in the Canadian employment growth rates, while provincial and industry-specific shocks played a smaller role in explaining Canadian labour market dynamics. As an attempt to discuss differences amongst regions in labour market dynamics beyond just employment growth, Blanchard et al. (1992) wrote a seminal paper in which they asked and attempted to answer questions about how the US labour market adjusted to shocks to employment and how wages declined relative to national averages. They also examined job creation and labour mobility responses to employment shocks. Their methodology of using VAR modeling techniques and impulse response functions (IRFs) set the stage in the literature for examining macroeconomic shocks. This paper is the main motivation for our study, as we consider many of their approaches to explore the impact of labour supply shocks in Canada and to whether such effects differ across provinces and regions.

## **2.1 Regional Evolutions**

In 1992 Blanchard, Katz, Hall, & Eichengreen discussed regional evolutions in labour market variables across states in America dating 1950 to 1990. The scope of their research is broad, covering univariate analysis of key variables, impulse response functions, to investigating factors of labour mobility across states and regions. Following the analysis of univariate models they construct a simple model that helps explain regional evolutions in employment, unemployment, and wages in univariate systems.

The main variables of interest are  $n$ ,  $u$ , and  $w$ , which are logarithmic deviations about the US average for employment, unemployment, and wages respectively. They investigate each of these

variables closely in univariate analyses; however, their multivariate VAR analysis extends to use labour force participation rate data. Their chief argument is that shocks to employment are shocks to the labour demand curve, and their effects can be traced to dynamics of wages, unemployment, the labour force participation rate, and lastly housing prices.

Their first multivariate VAR is a trivariate system with the first difference in employment, relative unemployment, and relative labour force participation rates. The estimates of their impulse response functions with a shock of -1% to employment summarize an increase in the unemployment rate and an initial decrease in the participation rate. The effect of the shock on unemployment and the participation rate persist for approximately 7 years. They extend this trivariate model to pooled borderstates and pooled non-border states. The impact is approximately the same under both systems.

They move to a bivariate VAR with employment and wages, omitting labour force participation and unemployment on the basis of low degrees of freedom, though it is preferred to include them on theoretical grounds. With a -1% shock to employment, they see a decrease in wages of approximately 0.4%, which returns to zero after its minimum after 6 years.

Abstracting slightly from the general model of their paper, Blanchard et al. (1992) estimate a bivariate model of employment and median house prices to investigate responses to an employment shock. Not surprisingly, a -1% shock to employment results in an approximately 2% decline in median house prices after about 4 years. Investigating this kind of dynamic relationship is one way to describe migration as a response to a decrease in employment.

The findings of this paper motivated future research in several areas. Papers extended the techniques outlined in Blanchard et al. (1992) in other countries. Several others extended upon the

time-series techniques used. Others investigated the question of migration as a response of shocks in the labour demand curve.

The impulse response functions and dynamic relationship are the motivation for our research. Namely, how specification of regional VARs may be affecting results, and how to test validity of Granger non-causal relationships in the VAR specification.

## **2.2 Vector Error Correction Models and Forecast Error Variance Decompositions**

Many papers examine the dynamics of labour supply shocks following on from Blanchard et al. (1992), often employing a wider range of methodologies for different countries and regions, including VECMs, extensions of VARs to allow for possible cointegration. Research in this area has taken on different questions using a range of variables, and adopting a multitude of macroeconomic time-series techniques. Some works look at sources of employment variation through the use of structural VAR models, Vector Error Correction Models (VECM), or Forecast Error Variance Decompositions (FEVD) within such frameworks (e.g., Clark, 1998; Altonji & Ham, 1990; Mäki-Arvela, 2003, Campolieti, Gefang, & Koop, 2014).

Thomas and Prasad (1998) examined labour market adjustments in Canada and the United States using a system of equations framework, with induced shocks modelled via dummy variables. This model demonstrates that employment growth shocks have larger and more persistent impacts on employment in Canada than in the United States, whereas real wage responses are smaller, which could not be explained by any differences in wage flexibility between the two countries. By accounting for endogeneity in a structural framework, they find that there is little difference between Canada and the United States in terms of overall labour market dynamics.

Perhaps one of the few papers that investigated employment dynamics prior to the work done by Blanchard et al. (1992) is that of Altonji & Ham (1990). Using annual Canadian employment data from 1962 to 1982 that is disaggregated by province and industry, they investigate aggregate and disaggregate shocks to employment via international, national, provincial, and industrial shocks in a univariate analysis and FEVD. A strong theoretical assumption in their econometric model and estimation is that industry shocks are uncorrelated across industries and provinces. Altonji & Ham (1990) suggest that international shocks, using US GDP as a proxy for international shocks, accounted for approximately two thirds of fluctuations in Canadian employment growth, while national (Canadian) shocks accounted for only a quarter of Canada's own employment growth.

Mäki-Arvela (2003) extends this to Finland, using a full system of five variables (employment, unemployment, labour force participation, number of net migrants and taxable income as a proxy for wages) with a shock in employment acting as a shock for labour demand. While the results of this paper may be slightly removed, as it uses Finnish data, the study illustrates the desire of researchers to explore regional labour dynamics outside of the framework of using region-specific shocks as determinations for variance in forecasted errors.

### **2.3 Seemingly Unrelated Regression Models and Structural Vector Autoregressions**

Further research in the American context models a structural VAR to estimate Forecast Error Variance Decompositions (FEVD) to extend beyond the national labour supply shocks motivated by Blanchard et al. (1992). Clark (1998) posits that not only are there national shocks, but region-specific and industry-specific shocks that account for variation in employment dynamics. Focusing on US data from 1947-1990, Clark finds that regional shocks accounted for approximately 40% of the variance in employment, while common and industrial shocks accounted for the remaining 40% and 20%,

respectively, and furthermore that region-specific shocks tend to propagate across regions over time. Other evidence of variation in employment growth can be traced to growth in real oil prices and US exchange rates.

## **2.4 Other avenues of research**

Work has also been undertaken on specific labour flows, abstracting from the VAR framework and investigating convergence or disintegration of wages or unemployment. Other papers tackle the labour mobility question with the help of logit models . For instance, Shearmur and Polese (2007) examine the impact of local factors on local employment growth via cross-sectional analysis. The work initially presented by Blanchard et al. (1992) has opened a vast dialogue about labour flows. As it is not possible here to fully elaborate on this vast literature, we focus on research that pertains to regional evolutions in employment, unemployment, and wages across Canada.

## **3. Data**

The data are collected from Statistics Canada as monthly figures. For all series, the second month in a quarter is taken as the data value for the quarter. Employment and unemployment figures were collected from the Labour Force Survey (LFS), dating back to 1976. The series for employment are seasonally unadjusted, aggregated across all industries for both genders aged 15 and older (by NAICS<sup>1</sup>). The unemployment rate is the average monthly unemployment rate across industries for both genders aged 15 and older. As is evident by the graphs of raw data for employment and unemployment (see Figures 17 and 18 in the Appendix), data are highly seasonal, with the Atlantic Provinces exhibiting higher seasonality than for the other provinces. According to a Centre for the Study of Living

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<sup>1</sup> North American Industry Classification System (NAICS) replaced the Standard Industrial Classification (SIC) in 1997 as a method of classifying economic activities undertaken by business practices.

Standards (CSLS) report for Human Resources and Skills Development Canada (HRDC) in 2005, Sharpe and Smith (2005) report that employment and unemployment seasonality in the Atlantic provinces was three times and twice the national average respectively, similar to our observations. Guillemette, L'Italien, and Grey (2000) find that between 1976 and 1996, 93% of the difference in seasonality between Atlantic and others regions' provinces is due to within-industry differences, and the remaining 7% of variation can be attributed to a greater proportion of highly seasonal industries. Therefore, the seasonality is not arising from a higher density of seasonal industries, such as fishing or natural resource based practices, but from varying economic behavior of firms, government agencies, and individuals. Within the Atlantic Provinces, PEI's seasonality is especially high compared to Newfoundland, Nova Scotia, and New Brunswick. Sharpe and Smith (2005) suggest that differences in labour force participation rates exacerbate the seasonal effects found by Guillemette, L'Italien, and Grey (2005). These findings suggest that we will need to account for seasonality in our models, and allow for patterns to vary across provinces.

Wages were collected from the Survey of Employment, Payroll, and Hours (SEPH), which dates back to 1961 in four different series, three of which are terminated. This is a dilemma that must be addressed given our desire for a continuous series. For this paper, average weekly earnings across all industry codes are used for the wage series. Two series are average weekly earnings across all industry codes using SIC, one of which is dated from 1961-1985 and the other from 1983-2000. The other two series are average weekly earnings across all industry codes using NAICS, one from 1991-2000, and the final one from 2001-2015. Due to the staggered and overlapping series, we opted to splice the wage series across the SIC to NAICS conversion in order to provide a longer continuous series. We adopted a simple approach of applying the percentage change from one quarter to the next in order to splice the four series together seamlessly, with, on occasion, a judicial choice of how to merge some of the

series. We recognize that results might be sensitive to this method of constructing this series, and it would be interesting to explore the sensitivity of our results to this approach to splicing.

### **3.1 A brief graphical look**

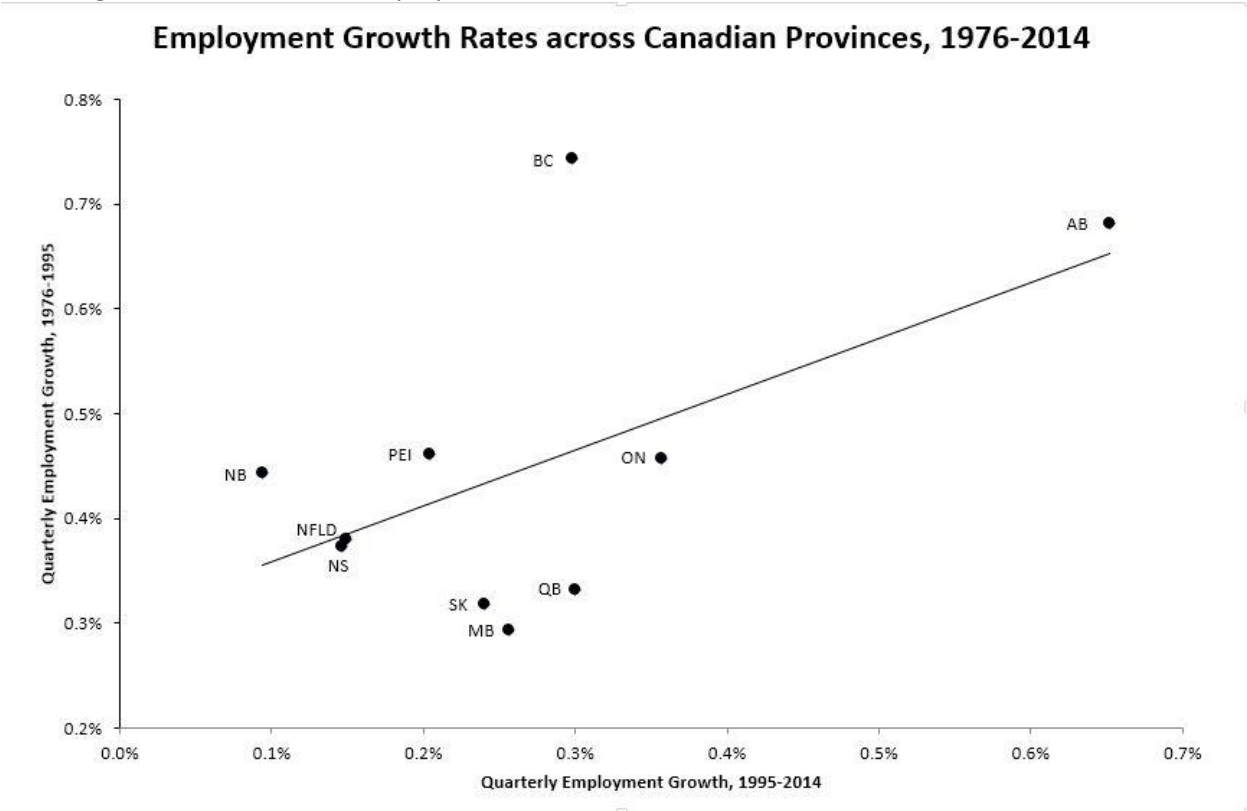
The employment series by province do not vary widely in story. All series are seasonal, and trend upwards dating back to around 1976, with the seasonality more severe in the Maritimes as discussed previously. Employment levels in Ontario, Quebec, Alberta, and BC and the Maritime provinces were all impacted by the recessions in 1981-1982 and 1990-1992. Employment levels declined in the most recent recession in 2008 in Alberta, BC, Ontario, and to a lesser extent Quebec. Manitoba and Saskatchewan both exhibited a steady trend upwards in employment levels over the time period. Alberta and BC saw a higher growth rate in employment numbers between 1985 and the recession commencing in 2009. Alberta's employment rebounded and continued to grow at an advanced pace, while BC employment figures tended to grow at a more sober pace.

The unemployment rate series tell differing stories across provinces and regions. For instance, the Atlantic Provinces demonstrate significant seasonality with upward and downward trends between 1976 and 2015. These provinces also have the greatest average unemployment rates across Canada; e.g., Newfoundland reached a level of 23.3% unemployed in 1994, while Prince Edward Island's unemployment rate generally trends upward until the early 1990's then trends downwards. Newfoundland, New Brunswick, and Nova Scotia follow similarly timed upward and downward trends, with unemployment generally decreasing from the 1990's onwards. Quebec, Ontario, and Manitoba also demonstrate similarities in seasonality and trend. Quebec reaches a maximum of 19.1% unemployment in 1983, whereas Ontario and Manitoba's maximum unemployment rates are 12.6% and 11% in 1983 respectively. Saskatchewan's unemployment history tells a different story.

Unemployment rates in this province trended upwards until the early 1980's. For a decade from 1982-1994, the unemployment rate fluctuated around approximately 8%, then trended downwards thereafter. Alberta and British Columbia followed a similar pattern to that of Quebec, Ontario, and Manitoba.

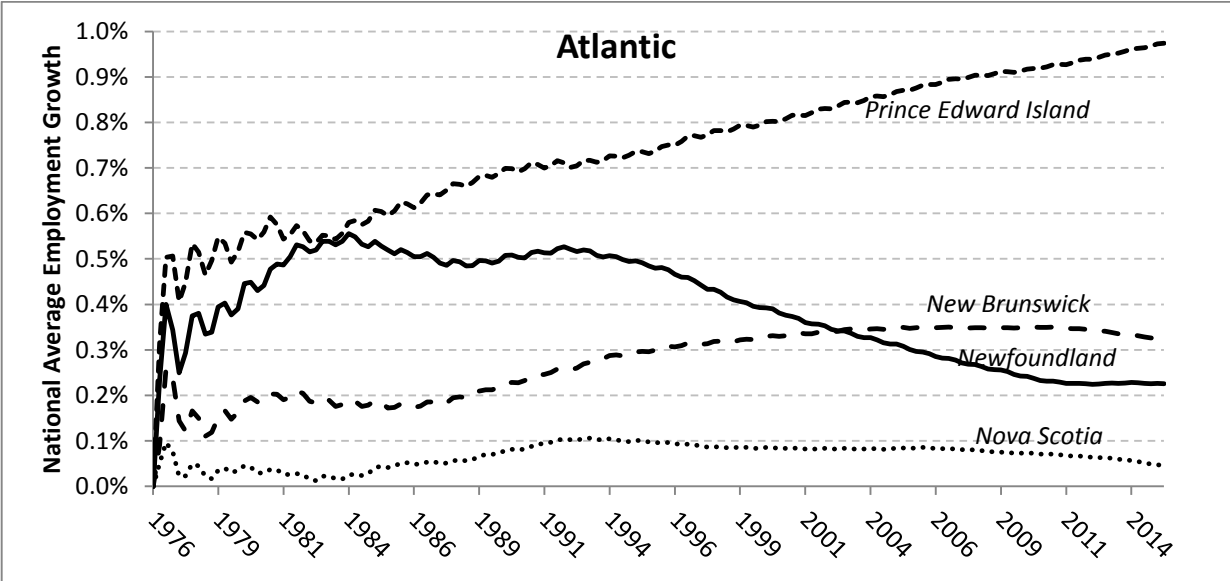
Given our goals, it is a natural introduction to explore some basic facts and graphical representations about evolutions of employment, unemployment, and wages across provinces going back to 1961. We begin with Figure 1, which provides average industrial aggregate quarterly employment growth rates for the periods 1976-1995 and 1996-2014 plotted against each other. The figure below illustrates the degree of persistence in employment growth amongst the Canadian provinces, and how this differs across provinces.

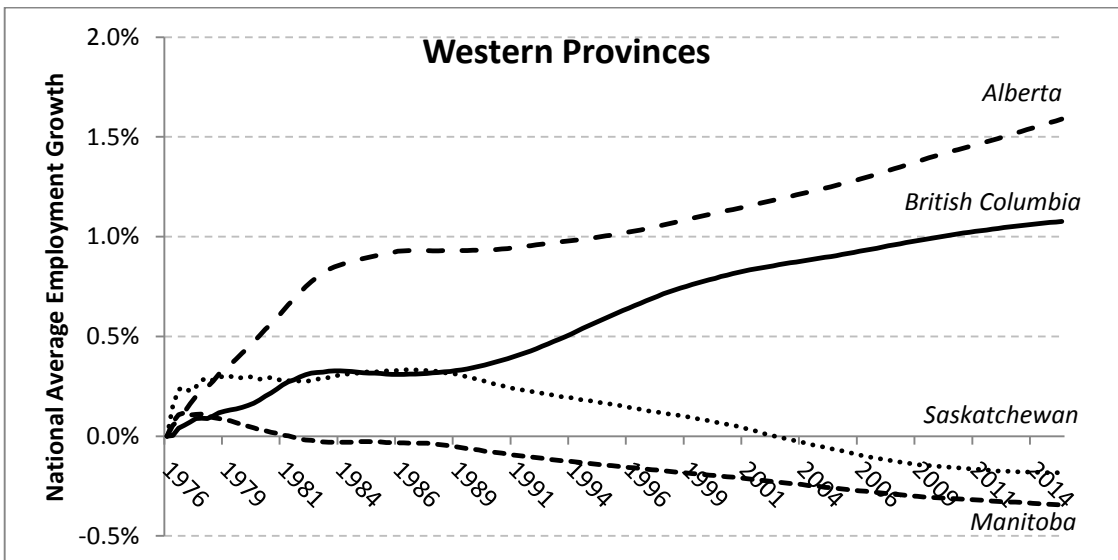
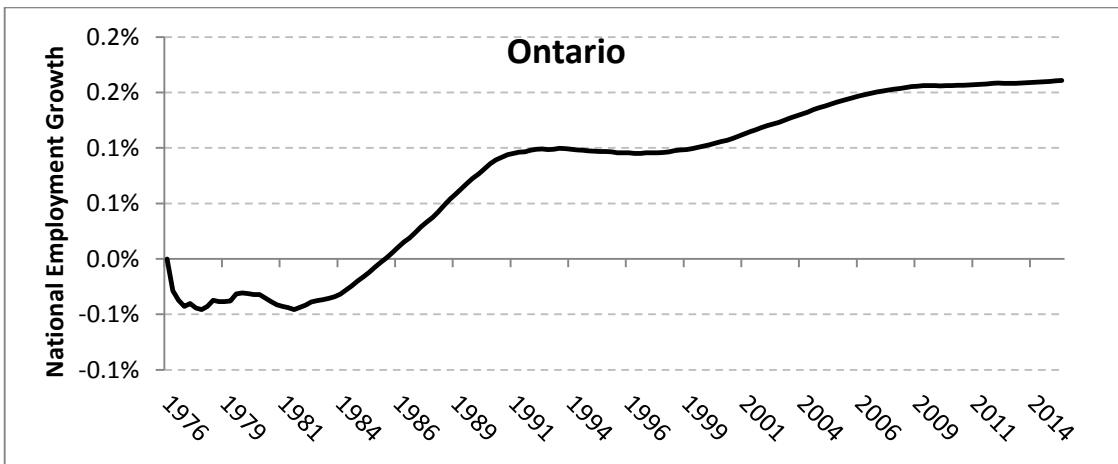
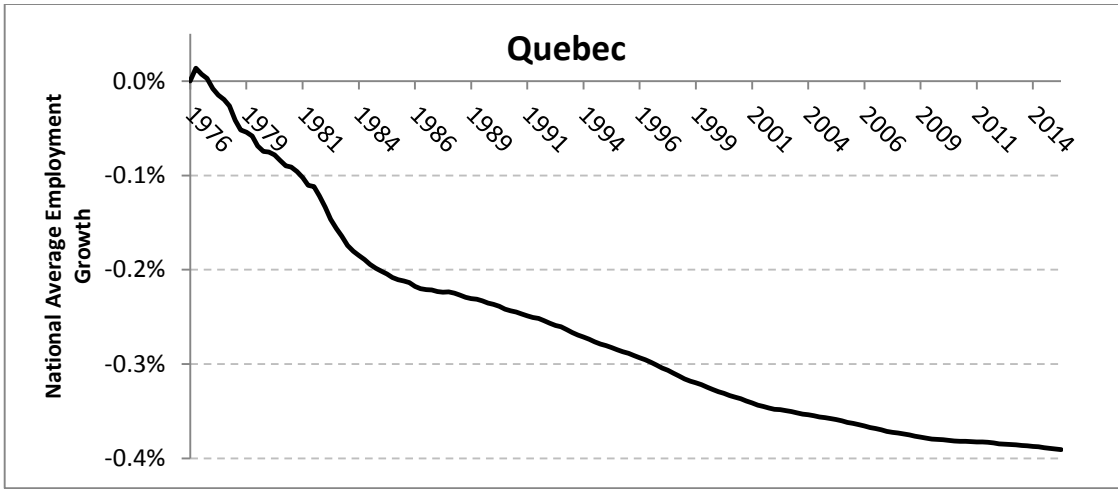
Figure 1: Persistence of Employment Growth Rates across Canadian Provinces, 1976-20



Over the last three decades, Canadian provinces experienced small but sustained differences in quarterly employment growth rates. The least squares regression line has a slope of 0.5532 with an  $R^2$  of 0.305; this estimated line provides a correlation of employment growth between the two considered time periods for each province, which indicates a degree of persistence in employment growth. Alberta and BC have grown over 0.5% per quarter, each over 0.1% above the national average. The Atlantic and Prairie provinces have consistently lower growth rates compared to the national average of 0.42% per quarter. This contrasts to the story report by Blanchard et al. (1992), where Massachusetts, New York, Pennsylvania, Rhode Island, and West Virginia had lower growth rates than the national average. Interestingly, this variation across Canadian provinces, is similar to the story reported by Blanchard et al. (1992) across US states; for instance, they find maritime states and mid-Western or Southern states grow a more sober paces than other states.

Figure 2: Cumulative Employment Growth, Canadian provinces relative to the National Average, 1976-2014





This story is more nuanced, as dynamics between regions across Canada vary significantly due to different industrial composition and variations in trends over time. Figure 2, which gives us an idea of regional trends and fluctuations over time, plots cumulative employment growth relative to the Canadian average by province across four regions since 1976. The Atlantic Provinces exhibit steady relative employment growth, with PEI leading the four provinces. Newfoundland's relative employment growth decreased in magnitude from the early 1990's onwards, while New Brunswick and Nova Scotia recorded modest relative employment growth figures. In contrast to other provinces, Quebec records a persistent downward trend in relative employment growth. Ontario is unique to the other provinces as well, recording relative employment decline from 1976 to 1986, and then growing persistently from 1986 onwards. Within the Western region, Alberta and BC tell similar stories of persistent relative employment growth at comparable rates and magnitudes. Relative employment growth in Manitoba and Saskatchewan are much more modest, and begin to decline in 1981 and 2003 respectively. These findings suggest that it might be unreasonable to consider regional analyses with traditional groupings<sup>2</sup>. Despite this reservation, given the prevalence of viewing provinces as groups, we pursue regional work, keeping in mind the difficulty of grouping some of the provinces together.

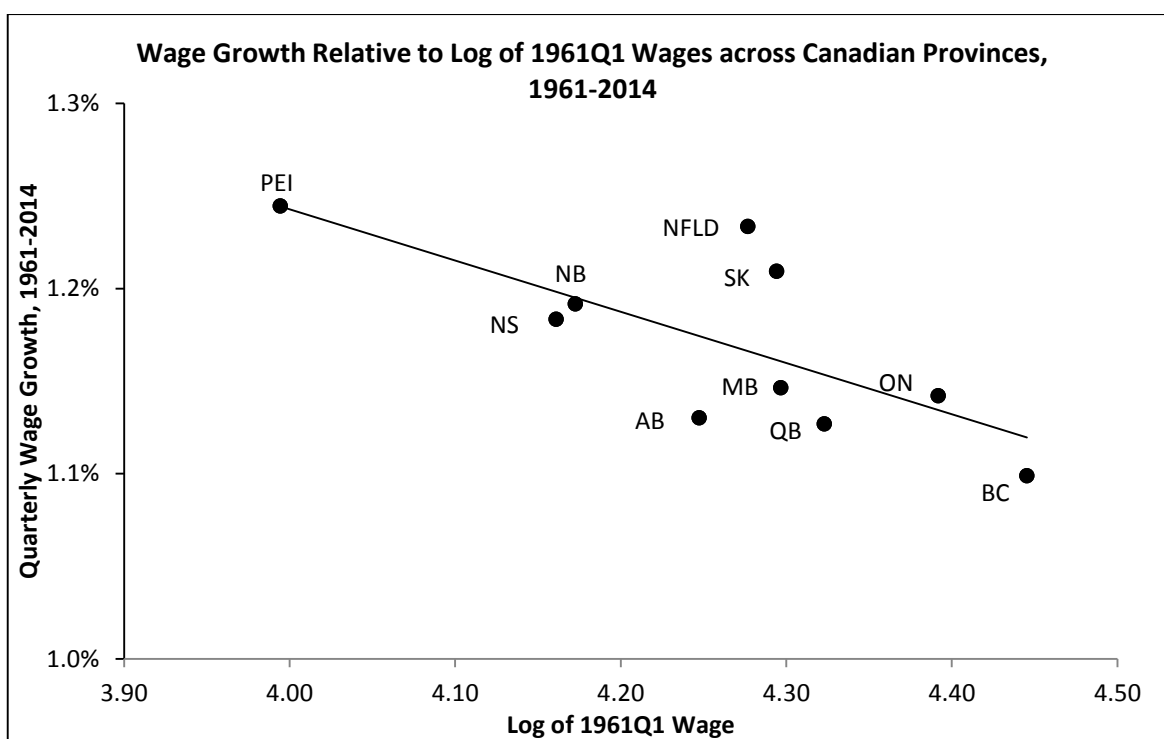
Figure 3 below plots Quarterly Wage Growth from 1961Q1 to 2014Q4 relative to the log of the wage in 1961Q1. This figure is constructed following a similar figure in Blanchard et Al. (1992), wherein they argue that the inverse relationship between wage growth and wages implies convergence of wages across states in the US. However, we cannot come to the conclusion that wages converge across provinces in Canada based on the information in Figure 3. Friedman (1992) discusses this tendency

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<sup>2</sup> We chose to specify regions in a traditional grouping that is consistent with a five-region model, the fifth of which is Northern Canada which is excluded from this analysis. This grouping is used for Regional Economic Development Agencies, and tends to reflect general similarities in trends between provinces.

towards regression fallacy, or Galton’s Fallacy, by accepting “the regression coefficients as supposedly unbiased estimates of structural parameters” (Friedman, 1992, p. 2131). There may also be a noted difference between convergence in wages and the rate of convergence<sup>3</sup>. That being said, Figure 3 illustrates that provinces with low wages in 1961Q1 are correlated with higher growth rates in wages from 1961 to 2014. By contrast, those provinces with higher initial wages in 1961Q1 were correlated with lower rates of wage growth.

Figure 3: Wage Growth Relative to Log of 1961Q1 Wages, 1961-2014



This relationship, while interesting to note, does not imply wage convergence in Canada by itself. It is more likely that market adjustment forces will lead to convergence of per capita income amongst provinces and regions, and that the main mechanisms for convergence arise from the flexibility of

<sup>3</sup> Some work in this area distinguish between  $\beta$ -convergence and  $\sigma$ -convergence in growth rate regressions, and stress the possibility that convergence in variance may be more important than convergence in growth rate parameters (Young, Higgins, & Levy, 2008).

wages and prices as well as the mobility of labour and substitutability of capital (Moazzami, 1997). Furthermore, these movements in prices and wages are more likely to impact labour mobility than the systematic convergence of wages. As our work does not investigate wage convergence or labour mobility, these questions are investigated within the Canadian context by Moazzami (1997), Yue (2008), and Coulombe (2006).

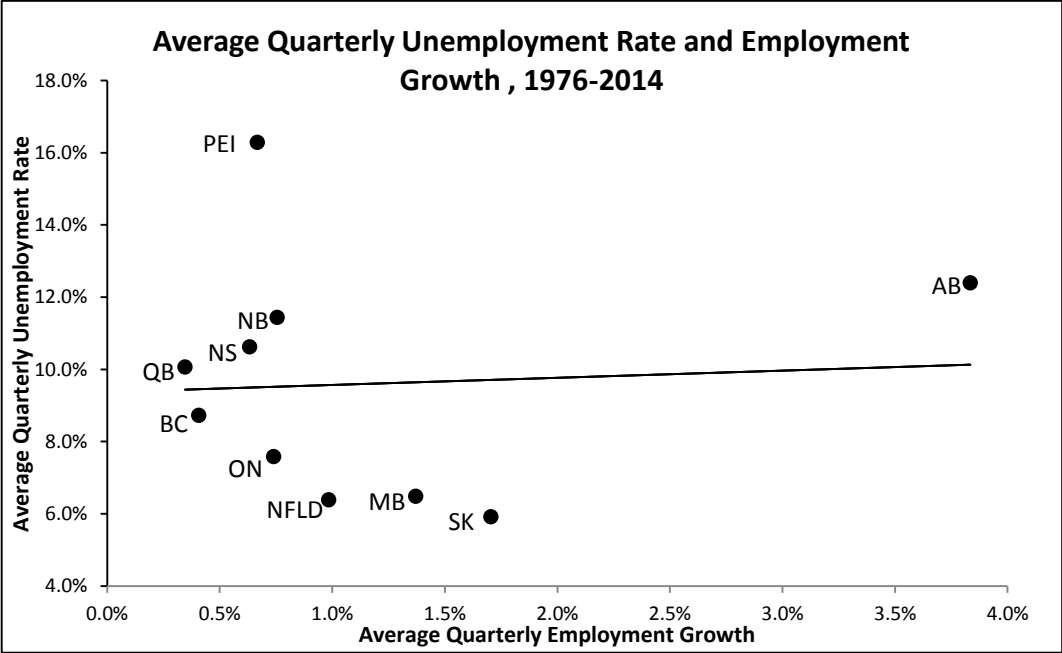
More interesting to note and investigate is the relationship between employment growth and wages, as well as the relationship between unemployment and employment growth. As done by Blanchard et al. (1992), we produce similar graphs to predict the correlation between unemployment and employment, as well as wages and employment. From this perspective, analysis of the correlation between unemployment rates and employment growth must draw upon our assumptions of the underlying sources of growth in the labour market. In fact, unexplained variations between provinces can reverse the correlations between employment growth and wages. From the preliminary graphical evidence presented by Blanchard et al. (1992), there is no correlation between employment growth and wages in the United States over the period of 1950-1990.

Similar to their findings, there is no clear evidence of correlation between average unemployment rates and average quarterly employment growth. As shown below in Figure 4, the relationship between the two variables is relatively negligible. The estimated slope coefficient is 0.199 and the linear trend has an  $R^2$  of 0.004. However, it is interesting to note the clustering of provinces, especially when the clustering does not appear to be regionally specific. Save New Brunswick and Nova Scotia, which both exhibit relatively low quarterly employment growth and average quarterly unemployment rates of around 11%, most provinces exhibit different relationships between their average unemployment rates and average quarterly employment growth. This story may certainly be

different using annual growth measures, but there appears to be no significant relationship between these variables within a given region. It is also important to note that provinces like Prince Edward Island have highly seasonal unemployment rates, and volatile employment patterns within a given year, which influence the average quarterly unemployment rate.

Nevertheless, if we were to take Figure 4 as evidence of positive correlation between unemployment and employment growth, there is a richer story to lend to migration behavior between provinces which may contribute to “wait unemployment”. This hypothesis is introduced by Harris and Todaro (1970) and suggests that workers may prefer to be unemployed in a region where there are higher wages, as workers’ expectations of future earnings are higher irrespective of the unemployment rate. To explore this further, we investigate the impact of shocks in a dynamic framework, and test Granger non-causal relationships in a multivariate VAR.

Figure 4: Average Quarterly Unemployment Rate and Employment Growth, 1976-2014



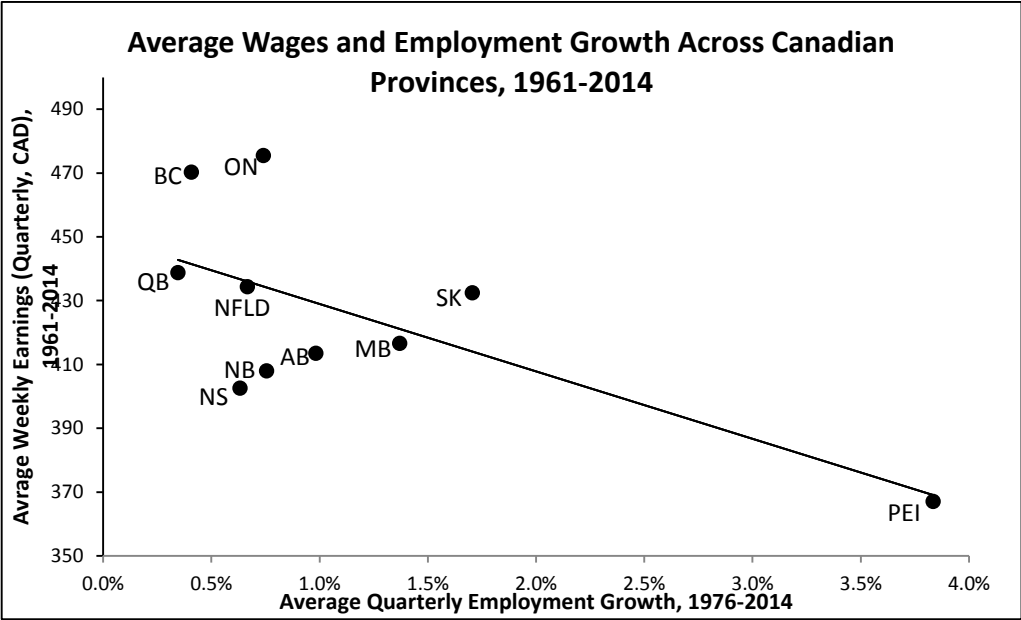
Turning to the relationship between wages and employment growth, Figure 5 below illustrates a linear relationship between average weekly earnings and average quarterly employment growth with

an  $R^2$  of 0.462 and an estimated slope coefficient of -2111.1. The slope coefficient is high in magnitude due to the higher covariance in average weekly earnings relative to the covariance of average quarterly employment growth. This contrasts greatly from the evidence in Blanchard et al. (1992), where the relationship between average wages and employment growth was close to zero. Our results may be sensitive to not only the choice in variable but also the time period and frequency used. While Blanchard et al. (1992) use the average manufacturing wage rate, we use average weekly earnings as a measure of wages. Furthermore, quarterly employment growth is likely more variant than the annual measure of employment growth. However, in our framework the negative correlation between wages and employment growth indicates some economic differences between labour markets in different provinces and underlying sources of economic growth, geographically or structurally.

While Blanchard et al. (1992) suggest that there is a negligible relationship between average quarterly wage growth and average quarterly employment growth, we assert that the negative correlation found in our Canadian data reflects an underlying structural relationship. In provinces with lower average rates of quarterly employment growth are more stable in a given year or four quarter period have higher average weekly earnings to reflect labour market stability. In contrast, those provinces with more labour market volatility have slightly higher employment growth rates but lower average weekly earnings. For example, labour must move in and out of the fishing and natural resource industries of the Maritime Provinces, while labour flows dependent on the change of seasons in oil and natural gas extraction in Alberta or British Columbia. Of course, this dynamic cannot be the dominant cause in the negative correlation. Other forces and dynamics within this time period frame drive this outcome in the static framework.

The clustering of provinces is more interesting and pertinent to our research, especially that in the Atlantic region. All provinces in the maritime region, except for PEI, are clustered near an average weekly earnings rate of \$410 and an average quarterly employment growth rate of 0.75%. Though Manitoba and Saskatchewan hold relatively similar relationships in both Figures 4 and 5, British Columbia and Alberta are quite different. These regional similarities and differences motivate our research in exploring the dynamics in a regional framework.

Figure 5: Average Wages and Employment Growth Across Canadian Provinces, 1961-2014

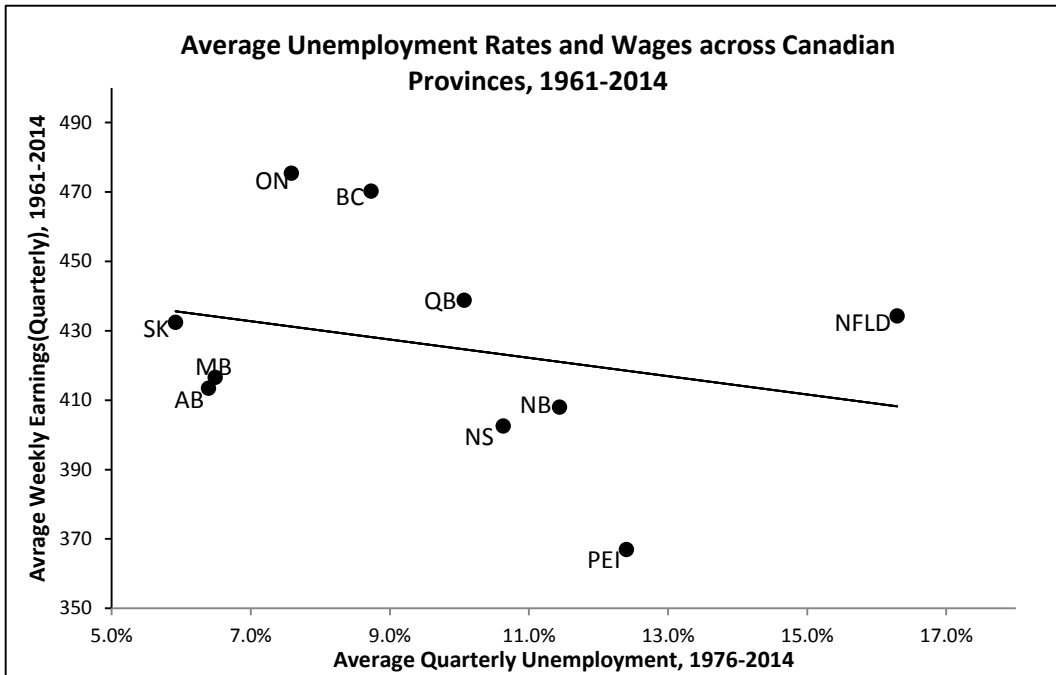


While Blanchard et al. (1992) suggest that there is a negligible relationship between average quarterly wage growth and average quarterly employment growth, we assert that the negative correlation found in our Canadian data reflects an underlying structural relationship. In provinces with lower average rates of quarterly employment growth are more stable in a given year or four quarter period have higher average weekly earnings to reflect labour market stability. In contrast, those provinces with more labour market volatility have slightly higher employment growth rates but lower average weekly earnings. For example, labour must move in and out of the fishing and natural

resource industries of the Maritime Provinces, while labour flows dependent on the change of seasons in oil and natural gas extraction in Alberta or British Columbia. Of course, this dynamic cannot be the dominant cause in the negative correlation. Other forces and dynamics within this time period frame drive this outcome in the static framework.

Figure 6 below completes our preliminary graphical look at our variables of interest. Our estimated relationship between average unemployment rates and average weekly earnings is a negative correlation. This, too, contrasts with the results yielded by Blanchard et al. (1992) in their preliminary analysis, in which they find a positive correlation between wages and unemployment. Their results are corroborated by other research as well (Hall, 1970; Blanchflower & Oswald, 1991; Katz & Krueger, 1991). As before, this result is sensitive to time period, frequency, and variable definition of wages. The negative correlation is being highly influenced by Prince Edward Island. Omitting PEI, the slope coefficient decreases in magnitude to -1716.9 and the estimated linear trend has an  $R^2$  of 0.086. The negative correlation remains, but at a slightly lower magnitude.

Figure 6: Average Unemployment Rates and Wages across Canadian Provinces, 1961-2014



As mentioned previously, these results are likely to be sensitive to choice of time period, frequency, and the use of weekly earnings instead of the average manufacturing wage. Economically, however, this negative correlation is a reasonable result. This points to strengths in the Canadian dataset and frequency choice, as this correlation aligns with economic theory.

These results are not robust. Though simple correlations among the variables help us gain information on the basic relationship and dynamics, these results largely depend on the underlying sources of growth, and differences in price level, unmeasured amenities, differing levels of industrial composition and firm attractiveness, as well as “wait unemployment” all likely impact the long- and short-run dynamics (Blanchard et al., 1992). We believe that these results and predictions are sensitive to the time period used, and that there is memory and an autoregressive process evident in the data. We also wish to control and explain any seasonal variation in the data. Thus, we turn to our preliminary univariate analysis and then to our multivariate VAR.

### 3.2 Preliminary univariate work

Following these graphical representations of some of the data, we now turn to characterizing the dynamics of each variable using preliminary univariate regressions. Following Blanchard et al. (1992), we define  $n_{it}$  as the logarithm of employment in province  $i$  in quarter  $t$  less the logarithm of employment in Canada in quarter  $t$ . Although the question of modelling trends in our series is important, and worthy of extensive work, we follow Blanchard et al. (1992) in this preliminary univariate study, of abstracting away from this question. We recognize the potential specification concerns of following such a route, but leave such issues for future research.

#### 3.2.1 Univariate Regression: Employment

Our preliminary univariate work consists of first examining whether each series is integrated at most of order one by estimating the following Augmented Dickey-Fuller (ADF) (Said & Dickey, 1984) regressions for each province and testing the statistical significance of  $\alpha_{3i}$ ; in the following regressions,  $t$  is a trend variable,  $D_{jt}$  is a seasonal dummy variable for each quarter, and  $\varepsilon_{it}$  is the disturbance term.

$$\Delta n_{it} = \alpha_{1i} + \alpha_{2i}(L)\Delta n_{i,t-1} + \alpha_{3i}n_{i,t-1} + \alpha_{4i}t + \sum_{j=1}^3 \gamma_{ij}S_{ijt} + \varepsilon_{it}$$

Allowing for three lags in  $(L)^4$ , we find evidence of unit roots for all provinces at typical significance levels, save PEI which had a t-statistic that suggested deterministic trend stationarity. Results from this preliminary work can be found in Table 5. Given these results, we treat relative

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<sup>4</sup> Three lags is sufficient to capture any autocorrelation in the residuals.

employment as having a unit root in our second univariate analysis, which comprised considering the following simple autoregressive (AR) regression for each  $i$ 'th province that aim to model innovations in employment growth with its past values.

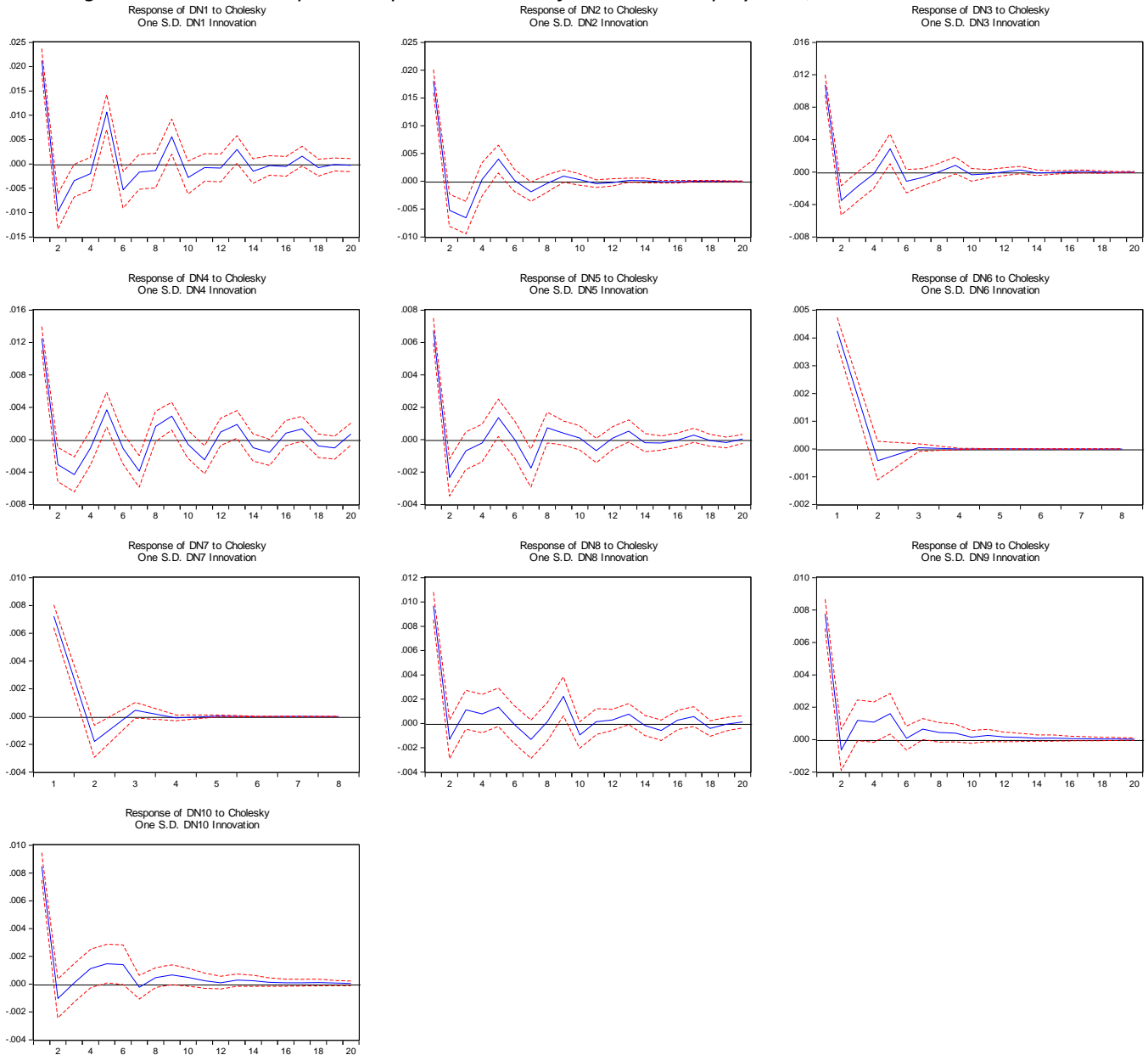
$$\Delta n_{it} = \alpha_{1i} + \alpha_{2i}(L)\Delta n_{i,t-1} + \sum_{j=1}^3 \gamma_{ij}S_{jt} + \varepsilon_{it}$$

Optimal lag lengths are chosen for each province individually according to the Hannan and Quinn (1979) Information Criterion (HQ); we report the lag orders in Table 8. Each province's univariate process for relative employment, except for Quebec, is estimated with seasonal dummy variables<sup>5</sup>. Using these univariate models, we generated impulse response functions for each province to show how a variable's own innovations responds to impulses or shocks in its own variable. In essence, by obtaining the IRF, we are estimating the coefficients of responses at each lag to a one standard deviation impulse or shock to the system. Eventually these shocks die, such that the impulses are transitory.

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<sup>5</sup> For Quebec's univariate regression for relative employment, seasonal dummy variables were not included as prior work suggested that these were not needed to capture any seasonal autocorrelation in the residuals.

**Figure 7: Univariate Impulse Response Functions for Relative Employment, 1976Q1-2014Q4**



Province variables:

- 1 - Newfoundland; 2 - PEI; 3 - Nova Scotia; 4 - New Brunswick; 5 - Quebec; 6 - Ontario; 7 - Manitoba; 8 - Saskatchewan;
- 9 - Alberta; 10 - British Columbia

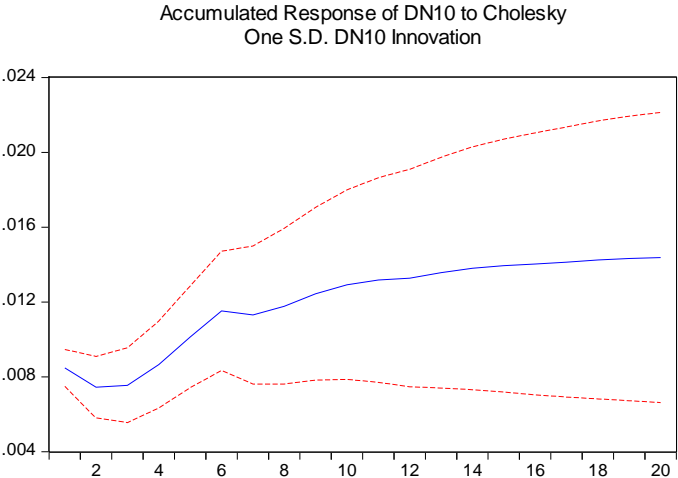
These IRFs are estimated in first differences, due to evidence of a unit root process in the series.

Though it may be easier to analyze and interpret the IRFs in levels, estimators of IRFs in levels for nonstationary series are inconsistent (Phillips, 1998). Thus, these IRFs are generated in first differences, which can be interpreted as changes in growth rates as a response to a percentage shock

to employment growth. The bands provided in the plots are confidence intervals about the point estimate of these growth rate responses.

Interpreting these IRFs is province dependent, as the standard deviations, and thus their shocks in each univariate IRF, vary by province and variable. Table 4 provides the standard deviations for each variable by province. For example, a one standard deviation shock to employment in BC, which corresponds with a 1% increase, results in negative employment growth in the following quarter, but is followed by positive employment growth in quarters 3 to 7, then gradually diminishes thereafter. The accumulated responses of a 1% increase in employment growth are represented below in Figure 8. In this illustration, the accumulated effect of a 1% increase in employment growth leads to an overall increase in employment growth up to 1.2%

*Figure 8: Accumulated Response of Employment Growth in BC due to a One Standard Deviation Shock to BC Employment Growth*



The story is very similar for the other provinces, though the one standard deviation shocks tend to be higher in magnitude in the Maritime provinces. For example, a one standard deviation shock is 6%, 7.7%, 2.2% and 4% in Newfoundland, PEI, Nova Scotia, and New Brunswick respectively. Quebec and Ontario’s one standard deviation shocks are significantly lower, at 0.7% and 0.6% respectively.

For each province, the IRFs show that quarters with good employment growth are followed by periods of poorer employment growth. This positive shock to employment growth in period 1 takes longer to diminish in its effect in Newfoundland, New Brunswick, Quebec, and Saskatchewan. Prince Edward Island, Nova Scotia, Alberta, and British Columbia see this positive shock effect diminish in approximately 4 years, whereas Ontario and Manitoba see this effect diminish after a year. An anecdotal example may involve a story in which seasonal hiring occurs in October, November, and December (quarter 4) for retail jobs during the holiday season followed by lower employment growth in January, February, March (quarter 1 of the following year) when those jobs are no longer required. This seasonality is adjusted for with seasonal dummies in the univariate specifications, but may still play a structural role in the patterns evident in the data.

### 3.2.2 Univariate Regression: Unemployment

Turning to examine relative unemployment rates, we follow the approach of Blanchard et al. (1992) by defining  $u_{it}$  as the unemployment rate in province  $i$  at quarter  $t$  less the Canadian unemployment rate in quarter  $t$ . As before, we test whether the relative unemployment series is integrated at most of order one by estimating the following ADF regressions for each  $i$ 'th province.

$$\Delta u_{it} = \alpha_{1i} + \alpha_{2i}(L)\Delta u_{i,t-1} + \alpha_{3i}u_{i,t-1} + \alpha_{4i}t + \sum_{j=1}^3 \gamma_{ij}S_{ijt} + \varepsilon_{it}$$

As with relative employment, three lags is sufficient in capturing autocorrelation, with our results showing evidence of a unit root in relative unemployment rates for each province; these results are summarized in Table 6. Our results contrast to those for the US states, where Blanchard et al. (1992) find mixed evidence regarding the stationarity of unemployment rates. Our outcomes are interesting, as often unemployment series, being quite bounded, are typically more compatible with being trend

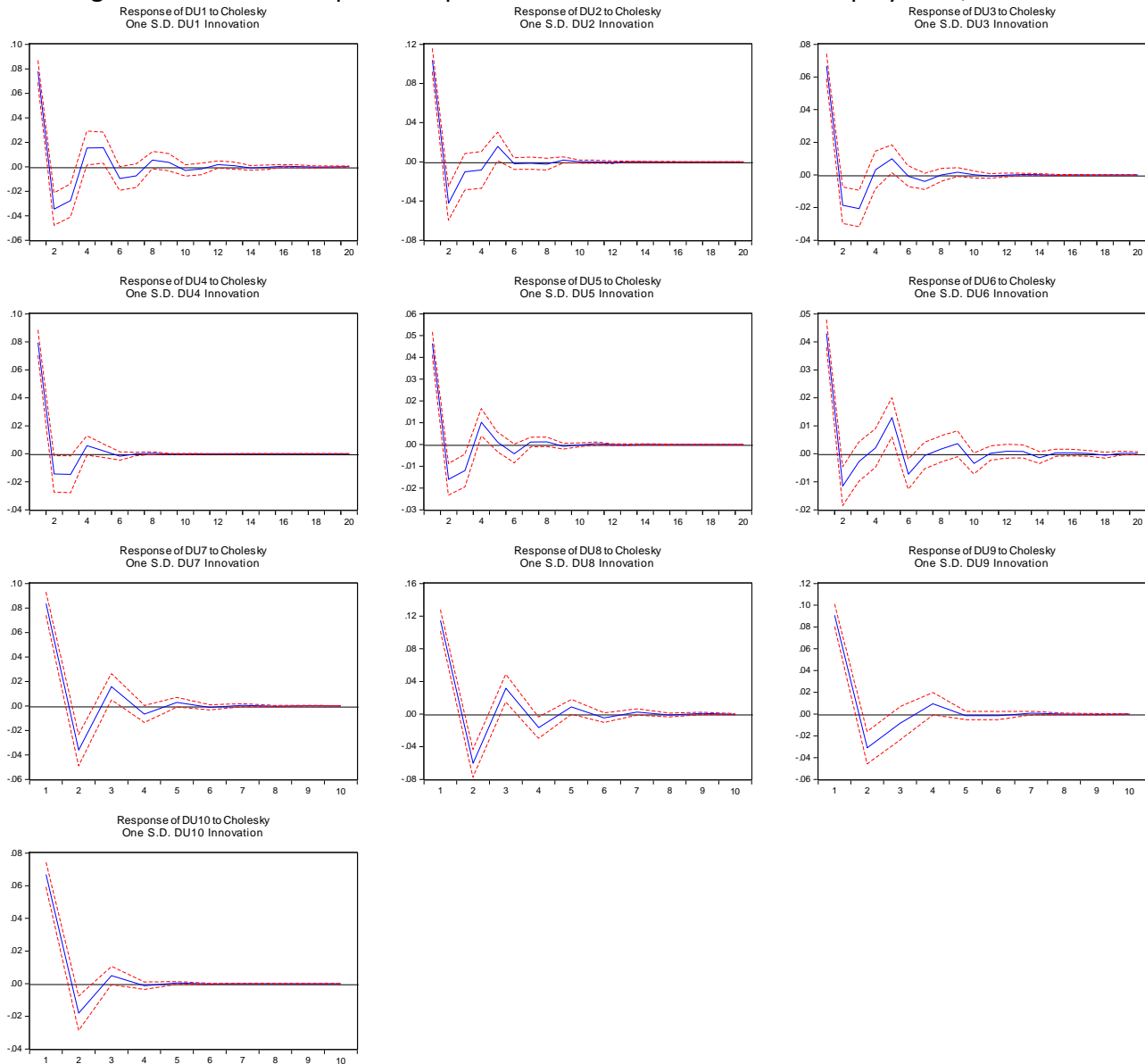
stationary rather than difference stationary. Here, however, our preliminary work suggests that the data are better approximated as a unit root process, rather than a trend stationary process. An advantage of working in first differences is that we can discuss unemployment growth, or changes in unemployment from one period to the next, in the estimated IRFs. With this in mind, we estimate the following first difference regression for each province ( $i=1,\dots,10$ ) relative unemployment rates between 1976Q1 and 2014Q4:

$$\Delta u_{it} = \alpha_{1i} + \alpha_{2i}(L)\Delta u_{i,t-1} + \sum_{j=1}^3 \beta_{ij}S_{jt} + \varepsilon_{it}$$

Again, seasonal dummy variables were not required for some provinces; specifically, for Saskatchewan, Alberta, and British Columbia.

In contrast to the story told for our preliminary employment dynamic shocks analysis, we find that shocks to unemployment growth, or increases in unemployment, result in lower unemployment growth in the following period as shown in Figure 9. For each province, a year following the positive shock leads to a smaller increase in unemployment after three quarters of declining unemployment rate changes. For the Western provinces and New Brunswick we see that the effects of a shock to the unemployment rate changes diminish after approximately two years, whereas for the other provinces we see these effects diminish in three or four years.

Figure 9: Univariate Impulse Response Functions for Relative Unemployment, 1976Q1-2014Q4



Province variables:

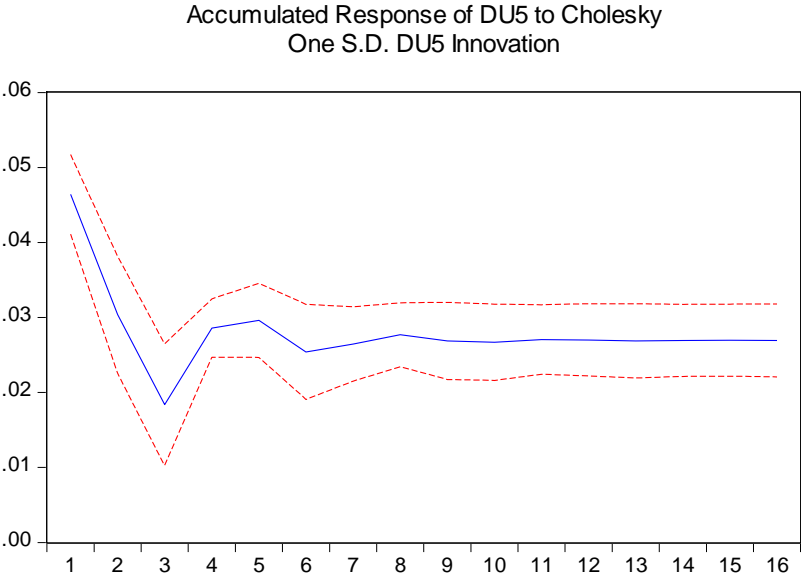
1 - Newfoundland; 2 - PEI; 3 - Nova Scotia; 4 - New Brunswick; 5 - Quebec; 6 - Ontario; 7 - Manitoba; 8 - Saskatchewan; 9 - Alberta; 10 - British Columbia

The difference in effects of shocks in our framework from the results found in the US from Blanchard et al. (1992) could be due to several factors. The lag length chosen, which is sensitive to the criteria used, will impact the persistence of a labour supply shock. It is also likely that the frequency of the data, quarterly in our work as opposed to annual in Blanchard et al. (1992), impacts the results. Because the Canadian quarterly data captures more memory of past quarterly observations, the

impact of a shock will diminish in a shorter time period. Furthermore, the estimation of the IRFs only capture short-run impacts, and the estimation of long-run effects are best estimated when co-integration is accounted for in a VECM framework.

If we investigate the accumulated response of a labour supply shock, we see evidence of a long-run impact from a transitory shock. In particular, Quebec responds to a 5% increase in unemployment growth in the first quarter, followed by quarters of decreased unemployment growth. The accumulated responses of this positive shock to the unemployment growth rate result in a diminished but stable increase in the unemployment growth rate of around 2.5% after approximately two years. In fact, this story is very similar to the accumulated IRF estimates in other provinces.

*Figure 10: Accumulated Response of Unemployment Growth in Quebec due to a One Standard Deviation Shock to Quebec Unemployment Growth*



Overall, the responses to a positive shock on unemployment growth are similar across provinces and regions, and diminish in somewhat similar time frames. We now turn to wage dynamics.

### 3.2.3 Univariate Regression: Wages

Similar to employment and unemployment, we follow Blanchard et al. (1992) in exploring wages by considering the variable  $w_{it}$ , the logarithm of the wage in province  $i$  at time  $t$  less the logarithm of the Canadian wage at time  $t$ . To begin, we estimate the following ADF regressions to test for integration of at most order one in the relative wage series for each province ( $i=1,\dots,10$ ):

$$\Delta w_{it} = \alpha_{1i} + \alpha_{2i}(L)\Delta w_{i,t-1} + \alpha_{3i}w_{i,t-1} + \alpha_{4i}t + \sum_{j=1}^3 \gamma_{ij}S_{ijt} + \varepsilon_{it}$$

In contrast to the findings of Blanchard et al. (1992) for US states, we observe strong evidence of nonstationarity in the wage series for each province; the results of these ADF tests are summarized in Table 7. Given these outcomes, we estimate the following regression for relative wages for each province from 1961Q to 2014Q4.

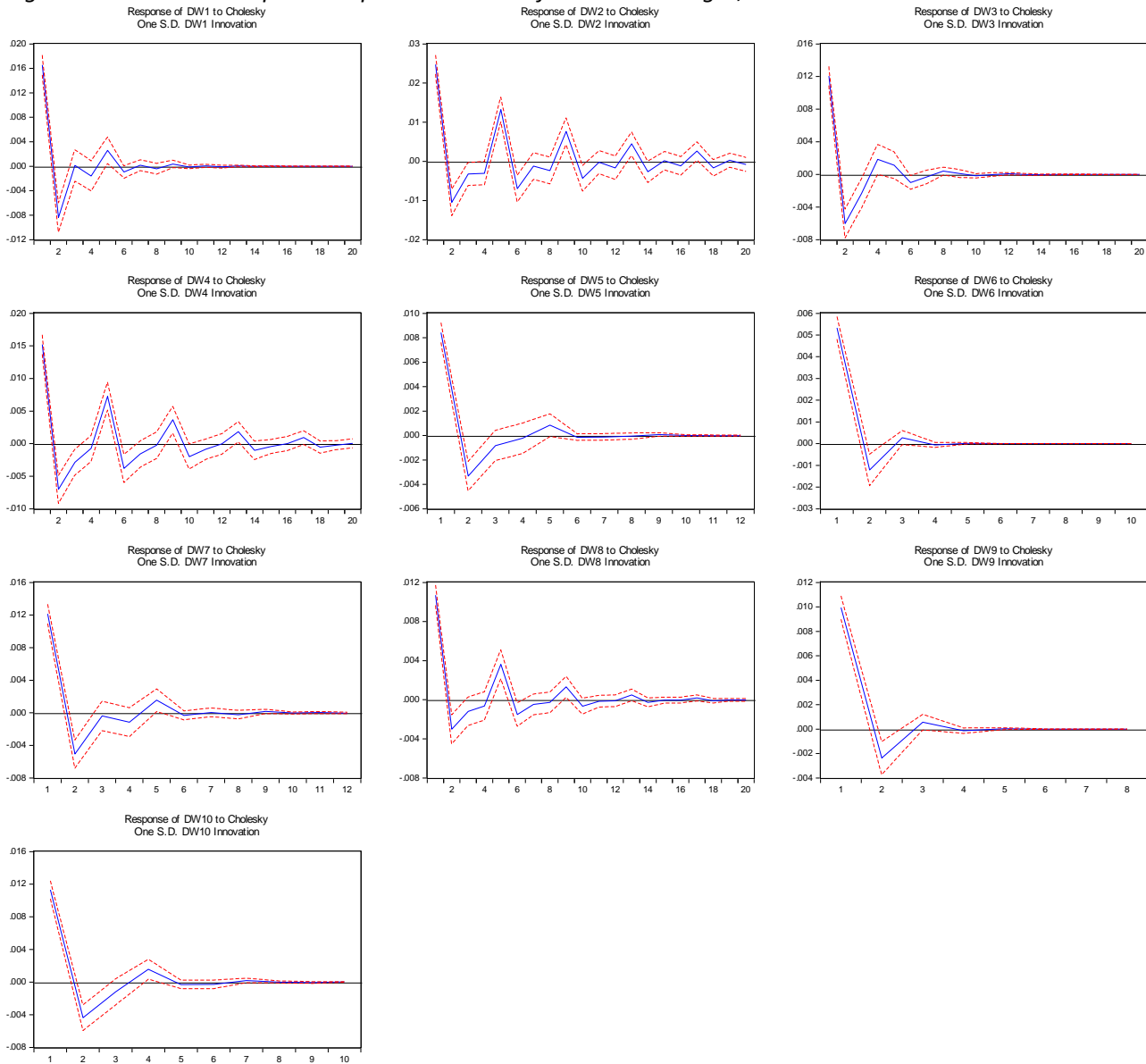
$$\Delta w_{it} = \alpha_{1i} + \alpha_{2i}(L)\Delta w_{i,t-1} + \alpha_{3i}\Delta w_{i,t-1} + \sum_{j=1}^3 \gamma_{ij}S_{ijt} + \varepsilon_{it}$$

Seasonal dummy variables were included or not based on an assessment of the autocorrelation present in the residuals; on this basis, PEI, Ontario, Manitoba, and BC did not require seasonal dummy variables. Optimal lag length was determined by province based on the HQ Criteria with outcomes ranging from 1 to 4 lags. The results are summarized in Table 8.

The responses of a positive shock to relative wage growth are similar across provinces in that the following quarter wage growth declines. The estimated IRFs from a positive shock to wage growth are shown in Figure 11. Alberta and Ontario see the effects of a shock to wage growth diminish within a year, whereas Quebec, Manitoba, and British Columbia take approximately two years for the effects of the shock to diminish. The remaining provinces see this diminishing effect after a longer period,

specifically with PEI and New Brunswick where we see some seasonal persistence in the effect of a shock.

Figure 11: Univariate Impulse Response Functions for Relative Wages, 1961Q1-2014Q4



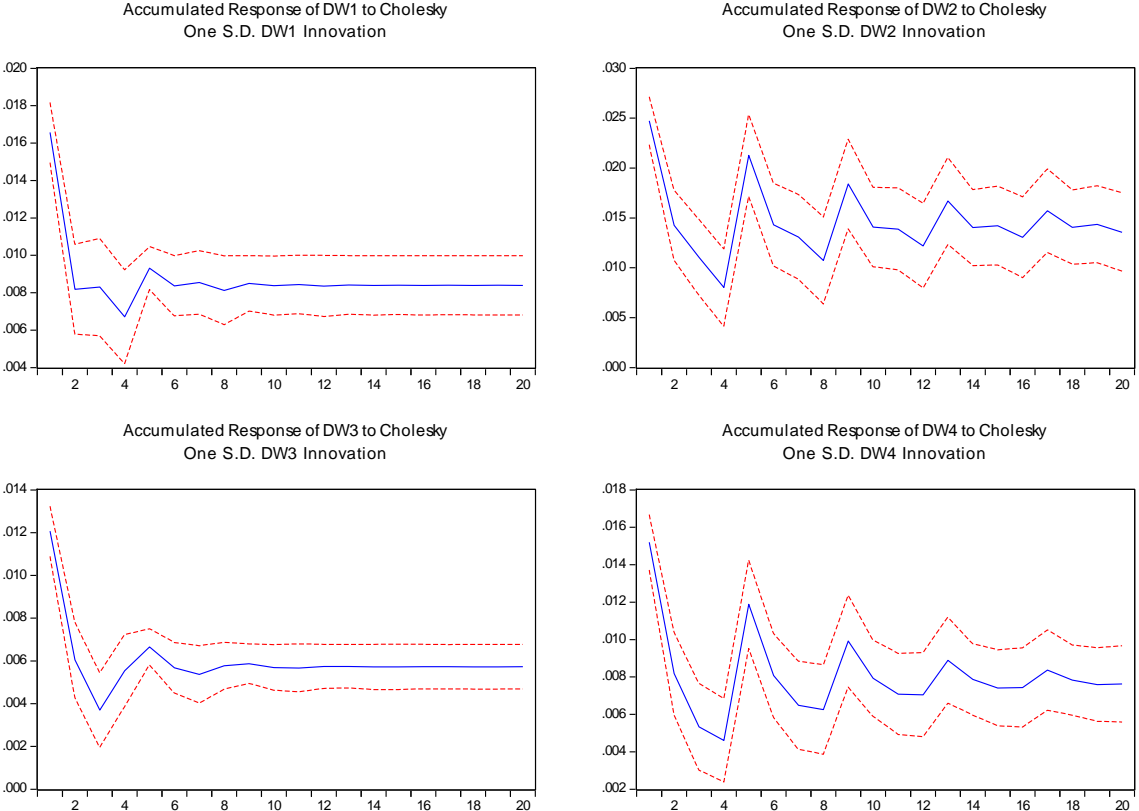
Province variables:

1 - Newfoundland; 2 - PEI; 3 - Nova Scotia; 4 - New Brunswick; 5 - Quebec; 6 - Ontario; 7 - Manitoba; 8 - Saskatchewan; 9 - Alberta; 10 - British Columbia

These results may imply that wages in PEI and New Brunswick are structurally seasonal. Until the Unemployment Insurance (UI) disentanglement in 1971 several workers in the Maritime Provinces supplemented their seasonal jobs with UI benefits and undertook repeat participation in the UI

program (Green & Riddell, 1993). Throughout the 1990's and early 2000's further reductions in Employment Insurance benefits were made, as well as amendments to qualifications and entitlements to increase the difficulty to access the program (Makarenko, 2009). We do not explore structural breaks, and leave this to be explored in future research.

Figure 12: Accumulated Response of Wage Growth in Maritime Provinces due to a One Standard Deviation Shock to a Province's own Wage Growth



Province variables:  
 1 - Newfoundland; 2 - PEI; 3 - Nova Scotia; 4 - New Brunswick;

Interestingly enough our hypothesis that PEI and New Brunswick are structurally seasonal is corroborated when looking into the accumulated response IRFs of the Maritime Provinces. As shown in Figure 12 above, even within a region there are differences between provinces. When Newfoundland and Nova Scotia's univariate systems are shocked, this leads to a small accumulated 0.5% to 0.1% increase in wage growth in the long run. PEI and New Brunswick, however, show accumulated responses to their one standard deviation shocks that are influenced by the seasonal component of

their underlying dynamics, even though the seasonality is controlled for in the univariate specifications. This could be evidence of “wait unemployment”.

In the univariate framework we have a much better idea of the long- and short-run responses and dynamics than in the graphical analysis of Section 3.1. However, in the univariate case we only allow for contemporaneous covariance within a given province for a certain variable. While other research includes labour force participation in their model specification, we leave this to future research and examine the relationship between unemployment, employment, and wages. We now turn to consider regional evolutions in labour dynamics in a trivariate framework and allowing for contemporaneous covariance across variables within a given province. We first undertake this part by province, and estimate the appropriate IRFs. For this analysis, we are abstracting from the literature where regional models are estimated from pooling data, and allow for contemporaneous covariance across provinces by estimating regional multivariate VAR models for the Atlantic and Western provinces.

#### **4. Multivariate Analysis**

To explore dynamic relationships between employment, unemployment and wages, we consider a log-linear trivariate system between the variables analyzed in the previous section, modelling them in first differences as a Seemingly Unrelated Regressions (SUR) system for each province and later within a regional model according to traditional regional groupings. While both specifications provide insight into how provinces or regions respond to labour supply shocks, they also enable us to evaluate the system where cross-provincial effects are present in the data, which is likely preferable on an economically theoretical ground.

The province specific VAR models will give us precursory evidence as to how labour market shocks responses differ between provinces. We also examine Granger-noncausal relationships

between variables, and how they differ from province to province. Ultimately, this supports the presumption that provinces react differently to labour market shocks, and that there are cross-border effects, explained by shocks to employment growth or perhaps by unexplained market structures that impact provinces differently.

Thus, the multivariate VAR model that is estimated by region accounts for cross-provincial variation in the parameters and the errors. We estimate the regional multivariate VAR model for the Atlantic region, as well as the Western region, omitting Ontario and Quebec as they exist as their own regions. Their province-specific VAR models presented in section 4.1 are sufficient models under the presumption that there are no cross-border effects, an assumption that is likely economically tenuous. We perform specific Granger-non causal tests, and further test some model restrictions on the underlying parameters.

#### 4.1 Province Specific VARs

For each province, we estimate the following trivariate VAR model with a constant and seasonal dummy variables:

$$\begin{bmatrix} \Delta n_{it} \\ \Delta u_{it} \\ \Delta w_{it} \end{bmatrix} = \begin{bmatrix} \alpha_{1i} \\ \alpha_{2i} \\ \alpha_{3i} \end{bmatrix} + \sum_{j=1}^3 \begin{bmatrix} \gamma_{1ij} \\ \gamma_{2ij} \\ \gamma_{3ij} \end{bmatrix} S_{jt} + \sum_{k=1}^{p_i} \begin{bmatrix} \beta_{i,11k} & \beta_{i,12k} & \beta_{i,13k} \\ \beta_{i,21k} & \beta_{i,22k} & \beta_{i,23k} \\ \beta_{i,31k} & \beta_{i,32k} & \beta_{i,33k} \end{bmatrix} \begin{bmatrix} \Delta n_{i,t-k} \\ \Delta u_{i,t-k} \\ \Delta w_{i,t-k} \end{bmatrix} + \begin{bmatrix} \varepsilon_{1,it} \\ \varepsilon_{2,it} \\ \varepsilon_{3,it} \end{bmatrix} \quad (1)$$

The assumptions for the error terms, because the system is estimated provincially, are as follows:

$$\varepsilon_t = \begin{bmatrix} \varepsilon_{1,it} \\ \varepsilon_{2,it} \\ \varepsilon_{3,it} \end{bmatrix} \sim (0, \Omega)$$

such that the diagonal (3X3) matrix  $\Omega$  of contemporaneous covariance parameters is:

$$\Omega = \begin{bmatrix} \sigma_{i,11} & \sigma_{i,12} & \sigma_{i,13} \\ \sigma_{i,12} & \sigma_{i,22} & \sigma_{i,23} \\ \sigma_{i,13} & \sigma_{i,23} & \sigma_{i,33} \end{bmatrix}$$

The lag order,  $p_i$ , for each provincial SUR model is chosen based on the Hannan-Quinn (1979) Information Criterion (HQ) with outcomes summarized in Table 8. As not all provinces multivariate regression required seasonal dummies to adjust for autocorrelation in the residuals, we note at the bottom of Table 8 which regressions did not include seasonal dummy variables.

In this provincial framework, there are several questions that may be interesting to explore, such as information in the autoregressive process, Granger's (1969) causality of variables within the provincial VAR, or information in the moving average process via IRF estimates.

#### **4.1.1 Hypothesis Tests and Granger Causality**

We aim to investigate the relationship of the dynamic responses of labour supply shocks on unemployment and wage growth. In order to evaluate whether or not a labour supply shocks affects the labour market variables statistically, we consider Granger non-causal (GNC) tests. The GNC tests of interest in Equation (1) can be generalized and performed by the following hypotheses tests:

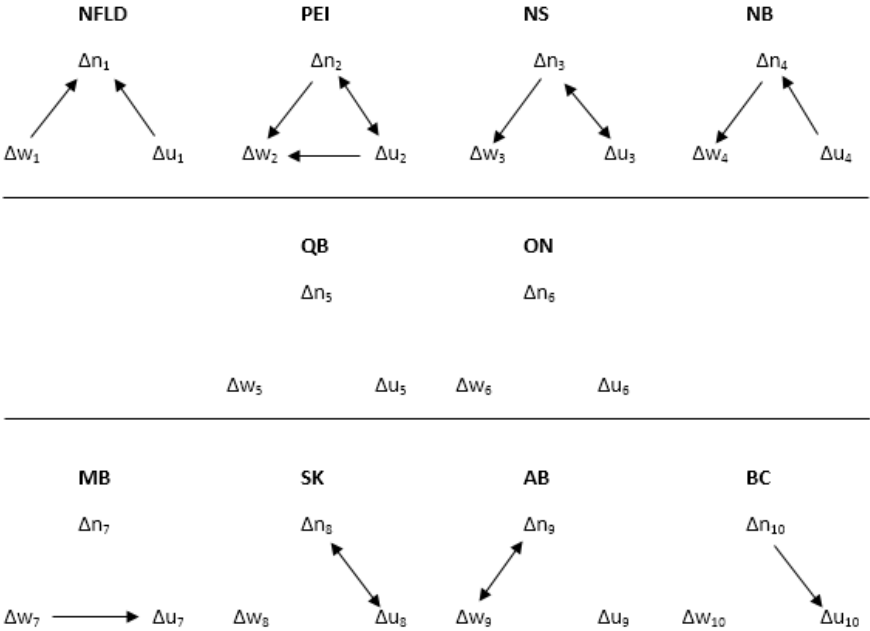
$$H_0: \beta_{i,lmk} = 0 \text{ for all } k = 1, \dots, p_i \text{ vs. } H_a: \text{not } H_0$$

In the case where  $m=1$  and  $l = 2$  &  $l = 3$  the test determines if a labour supply shock is GNC for employment and wages respectively. Similarly, if  $m=2$  and  $l=1$  and  $l=3$ , we are testing the null hypothesis that unemployment is Granger non-causal for employment and wages. These results are summarized in Table 9. A figure representation of Granger causal maps are illustrated by province in Figure 13 below.

The implications from Figure 13 suggests that not all Granger causal relationships originate from a labour supply shock. For instance, in Quebec and Ontario we do not see Granger causal relationships in any direction between any variables. Other provinces show contrary evidence. On theoretical

grounds, we are interested in the effects of a labour supply shock on the dynamics of the other variables in our trivariate VARs, but GNC tests suggests that there are other causal relationships evident. As suggested by Blanchard et al. (1992), shocks from either the labour supply or labour demand curves propagate in different ways, and the underlying sources of these shocks are different by province and over time.

Figure 13 : Granger Causal Maps



Province variables:  
 1 - Newfoundland; 2 - PEI; 3 - Nova Scotia; 4 - New Brunswick; 5 - Quebec; 6 - Ontario; 7 - Manitoba; 8 - Saskatchewan; 9 - Alberta; 10 - British Columbia

Note that Figure 13 only captures the horizon-1 Granger causal mapping, and the test outlined above does not account for higher-horizon Granger causality.

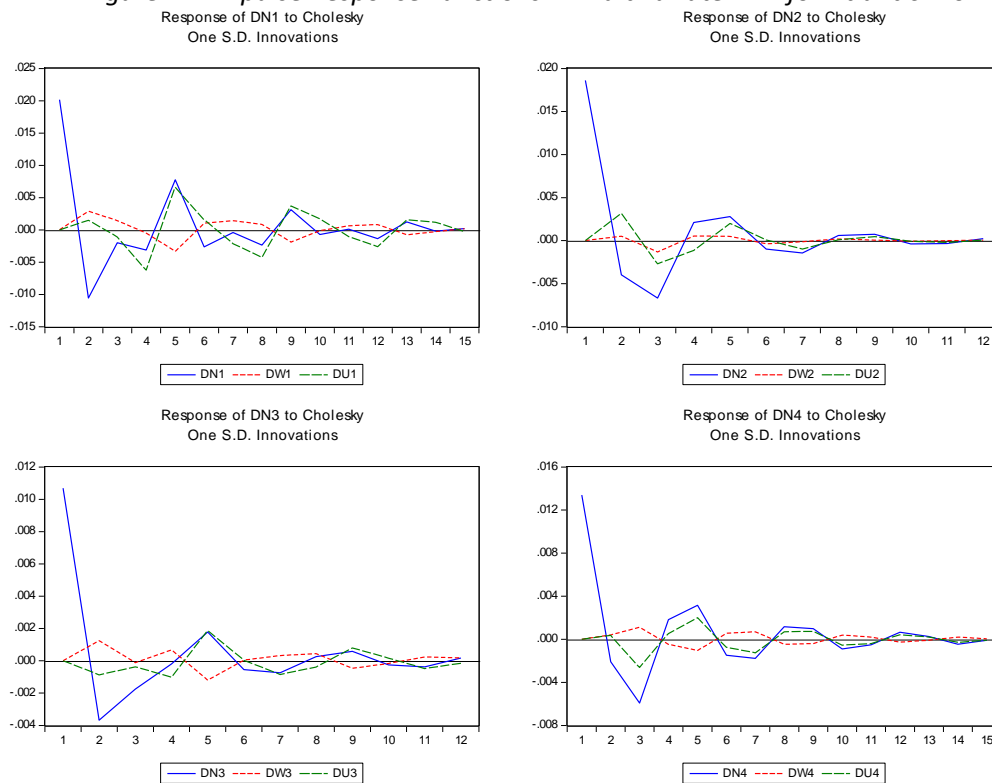
**4.1.2 Impulse Response Functions**

Similar to the univariate IRFs, multivariate IRFs are estimates of responses of variables in the system to a shock or impulse of one variable within that system. Here, the economic intuition states

that a labour demand or supply shock influences wages and unemployment, thus a positive one standard deviation shock in employment growth propagates responses in employment growth, unemployment rate growth, and wage growth.

Below in Figure 14, IRFs within the Atlantic region are estimated with a one standard deviation shock to employment growth within its own province. For example, the bottom left graph in Figure 14 shows the effect of a 5% increase in employment growth in Nova Scotia on the employment growth, unemployment rate growth, and wage growth in Nova Scotia. The transitory shock of employment growth in Nova Scotia leads to lower employment growth in the following three quarters, with slightly higher employment growth in the beginning of the next year. This effect diminishes within three years.

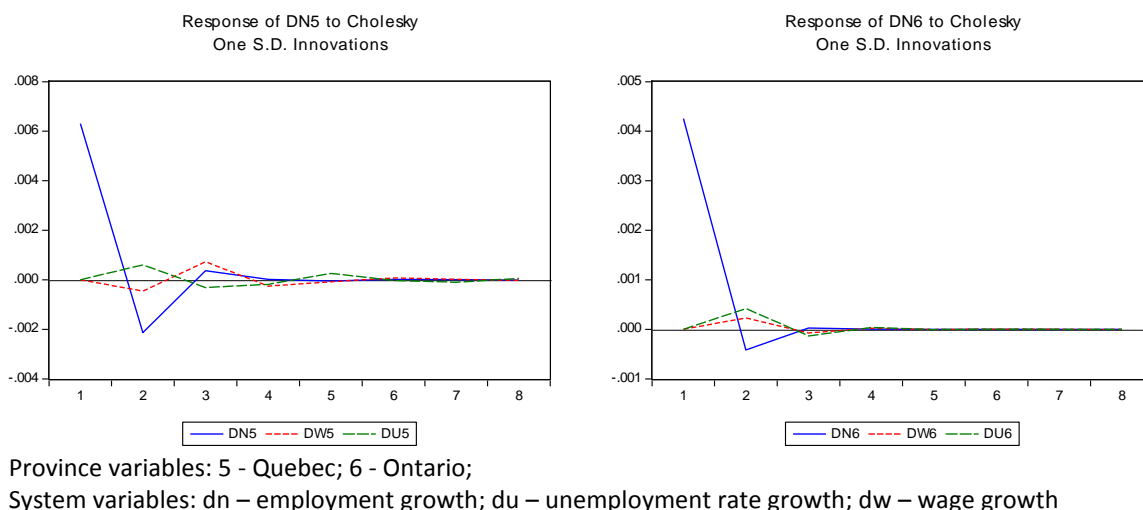
*Figure 14: Impulse Response Functions in Multivariate VAR for Atlantic Province*



Province variables: 1 - Newfoundland; 2 - PEI; 3 - Nova Scotia; 4 - New Brunswick  
 System variables: dn – employment growth; du – unemployment rate growth; dw – wage growth

Turning to Ontario and Quebec, we provide the estimated IRFs in Figure 15. In Quebec, a positive shock to employment growth results in a decline in wage growth and employment growth but an increase in unemployment growth. While wage growth and employment growth recover and increase in the third quarter, the effect on unemployment rate growth diminishes. Overall, this shock diminishes within a year. By contrast, a labour demand shock to Ontario results in a decrease in employment growth in the following quarter, but an increase in unemployment rate growth as well as wage growth. This effect diminishes within half a year.

Figure 15: Impulse Response Functions in Multivariate VAR for Quebec and Ontario

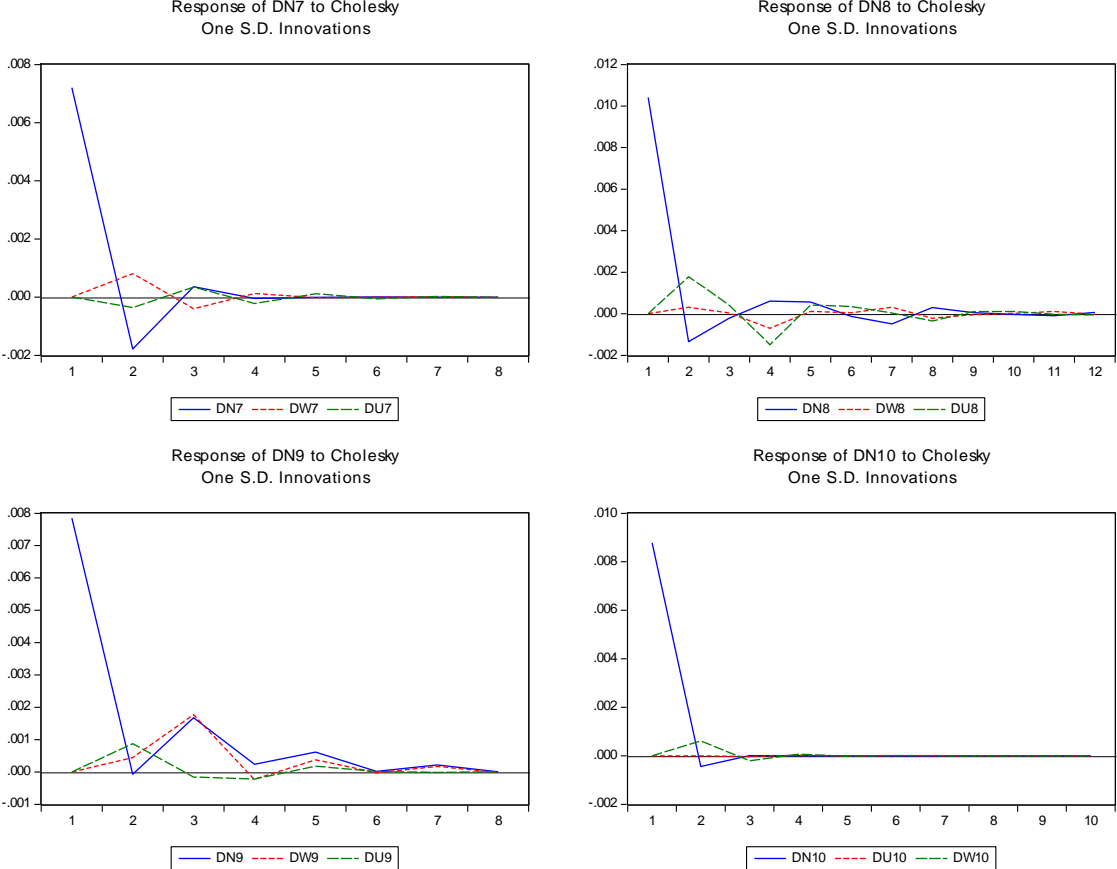


Lastly, we estimate the IRFs for the Western provinces and summarize our findings in Figure 16. The effect of a positive labour supply shock in Saskatchewan, Alberta, and British Columbia is similar to that in Ontario, where wage growth and unemployment rate growth increase in the quarter following the initial shock. Manitoba responds slightly differently, where unemployment rate growth declines the quarter following the initial shock. The effect of a shock lasts approximately two years in Saskatchewan and Alberta, but only about one year in British Columbia and Manitoba.

As discussed previously, the persistence of shocks may depend on lag length choice, or structural or unexplained factors in the residuals. For instance, the optimal lag length in British Columbia is one,

whereas the optimal lag length in Saskatchewan is three. Naturally, the difference in optimal lag length will impact the estimation of the moving average parameters and the persistence of a labour supply shock in the IRF.

Figure 16: Impulse Response Functions in Multivariate VAR for Western Provinces



Province variables: 7 - Manitoba; 8 - Saskatchewan; 9 - Alberta; 10 - British Columbia  
 System variables: dn – employment growth; du – unemployment rate growth; dw – wage growth

These IRF estimates tell us a story that differs slightly between provinces. In all cases, the effect of a shock lasts no longer than three or four years, but more often than not lasts about two. In Manitoba and Quebec, the short-run impact of a positive labour supply shock is a decline in growth, whereas it's an increase in wage growth in all other provinces. This positive response in most of the provinces is different than that shown in Figure 5. While Blanchard et al. (1992) found that there is a negligible relationship between average quarterly wage growth and average

employment growth, we assert that the negative correlation found in our Canadian data underlying structural relationship. In provinces with lower average rates of quarterly growth are more stable in a given year or four quarter period have higher average weekly reflect labour market stability. In contrast, those provinces with more labour market volatility slightly higher employment growth rates but lower average weekly earnings. For example, move in and out of the fishing and natural resource industries of the Maritime Provinces, while flows dependent on the change of seasons in oil and natural gas extraction in Alberta or British Columbia. Of course, this dynamic cannot be the dominant cause in the negative correlation. forces and dynamics within this time period frame drive this outcome in the static framework.

*Figure 5* Furthermore, this positive response in wages corroborates the evidence found in Blanchard et al. (1992), where they illustrated an adverse shock to employment also led to a decline in wages. However, the impact of that shock lasted 20 years, which is far longer than the effect of the shock that is estimated within our model.

#### **4.2 Regional VARs**

Following the estimation of trivariate VARs across provinces, we seek to follow the literature and estimate VARs by region. However, unlike the approach used by Blanchard et al. (1992) and the following literature on regional evolutions, where they pooled each variable across states within a region and allowed regional differences only via fixed effects terms in their VAR specifications, we propose that there exists variation from the parameters and covariances across provinces. Thus, instead of estimating a trivariate VAR for each region with pooled data, we estimate a multivariate VAR by region.

Using the regional definitions used previously in this paper, we estimate the regional multivariate VAR specification for the Atlantic and Western regions. The provinces included in the Atlantic region

are Newfoundland Prince Edward Island, nova Scotia, and New Brunswick, while the provinces in the Western region are Manitoba, Saskatchewan, Alberta, and British Columbia. We do not estimate the model for Quebec and Ontario, as each province are considered their own region according to our regional definition.

The main advantage of estimating a system like this for each region is to allow for unexplained variations in the data to impact the system cross-provincially. The explicit assumption of Equation (1) is that each province is a closed system, where institutional factors in one province do not affect on province's own innovations in the choice variables. While easy, we find that assumption restrictive and limiting from an economic perspective. Thus, the estimation of Equation (2) below allows for covariance across the autoregressive parameters as well as the contemporaneous correlations. To investigate the dynamic relationship between provinces, we estimate the follow multivariate regression by region:

$$\begin{bmatrix} \Delta n_{1+q,t} \\ \Delta u_{1+q,t} \\ \Delta w_{1+q,t} \\ \Delta n_{2+q,t} \\ \Delta u_{2+q,t} \\ \Delta w_{2+q,t} \\ \Delta n_{3+q,t} \\ \Delta u_{3+q,t} \\ \Delta w_{3+q,t} \\ \Delta n_{4+q,t} \\ \Delta u_{4+q,t} \\ \Delta w_{4+q,t} \end{bmatrix} = \begin{bmatrix} \alpha_{1+q,1} \\ \alpha_{1+q,2} \\ \alpha_{1+q,3} \\ \alpha_{2+q,1} \\ \alpha_{2+q,2} \\ \alpha_{2+q,3} \\ \alpha_{3+q,1} \\ \alpha_{3+q,2} \\ \alpha_{3+q,3} \\ \alpha_{4+q,1} \\ \alpha_{4+q,2} \\ \alpha_{4+q,3} \end{bmatrix} + \sum_{j=1}^3 \begin{bmatrix} \gamma_{1+q,1} \\ \gamma_{1+q,2} \\ \gamma_{1+q,3} \\ \gamma_{2+q,1} \\ \gamma_{2+q,2} \\ \gamma_{2+q,3} \\ \gamma_{3+q,1} \\ \gamma_{3+q,2} \\ \gamma_{3+q,3} \\ \gamma_{4+q,1} \\ \gamma_{4+q,2} \\ \gamma_{4+q,3} \end{bmatrix} S_{jt}$$

$$+ \sum_{k=1}^p \begin{bmatrix} \delta_{1+q,11k} & \delta_{1+q,12k} & \delta_{1+q,13k} & \cdots & \delta_{1+q,41k} & \delta_{1+q,42k} & \delta_{1+q,43k} \\ \theta_{1+q,11j} & \theta_{1+q,12j} & \theta_{1+q,13j} & \cdots & \theta_{1+q,41k} & \theta_{1+q,42k} & \theta_{1+q,43k} \\ \lambda_{1+q,11j} & \lambda_{1+q,12j} & \lambda_{1+q,13j} & \cdots & \lambda_{1+q,41k} & \lambda_{1+q,42k} & \lambda_{1+q,43k} \\ \vdots & \vdots & \vdots & \ddots & \vdots & \vdots & \vdots \\ \delta_{4+q,11k} & \delta_{4+q,12k} & \delta_{4+q,13k} & \cdots & \delta_{4+q,41k} & \delta_{4+q,42k} & \delta_{4+q,43k} \\ \theta_{4+q,11k} & \theta_{4+q,12k} & \theta_{4+q,13k} & \cdots & \theta_{4+q,41k} & \theta_{4+q,42k} & \theta_{4+q,43k} \\ \lambda_{4+q,11k} & \lambda_{4+q,12k} & \lambda_{4+q,13k} & \cdots & \lambda_{4+q,41k} & \lambda_{4+q,42k} & \lambda_{4+q,43k} \end{bmatrix} \times \begin{bmatrix} \Delta n_{1+q,t-k} \\ \Delta u_{1+q,t-k} \\ \Delta w_{1+q,t-k} \\ \Delta n_{2+q,t-k} \\ \Delta u_{2+q,t-k} \\ \Delta w_{2+q,t-k} \\ \Delta n_{3+q,t-k} \\ \Delta u_{3+q,t-k} \\ \Delta w_{3+q,t-k} \\ \Delta n_{4+q,t-k} \\ \Delta u_{4+q,t-k} \\ \Delta w_{4+q,t-k} \end{bmatrix} + \begin{bmatrix} \varepsilon_{1+q,1t} \\ \varepsilon_{1+q,2t} \\ \varepsilon_{1+q,3t} \\ \varepsilon_{2+q,1t} \\ \varepsilon_{2+q,2t} \\ \varepsilon_{2+q,3t} \\ \varepsilon_{3+q,1t} \\ \varepsilon_{3+q,2t} \\ \varepsilon_{3+q,3t} \\ \varepsilon_{4+q,1t} \\ \varepsilon_{4+q,2t} \\ \varepsilon_{4+q,3t} \end{bmatrix} \quad (2)$$

where  $k = 1, \dots, p$

$$q = \begin{cases} 0 & \text{for Atlantic region} \\ 6 & \text{for Western region} \end{cases}$$

The assumptions for the error terms, as the system is estimated regionally, are as follows:

$$\varepsilon_t = \begin{bmatrix} \varepsilon_{1+q,1t} \\ \varepsilon_{1+q,2t} \\ \varepsilon_{1+q,3t} \\ \varepsilon_{2+q,1t} \\ \varepsilon_{2+q,2t} \\ \varepsilon_{2+q,3t} \\ \varepsilon_{3+q,1t} \\ \varepsilon_{3+q,2t} \\ \varepsilon_{3+q,3t} \\ \varepsilon_{4+q,1t} \\ \varepsilon_{4+q,2t} \\ \varepsilon_{4+q,3t} \end{bmatrix} \sim (0, \Omega^*)$$

where the diagonal (12x12) matrix  $\Omega^*$  of contemporaneous covariance parameters is:

$$\Omega^* = \begin{bmatrix} \sigma_{11,11} & \sigma_{11,12} & \sigma_{11,13} & \cdots & \sigma_{11,41} & \sigma_{11,42} & \sigma_{11,43} \\ \sigma_{11,12} & \sigma_{12,12} & \sigma_{12,13} & \cdots & \sigma_{11,41} & \sigma_{12,42} & \sigma_{11,43} \\ \sigma_{11,13} & \sigma_{12,13} & \sigma_{13,13} & \cdots & \sigma_{13,41} & \sigma_{13,42} & \sigma_{13,43} \\ \vdots & \vdots & \vdots & \ddots & \vdots & \vdots & \vdots \\ \sigma_{11,41} & \sigma_{11,42} & \sigma_{11,43} & \cdots & \sigma_{41,41} & \sigma_{41,42} & \sigma_{41,43} \\ \sigma_{11,42} & \sigma_{11,42} & \sigma_{12,43} & \cdots & \sigma_{41,42} & \sigma_{42,42} & \sigma_{42,43} \\ \sigma_{11,43} & \sigma_{12,43} & \sigma_{13,43} & \cdots & \sigma_{41,43} & \sigma_{42,43} & \sigma_{43,43} \end{bmatrix}$$

Under these assumptions, provinces within a region are linked via the parameters as well as contemporaneous correlation of the error terms. We can investigate these causal linkages across provinces and test some model restrictions that may assist in model preference decisions.

#### 4.2.1 Provincial Influences via Contemporaneous Covariances

One way to investigate how variables are affected across provinces via the autoregressive parameters is by performing GNC tests within the system estimated in Equation 2. There are several tests that can be executed in this framework, thus we examine the intuitive case of an effect of a labour supply shock on wage growth. A generalized form of the GNC hypothesis tests can be written as follows:

$$H_0: \varphi_{o+q,rsk} = 0, \dots, \varphi_{o+q,rsp1} = 0 \\ vs H_a: not H_0 ;$$

$$where \varphi = \delta, \lambda \\ o = 1, \dots, 4, r = 1, \dots, 4, s = 1, \dots, 3, k = 1, \dots, p \\ q = 0 \text{ for Atlantic Region,} \\ q = 6 \text{ for Western Region}$$

Thus, we test the joint null hypotheses across all lags. In essence, when  $\varphi = \delta$ , we are testing Granger non-causality of a shock to labour supply in one province within a region on unemployment growth another province within that same region, or  $\Delta n_h \rightarrow \Delta u_i$  for provinces  $h$  and  $i$ , for  $h \neq i$ . If  $\varphi = \lambda$ , we are testing for Granger non-causality of a shock to labour supply on wage growth, or  $\Delta n_h \rightarrow$

$\Delta w_i$ . This test can be performed on both multi-province regions, like the Western and Atlantic regions, with outcomes summarized in Table 1 and Table 2 respectively.

In the Western region, there are some interesting inter-provincial causal relationships to observe. For example, we reject Granger non-causality of labour growth in Saskatchewan for unemployment growth in Manitoba, Alberta, and British Columbia, and wages in British Columbia. Shocks to employment growth in BC have a Granger causal effect on Manitoba and Saskatchewan, but not Alberta. Our a priori expectations regarding these GNC tests were such that Alberta and BC would have some Granger causal relationships in the data. However, we can only reject GNC of labour growth in Alberta on wage growth in BC at the 5% significance level.

Table 1: GNC test results in the Western Regional VAR

|              |    | $\Delta u_h$      |                   |                   |                  | $\Delta w_h$     |                  |                  |                   |
|--------------|----|-------------------|-------------------|-------------------|------------------|------------------|------------------|------------------|-------------------|
|              |    | MB                | SK                | AB                | BC               | MB               | SK               | AB               | BC                |
| $\Delta n_i$ | MB | -                 | 3.158<br>(0.368)  | 4.346<br>(0.226)  | 2.803<br>(0.423) | -                | 1.364<br>(0.714) | 3.024<br>(0.388) | 4.994<br>(0.172)  |
|              | SK | 6.845<br>(0.077)  | -                 | 10.182<br>(0.017) | 8.991<br>(0.029) | 2.147<br>(0.542) | -                | 3.291<br>(0.349) | 10.976<br>(0.012) |
|              | AB | 1.977<br>(0.577)  | 13.026<br>(0.005) | -                 | 4.793<br>(0.188) | 4.527<br>(0.210) | 5.615<br>(0.132) | -                | 7.946<br>(0.047)  |
|              | BC | 11.993<br>(0.007) | 13.234<br>(0.004) | 3.794<br>(0.285)  | -                | 1.529<br>(0.676) | 2.121<br>(0.548) | 2.595<br>(0.458) | -                 |

Test statistic values are under the null distribution of  $\chi^2_{(3)}$ , and associated p-values are below in parenthesis.

Economically, it is difficult to distinguish what the effect of a labour supply shock in Saskatchewan has on unemployment growth in Manitoba, Alberta, and British Columbia. One possible hypothesis for this kind of relationship may be that an adverse shock to labour supply results in labour substitution to other provinces within the region, thus decreasing unemployment rates in the other provinces. As the Granger non-causal tests we perform do not account for signs, we cannot say

whether or not a positive shock to employment growth in Saskatchewan leads to an increase or decrease in unemployment rate growth in the other provinces within the Western region.

Turning to the Atlantic region, there are surprisingly fewer Granger causal relationships than in the Western region. We reject the null hypothesis of Granger non-causality of employment growth in PEI on unemployment growth in New Brunswick at the 5% significance level. Interestingly, employment growth in New Brunswick is Granger causal for wage growth in PEI. This would be an interesting bi-directional causal relationship to explore in future research. Employment growth in Nova Scotia is Granger causal for wage growth in Newfoundland and New Brunswick, but not in PEI.

Table 2: GNC test results in the Atlantic Regional VAR

|              |      | $\Delta u_h$     |                  |                  |                  | $\Delta w_h$     |                  |                  |                   |
|--------------|------|------------------|------------------|------------------|------------------|------------------|------------------|------------------|-------------------|
|              |      | NFLD             | PEI              | NS               | NB               | NFLD             | PEI              | NS               | NB                |
| $\Delta n_i$ | NFLD | -                | 2.496<br>(0.476) | 5.186<br>(0.159) | 0.538<br>(0.911) | -                | 5.888<br>(0.117) | 4.660<br>(0.199) | 1.815<br>(0.612)  |
|              | PEI  | 6.006<br>(0.111) | -                | 4.864<br>(0.182) | 8.835<br>(0.032) | 5.636<br>(0.131) | -                | 0.958<br>(0.811) | 0.808<br>(0.848)  |
|              | NS   | 2.085<br>(0.555) | 1.133<br>(0.769) | -                | 0.783<br>(0.854) | 7.458<br>(0.059) | 3.446<br>(0.328) | -                | 10.224<br>(0.017) |
|              | NB   | 3.417<br>(0.332) | 2.002<br>(0.572) | 1.487<br>(0.685) | -                | 5.719<br>(0.126) | 8.851<br>(0.031) | 5.486<br>(0.140) | -                 |

Test statistic values are under the null distribution of  $\chi^2_{(3)}$ , and associated p-values are below in parenthesis.

In summary, in the Western and Atlantic regions, labour supply shocks within one province affect the dynamics of unemployment and wage growth in some, but not all, of the other provinces. Of course, we can execute similar Granger non-causal tests for shocks of unemployment growth and shocks to wage growth on the other variables across provinces, but this can be explored in future research. From this evidence, along with the Granger Causal mapping in Figure 13, there is a motivation to explore testing for common provincial effects.

#### 4.2.1.1 Common Provincial Effects

While it is especially interesting to investigate causal linkages across provinces within a region under the model of Equation 2, it begs the question whether or not that model is preferable to a simple one. One way of answering this question lies in testing the restriction of coefficients on variables across provincial equations with the regressors  $\Delta n$ ,  $\Delta u$ , and  $\Delta w$  within the SUR framework. For example, we may be interested in testing whether or not the coefficients on employment when regressed on wages are the same across all provinces within a region. This can be done for a specific lag, or jointly across lags. These hypothesis tests can be formalized as follows:

$$H_0: v_{1+q,rsk} = v_{2+q,rsk} = v_{3+q,rsk} = v_{4+q,rsk} \text{ vs } H_a: \text{not } H_0 ;$$

*where  $v = \delta, \theta, \text{ or } \lambda, r = 1, \dots, 4, s = 1, \dots, 3, k = 1, \dots, p$*   
 *$q = 0$  for Atlantic Region,*  
 *$q = 6$  for Western Region*

Note that  $s$  denotes the variable of interest, employment being 1, unemployment being 2, and wages being 3. Furthermore, we test the joint restriction across lags for all  $k$ .

$$H_0: v_{1+q,rsk} = v_{2+q,rsk} = v_{3+q,rsk} = v_{4+q,rsk}, \dots, v_{1+q,rsp} = v_{2+q,rsp} = v_{3+q,rsp} = v_{4+q,rsp} \quad \forall k$$

*vs  $H_a: \text{not } H_0 ;$*   
*where  $v = \delta, \theta, \text{ or } \lambda, r = 1, \dots, 4, s = 1, \dots, 3, k = 1, \dots, p$*   
 *$q = 0$  for Atlantic Region,*  
 *$q = 6$  for Western Region*

The test statistics and corresponding p-values of these tests for the Atlantic and Western regions can be found in Table 10 through Table 15 in Appendix B. These results suggest that there is a statistically significant difference between the restricted model in which coefficients are restricted to be the same across variables and lags within the regional multivariate VAR model and the unrestricted model in which variation is allowed across parameters. Not all restrictions are statistically significant, jointly or otherwise.

We do not aim to report any economic significance from these test results, but we do acknowledge that due to the results we've reported, it may not be statistically appropriate to pool variables within a region and ignore the likely variation in provincial parameters and variables within a given region. Given the complexity of the possible interprovincial relationships implied in equation (2), both in terms of autoregressive parameters and contemporaneous covariance parameters, there are potentially a plethora of possible restricted models that might be explored, which lead to the fully restricted model given in equation (1). We leave a detailed exploration of these many restricted models to future work, though we recognize the potential interest in such hypothesis tests that could be readily examined using appropriate Likelihood Ratio tests.

There is a tradeoff between the province-specific trivariate VAR model and the regional multivariate VAR model. In previous research with pooling and allowing for state or province fixed effects, you can estimate IRFs and FEVDs with ease. However, the model restricts the covariance matrix and makes some underlying assumptions about the homogeneity of provinces within a region, which this paper has demonstrated is not an appropriate assumption. While some univariate relationships behave more or less similarly within a region, say the Atlantic provinces, once taken into a multivariate VAR framework and allowing for heterogeneity in the error term structure, the differences become evident. This conclusion will be collected with those of previous sections to provide an overview of the results and the significance of the findings this paper aims to demonstrate.

## **5. Conclusion**

Since 1976, provinces across Canada exhibit different rates of growth, and even different responses to shocks in labour supply growth. Some trends can be described and summarized by regional groupings, whereas some cases are best described at a disaggregated level by province. The

evidence that is outlined in our findings suggests that ignoring the variation in coefficients in the regional model by pooling may be ignoring important cross provincial Granger causality that is evident in our panel multivariate VAR model. Though it may be advantageous for practical reasons to pool by region, explanatory power lies in estimating the multivariate VAR models by province or by region and allowing for heterogeneity in the error term and coefficients.

The conclusion of our research is separated into three separate sections. The first is the implications and tradeoffs for future research, the second addresses implications for policy decisions in Canada, and the third addresses the shortcomings of our research and how we may further align our findings within the growing body of literature in regional evolutions.

### **5.1 Underlying Sources of Growth**

This section mainly focuses on the overall results of the impact on wages and unemployment rate growth from a labour supply shock induced by a positive shock to employment growth. The preliminary graphical representations of correlations in the data resulted in conflicting conclusions to those in Blanchard et al. (1992). For example, the negative relationship between wages and unemployment in Canadian provinces contrasts to that which is taken as fact to be a negative relationship and found in the data (Barro & Sala-i-Martin, 1991; Blanchflower & Oswald, 1992; Hall, 1970). Furthermore, our data suggested a negative relationship between average wages and employment growth, whereas Blanchard et al. (1992) found no significant relationship between the two variables. However, upon investigation of dynamics within the province-specific trivariate VAR IRF estimation, there are positive wage growth responses to positive impulses on employment growth in all provinces, save Quebec and British Columbia. Quebec shows a negative wage growth response, while British Columbia shows no response wage growth to a positive labour supply shock.

Outside of the data, these relationships are subject to heterogeneous and structural differences in the underlying sources of economic and employment growth within Canada and especially by province. Differences in price levels, costs of living standards, unmeasured amenities, and differences in industrial composition and training programs are some of the many possible unaccounted factors that may influence the sources of growth. Not only does this affect the dynamics of the variables within the system, but it also introduces difficulty in confidently assuming that shocks to employment growth are from the demand or supply side of the labour market.

## **5.2 Implications for Policy**

As the findings of our research suggest there are differing responses of wage growth and unemployment growth in the short-run context to positive shocks in labour supply in province-specific VAR models, we posit that there is not a one-size-fits-all type of fiscal policy to address labour economic outcomes from a federal policy perspective. Furthermore, the causal relationships identified between employment growth and the other choice variables of our research when examined in a regional multivariate VAR context are very different between provinces, even when heterogeneity is accounted for amongst the parameters and the underlying unexplained market forces captured by the residual structure. This would imply that even regionally targeted fiscal policy will result in differing responses of wage and unemployment growth for a given positive shock to employment growth.

A key implication of our findings is that labour targeted fiscal policy may be best executed at the regional level, or at least be funded federally but administered and overseen by provincial authorities. Higher horizon Granger non-causal tests and examination of accumulated IRFs may highlight some of the long-run dynamics between macroeconomic variables.

### 5.3 Frequency, time period, structural breaks

There are several ways in which our research deviated away from the methodology introduced by Blanchard et al. (1992) aside from choosing another country entirely to evaluate regional evolutions. In some ways, our deviations added robustness to the results, whereas in other ways our research ends with asking more questions of future work.

The first is our choice of frequency. While Blanchard et al. (1992) used annual data, we opted for quarterly data and the use of seasonal dummy variables to control for any seasonal component of the data. This has the potential to provide different, but easily transferable results. The main conclusions of our research suggest very similar outcomes, with a couple of different statistical results. For example, we corroborate the findings of Blanchard et al. (1992) when we estimated the IRFs with a positive labour supply shock. Wage growth, and hence wages, increased with a positive shock to employment growth in all provinces except Manitoba and Quebec in the first quarter. This result would imply a positive short-run relationship between wage growth and employment growth. The transitory shocks in the IRFs diminish within a much shorter period of time than those in the estimation of IRF using American annual data. Future work may consider using annual data to compare results to those in the United States as well as in other countries explored by the literature, such as those in Europe.

The second is the difference in time period. The choice of time period to analyze impacts the results of our research. While we followed the sentiment of Blanchard et al. (1992) and did not explore deterministic trends, there are other tools in which future research can use to supplement the findings of our research. Furthermore, looking at the preliminary univariate work with the use of structural breaks to reflect changes in fiscal policy is an interesting avenue of future research.

The third, which may have been forced by our unit-root test results, is our analysis of the VAR system in first differences. Blanchard et al. (1992) do not take the first differences of wages or unemployment. Thus, our analysis is done in terms of growth in our choice variables.

The fourth is the omission of labour force participation in this model. We chose not to include labour force participation in the model specifications as being outside our limited scope and the desire to simplify the analysis. While we believe this would have added a lot of strength to the economic analysis of the model, we leave it to future research to explore this question. Also beyond the scope of our work is the question around labour mobility. The breadth of research in Blanchard et al. (1992) is so wide and has opened up several avenues of research and introduced ways to explore several questions in the macroeconometric framework. This research question has been explored in the Canadian literature. We suggest that another way to explore labour mobility would be through Granger non-causal tests in the multivariate VAR framework introduced in section 4.2.

The fifth, and likely most important deviation, is the regional framework. Blanchard et al. (1992) execute their IRF estimation using aggregate American data. Research has since opted for regional disaggregation, but pool at the regional level (Mäki-Arvela, 2003). Our research's main contribution to the literature is the multivariate VAR analysis by region and the assumption of heterogeneity between provinces within a region. Our main conclusion is that the estimated parameters under this framework are statistically significantly different than if we were to restrict the model's parameters to be the same across provinces, yet allow for heteroskedasticity. Further research could extend this hypothesis to further disaggregate by region within each province.

Finally, depending on how much explanatory power is gained from introducing structural breaks, or annual frequency, or even further disaggregation or estimation of IRFs and FEVDs in the regional

multivariate VAR framework, it would be nice to extend this research into Vector Error Correction Model estimation as these series are most likely cointegrated. Irrespective of the direction the research takes, it would be interesting to see how robust the results are to the relaxation of some assumptions that are held regarding the data.

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## **Appendix A: Variables**

### **A.1 Data Sources**

Monthly employment and unemployment figures are acquired through the Labour Force Survey (LFS) from January 1976 to November 2014, while weekly wages are collected via the Survey of Employment, Payroll, and Hours (SEPH) in four different monthly series, 1961-1985, 1983-2000, 1991-2000, and 2001-2014. These data are converted to quarterly data by taking the middle month of the quarter as the quarterly observation. We decided that taking the average of the monthly data by each quarter introduced unnecessary inefficiency.

#### **A.1.1 Employment**

Employment data are monthly aggregate employment figures that are seasonally unadjusted, and are collected for both sexes, and age groups above 15 years of age by province and for Canada as a whole from CANSIM<sup>6</sup>. The following is a list of the series numbers:

Canada: v2064890

Newfoundland: v2065079

Prince Edward Island: v2065268

Nova Scotia: v2065457

New Brunswick: v2065646

Quebec: v2065835

Ontario: v2066024

Manitoba: v2066213

Saskatchewan: v2066402

Alberta: v2066591

British Columbia: v2066780

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<sup>6</sup> Statistics Canada data are retrieved from the University of Toronto's CHASS database <http://dc.chass.utoronto.ca/chasscansim/>

### **A.1.2 Unemployment Rate**

As with the employment data, unemployment figures are monthly average unemployment rates by province and in Canada. These data are seasonally unadjusted, and collected for both sexes, and age groups above 15 years of age from CANSIM. The following is a list of the series numbers:

Canada: v2064894  
Newfoundland: v2065083  
Prince Edward Island: v2065272  
Nova Scotia: v2065461  
New Brunswick: v2065650  
Quebec: v2065839  
Ontario: v2066028  
Manitoba: v2066217  
Saskatchewan: v2066406  
Alberta: v2066595  
British Columbia: v2066784

### **A.1.3 Wages**

As explained in Section 3, wage data were spliced across the four different series, due to a switch from SIC to NAICS standards of industry codes. As our research looks at the dynamics of average aggregate weekly wages, splicing these series seemed appropriate. Any variation or trend in the data is captured, irrespective of the structural changes behind the disaggregation by industry under different industrial code mappings. All data are collected via CANSIM, and capture average weekly earnings for all employees including overtime, are not seasonally adjusted or disaggregated by industry. The following table lists the series numbers for each time period and industrial code system, SIC or NAICS.

Table 3: Series Numbers for Wage Data for Time Periods in Canada and by Province

|                             | SIC       |           | NAICS     |           |
|-----------------------------|-----------|-----------|-----------|-----------|
|                             | 1961-1985 | 1983-2000 | 1991-2000 | 2001-2014 |
| <b>Canada</b>               | v75249    | v250529   | v78938414 | v1558664  |
| <b>Newfoundland</b>         | v76132    | v257567   | v78940418 | v1558942  |
| <b>Prince Edward Island</b> | v76197    | v261373   | v78941068 | v1559046  |
| <b>Nova Scotia</b>          | v76233    | v265027   | v78941466 | v1559117  |
| <b>New Brunswick</b>        | v76325    | v270349   | v78942334 | v1559237  |
| <b>Quebec</b>               | v76493    | v275763   | v78943178 | v1559380  |
| <b>Ontario</b>              | v76943    | v283107   | v78944890 | v1559645  |
| <b>Manitoba</b>             | v77638    | v290329   | v78946736 | v1559907  |
| <b>Saskatchewan</b>         | v77772    | v296195   | v78947942 | v1560081  |
| <b>Alberta</b>              | v77888    | v301891   | v78948932 | v1560222  |
| <b>British Columbia</b>     | v78082    | v308359   | v78950324 | v1560414  |

## A.2 Variable Definitions

The variables  $n_{it}$ ,  $u_{it}$ , and  $w_{it}$  as defined by Blanchard et al. (1992), are meant to capture the stochastic process of relative employment, unemployment rates, and wages respectively. More formally, logarithmic deviations of the aggregate employment level in province  $i$  in quarter  $t$  is defined as

$$n_{it} = \ln(\text{employment}_{it}) - \ln(\text{employment}_{CA,t})$$

Relative unemployment, or deviations about the national unemployment rate in province  $i$  in quarter  $t$ , is defined as

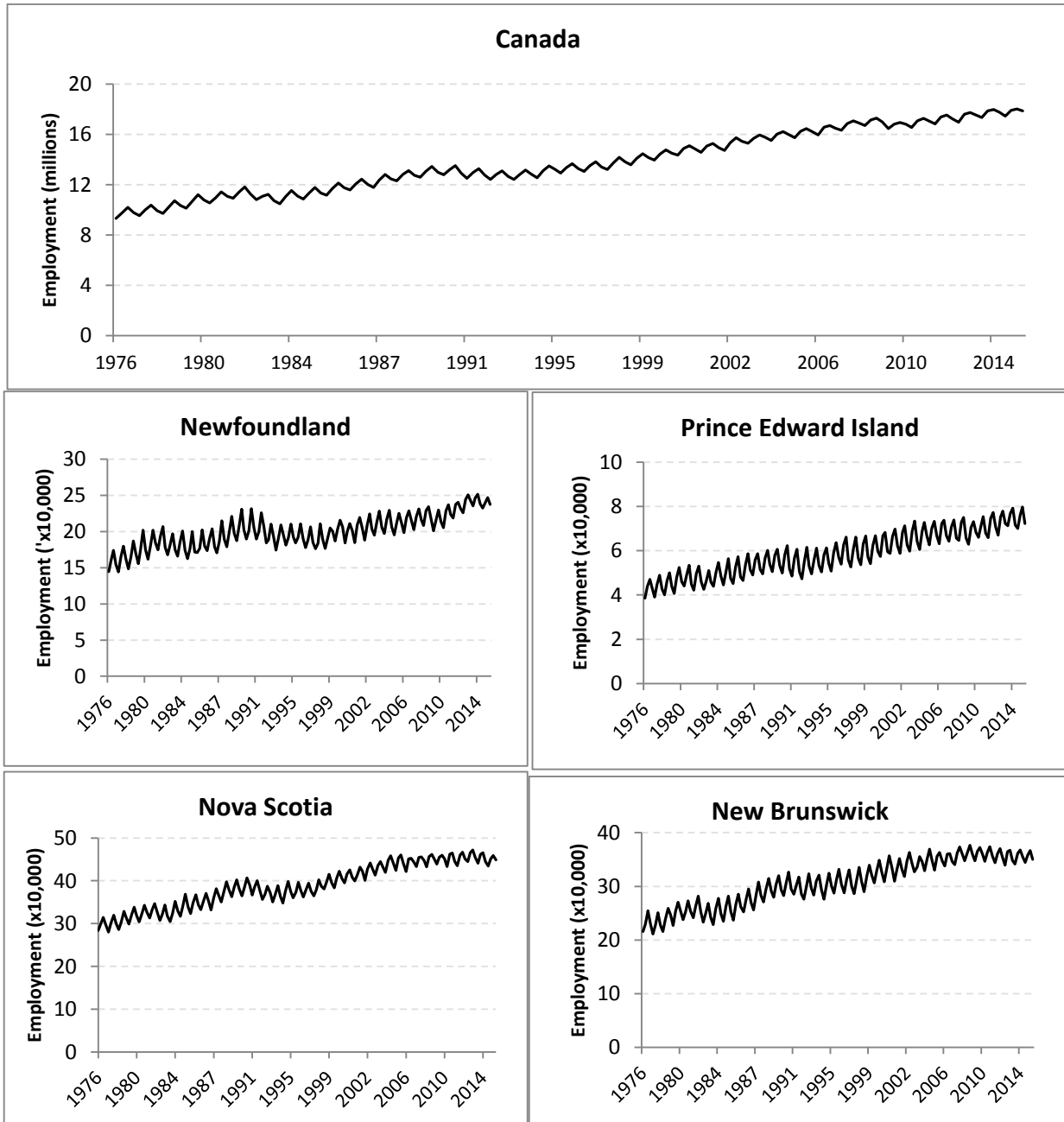
$$u_{it} = \text{unemployment}_{i,t} - \text{unemployment}_{CA,t}$$

Lastly, relative wages, or logarithmic deviations about the national weekly wage earnings in province  $i$  in quarter  $t$ , is defined as

$$w_{it} = \ln(\text{wage}_{it}) - \ln(\text{wage}_{CA,t})$$

### A.3 Graphical Representations of Data

Figure 17: Employment, 1976Q1-2015Q1



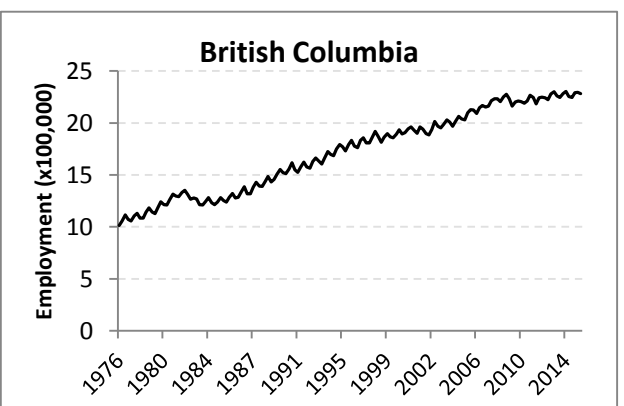
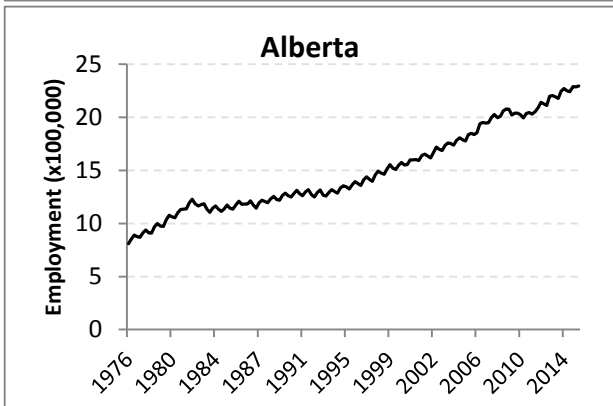
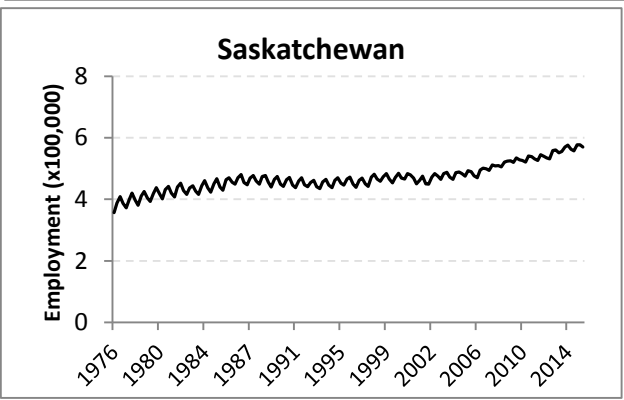
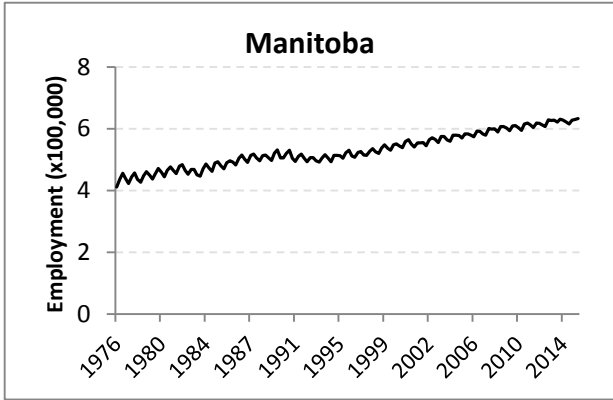
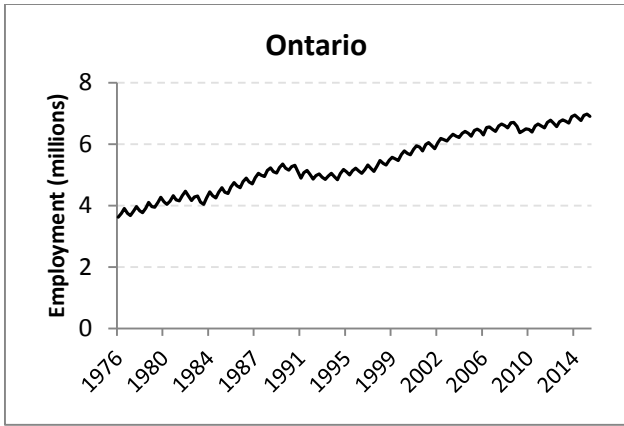
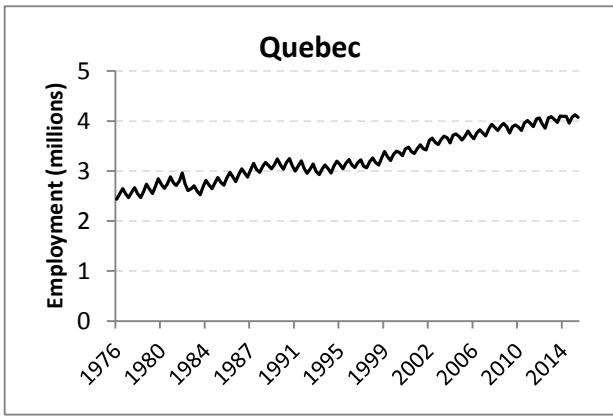
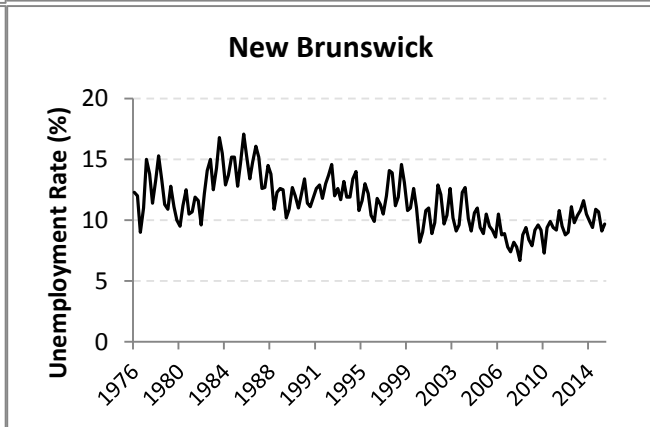
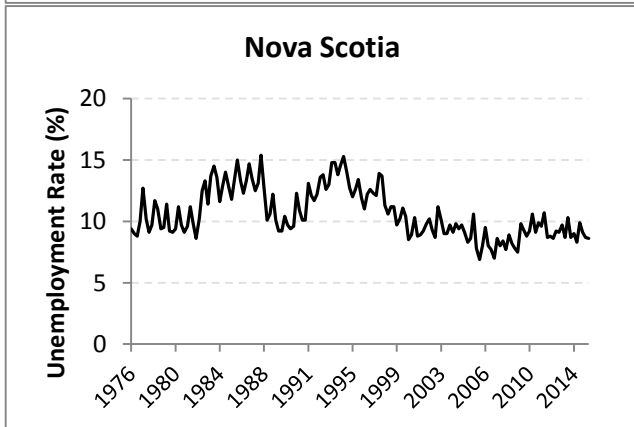
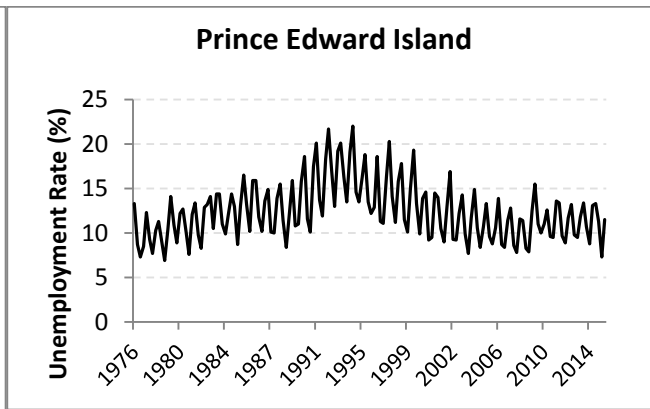
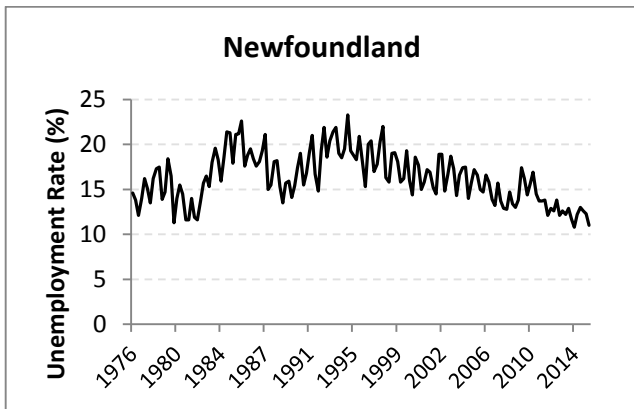
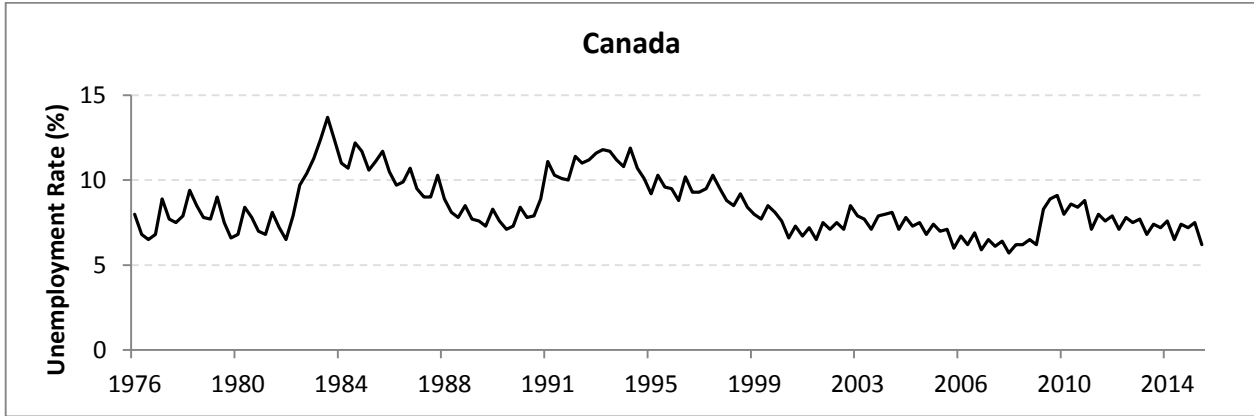


Figure 18: Unemployment Rates (1976Q1-2015Q1)



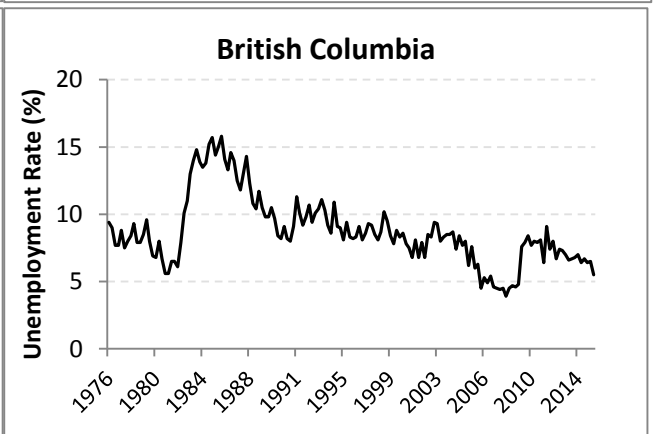
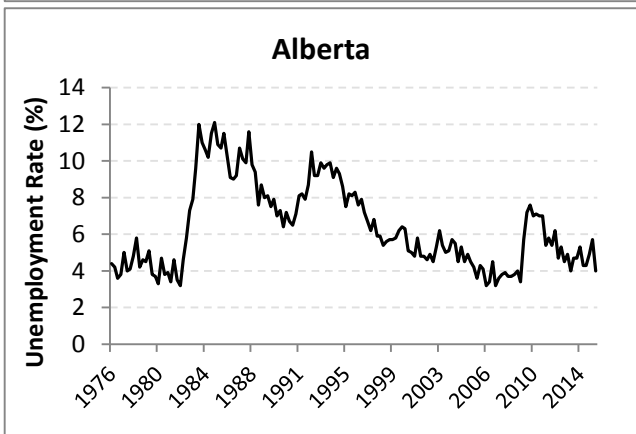
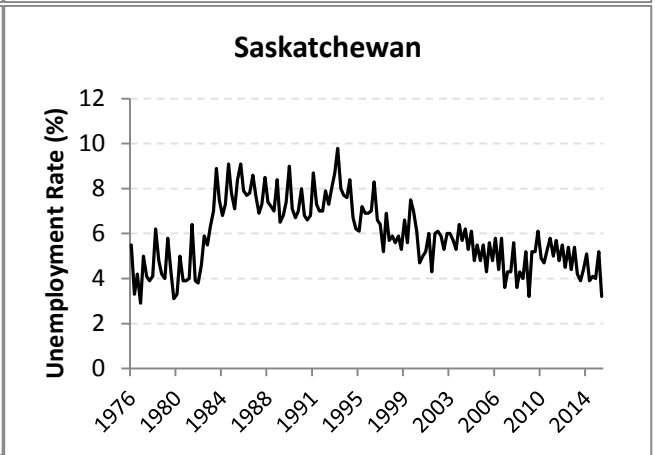
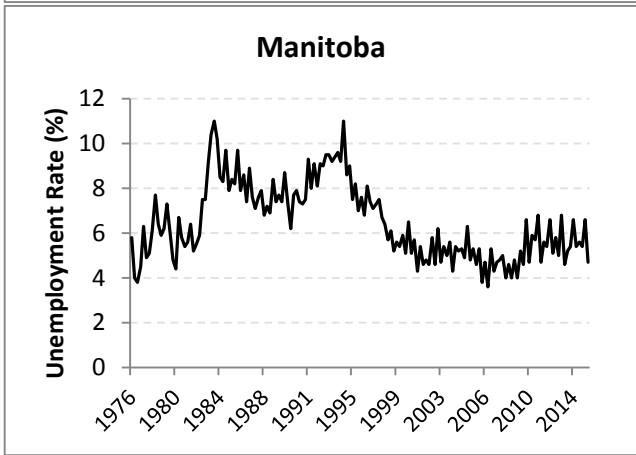
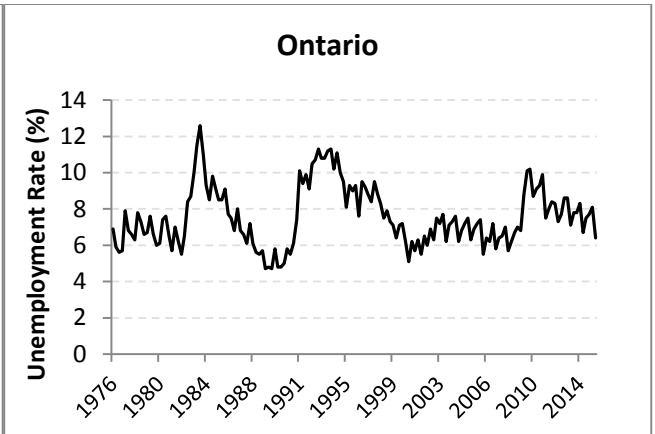
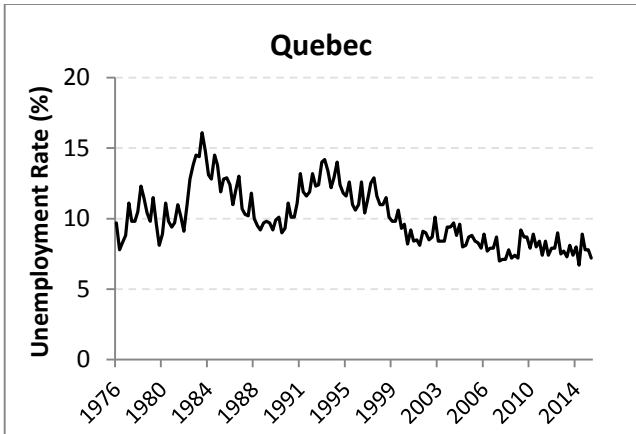
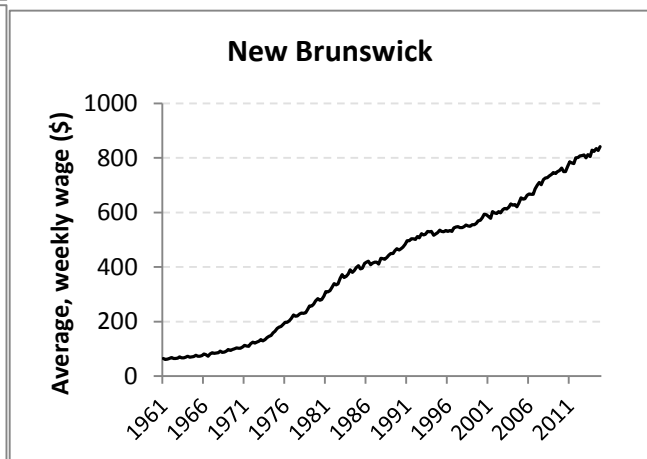
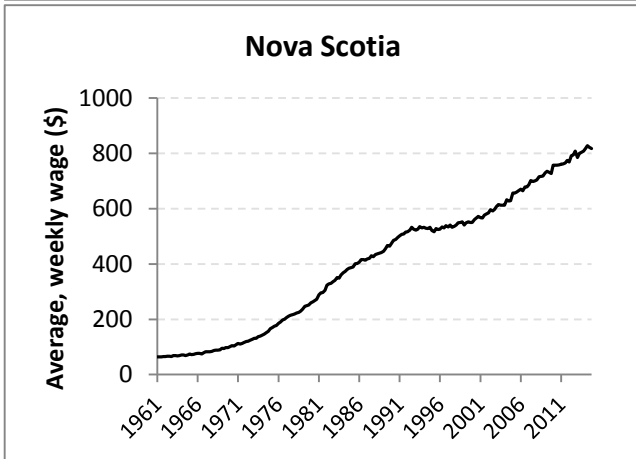
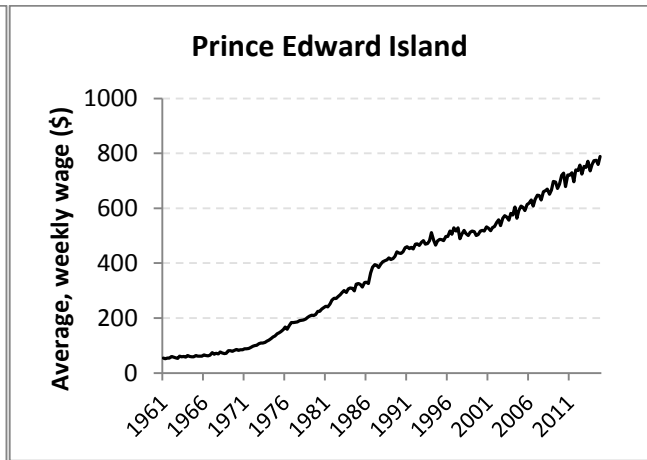
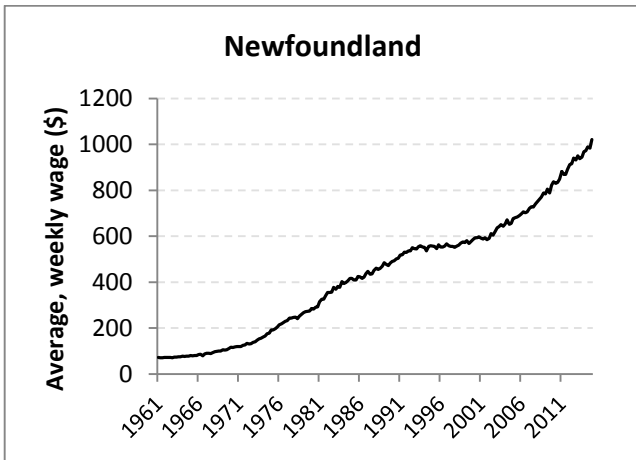
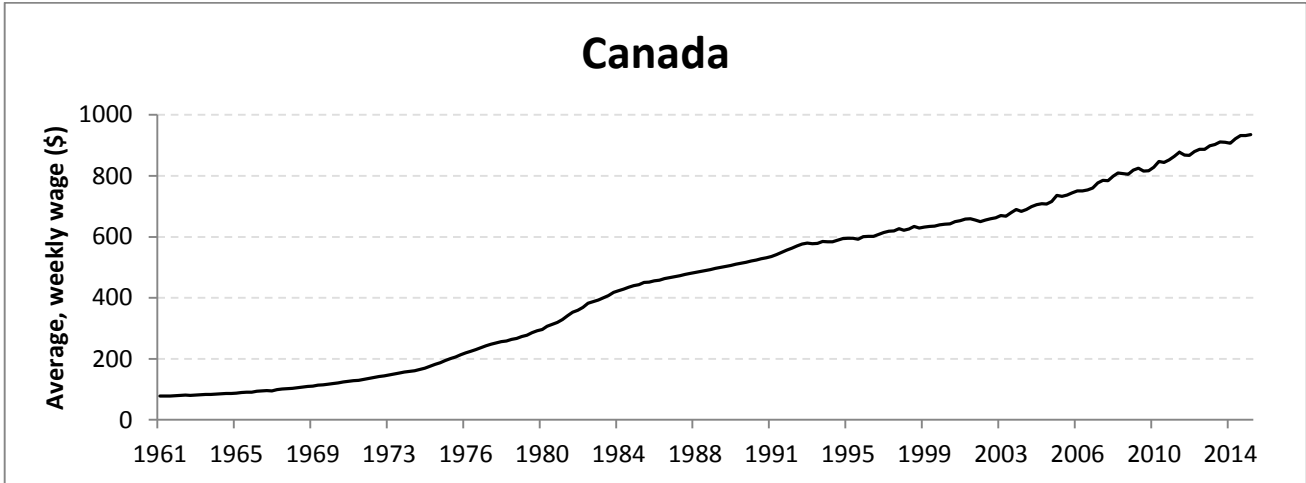
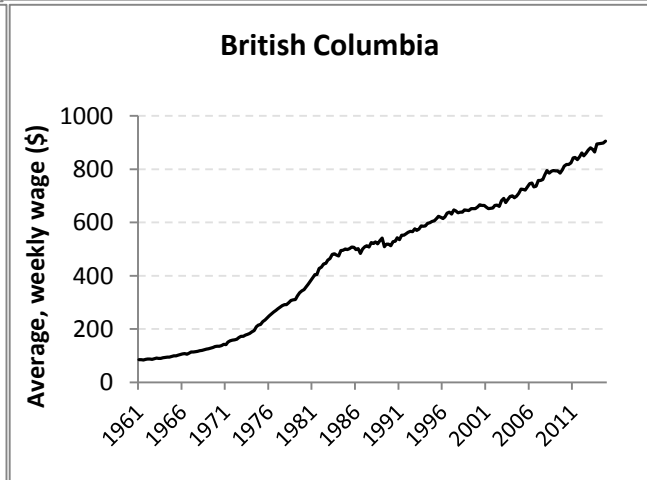
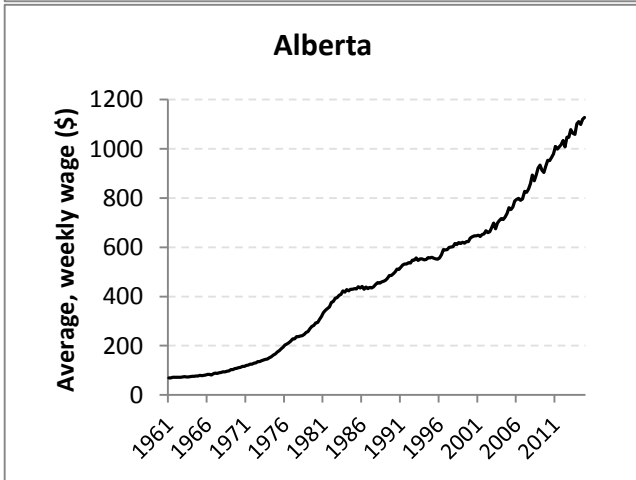
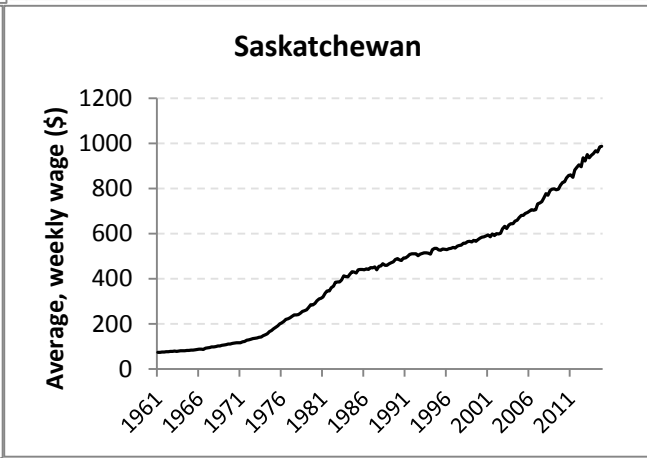
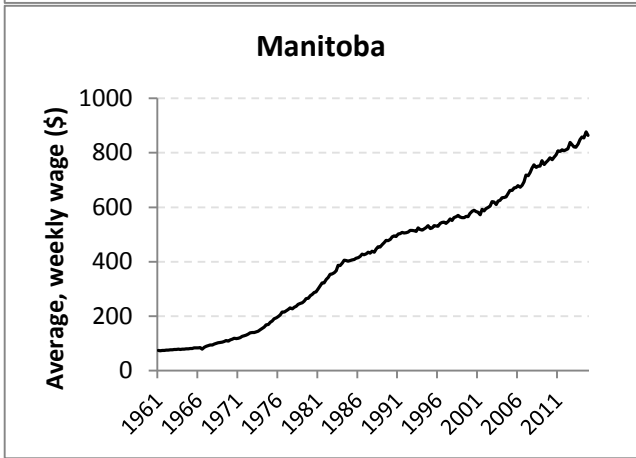
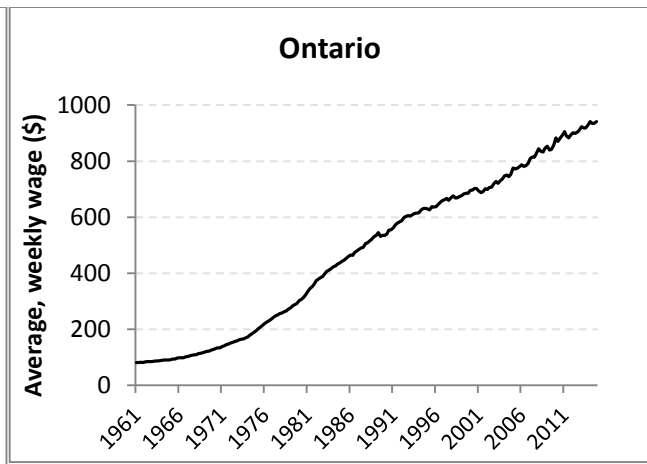
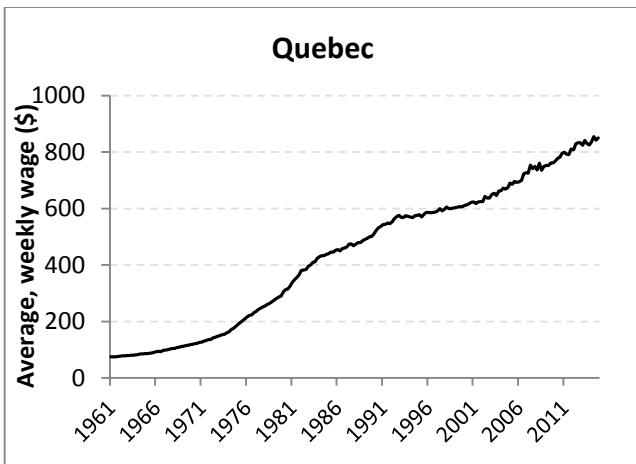


Figure 19: Wages, 1961Q1-2015Q1





#### A.4 Summary Statistics by Variable

Table 4: Means and Standard Deviations by Province and Variable

|                             | Means  |        |        | Standard Deviations |       |       |
|-----------------------------|--------|--------|--------|---------------------|-------|-------|
|                             | n      | u      | w      | n                   | u     | w     |
| <b>Newfoundland</b>         | -4.228 | 7.846  | -0.027 | 0.096               | 1.982 | 0.026 |
| <b>Prince Edward Island</b> | -5.459 | 3.952  | -0.113 | 0.058               | 2.725 | 0.046 |
| <b>Nova Scotia</b>          | -3.566 | 2.183  | -0.061 | 0.051               | 0.892 | 0.029 |
| <b>New Brunswick</b>        | -3.802 | 2.991  | -0.055 | 0.052               | 1.394 | 0.027 |
| <b>Quebec</b>               | -1.438 | 1.624  | -0.011 | 0.037               | 0.812 | 0.023 |
| <b>Ontario</b>              | -0.943 | -0.863 | 0.017  | 0.015               | 1.037 | 0.022 |
| <b>Manitoba</b>             | -3.251 | -1.958 | -0.039 | 0.072               | 0.766 | 0.021 |
| <b>Saskatchewan</b>         | -3.371 | -2.528 | -0.026 | 0.099               | 1.082 | 0.024 |
| <b>Alberta</b>              | -2.243 | -2.056 | -0.039 | 0.093               | 1.215 | 0.034 |
| <b>British Columbia</b>     | -2.095 | 0.285  | 0.027  | 0.075               | 1.552 | 0.029 |

## Appendix B: Test Results

### B.1 Unit Root Test Results

Table 5 : ADF Test Results for  $n_i$

| Levels                                |                   |                            |
|---------------------------------------|-------------------|----------------------------|
|                                       | ADF: t-Statistics | Decision                   |
| $n_{ffd}$                             | -1.416            | support I(1) at all levels |
| $n_{pei}$                             | -3.687            | support I(1) at 5% and 10% |
| $n_{ns}$                              | -1.671            | support I(1) at all levels |
| $n_{nb}$                              | -0.754            | support I(1) at all levels |
| $n_{qb}$                              | -2.620            | support I(1) at all levels |
| $n_{on}$                              | -1.484            | support I(1) at all levels |
| $n_{mb}$                              | -0.397            | support I(1) at all levels |
| $n_{sk}$                              | -0.369            | support I(1) at all levels |
| $n_{ab}$                              | -1.707            | support I(1) at all levels |
| $n_{bc}$                              | -0.015            | support I(1) at all levels |
| ADF critical values: MacKinnon (1996) |                   |                            |
| 1% level                              |                   | -4.020                     |
| 5% level                              |                   | -3.440                     |
| 10% level                             |                   | -3.144                     |

\*, \*\*, \*\*\* denote statistical significance at the 10%, 5%, and 1% levels respectively.

Table 6 : ADF Test Results for  $u_i$

| Levels                                |                   |                            |
|---------------------------------------|-------------------|----------------------------|
|                                       | ADF: t-Statistics | Decision                   |
| $u_{ffd}$                             | -1.657            | support I(1) at all levels |
| $u_{pei}$                             | -2.938            | support I(1) at all levels |
| $u_{ns}$                              | -3.885**          | support I(1) at 5% and 10% |
| $u_{nb}$                              | -3.087            | support I(1) at all levels |
| $u_{qb}$                              | -2.591            | support I(1) at all levels |
| $u_{on}$                              | -1.855            | support I(1) at all levels |
| $u_{mb}$                              | -3.041            | support I(1) at all levels |
| $u_{sk}$                              | -1.890            | support I(1) at all levels |
| $u_{ab}$                              | -1.707            | support I(1) at all levels |
| $u_{bc}$                              | -2.101            | support I(1) at all levels |
| ADF critical values: MacKinnon (1996) |                   |                            |
| 1% level                              |                   | -4.020                     |
| 5% level                              |                   | -3.440                     |
| 10% level                             |                   | -3.144                     |

\*, \*\*, \*\*\* denote statistical significance at the 10%, 5%, and 1% levels respectively.

Table 7 : ADF Test Results for  $w_i$

| Levels                                |                   |                            |
|---------------------------------------|-------------------|----------------------------|
|                                       | ADF: t-Statistics | Decision                   |
| $w_{nfld}$                            | -0.479            | support I(1) at all levels |
| $w_{pei}$                             | -1.985            | support I(1) at all levels |
| $w_{ns}$                              | -1.474            | support I(1) at all levels |
| $w_{nb}$                              | -1.800            | support I(1) at all levels |
| $w_{qb}$                              | -1.792            | support I(1) at all levels |
| $w_{on}$                              | -0.915            | support I(1) at all levels |
| $w_{mb}$                              | -3.488            | support I(1) at 5% and 10% |
| $w_{sk}$                              | 0.310             | support I(1) at all levels |
| $w_{ab}$                              | -0.817            | support I(1) at all levels |
| $w_{bc}$                              | -2.066            | support I(1) at all levels |
| ADF critical values: MacKinnon (1996) |                   |                            |
| 1% level                              |                   | -4.020                     |
| 5% level                              |                   | -3.440                     |
| 10% level                             |                   | -3.144                     |

\*, \*\*, \*\*\* denote statistical significance at the 10%, 5%, and 1% levels respectively.

Table 8: Lag Order Selection for Univariate and DVAR Models

|      | Hannan-Quinn Information Criteria |                |                |                |
|------|-----------------------------------|----------------|----------------|----------------|
|      | $\Delta n$                        | $\Delta u$     | $\Delta w$     | DVAR           |
| NFLD | 4                                 | 3              | 3              | 3              |
| PEI  | 3                                 | 3              | 4 <sup>i</sup> | 2              |
| NS   | 4                                 | 3              | 3              | 3              |
| NB   | 6                                 | 2              | 4              | 2              |
| QB   | 1                                 | 2              | 3              | 2              |
| ON   | 1                                 | 4              | 1              | 4 <sup>i</sup> |
| MB   | 1                                 | 1              | 3              | 1              |
| SK   | 8                                 | 1 <sup>i</sup> | 4              | 3              |
| AB   | 4                                 | 2 <sup>i</sup> | 1              | 2              |
| BC   | 5                                 | 1 <sup>i</sup> | 2              | 1              |

<sup>i</sup> denotes univariate regressions that did not include seasonal dummy variables.

## B.2 Test Results for Provincial and Regional VARs

Table 9: Granger Non-causality tests in Provincial VARs

| $H_0:$ | $\Delta u_i \nrightarrow \Delta n_i$ | $\Delta w_i \nrightarrow \Delta n_i$ | $\Delta n_i \nrightarrow \Delta w_i$ | $\Delta u_i \nrightarrow \Delta w_i$ | $\Delta n_i \nrightarrow \Delta u_i$ | $\Delta w_i \nrightarrow \Delta u_i$ |
|--------|--------------------------------------|--------------------------------------|--------------------------------------|--------------------------------------|--------------------------------------|--------------------------------------|
| NFLD   | 23.229<br>(0.000)                    | 7.257<br>(0.064)                     | 3.378<br>(0.337)                     | 5.407<br>(0.144)                     | 4.694<br>(0.196)                     | 0.709<br>(0.871)                     |
| PEI    | 6.045<br>(0.049)                     | 0.570<br>(0.752)                     | 11.004<br>(0.004)                    | 7.041<br>(0.030)                     | 5.557<br>(0.062)                     | 2.746<br>(0.253)                     |
| NS     | 7.485<br>(0.058)                     | 3.467<br>(0.325)                     | 18.892<br>(0.000)                    | 2.677<br>(0.444)                     | 6.258<br>(0.100)                     | 3.188<br>(0.364)                     |
| NB     | 6.144<br>(0.046)                     | 0.574<br>(0.751)                     | 8.979<br>(0.011)                     | 2.468<br>(0.291)                     | 0.934<br>(0.627)                     | 2.039<br>(0.361)                     |
| QB     | 2.181<br>(0.336)                     | 0.535<br>(0.765)                     | 2.181<br>(0.336)                     | 0.535<br>(0.765)                     | 2.181<br>(0.336)                     | 0.535<br>(0.765)                     |
| ON     | 1.216<br>(0.875)                     | 2.070<br>(0.723)                     | 1.216<br>(0.875)                     | 2.070<br>(0.723)                     | 1.216<br>(0.875)                     | 2.070<br>(0.723)                     |
| MB     | 0.101<br>(0.751)                     | 3.202<br>(0.074)                     | 0.101<br>(0.751)                     | 3.202<br>(0.074)                     | 0.101<br>(0.751)                     | 3.202<br>(0.074)                     |
| SK     | 8.145<br>(0.043)                     | 1.080<br>(0.782)                     | 8.145<br>(0.043)                     | 1.080<br>(0.782)                     | 8.145<br>(0.043)                     | 1.080<br>(0.782)                     |
| AB     | 1.942<br>(0.379)                     | 9.237<br>(0.010)                     | 1.675<br>(0.433)                     | 0.762<br>(0.683)                     | 7.765<br>(0.021)                     | 3.005<br>(0.223)                     |
| BC     | 0.014<br>(0.905)                     | 0.785<br>(0.905)                     | 5.056<br>(0.025)                     | 0.022<br>(0.881)                     | 0.608<br>(0.436)                     | 0.423<br>(0.516)                     |

GNC tests are under  $H_0 \sim \chi^2$   
*p*-values in parentheses

Table 10: Atlantic VAR Wald Test Results with dependent variable  $\Delta n$

| Dependent Variable: $\Delta n$ |       |                   |                   |                  |               |       |                   |                   |                  |
|--------------------------------|-------|-------------------|-------------------|------------------|---------------|-------|-------------------|-------------------|------------------|
|                                | Lag   | $\Delta n$        | $\Delta u$        | $\Delta w$       |               | Lag   | $\Delta n$        | $\Delta u$        | $\Delta w$       |
| Newfoundland                   | 1     | 22.257<br>(0.000) | 1.819<br>(0.611)  | 3.035<br>(0.386) | PEI           | 1     | 0.125<br>(0.989)  | 5.402<br>(0.145)  | 3.035<br>(0.386) |
|                                | 2     | 2.812<br>(0.422)  | 3.847<br>(0.279)  | 2.158<br>(0.540) |               | 2     | 7.781<br>(0.051)  | 3.985<br>(0.263)  | 2.158<br>(0.540) |
|                                | 3     | 19.197<br>(0.000) | 9.317<br>(0.025)  | 2.888<br>(0.409) |               | 3     | 5.432<br>(0.143)  | 6.226<br>(0.101)  | 2.888<br>(0.409) |
|                                | Joint | 45.854<br>(0.000) | 16.769<br>(0.053) | 8.356<br>(0.499) |               | Joint | 12.599<br>(0.182) | 12.601<br>(0.182) | 6.661<br>(0.672) |
|                                | Lag   | $\Delta n$        | $\Delta u$        | $\Delta w$       |               | Lag   | $\Delta n$        | $\Delta u$        | $\Delta w$       |
| Nova Scotia                    | 1     | 3.299<br>(0.348)  | 7.433<br>(0.059)  | 1.393<br>(0.707) | New Brunswick | 1     | 11.347<br>(0.010) | 1.713<br>(0.634)  | 0.690<br>(0.876) |
|                                | 2     | 1.794<br>(0.616)  | 7.995<br>(0.046)  | 0.240<br>(0.971) |               | 2     | 11.392<br>(0.010) | 0.879<br>(0.831)  | 5.028<br>(0.170) |
|                                | 3     | 11.577<br>(0.009) | 2.079<br>(0.556)  | 1.680<br>(0.641) |               | 3     | 9.857<br>(0.020)  | 1.022<br>(0.796)  | 3.354<br>(0.340) |
|                                | Joint | 15.805<br>(0.071) | 18.538<br>(0.029) | 3.553<br>(0.938) |               | Joint | 30.236<br>(0.000) | 4.034<br>(0.909)  | 9.969<br>(0.353) |

Tests are executed across regressions in the SUR model for the regressor  $\Delta n$  under  $H_0 \sim \chi^2_{(3)}$  for each lag.

Joint tests are under  $H_0 \sim \chi^2_{(9)}$

*p-values in parentheses*

Table 11: Atlantic VAR Wald Test Results with dependent variable  $\Delta u$

| Dependent Variable: $\Delta u$ |       |                  |                   |                   |               |       |                   |                   |                   |
|--------------------------------|-------|------------------|-------------------|-------------------|---------------|-------|-------------------|-------------------|-------------------|
|                                | Lag   | $\Delta n$       | $\Delta u$        | $\Delta w$        |               | Lag   | $\Delta n$        | $\Delta u$        | $\Delta w$        |
| Newfoundland                   | 1     | 6.607<br>(0.086) | 32.579<br>(0.000) | 5.806<br>(0.121)  | PEI           | 1     | 7.232<br>(0.065)  | 42.085<br>(0.000) | 2.195<br>(0.533)  |
|                                | 2     | 1.350<br>(0.717) | 20.757<br>(0.000) | 1.830<br>(0.608)  |               | 2     | 3.822<br>(0.281)  | 8.601<br>(0.035)  | 2.048<br>(0.563)  |
|                                | 3     | 0.691<br>(0.875) | 2.890<br>(0.281)  | 0.796<br>(0.850)  |               | 3     | 1.489<br>(0.685)  | 9.572<br>(0.023)  | 0.737<br>(0.865)  |
|                                | Joint | 8.332<br>(0.501) | 0.409<br>(0.000)  | 9.724<br>(0.373)  |               | Joint | 10.632<br>(0.302) | 49.188<br>(0.000) | 5.968<br>(0.743)  |
|                                | Lag   | $\Delta n$       | $\Delta u$        | $\Delta w$        |               | Lag   | $\Delta n$        | $\Delta u$        | $\Delta w$        |
| Nova Scotia                    | 1     | 0.352<br>(0.950) | 26.828<br>(0.000) | 2.812<br>(0.422)  | New Brunswick | 1     | 1.330<br>(0.722)  | 6.520<br>(0.089)  | 1.021<br>(0.796)  |
|                                | 2     | 1.433<br>(0.698) | 18.952<br>(0.000) | 4.964<br>(0.174)  |               | 2     | 1.479<br>(0.687)  | 14.363<br>(0.003) | 9.075<br>(0.028)  |
|                                | 3     | 1.147<br>(0.766) | 14.794<br>(0.002) | 8.480<br>(0.037)  |               | 3     | 4.083<br>(0.253)  | 1.623<br>(0.654)  | 1.256<br>(0.740)  |
|                                | Joint | 4.294<br>(0.891) | 46.934<br>(0.000) | 15.522<br>(0.078) |               | Joint | 8.226<br>(0.512)  | 20.210<br>(0.017) | 11.891<br>(0.220) |

Tests are executed across regressions in the SUR model for the regressor  $\Delta u$  under  $H_0 \sim \chi^2_{(3)}$  for each lag.

Joint tests are under  $H_0 \sim \chi^2_{(9)}$

*p*-values in parentheses

Table 12: Atlantic VAR Wald Test Results with dependent variable  $\Delta w$

| Dependent Variable: $\Delta w$ |       |                   |                   |                   |               |       |                   |                   |                   |
|--------------------------------|-------|-------------------|-------------------|-------------------|---------------|-------|-------------------|-------------------|-------------------|
|                                | Lag   | $\Delta n$        | $\Delta u$        | $\Delta w$        |               | Lag   | $\Delta n$        | $\Delta u$        | $\Delta w$        |
| Newfoundland                   | 1     | 6.408<br>(0.093)  | 2.290<br>(0.514)  | 34.088<br>(0.000) | PEI           | 1     | 10.359<br>(0.016) | 2.061<br>(0.560)  | 14.616<br>(0.002) |
|                                | 2     | 0.260<br>(0.967)  | 12.196<br>(0.007) | 2.609<br>(0.456)  |               | 2     | 5.945<br>(0.114)  | 2.895<br>(0.408)  | 3.323<br>(0.345)  |
|                                | 3     | 10.950<br>(0.012) | 6.335<br>(0.096)  | 8.317<br>(0.040)  |               | 3     | 2.892<br>(0.409)  | 19.452<br>(0.000) | 20.848<br>(0.000) |
|                                | Joint | 20.931<br>(0.013) | 17.377<br>(0.043) | 43.900<br>(0.000) |               | Joint | 16.152<br>(0.064) | 23.156<br>(0.006) | 34.690<br>(0.000) |
|                                | Lag   | $\Delta n$        | $\Delta u$        | $\Delta w$        |               | Lag   | $\Delta n$        | $\Delta u$        | $\Delta w$        |
| Nova Scotia                    | 1     | 9.927<br>(0.019)  | 2.148<br>(0.542)  | 8.378<br>(0.039)  | New Brunswick | 1     | 2.940<br>(0.401)  | 0.830<br>(0.842)  | 30.228<br>(0.000) |
|                                | 2     | 4.865<br>(0.182)  | 2.531<br>(0.470)  | 6.603<br>(0.086)  |               | 2     | 1.934<br>(0.586)  | 0.642<br>(0.887)  | 10.424<br>(0.015) |
|                                | 3     | 3.632<br>(0.304)  | 5.875<br>(0.118)  | 1.151<br>(0.765)  |               | 3     | 3.676<br>(0.299)  | 5.366<br>(0.147)  | 10.776<br>(0.013) |
|                                | Joint | 23.717<br>(0.005) | 12.759<br>(0.174) | 16.884<br>(0.051) |               | Joint | 10.742<br>(0.294) | 9.339<br>(0.407)  | 42.315<br>(0.000) |

Tests are executed across regressions in the SUR model for the regressor  $\Delta w$  under the null distribution  $\sim \chi^2_{(3)}$  for each lag.

Joint tests are under  $H_0 \sim \chi^2_{(9)}$

*p*-values in parentheses

Table 13: West VAR Wald test Results with dependent variable  $\Delta n$

| Dependent Variable: $\Delta n$ |       |                   |                   |                   |                         |       |                   |                   |                   |
|--------------------------------|-------|-------------------|-------------------|-------------------|-------------------------|-------|-------------------|-------------------|-------------------|
|                                | Lag   | $\Delta n$        | $\Delta u$        | $\Delta w$        |                         | Lag   | $\Delta n$        | $\Delta u$        | $\Delta w$        |
| <b>Manitoba</b>                | 1     | 28.024<br>(0.000) | 7.364<br>(0.061)  | 4.022<br>(0.259)  | <b>Saskatchewan</b>     | 1     | 13.706<br>(0.003) | 4.311<br>(0.230)  | 1.846<br>(0.605)  |
|                                | 2     | 19.433<br>(0.000) | 14.585<br>(0.002) | 13.462<br>(0.004) |                         | 2     | 6.929<br>(0.074)  | 8.861<br>(0.031)  | 0.670<br>(0.880)  |
|                                | 3     | 1.855<br>(0.603)  | 11.817<br>(0.008) | 13.587<br>(0.004) |                         | 3     | 3.618<br>(0.306)  | 5.611<br>(0.132)  | 4.664<br>(0.198)  |
|                                | Joint | 36.742<br>(0.000) | 21.048<br>(0.012) | 27.138<br>(0.001) |                         | Joint | 20.539<br>(0.015) | 18.626<br>(0.029) | 8.371<br>(0.497)  |
|                                | Lag   | $\Delta n$        | $\Delta u$        | $\Delta w$        |                         | Lag   | $\Delta n$        | $\Delta u$        | $\Delta w$        |
| <b>Alberta</b>                 | 1     | 4.407<br>(0.221)  | 0.745<br>(0.863)  | 11.726<br>(0.008) | <b>British Columbia</b> | 1     | 1.660<br>(0.646)  | 2.811<br>(0.422)  | 5.632<br>(0.131)  |
|                                | 2     | 8.768<br>(0.033)  | 3.155<br>(0.368)  | 10.828<br>(0.013) |                         | 2     | 1.544<br>(0.672)  | 2.514<br>(0.473)  | 3.566<br>(0.312)  |
|                                | 3     | 13.849<br>(0.003) | 5.819<br>(0.121)  | 1.936<br>(0.586)  |                         | 3     | 12.485<br>(0.006) | 2.457<br>(0.483)  | 3.845<br>(0.279)  |
|                                | Joint | 26.895<br>(0.002) | 8.454<br>(0.489)  | 20.934<br>(0.013) |                         | Joint | 16.108<br>(0.065) | 7.861<br>(0.548)  | 10.203<br>(0.334) |

Tests are executed across regressions in the SUR model for the regressor  $\Delta w$  under the null distribution  $\sim \chi^2_{(3)}$  for each lag.  
 Joint tests are under  $H_0 \sim \chi^2_{(9)}$   
 p-values in parentheses

Table 14: West VAR Wald test Results with dependent variable  $\Delta u$

| Dependent Variable: $\Delta u$ |       |                   |                   |                   |                         |       |                   |                   |                  |
|--------------------------------|-------|-------------------|-------------------|-------------------|-------------------------|-------|-------------------|-------------------|------------------|
|                                | Lag   | $\Delta n$        | $\Delta u$        | $\Delta w$        |                         | Lag   | $\Delta n$        | $\Delta u$        | $\Delta w$       |
| <b>Manitoba</b>                | 1     | 6.914<br>(0.075)  | 25.186<br>(0.000) | 1.916<br>(0.259)  | <b>Saskatchewan</b>     | 1     | 6.014<br>(0.111)  | 45.775<br>(0.000) | 0.401<br>(0.940) |
|                                | 2     | 9.791<br>(0.020)  | 4.790<br>(0.188)  | 2.569<br>(0.004)  |                         | 2     | 3.540<br>(0.316)  | 17.208<br>(0.001) | 1.153<br>(0.880) |
|                                | 3     | 6.917<br>(0.075)  | 6.694<br>(0.082)  | 5.721<br>(0.004)  |                         | 3     | 5.895<br>(0.117)  | 3.038<br>(0.386)  | 0.764<br>(0.671) |
|                                | Joint | 15.860<br>(0.070) | 32.408<br>(0.000) | 10.742<br>(0.001) |                         | Joint | 18.996<br>(0.025) | 49.613<br>(0.000) | 3.966<br>(0.914) |
|                                | Lag   | $\Delta n$        | $\Delta u$        | $\Delta w$        |                         | Lag   | $\Delta n$        | $\Delta u$        | $\Delta w$       |
| <b>Alberta</b>                 | 1     | 6.412<br>(0.093)  | 34.978<br>(0.000) | 3.397<br>(0.334)  | <b>British Columbia</b> | 1     | 1.740<br>(0.628)  | 16.989<br>(0.001) | 0.640<br>(0.887) |
|                                | 2     | 8.128<br>(0.043)  | 13.666<br>(0.003) | 9.486<br>(0.024)  |                         | 2     | 9.901<br>(0.019)  | 12.867<br>(0.005) | 0.788<br>(0.852) |
|                                | 3     | 6.233<br>(0.101)  | 1.459<br>(0.692)  | 2.276<br>(0.517)  |                         | 3     | 3.949<br>(0.267)  | 0.804<br>(0.849)  | 1.841<br>(0.606) |
|                                | Joint | 20.262<br>(0.016) | 42.147<br>(0.000) | 11.836<br>(0.223) |                         | Joint | 16.642<br>(0.055) | 27.858<br>(0.001) | 2.929<br>(0.967) |

Tests are executed across regressions in the SUR model for the regressor  $\Delta w$  under the null distribution  $\sim \chi^2_{(3)}$  for each lag.

Joint tests are under  $H_0 \sim \chi^2_{(9)}$

p-values in parentheses

Table 15: West VAR Wald test Results with dependent variable  $\Delta w$

| Dependent Variable: $\Delta w$ |       |                   |                   |                   |                         |       |                   |                   |                   |
|--------------------------------|-------|-------------------|-------------------|-------------------|-------------------------|-------|-------------------|-------------------|-------------------|
|                                | Lag   | $\Delta n$        | $\Delta u$        | $\Delta w$        |                         | Lag   | $\Delta n$        | $\Delta u$        | $\Delta w$        |
| <b>Manitoba</b>                | 1     | 7.961<br>(0.047)  | 1.238<br>(0.744)  | 4.628<br>(0.201)  | <b>Saskatchewan</b>     | 1     | 8.118<br>(0.044)  | 1.821<br>(0.610)  | 16.259<br>(0.001) |
|                                | 2     | 0.089<br>(0.993)  | 2.755<br>(0.431)  | 1.622<br>(0.655)  |                         | 2     | 1.965<br>(0.580)  | 6.301<br>(0.098)  | 17.035<br>(0.001) |
|                                | 3     | 1.693<br>(0.639)  | 2.282<br>(0.516)  | 2.367<br>(0.500)  |                         | 3     | 6.702<br>(0.082)  | 2.712<br>(0.438)  | 18.399<br>(0.000) |
|                                | Joint | 11.549<br>(0.240) | 9.634<br>(0.381)  | 8.200<br>(0.514)  |                         | Joint | 17.504<br>(0.041) | 14.970<br>(0.092) | 37.688<br>(0.000) |
|                                | Lag   | $\Delta n$        | $\Delta u$        | $\Delta w$        |                         | Lag   | $\Delta n$        | $\Delta u$        | $\Delta w$        |
| <b>Alberta</b>                 | 1     | 3.596<br>(0.309)  | 0.475<br>(0.924)  | 11.267<br>(0.010) | <b>British Columbia</b> | 1     | 4.138<br>(0.247)  | 1.626<br>(0.654)  | 12.309<br>(0.006) |
|                                | 2     | 1.337<br>(0.721)  | 4.535<br>(0.209)  | 4.928<br>(0.177)  |                         | 2     | 2.611<br>(0.456)  | 0.237<br>(0.971)  | 2.262<br>(0.520)  |
|                                | 3     | 1.797<br>(0.616)  | 8.200<br>(0.042)  | 3.067<br>(0.381)  |                         | 3     | 2.428<br>(0.489)  | 2.454<br>(0.484)  | 4.238<br>(0.237)  |
|                                | Joint | 6.769<br>(0.661)  | 12.705<br>(0.176) | 19.965<br>(0.018) |                         | Joint | 8.305<br>(0.504)  | 5.070<br>(0.828)  | 21.150<br>(0.012) |

Tests are executed across regressions in the SUR model for the regressor  $\Delta w$  under the null distribution  $\sim \chi^2_{(3)}$  for each lag.

Joint tests are under  $H_0 \sim \chi^2_{(9)}$

*p*-values in parentheses