ON THE INTERDEPENDENT NATURE OF URBAN GROWTH:

A SIMULTANEOUS ANALYSIS OF THE DETERMINANTS AND THE DIMENSIONS OF GROWTH

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Abstract

The paper applies an urban growth model in which determinants and indicators of growth (population, employment, wages, and human capital) appear on both sides of the equation. The model captures feedback and circular effects grounded in a general equilibrium perspective. The econometric model, a seemingly unrelated regression panel (SUR-P) with city fixed effects, is estimated for a system of 135 Canadian cities. The results reveal a system in which the determinants of growth for cities are largely consistent with the literature but also that the same determinants (city attributes) affect differently growth depending on the indicators selected.

Key Words:

Growth Model, Urban Growth, Urban Economics, Seemingly Unrelated Regression, Panel Data

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Résumé

La recherche développe un modèle de croissance urbaine dans lequel les indicateurs de la croissance urbaine (population, emploi, masse salariale et capital humain) jouent également le rôle de déterminants. Le modèle permet ainsi de capter les effets croisés et circulaires des relations entre les multiples déterminants de la croissance urbaine. Le modèle économétrique, basé sur un panel de régressions apparemment non-reliées avec effets fixes (SUR-P), est estimé pour les 135 plus grandes agglomérations urbaines du Canada entre 1971 et 2011. Les résultats montrent que les déterminants ne jouent pas nécessairement de manière identique sur les indicateurs de croissance sélectionnés et que les trajectoires de croissances peuvent donc être multiples.

Mots clés :

Modèle de croissance, Croissance urbaine, Économie urbaine, Régressions apparemment non-reliées, données de panel

INTRODUCTION

An abundant literature has accumulated in recent years on urban growth asking why some cities have grown more rapidly than others. Duranton and Puga (2014) provide an excellent synthesis. The majority of empirical studies are for the U.S. with some European cases, based generally on regression models examining the relationship between given growth indicators (population, employment, wages…) and initial place attributes. Without wishing to oversimplify a complex subject, two factors stand out as consistent predictors of urban growth, notably in U.S. studies: human capital and amenities. Cities initially well-endowed with human capital (above-average educational levels) and with natural amenities (sun, sea…) grow more rapidly than those not so endowed. Other variables related to initial industry mix and location are also often cited. Such findings are largely uncontroversial, although they need always be seen in the light of their national and temporal context.

This paper adopts a perspective in which cities are seen as parts of urban systems, growth expressed via multiple interdependent dimensions. The multiple dimensions of urban growth are captured through a system of equations allowing for feedback effects across the urban system where key variables appear on both sides of the equation. Indicators of urban growth (population, employment, wages) are also treated as determinants in addition to human capital. As such, the model seeks to reconcile two theoretical (and empirical) threads: growth model approaches, cited above, aimed at identifying the determinants of growth for individual cities; a general equilibrium framework in which the causal process at work regulate growth, preventing the system from exploding.

The empirical analysis is applied to the Canadian urban system (135 urban areas) over a forty year period (1971-2011) using a Seemingly Unrelated Regressions (SUR) system of equations with a fixed-effect panel model. The results confirm the weight of common growth determinants such as human capital while at the same time pointing to a system in which the determinants of growth (initial city attributes) are converging across the system.

The paper is divided into five sections, beginning with an overview of urban growth determinants. The second section presents the econometric model. The third introduces the data. The fourth presents results for two successive model applications. A conclusion ends the paper in which broader issues flowing from the results are considered.

THE INTERLINKED DETERMINANTS OF URBAN GROWTH

Why might some cities grow faster than others, at the same time allowing for steady state urban growth across the system? The natural starting point is *urban size*. The literature on urban systems, rank-size rule, and Gibrat's law of urban growth points in same direction: we would not normally expect urban size to be a consistent predictor of growth, specifically population growth (Black and Henderson 2003, Córdoba 2008, Desmet et Rappaport 2014, Dittmar 2011, Eeckhout 2004, Gabaix 1999, Guérin-Pace 1995, Lalanne 2014). We should expect city systems to tend over time towards steady state growth in which population growth is independent of city size and previous growth. Getting there may require some time as urban systems mature with large cities growing faster during some periods but not others (Dittmar 2011, Desmet and Rappaport 2014).

Coming back to the urban growth literature, findings do not (predictably) point to a systematic relationship with initial size, not only for population but also other variables. For income and population, Glaser *et al* (2014), the most exhaustive study for U.S. metropolitan areas, find no significant relationship between initial population size and growth (1970-2000). For European urban areas, Cheshire and Magrini (2009) find a weak but positive relationship for GDP per capita growth (1990-2000). For population, Dijkstra *et al* (2013) observe a negative relationship for European cities, noting the slower growth of larger cities. Findings for Canada point to a time-variant relationship. Lalanne (2014) finds a negative relationship for population growth for 1971-1981, but a positive relationship for the following two decades, similar to Shearmur and Polèse (2007) for employment growth[1].

The weak predictive power of urban size begs the broader question of the relationship between agglomeration economies, specifically urbanization economies, and growth. Do agglomeration economies have (predictable) dynamic effects? While the existence of static agglomeration economies (the positive relationship between urban concentration and productivity) has been confirmed time and again, the evidence for dynamic agglomeration economies, as Duranton and Puga (2014) note, is weak. Cheshire and Magrini (2009) find a negative relationship between urban population density and subsequent per capita GDP growth. Henderson (2003), looking at manufacturing activity in U.S. cities over a thirty-year period, finds no evidence of dynamic urbanization economies. The evidence for a positive relationship between (initial) urban concentration and subsequent income growth at the nation level is also weak (Brülhart and Sbergami 2009, Polèse, 2005), all of which again begs the question of the feedback effects of urban size on other determinants of growth.

Human capital is a consistently powerful predictor of urban growth, measured usually by the initial share of population with a tertiary degree (college +). Whether for population or for employment growth, the evidence is overwhelming, certainly for U.S. cities (Glaeser *et al* 1995, 2014, Glaeser and Saiz 2004, Simon 1998, Simon and Nardinelli 2002). Glaeser and Saiz (2004) also provide evidence for the United Kingdom. Both Glaeser and Simon sometimes go back as far as the early 19th century; the relationship with initial (or lagged) endowments of human capital is almost always

[1] Shearmur and Polèse (2007) examine 359 Canadian spatial units, which include both urban and rural areas.

positive and significant. However, Glaeser *et al* (2014) observe a positive relationship for population growth, but not for income growth. Also, the relationship is generally stronger for larger urban areas (100,000+).

For Canada, Shearmur and Polèse (2007) observe a positive relationship between (initial) percentages of B.A. degree holders and employment growth (1971-2001), but only significant for one out of three decades. The explanation, the authors suggest, lies in the importance of natural resources (oil, mining, and forestry, chiefly) as drivers of growth, which varies over the three decades. The importance of human capital declines during resource booms. Dubé and Polèse (2015) argue that resource specialization can have a depressive effect on human capital accumulation where high-wage blue-collar job opportunities reduce the incentives to go on to higher education.

In short, while a stronger initial endowment of human capital is an undisputed asset, it does not necessarily follow that that asset (high shares of educated cohorts) will continue to grow in the same cities over time. Not only is human capital a mobile asset but, as the Canadian findings suggest, the incentives to go on to a tertiary education may vary across cities with no *a priori* link to urban size. On the other hand, the creative class literature implicitly suggests that "cool" or "Bohemian" places, an attribute generally associated with size, are more likely to attract educated populations (Florida 2002, 2002a) , which leads us into urban *amenities*.

The evidence for *natural amenities*, notably seacoasts and warmer climates, as drivers of urban growth is overwhelming, both for the U.S. and Europe (Cheshire and Magrini 2009, Glaeser *et al* 2001, Rappaport 2007, 2009, Rappaport and Sachs 2003). Duranton and Puga (2014) conclude that weather - as measured by January temperatures - remains one of the most reliable predictors of growth for U.S. cities. Portnov and Schwartz (2009) put forward the idea of a 'location package' looking at 4,600 European localities. Using a principal components approach, they find that the best predictors are vectors of location attributes (distance to seashore, elevation…), but with no necessary link to city size. The important point here is that natural attributes, including rich resource endowments (i.e. oil and gas), are largely invariant over time and thus implicitly captured in econometric applications by geographical and historical fixed effects[2]. All studies cited for Canada show strong provincial effects, generally favoring the Western provinces of British Columbia and Alberta.

Urban amenities are a different matter. There is strong evidence, at least for the U.S., that cultural and other amenities are becoming increasingly important. Glaeser and Gottlieb (2006) find for U.S. cities that the relationship between city-size and real wages has turned negative since 1990, a sign that workers, highly educated one may presume, are increasingly prepared to pay for the privilege of 'consuming' big cities. On the other hand, one would expect amenities to be capitalized in

[2] Note also that climate-driven migration, common in nations such as the U.S. and France with major climatic differences, is much less relevant for nations such as Canada (or Spain or Italy for example) where most of the population lives in zones with similar climates.

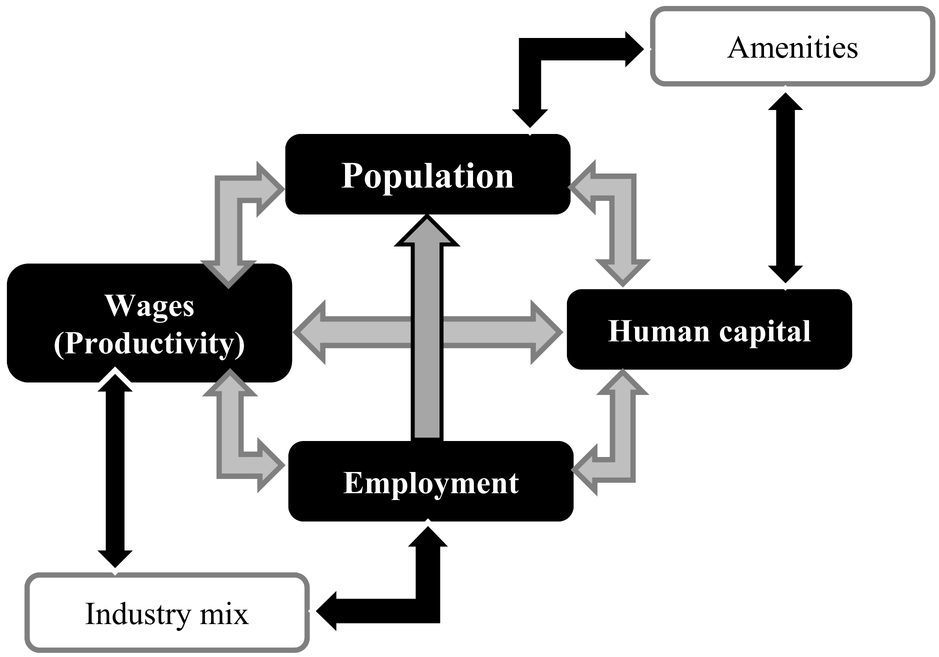
housing prices driving up nominal wages, which in turn might possibly dampen future growth. The relationship between *wages* and growth can go both ways. Glaeser *et al* (2014) observe a negative effect using median income for U.S. metropolitan areas for both income and population growth, which they attribute to high-wage manufacturing cities. Shearmur and Polèse (2007) observe a negative effect for wages on employment growth for Canadian regions; for cities, Dubé and Polèse (2015) find a negative relationship with subsequent wage growth. Using a geographically weighted regression, Shearmur *et al* (2007) shed further light on the possible contradictory effects of wages. The effect on employment growth is positive in and near large wealthy cities (i.e. Toronto) but turns negative when smaller resource-based cities are given greater weight, where higher wages do not necessarily reflect higher productivity, but rather resource rents.

Industry mix is a recurrent theme in the European literature. Cheshire and Magrini (2009) introduce a coal mining variable which predictably renders a negative coefficient. At the other end of the spectrum, Illy *et al* (2011) observe a positive relationship between employment growth and diversification for German cities. For Canada, Shearmur and Polèse (2007) also find a positive association with diversification, using a dissimilarity index, in turn correlated with urban size. Kok and ter Weel (2014) compute an indicator of task-based connectiveness across industries for 168 U.S. metropolitan areas which they find to be positively associated with employment growth (1990-2009). Finally, *age structures* are among the more obvious determinants of growth. For European cities Gagliardi and Percoco (2015) find, unsurprisingly, that high dependency ratios are associated with slower population growth. But then, dependency ratios are ultimately the outcome of past events among which inherited industry mixes.

In the recurrent debate around jobs versus amenities as initial drivers of growth, Scott (2010) and Storper and Scott (2009) clearly come down on the side of jobs, arguing that job opportunities remain the principal motivation of worker migration, overriding wages; that the move South of jobs in the U.S. primarily reflects so-called (anti-union) Right-to-Work laws in Southern states. The initial strength of local labor markets (measured for example by employment rates) thus becomes a primary determinant of employment and population growth, but which leads us back to the question of why initial labor demand is stronger in place y than place x (is human capital the vital ingredient?). Taking a big-picture perspective, Moretti (2013) leans towards the 'great man' theory of urban growth (Seattle took off because Bill Gates settled there) which is perhaps not totally mistaken and certainly consistent with theories of random urban growth, but largely leaves aside the intertwined mechanics of urban growth with varying opposing forces simultaneously at play.

In an attempt at synthesis, a schematic illustration of basic relationships and feedback effects for indicators and determinants of growth is proposed below (Figure 1). The schema postulates four "active" variables (in black) with both static (initial values) and dynamic (growth) properties, acting simultaneously as determinants and outcomes. Thus, population, employment, wages (productivity) and human capital can refer both to the number (quantity) in a given city at a given moment and to subsequent growth in both indicators.

Figure 1 – Urban Growth Circle



Staring at the top of the circle, population growth (city size) is primarily a function of employment opportunities (upward pointing line), workers following jobs, in turn fueled by higher productivity and initial superior human capital endowments. If the relationship with city size is consistently positive, signifying the presence of dynamic agglomeration economies, the system will ultimately explode with larger cities growing ever larger. Equilibrium (non-explosive growth) is re-established via possible negative feedback effects of city size on subsequent wage (productivity) and human capital growth; note the bi-directional arrows for "employment" with human capital and productivity.

Figure 1 thus allows for scenarios in which initial high human capital endowments stimulate employment growth and in turn population growth, but where city size is negatively associated with human capital growth, human capital growing more rapidly in smaller places, suggesting convergence in relative human capital endowments across the system. To take another example, high wages (productivity) may drive employment growth and also act as a magnet for human capital further fueling wage growth. But, high wages can also have a dampening effect on employment growth in situations where wages outrun productivity.

The mechanics are necessarily simplified, illustrating general relationships and interdependencies consistent with a general equilibrium perspective. This conceptual framework implicitly assumes that amenities and industry mix, although contributing to system dynamics, are not "active" agents at the same level as other variables, which is why they are pictured outside the interactive circle. Amenities, especially natural amenities, are largely fixed and industry mixes vary only slowly over time. The principal mechanism by which the system adjusts are wages and the movement of households and workers.

THE MODEL

Most econometric urban growth models are derived from a neo-classical Solow framework (Baro and Sala-i-Martin, 1991, 1992) as in Gleaser *et al.* (1995). In the specifications, the dependent variables express the logarithmic difference between the value of a given growth indicator for a city (or a region) i between year t and t + s ($\Delta_s y_{it} = \log(y_{it+s}) - \log(y_{it})$).[3] The growth rate is usually expressed as a function of local conditions such as climate, and other attributes such as urban size, industry mix, and human capital endowments for the initial time period stacked in a matrix $\mathbf{X}_{it}$, of dimension (N × K). The model formally tests for convergence by introducing initial values of the variables of interest (equation 1).

$$\Delta_s \mathbf{y}_{it} = \boldsymbol{\iota}\alpha + \log(\mathbf{y}_{it})\beta + \mathbf{X}_{it}\boldsymbol{\theta} + \boldsymbol{\varepsilon}_{it} \qquad (1)$$

Where $\boldsymbol{\iota}$ is a vector of one of dimension (N × 1), α is a (scalar) constant term, β is a scalar parameter usually interpreted as the speed of convergence[4], $\boldsymbol{\theta}$ is a vector of parameters of dimension (K × 1) related to the attributes of the individual observations, and $\boldsymbol{\varepsilon}_{it}$ is the error term.

Most empirical applications, as noted, examine growth using single indicators (population, employment, wage or GDP growth) which are necessarily correlated. Few models explicitly approach the study of growth using multiple indicators. As correlations among growth indicators are rarely perfect, sets of g indicators, $\Delta_s \mathbf{y}_{git}$, were pooled in a system of G equations, which conceptually produces a system close to a general equilibrium model[5] (equation 2).

$$\Delta_s \mathbf{y}_{git} = \boldsymbol{\iota}\alpha_g + \log(\mathbf{y}_{git})\beta_g + \mathbf{X}_{it}\boldsymbol{\theta}_g + \boldsymbol{\varepsilon}_{git} \qquad (2)$$

Where the individual vectors of dependent variables, $\Delta_s \mathbf{y}_{igt}$, are of dimension (N × 1), the initial (time-lagged) values of the dependent variables, $\log(\mathbf{y}_{git})$, is a vector of dimension (N × 1), and the matrix of independent variables, $\mathbf{X}_{it}$, is now of dimension (N × [(G – 1) + K]). The list of

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[3] Divided by time periods, the logarithmic difference is an approximation of the mean annual growth rate, r_{y_i} ($r_{y_i} \approx \Delta_s y_i/s$).

[4] That is, unconditional convergence when no other independent variables are included in the model or conditional convergence when the model controls for some attributes. .

[5] Other examples of general equilibrium based approaches are Carlino and Mills (1987), Boarnet *et al*. (2005), and Boarnet1994)

independent variables is augmented by time-lagged initial values of the different growth indicator, stack in the matrix $\mathbf{X}_{it}$. As previously, the coefficients β_g are scalars, while the vectors of coefficients $\boldsymbol{\theta}_g$ are of dimension ([(G – 1) + K] × 1).

A major challenge in estimating the equation system is accounting for correlation among initial (time-lagged) growth indicators. A simple solution procedure for such problem is to choose one variable as benchmark, expressing the others as ratios to the benchmark (equation 3).[6]

$$\begin{aligned} \Delta_s y^*_{git} &= (1/s) \times \{[\log(y_{git+s}/y_{1it+s})] / \log[(y_{git}/y_{1it})]\} \\ &= (1/s) \times [\Delta_s y_{git} - \Delta_s y_{1it}] \;\; \vee\, g = 2, \ldots, G \end{aligned} \tag{3}$$

The final system of equation is re-written as:

$$\begin{aligned} \Delta_s \mathbf{y}_{1it} &= \boldsymbol{\iota}\alpha_1 + \log(\mathbf{y}_{1it})\beta_1 + \mathbf{X}_{it}\boldsymbol{\theta}_1 + \boldsymbol{\varepsilon}_{1it} \\ \Delta_s \mathbf{y}^*_{git} &= \boldsymbol{\iota}\kappa_g + \log(\mathbf{y}^*_{git})\psi_g + \mathbf{X}_{it}\boldsymbol{\pi}_g + \boldsymbol{\xi}_{git} \;\; \vee\, g = 2, \ldots, G \end{aligned} \tag{4}$$

Where $\kappa_g = (\alpha_g - \alpha_1)$ are new constant terms, $\psi_g = (\beta_g - \beta_1)$ parameters related to the transformed dependent variables, $\boldsymbol{\pi}_g = (\boldsymbol{\theta}_g - \boldsymbol{\theta}_1)$ parameters related to independent variables, and $\boldsymbol{\xi}_{git}$ are the new vectors of errors terms, assumed to be of zero mean and homogenous variance.

It is possible to implicitly capture the correlation among equations by estimating the full system using a Seemingly Unrelated Regression (SUR) model (Zellner, 1962) in which a measurement error in one equation can also influence errors in the remaining equations. However, the real advantage of the SUR approach is that it allows for direct cross-equation tests among the estimated coefficients, impossible otherwise. The significance of the individual parameters for g = 2, …, G on the original growth dependent variables (or indicators) can be obtained by a simple re-organization of the identity appearing in equation (2), testing if $\alpha_g = \delta_g + \alpha_1 = 0$; $\beta_g = \psi_g + \beta_1 = 0$; and $\theta_g = \pi_g + \theta_1 = 0$ (or not). Thus, a SUR approach remains advantageous even where estimated coefficients from OLS and SUR applications show similar results for identical independent variables[7]

The model can be estimated using a cross-section approach but this approach fails to account for endogeneity issues related to potential omitted variables. A panel model with city fixed effects is thus preferable (Greene, 2005; Baltagi, 1999, 2005; Hsiao, 2003; Wooldridge, 2000). The original model was extended to a panel structure by introducing time-period subscripts for dependent and

[6] See Appendix 1 for the mathematical derivation of the equivalence.

[7] The coefficients estimated by SUR are identical to those obtained by OLS: i) when the independent variables (regressors) are identical; or ii) when there is no correlation among the error terms, i.e. the variance-covariance matrix is block-diagonal.

independent variables and terror terms, plus two additional effects controlling for time-invariant omitted variables, γ_{gi}, and for city-invariant omitted variables, δ_{gt} (equation 5).

$$\begin{aligned} \Delta_s \mathbf{y}_{1it} &= \boldsymbol{\iota}\alpha_1 + \log(\mathbf{y}_{1it})\beta_g + \mathbf{X}_{it}\boldsymbol{\theta}_g + \gamma_{1i} + \delta_{1t} + \boldsymbol{\varepsilon}_{1it} \\ \Delta_s \mathbf{y}^*_{git} &= \boldsymbol{\iota}\kappa_g + \log(\mathbf{y}^*_{git})\psi_g + \mathbf{X}_{it}\boldsymbol{\pi}_g + \gamma_{gi} + \delta_{gt} + \boldsymbol{\xi}_{git} \quad \vee\ g = 2, \ldots, G \end{aligned} \tag{5}$$

Where the vector of dependent variables and the error terms are of dimension (NT × 1), the vector $\log(\mathbf{y}_{1it})$ and $\log(\mathbf{y}^*_{git})$ is of dimension (NT × 1), and the matrix $\mathbf{X}_{it}$ is of dimension (NT × [(G – 1) + K]), while the vectors of parameters are of the same dimension as before.

In the end, the final system is estimated using a SUR-panel with fixed effects approach, taking into account both cross-sectional and time dimensions of growth while controlling for individual heterogeneity and endogeneity, allowing for the implicit structure of correlations among error terms and direct cross-equation tests on the estimated coefficients.

DATA AND MEASUREMENT ISSUES

The proper definition of cities and city systems is not a minor issue, although too often glossed over in the literature. Different statistical agencies have different criteria for identifying cities or urban areas, the latter label generally preferred, as here, to avoid confusion with 'cities' (municipalities) as administrative units. For Canada, researchers have the good fortune that Statistics Canada applies well-defined criteria for defining, respectively, census metropolitan areas (CMAs) and census agglomerations (CAs), each consisting of one or more neighboring municipalities situated around an urban core where a CMA must have a population of at least 100,000 of which 50,000 or more live in the urban core and a CA an urban core population of at least 10,000 (Stat Can on-line).To be included in a CMA or CA, adjacent municipalities must have a high degree of integration with the urban core, as measured by commuting flows. If the population of a CA declines below 10,000, the CA is retired. CMAs are similar to the U.S. concept of MSA (Metropolitan Statistical Area), but are generally more accurate measures of local labor markets because of higher core commuting thresholds (50% versus 25%) and smaller base spatial units, municipalities rather counties in the U.S. (except for New England).

A second issue is the definition of the *system*, which urban areas to include. The combined CAs and CMAs provide the base for the urban system, to which seven (7) stand-alone municipalities were added with populations of 10,000 or more at the beginning of the forty-year time-period (1971) for a total of 135 urban areas[8]. However, urban areas change over time. The geographical expansion of certain urban areas may mean the elimination of others close-by, the latter absorbed into the first[9]. The list of Statistics Canada CMAs and CAs changes for each census year. We

[8] Appendix 2 gives the full list of 135 urban areas.

[9] St-Jérôme, near Montreal, is an example, a distinct CA in 1971, but since absorbed by the Montreal CMA

ideally require a time-consistent dataset[10]: observations *(*N) should the same at the beginning and at the end. To build a consistent universe, sixteen (16) newly emerged CMAs or CAs, present in 2011 but not in 1971, were excluded from the system[11] and thirteen (13) were dropped from the system that longer qualified, either falling below the 10,0000 threshold or absorbed by growing larger neighbors. Although the system thus built is consistent over time, the possibility that city geographies may have changed over time means that observed changes (in given variable values) may in part be attributable to changes in urban perimeters, a problem inherent to all studies that examine the evolution of urban areas over long time periods.

Finally, all data are drawn from special Statistics Canada census tabulations and the 2011 National Household Survey (NHS). Although NHS is a survey, not a census, the 10,000 threshold used here greatly reduces the probability of errors or biases resulting from small sample size[12].

VARIABLES

Consistent with figure 1, the empirical analysis postulates four base indicators of growth which when set as initial city attributes also double as independent variables:

1) Population (15-64 years) – y_1;

2) Total Employment – y_2;

3) Total Wages – y_3;

4) Population with a B.A. Degree or higher – y_4.

As we would expect, absolute values (totals) are highly correlated (Table 1). The transformed dependent variables, expressed as ratio of working age population, exhibit significantly lower correlations (Table 1)[13] and can be interpreted thus (keeping the same numbers as above):

2) *Employment rate* (employment/working age population): the probability of finding a job; indicator of the overall strength of the local labor market;

3) *Mean wage*: a proxy for productivity where wages are not primarily driven by other factors;

4) *Ratio of College Graduates* (B.A. degree or higher): a common measure of human capital concentration;

[10] Even the best studies do not necessarily fulfill this criterion. Thus, Simon and Nardinelli (2002), in their study of urban growth in the U.S. between 1900 and 1986, progressively add in new spatial units (metropolitan areas) as they appear. This is not necessarily methodologically unsound, but means that one is not comparing the same universe over time.

[11] The rapidly expanding town of Squamish near Vancouver is an example.

[12] A number of tests were carried out on NIHS data, confirming the absence of bias.

[13] The new dependent variables then become y_1; $y^*_2 = (y_2/y_1)$; $y^*_3 = (y_3/y_1)$; $y^*_4 = (y_4/y_1)$.

Table 1 : Correlations among Growth Indicators

	Work-age Population (n)	Employment (n)†	Wages ($)†	B.A. degree (n)†
Without transformation				
Work-age Population (n)	1			
Employment (n)	0.9958	1		
Wages ($)	0.8999	0.9250	1	
Population with B.A.(n)	0.9303	0.9502	0.9927	1
With transformation				
Work-age Population (n)	1			
Employment (n)†	0.1485	1		
Wages ($)†	0.1315	0.6723	1	
Population with B.A. (n)†	0.3716	0.6215	0.7485	1
Dependent variables (growth)				
Work-age Population (n)	1			
Employment (n)†	0.1335	1		
Wages ($)†	0.4564	0.4612	1	
Population with B.A. (n)†	0.1993	0.2757	0.5113	1

Legend: (n) in number; † expressed as ratio to Work-age population (15-64 years)

Table 2 : Descriptive Statistics: Dependent and Independent Variables

	N	Mean	Standard Error	Minimum	Maximum
Dependent Variables					
Work-age Population Growth	540	0.0112	0.0161	-0.0635	0.1084
Employment Growth†	540	0.0060	0.0106	-0.1767	0.0314
Wages Growth†	540	0.0557	0.0313	-0.0316	0.1453
Population with B.A. Degree Growth†	540	0.0351	0.0146	-0.0184	0.0988
Independent Variables‡					
Herfindahl Index‡	540	0.0626	0.0398	0.0175	0.3129
Dissimilarity Index‡	540	0.1730	0.0629	0.0709	0.5127
Location quotient - Cultural Industries‡	540	0.3781	0.3697	0.0000	3.7524
Population < 15 †‡	540	0.3631	0.0916	0.2003	0.7942
Population > 65 †‡	540	0.1561	0.0626	0.0037	0.4043
Work-age Population ‡	540	98,305	305,070	3,565	3,225,250
Employment Rate†‡	540	0.6457	0.0855	0.3826	0.8286
Mean Wage Rate†‡	540	13,814	8,089	2,448	39,091
Population with B.A.(in log)†‡	540	0.0864	0.0462	0.0235	0.2945

Legend: † expressed as ratio to Work-age population (15-64 years);
‡: Independent variables are time-lagged (values in t - 1)

In addition to the four growth indicators above when used as independent variables (Table 2), the model introduces five stand-alone independent variables, consistent with similar variables in the literature, correlations among independent variables well within acceptable limits (Table 3).

Youth Share: Ratio of population under 15 of age to working age population, which we would a priori expect to be associated with population growth;

Senior Share: Ratio of seniors (65 +), a priori indicative of an aging slower growing population;

Standardized Herfindahl Index: A common measure of industrial diversification, calculated for employment at the two digit NAICS level[14]. The higher the index for a given urban area the more concentrated employment is in a limited number of industries.

Dissimilarity Index: A second measure of industrial diversification, also called the Krugman Dissimilarity Index, again calculated for employment at the two digit NAICS level, which compares the local distribution of employment across industries with that of the nation. A higher index indicates a more specialized local economy;

Cultural Industries: A proxy for the presence of urban amenities, measured by the location quotient for employment in three industry classes: performing arts and related sectors; motion picture and sound recording studios; book and music stores.

Table 3 : Correlations among Remaining Independent Variables (in t-1)

Independent variables‡	Herfindahl Index	Dissimilarity Index	QL-Cultural Industries	Population < 15 (n)†	Population > 65 (n)†
Herfindahl Index	1				
Dissimilarity Index	0.6682	1			
QL - Cultural Industries	-0.2124	-0.155	1		
Population < 15 (in log)†	0.2276	0.4043	-0.4837	1	
Population > 65 (in log)†	-0.3141	-0.5729	0.2887	-0.4713	1
Work-age Population (in log)	-0.1086	-0.0527	0.2409	-0.1526	0.0019
Employment (in log)†	-0.2329	-0.1062	0.4039	-0.4586	0.2098
Wages (in log)†	-0.2844	-0.2092	0.5846	-0.7207	0.2154
Population with B.A.(in log)†	-0.3487	-0.2312	0.6359	-0.6491	0.2400

Legend: † expressed as the ratio to Work-age population (15-64 years old)
‡: The independent variables are time-lagged (values in t - 1)

[14] North American Standard Industrial Classification.

RESULTS

We shall consider the results on tables 4 and 5 together, allowing us to trace the various relationships and feedback effects between dependent and independent variables. Table 4 shows model estimates for the SUR-panel model (see equation 5) where three of the dependent variables (employment, wage, and graduate population growth) are expressed as *rates*; that is, ratios of the work-age population, while table 5 gives the transformed results for the same variables expressed in quantities (i.e. % growth in employment: column 2 – see equation 2) the common metric used in the urban growth literature. The first dependent variable, the work-age population, which we shall henceforth simply refer to as *population*[15], is common to both tables, linking the two, where the three left-hand, or dependent, variables on table 5 are the numerators in the *rate* variables in table 4, the operative model. Although growth for the base values (table 5: population, employment, wages…) are highly correlated, recalling table 2, the results indicate that growth paths and determinants are not necessarily the same.

Let us begin with, arguably, the most straightforward dependent variable: *employment growth* (table 5, column 2). The results are largely consistent with the literature. Employment growth is a positive function of initial human capital endowments (share of college graduates), wages, an employment mix close to the Canadian urban average (negative sign with dissimilarity index), and initial population, including a higher share of population over fifteen years of age. The picture, thus, is that of a growth process that favors larger, more productive cities (assuming wages are a valid reflection) with higher initial human capital endowments; in short, an urban system in which agglomeration economies are a major driving force. Were we to stop there, the obvious prediction would be continued above-average growth for larger metropolitan areas well-endowed with human capital; that is, assuming that employment growth fuels population growth (recall figure 1).

However, the coefficients for the population equation (column 1) suggest a more complex causal chain. Population growth is a positive function of an initially younger population, a fairly obvious result, and of relative job opportunities (employment rate), also as one would expect, consistent with the notion that people follow jobs. But, the coefficients for column 1 also indicate that population growth is negatively correlated with initial wages and, more significantly, with initial population size. Lower wages promote subsequent population growth (the opposite of the relationship for employment growth), as do lower initial populations (smaller cities), again the opposite of employment growth. This seemingly contradictory result suggests a chain of causation in which local labor market conditions act as the primary drivers of worker and population adjustments over time, favoring here initially smaller, relatively lower wage cities, apparently counter-acting the effects of agglomeration-driven employment growth.

[15] For reasons explained in the model presentation, the use of the work-age population is a necessary step in building a two-stage model linking the four active variables. We can safely assume that work-age population is a reasonably good proxy for population as a whole.

Table 4 : Estimation Results for SUR-panel System with 10 Year Spans (1971-2011)

	Work-age population growth		Employment rate growth		Mean wages growth		Growth of % having B.A. degree	
Variables (from t-1)	β	sign.	β	sign.	β	sign.	β	sign.
Standardized Herfindahl Index	-0.0506		0.1181	***	0.0559	*	-0.0383	
	0.0300		*0.0283*		*0.0257*		*0.0326*	
Dissimilarity Index	0.0308		-0.0809	***	-0.0115		-0.0047	
	0.0166		*0.0157*		*0.0142*		*0.0180*	
Location Quotient - Cultural Industries	0,0015		0.0028		0.0028		0.0039	
	0.0019		*0.0018*		*0.0017*		*0.0021*	
Population under 15 (log)†	0.0506	***	-0.0112	*	-0.0124	**	-0.0197	**
	0.0052		*0.0049*		*0.0045*		*0.0057*	
Population over 65 (log)†	-0.0088		-0.0079	**	-0.0166	***	0.0014	
	0.0027		*0.0026*		*0.0023*		*0.0029*	
Work Age Population :15-64 (log)	-0.0403	***	-0.0188	***	-0.0070	**	-0.0020	
	0.0027		*0.0026*		*0.0023*		*0.0030*	
Employment Rate (log)†	0.0409	***	-0.0584	***	0.0115		0.0064	
	0.0093		*0.0088*		*0.0080*		*0.0101*	
Wages (log)†	-0.0313	**	-0.0088		-0.1039	***	-0.0081	
	0.0072		*0.0068*		*0.0062*		*0.0078*	
Population with B.A. Degree (log)†	0.0051		0.0096	**	-0.0026		-0.0771	***
	0.0035		*0.0033*		*0.0030*		*0.0038*	
Temporal Fixed Effects	Yes		Yes		Yes		Yes	
City Fixed Effects	Yes		Yes		Yes		Yes	
N	540		540		540		540	
R^2	0.7911		0.5690		0.9595		0.7014	
F-stat	14.01	***	4.88	***	87.67	***	8.69	***

Legend: *** p≤0.001; ** p≤0.01; * p≤0.05 ; †: expressed as a ratio of work-age population (15-64);
Independent variables are expressed using values in t-1

Table 5 : Re-estimations for Orginal Variables: SUR-Panel System with 10 Year Spans (1971-2011)

	Work-age Population; Growth (%)		Employment; Growth (%)		Total Wage Bill; Growth (%)		Population with B.A. Degree; Growth (%)	
Variables	β	sign.	β	sign.	β	sign.	β	sign.
Standardized Herfindahl Index	-0.0506		0.0675		0.0053		-0.0889	*
Dissimilarity Index	0.0308		-0.0501	*	0.0193		0.0261	
Location Quotient - cultural industries	0.0015		0.0043		0.0043		0.0054	
Population under 15 (log)†	0.0506	***	0.0394	***	0.0382	***	0.0310	***
Population over 65 (log)†	-0.0088		-0.0167	***	-0.0254	***	-0.0074	
Work Age Population :15-64 (log)	-0.0403	***	-0.0590	***	-0.0472	***	-0.0422	***
Employment Rate (log)†	0.0409	***	-0.0175		0.0525	***	0.0474	***
Wages (log)†	-0.0313	**	-0.0401	***	-0.1352	***	-0.0394	***
Population with B.A. Degree (log)†	0.0051		0.0147	**	0.0025		-0.0720	***
N	540		540		540		540	
Pseudo-R^2	0.7911		0.7581		0.9218		0.8037	

Legend: *** p≤0.001; ** p≤0.01; * p≤0.05 ; †: expressed as a ratio of work-age population (15-64);
Independent variables are in expressed using values in t-1

The mechanics underlying the interrelationship between the determinants of employment growth and population growth become clearer when we consider the impact of (initial) population size on employment and wage growth expressed as rates (table 4). In both cases, the coefficients are negative (columns 2 and 3). Mean wage and employment rate growth are negative functions of population size, suggesting a catching-up process for smaller cities. While employment growth should in principle stimulate population growth recalling the mechanics depicted on figure 1 (the model does not directly test this relationship), the coefficients in table 4 suggest that the feedback effects of population size on mean wage growth and on relative employment opportunities are negative. For the employment rate, the negative relationship with city size may indirectly reflect the dampening effects of faster population growth (in-migration) but also of rising female labor force participation rates as smaller places reproduce the behavior of larger cities.

More to the point, the results on table 4 point to a process of convergence across the system for the four active variables: population, employment rates, mean wages, and human capital. For all four, initial city attribute values are negatively associated with subsequent growth. The higher the initial wage rate and relative presence of college graduate, the slower the subsequent growth in either attribute. Convergence, thus observed, suggest an urban universe (in this case, composed of 135 urban areas) that functions as a self-correcting system in which the determinants of urban growth – human capital, industry mix, agglomeration economies; etc.., – do not consistently favor the *same* cities systematically causing the same (large) cities to grow.

Let us take a closer look at human capital, a recurring predictor of urban growth in the literature, consistent, we saw, with the results on table 5 for employment growth. For human capital growth, both relative and absolute (last columns: tables 4 and 5), the negative coefficient with initial endowments (% college graduates) means that cities with the highest initial proportion of graduates will see their comparative human capital advantage diminish over time. Contrary to Moretti (2012) for U.S. cities, the results for Canada do not point to a "Great Divergence" (to use his expression) between initially intellectually well-endowed cities and the rest. Convergence in educational attainment across the system can be the result of local catching-up or the migration of college-educated populations, undoubtedly a combination of both. The negative sign with the population variable (table 4: last column) suggests that smaller places are the chief beneficiaries. Note the absence of a significant relationship with the cultural amenities variable, consistent also with the relative attractiveness of smaller cities.

These results may in part be colored by the size distribution of the observed urban universe, which contains a majority of urban agglomerations with populations below 100,000[16]. Most studies in the literature look at urban agglomerations above that threshold. Perhaps the convergence/ catching-up process revealed by table 4 can in part be attributed to the inclusion of a wider, arguably more complete, urban system. But that is not the main point. The results, specifically for the human

[16] In 1971, 108 urban areas registered populations below 100, 000; 101 in 2011.

capital variable, allow us to understand why human capital can be both a robust predictor of urban growth and at the same time an equalizer of urban growth. Higher initial human capital endowments *are* good predictors of growth (employment in this case), but the same cities are not necessarily systematically the beneficiaries of this relationship over time. .

Geography and history of course also matter. Fixed effects capturing invariant city attributes are significant, as we would expect. These account for close to half (give or take) of explained variance of the dependent variables (table 6). Wage growth, whether relative or absolute, is the exception with fixed effects accounting for only a small proportion of variance. The results are not entirely surprising for a nation such as Canada in which geography looms large; but, by the same token, underscore the role of “active’ variables as adjustment mechanism and moderators of growth, recalling the dynamics depicted on figure 1. The difference with wages is instructive: the other three, unlike wages, imply the movement of people. In the end, the picture conveyed is that of an urban universe in which the ultimate drivers of differential urban growth are exogenous to the system (international demand, changing life-style preferences, technological change…), city populations and workers reacting (adjusting) to outside forces by moving or by entering/ withdrawing from the labor force. Wage adjustments, on the other hand, take a different path, largely explained by the determinants identified the model (table 4). This does not mean that geography does not matter in explaining wage differences (at a given point in time), but rather that differences in mean wage *growth* are mainly driven by other factors.

Finally, by way of a summary, let us return to the interrelationship between the dynamics of (dependent) growth variables as usually expressed in the literature (table 5) and growth in underlying rates (table 4), which in turn loop back to affect initial values, again recalling figure 1. A simple reading of the relationship between the initial population variable on table 6 and the other three dependent variables, ignoring the population column for the moment, would suggest that employment growth, wage bill growth, and growth in college graduates are systematically positive functions of city size. In short, bigger cities are getting richer and more educated. However, once we look at the same relationship in terms of rates, we saw, the portrait changes (table 4). The rate variables serve to level the playing field across the urban system, revealed in the convergence coefficients, dampening the growth of initially larger urban areas.

Table 6 : R^2 Values With and Without City Fixed Effects

Table 4	No Fixed Effects (1)	With Fixed Effects (2)	Difference [(2) - (1)]	% Variance due to Fixed Effects
Work-age Population (n)	0.3793	0.7911	0.4118	52.05%
Employment Rate†	0.3035	0.5690	0.2656	46.67%
Mean Wages ($)†	0.9215	0.9595	0.0380	3.96%
% Population with B.A. Degree†	0.3715	0.7014	0.3299	47.04%
Table 5				
Work-age Population (n)	0.3793	0.7911	0.4118	52.05%
Employment (n)	0.3896	0.7581	0.3685	48.60%
Total Wages ($)	0.8116	0.9218	0.1102	11.95%
Population with B.A. Degree (n)	0.4821	0.8037	0.3216	40.02%

†: Expressed as a ratio to work-age population

CONCLUSION

The paper looks at urban growth through a multidimensional lens grounded in part in a general equilibrium perspective in which growth is measured via various interdependent dimensions. An econometric model based on a system of growth equations was estimated using a seemingly unrelated regression panel (SUR-P) approach with city and temporal fixed effects in which the determinants and the outcomes of urban growth are interlinked, common growth indicators (population, employment, wages) appearing on both sides of the equation together with a human capital variable, applied to 135 Canadian urban areas over a forty year period (1971-2011) with ten year spans.

The results are compatible with most findings on the determinants of urban growth for other urban systems, notably for employment and population growth. Employment growth is a positive function of initial human capital endowments (share of college graduates) and a favorable industry mix. However, the model also allows for the conformation with backward relationships in which growth is expressed both directly, as is common in the growth literature (i.e. % employment growth), and in relative terms (relative to the work-age population). The latter bring out system-wide relationships, allowing us to reconcile two apparently opposing "facts”: i) the predictive power of given determinants of urban growth (i.e. human capital) consistent with the urban growth literature; ii) the generally converging growth of cities, consistent with the urban systems and urban hierarchy literature. Mean wages, employment rates, and human capital shares all exhibit convergence patterns over time across the urban system (negative coefficients with initial attribute values), together with a negative relationship between initial urban size and subsequent population growth.

Stated differently, while given determinants stimulate growth in cities thus favored, the urban universe as a whole appears to behave like a self-correcting system with favored cities in one period are not necessarily the same in the next. Thus, human capital is a positive asset, but the growth of that asset does not necessarily always favor the same cities over time.

The observed dynamics suggest two simultaneous processes at work: agglomeration and convergence. The mechanics of employment growth nicely illustrate the contrasting processes. When employment growth is expressed in usual aggregate terms, determinants are found to be initial size, wages (productivity), and human capital, conveying the image of large, more productive, better educated cities with above average growth. But, when employment growth is expressed in relative terms (as a rate) the picture changes with a negative relationship now with both initial population size and employment rates, with labor force movements (migration or labor force entry or exist) an implicit adjustment mechanism, driving the convergence of employment rates over time.

Finally, the observed coefficients and relationships are of course contingent on context, the Canadian urban system in this case. However, the over-all picture of urban growth dynamics portrayed here would apply, we argue, to most national urban systems. Implicit in this perspective is the postulate that the ultimate drivers of urban growth are exogenous (technological change, international demand, changing preferences…), workers and populations continually reacting to change.

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APPENDIX 1

A1.1 - Retrieving the growth of original indicators

Let us start with the mathematical approximation of the growth rate of a given variable expressed as a ratio of a given indicator, y^*_g. By taking its logarithmic decomposition and using the properties of the log operators, we have:

$$\begin{aligned}
\Delta_s y^*_g &= (1/s) \times \log\{[(y_{gt+s}/y_{1t+s})] / [(y_{gt}/y_{1t})]\} \\
&= (1/s) \times \{\log[(y_{gt+s}/y_{1t+s})] - \log[(y_{gt}/y_{1t})]\} \\
&= (1/s) \times \{[\log(y_{gt+s}) - \log(y_{1t+s})] - [\log(y_{gt}) - \log(y_{1t})]\} \\
&= (1/s) \times \{[\log(y_{gt+s}) - \log(y_{gt})] - [\log(y_{1t+s}) - \log(y_{1t})]\} \qquad \text{(A1)} \\
&= (1/s) \times \{\log[(y_{gt+s}/ y_{gt})] - \log[(y_{1t+s}/y_{1t})]\} \\
&= (1/s) \times [\Delta_s y_g - \Delta_s y_1] \\
&= \Delta_s y_g/s - \Delta_s y_1/s
\end{aligned}$$

Since $\Delta_s y_g/s \approx r_g$ for all g, the growth of the new dependent variable expresses the difference in growth between a given indicator ($r_g \approx \Delta_s y_g/s$) and the reference indicator ($r_1 \approx \Delta_s y_1/s$):

$$r^*_g = r_g - r_1 \quad \vee\ g = 2, \ldots, G \qquad \text{(A2)}$$

By extension, it is possible to retrieve the effect of the different indicators on the original dependent variables (or growth indicators) by isolating r_g (equation A3).

$$r_g = r^*_g + r_1 \quad \vee\ g = 2, \ldots, G \qquad \text{(A3)}$$

A1.2 - Retrieving original coefficients and measuring goodness-of-fit

The effect of the independent variables on the original growth indicators is retrieved thus. By substituting the r^*_g and r_1 variables in equation (A3) by their respective identity (equation 5), \the equation for growth of the remaining g = 2, …, G equations can be expressed relative to the evolution of the indicator of reference:

$$r_g = r^*_g + r_1 \qquad \text{(A4)}$$

$$\Delta_s \mathbf{y}_{git} = \Delta_s \mathbf{y}^*_{git} - \Delta_s \mathbf{y}_{1it}$$

$$\Delta_s \mathbf{y}_{git} = \boldsymbol{\iota}(\kappa_g - \alpha_1) + \log(\mathbf{y}^*_{it})(\psi_g - \beta_1) + \mathbf{X}_{it}(\boldsymbol{\pi}_g - \boldsymbol{\theta}_1) + (\gamma_{gi} - \gamma_{1i}) + (\delta_{gt} - \delta_{1t})$$

Thus, the original coefficients can be retrieved and the impact on the original indicators by calculating the values of the original parameters (equation A5), while the significance of the individual parameters for $g = 2, \ldots, G$ can be tested through the SUR-panel system.

$$\begin{aligned} \alpha_g &= \kappa_g + \alpha_1 \\ \beta_g &= \psi_g + \beta_1 \\ \boldsymbol{\theta}_g &= \boldsymbol{\pi}_g + \boldsymbol{\theta}_1 \end{aligned} \tag{A5}$$

Moreover, using the predicted values of the individual equations, $\Delta_s \hat{\mathbf{y}}^*_{git}$ and $\Delta_s \hat{\mathbf{y}}_{1it}$, allowing us to evaluate the goodness-of-fit for the original equation by calculating the square correlation between the original values, $\Delta_s \mathbf{y}_{git}$, and the predicted values, $\Delta_s \hat{\mathbf{y}}_{git} = \Delta_s \hat{\mathbf{y}}^*_{git} - \Delta_s \hat{\mathbf{y}}_{1it}$.

$$\text{Pseudo } R^2 = \text{corr}(\Delta_s \mathbf{y}_{git} \,;\, \Delta_s \hat{\mathbf{y}}_{git})^2 \tag{A6}$$

APPENDIX 2

List of the 135 cities

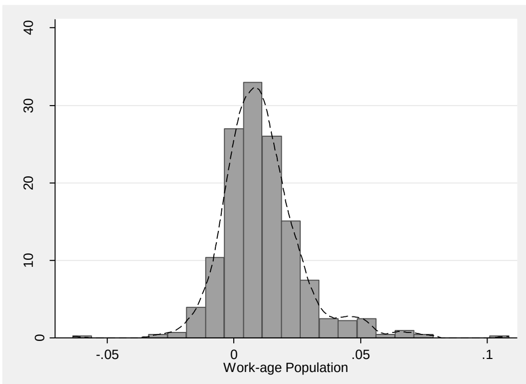
Cities	Province	Population (in 2011)	Cities	Province	Population (in 2011)
St. John's	New Foundland	193,825	Lachute	Quebec	12,175
Grand Falls	New Foundland	13,485	Val-d'Or	Quebec	32,615
Corner Brook	New Foundland	26,135	Amos	Quebec	17,425
Charlottetown	Prince Edward Island	62,125	Rouyn-Noranda	Quebec	39,990
Summerside	Prince Edward Island	16,115	Gaspé	Quebec	14,740
Halifax	Nova Scotia	384,540	Montmagny	Quebec	11,070
Kentville	Nova Scotia	26,030	Sainte-Marie	Quebec	12,640
Truro	Nova Scotia	45,040	Roberval	Quebec	9,720
New Glasgow	Nova Scotia	35,230	Cornwall	Ontario	57,420
Cape Breton	Nova Scotia	99,690	Hawkesbury	Ontario	11,660
Moncton	New Brunswick	135,520	Ottawa	Ontario	1,212,825
Saint John	New Brunswick	125,005	Brockville	Ontario	38,205
Fredericton	New Brunswick	92,600	Pembroke	Ontario	23,155
Bathurst	New Brunswick	30,320	Kingston	Ontario	153,900
Campbellton	New Brunswick	17,280	Belleville	Ontario	90,660
Edmundston	New Brunswick	20,270	Cobourg	Ontario	17,850
Matane	Quebec	15,700	Port Hope	Ontario	15,710
Rimouski	Quebec	46,965	Peterborough	Ontario	116,175
Rivière-du-Loup	Quebec	24,525	Oshawa	Ontario	351,690
Baie-Comeau	Quebec	28,165	Toronto	Ontario	5,521,235
Saguenay	Quebec	149,730	Hamilton	Ontario	708,175
Alma	Quebec	32,895	St. Catharines	Ontario	383,970
Dolbeau	Quebec	13,690	Kitchener	Ontario	469,935
Sept-Îles	Quebec	28,130	Brantford	Ontario	133,250
Québec	Quebec	742,800	Woodstock	Ontario	36,570
Saint-Georges	Quebec	32,255	Tillsonburg	Ontario	15,060
Thetford Mines	Quebec	24,835	Guelph	Ontario	132,740
Sherbrooke	Quebec	191,610	Stratford	Ontario	29,755
Cowansville	Quebec	12,515	London	Ontario	467,255
Victoriaville	Quebec	50,175	Leamington	Ontario	46,565
Trois-Rivières	Quebec	143,600	Windsor	Ontario	315,455
Shawinigan	Quebec	52,835	Sarnia	Ontario	88,175
La Tuque	Quebec	14,845	Owen Sound	Ontario	31,055
Drummondville	Quebec	80,975	Collingwood	Ontario	18,625
Granby	Quebec	72,245	Barrie	Ontario	184,325
Saint-Hyacinthe	Quebec	55,570	Orillia	Ontario	39,610
Sorel-Tracy	Quebec	48,235	Midland	Ontario	34,180
Joliette	Quebec	45,580	North Bay	Ontario	62,705
Saint-Jean	Quebec	90,375	Sudbury	Ontario	158,260
Montréal	Quebec	3,752,480	Elliot Lake	Ontario	11,165
Valleyfield	Quebec	38,725	Haileybury	Ontario	12,405

Cities	Province	Population (in 2011)
Timmins	Ontario	42,440
Sault Ste. Marie	Ontario	78,480
Thunder Bay	Ontario	119,140
Kenora	Ontario	14,985
Bracebridge	Ontario	15,010
Huntsville	Ontario	18,560
Kapuskasing	Ontario	8,065
Winnipeg	Manitoba	714,640
Portage la Prairie	Manitoba	19,155
Brandon	Manitoba	51,980
Thompson	Manitoba	12,730
Regina	Saskatchewan	207,215
Yorkton	Saskatchewan	17,970
Moose Jaw	Saskatchewan	33,600
Swift Current	Saskatchewan	17,045
Saskatoon	Saskatchewan	256,435
North Battleford	Saskatchewan	18,390
Prince Albert	Saskatchewan	40,955
Estevan	Saskatchewan	11,850
Medicine Hat	Alberta	71,070
Lethbridge	Alberta	102,785
Calgary	Alberta	1,199,125
Red Deer	Alberta	88,390
Camrose	Alberta	16,900
Edmonton	Alberta	1,139,580
Lloydminster	Alberta	30,295
Grande Prairie	Alberta	81,775
Wood Buffalo	Alberta	66,990
Wetaskiwin	Alberta	12,010

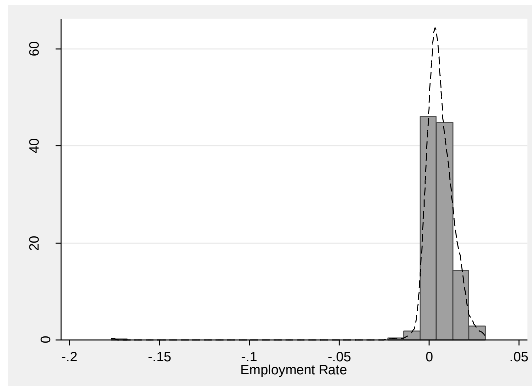
Cities	Province	Population (in 2011)
Cranbrook	British Columbia	24,530
Penticton	British Columbia	43,140
Kelowna	British Columbia	176,435
Vernon	British Columbia	56,715
Kamloops	British Columbia	96,685
Chilliwack	British Columbia	88,815
Abbotsford	British Columbia	166,685
Vancouver	British Columbia	2,280,695
Victoria	British Columbia	336,180
Duncan	British Columbia	42,220
Nanaimo	British Columbia	95,680
Port Alberni	British Columbia	24,915
Courtenay	British Columbia	52,255
Campbell River	British Columbia	37,395
Powell River	British Columbia	16,355
Quesnel	British Columbia	23,305
Prince Rupert	British Columbia	13,110
Kitimat	British Columbia	8,340
Terrace	British Columbia	18,475
Prince George	British Columbia	82,865
Dawson Creek	British Columbia	11,240
Fort St. John	British Columbia	26,270
Whitehorse	Yukon Territory	25,570
Yellowknife	North Western Territory	18,830

APPENDIX 3

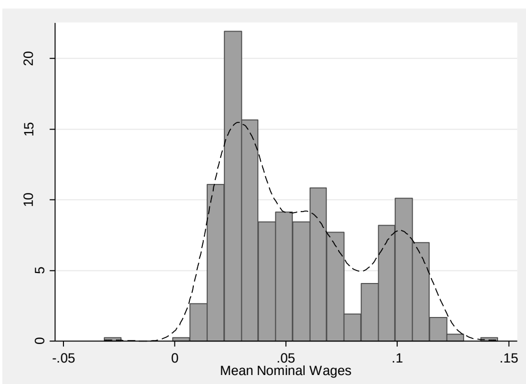
Distribution of the dependent variables, 1971-2011



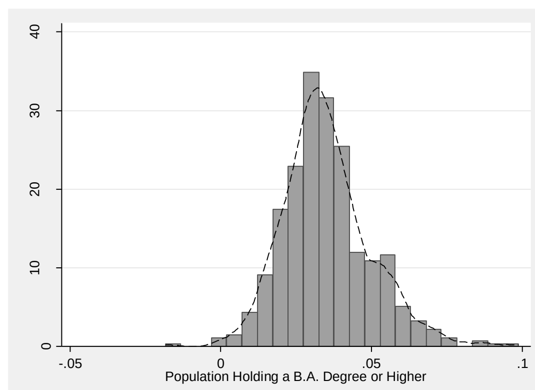
Work-age Population



Employment Rate†



Mean Nominal Wages†



% of Population with B.A. degree†

†: expressed as a ratio of work-age population (15-64)