Catching Up?

An Exploration of Convergence in Income and Human Capital

At the Sub-Provincial Level in Canada

By

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A Thesis submitted to the Faculty of Graduate Studies of

The University of Manitoba

in partial fulfilment of the requirements of the degree of

Master of Science

Department of Agribusiness and Agricultural Economics

University of Manitoba

Winnipeg. Manitoba

THE UNIVERSITY OF MANITOBA

FACULTY OF GRADUATE STUDIES
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Abstract

Much of the research into the study of convergence in income and human capital in Canada has been focused on the evidence of this phenomenon at the provincial level. As such, it appears that support for conditional convergence in Canada at the sub-provincial level has not yet been found.

The purpose of this thesis is to determine if support for convergence can be found for income and human capital in Canada at the sub-provincial level, with the effects of migration also taken into account. To address this objective, a simultaneous system of endogenous equations was constructed and estimated using three-stage least squares.

The results show that incomes and human capital stocks were growing faster in areas that had lower initial incomes and human capital stocks, over the 1986 to 2001 time period. These results provide support the convergence hypothesis at the sub-provincial level in Canada.

Acknowledgements

First and foremost, I would like to thank my Lord and my God and my Savior, Jesus Christ. I could not come this far in my journey without His help and saving grace. Philippians 4:13. It is my sincere hope that in some small way, this thesis brings glory, honor and praise to the King of kings and the Lord of lords.

I would like to thank my head supervisor, Dr. Derek Brewin, for taking me on as his student, as well as for his continual support and guidance throughout this process. Thank you to Dr. Ryan Cardwell for his excellent comments and suggestions that really brought to life many aspects of this thesis. Thank you to Dr. Daniel Monchuk for his willingness to join the committee and for inspiring some "out of the box" thinking. Thank you to Rose Olfert for her helpful direction in the earlier stages of this thesis. Thank you to Mike St. Louis and the Canada-Rural Economy Research Lab for access to the database and for their helpful assistance.

I wish to acknowledge the generous financial assistance that was provided from the Canadian Agricultural Innovation Research Network that helped support this academic project.

To my friends, your presence in my life has been an untold blessing to me. Thank you for all the good times, the help, the prayers and the encouragement you have given me. I cannot imagine what life would be like without each one of you.

Lastly, but certainly not the least, to my family, your unwavering love, support and belief in me has helped make me the man I am today. Where ever I may go, I know that I will always have a place to come home to, with a family that loves me and is always there for me. Thank you.

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Chapter 1: Introduction

1.1 Introduction

In 1986, the municipality of Wood Buffalo, Alberta had the largest per capita income of any region in Canada, with an average of $24,338[1] per person. Obedjiwan, Quebec, on the other extreme, had the unenviable title as Canada's lowest per capita income area, with a per capita income of just $4,253. Fifteen years later, Wood Buffalo enjoyed a per capita income of $40,622, with Obedjiwan residents averaging only $10,600 in 2001. Despite the increased discrepancy in per capita income between these two communities, the per capita income growth rate in Obedjiwan of 8.7% was more than twice as high as Wood Buffalo's growth rate of 3.5%. In growth and development economics, this faster rate of growth in poorer regions is referred to as convergence.

In the above example, should these growth rates remain unchanged, in about 50 years Obedjiwan would eventually converge or "catch up" to Wood Buffalo's per capita income in nominal terms. Economists have studied this phenomenon over the years, sometimes concluding that convergence in incomes or output was taking place (Barro and Sala-i-Martin, 1992; Coulombe, 2000; James and Krieckhaus, 2008) and sometimes not (Romer, 1987; Chatterji and Dewhurst, 1996; Siriopoulous and Asteriou, 1998). Generally, the work on this topic by academics has been focused on either the national level, comparing the economies of different countries (Baumol, 1986; Pritchett, 1997), or

[1] This statistic was gathered from the Canada Rural Economy Research Laboratory (C-RERL) database, which draws upon the Canadian census data from Statistics Canada. The remaining statistics in this chapter, unless otherwise noted are either sourced or calculated from the C-RERL database.

the state/provincial level of a particular nation (Barro and Sala-I-Martin, 1992; Coulombe and Lee, 1995).

Most of the researchers have been using simultaneous models of income growth and population change (Barro and Sala-I-Martin, 1992; Deller et al., 2001) or human capital change (Goetz and Hu, 1996; Coulombe and Tremblay, 2001; Coulombe, 2003). The test of convergence is to check the sign of the parameter for starting income level in an income growth equation. If its sign is negative, convergence is supported.

In Canada, the focus on this topic has been centered on the provincial level, with many results showing evidence of convergence. However, at the sub-provincial or community level, evidence of the convergent pattern[2] of growth has not been confirmed. In the United States, convergence was found at the county level (Brewin, 2004; Goetz and Hu, 1996). For Canada, however, Partridge et al (2007) suggest that the linear nature[3] of Canada's population distribution along the U.S. border and lower density may result in behaviour that is dissimilar to the U.S. Bollman (1999) in his study on rural development and human capital briefly noted that Canadian communities with a higher proportion of low income earners appeared to have been "catching up" to in the 1980s. But, he did not specifically investigate this finding as the standard regression of starting income or subsequent growth rates was not shown.

With this in mind, the purpose of this thesis will be to determine if convergence is occurring in Canada at the sub-provincial level in per capita incomes, while accounting

[2] The pattern that convergence demonstrates is an inverse relationship between starting levels of capital or income and subsequent capital or income growth rate.
[3] Partridge et al. (2007), citing C-RERL and U.S. Census 2000 data, state that if a line was drawn from Victoria and Vancouver, BC and Edmonton, AB to Winnipeg, MB and another line beginning in Southern Ontario that stretches up to Ottawa, ON, on to Montreal, PQ and ending in Halifax, NS, about 81% of the Canadian population were situated below this narrow east-west expanse in 2001.

for migration. When people migrate from one place to another, the dynamics of their home and destination communities are altered, thus affecting incomes and income growth rates. Therefore, it is necessary to account for migration even if the focus is on incomes.

Additionally, since convergence is expected to occur in other forms of capital[4], an exploration will be made in the area of human capital growth. The intention of this, as above, is to determine if convergence holds for human capital growth in the presence of migration, and to see if migrants carry enough human capital stock into a region to become contributors or net suppliers to income growth in Canada. As well, there is an opportunity to determine if there are differences between the patterns of growth in income, human capital and population change between rural and urban settings. In the U.S., evidence has been found by Brewin (2004) that differing growth patterns are present in county-level income growth for urban and rural regions. Therefore, a test for convergence will completed using a model that includes income growth, human capital growth and migration and categorizes communities as rural or urban.

1.2 Importance of this Study

The key element of importance pertaining to this study is that its findings will provide an integral view into growth in income and human capital at the sub-provincial or community level. The two general community types found in Canada are rural communities and urban communities. As Brewin (2004) has said, a common sentiment among rural development advocates is that the concerns associated with rural areas are dissimilar to urban issues, and thus a "one size fits all" approach to growth and

[4] Examples of the different forms of capital can include but are not limited to human capital, political capital, physical capital and social capital.

development may not benefit many of the communities that such a policy attempts to help. By studying convergence at the community level, some light will be shed on economic and educational growth. This will serve to better inform government and policy makers when creating and enacting new policy measures in the future aimed at growth and development.

It is also noted that, in a general sense, the findings of this study will also provide an important and new contribution to the body of Canadian literature in the field of economic growth and development. This is due to the apparent lack of research on convergence at the community level. There have been a number of studies in Canada on convergence in incomes and human capital at the provincial level which have found support for this growth pattern (Coulombe and Lee, 1995; Coulombe, 2003; James and Krieckhaus, 2008). However, these findings at the provincial level do not imply or dictate that growth in income or human capital will follow the same pattern. Being as it may, it can only be speculated upon as to whether or not convergence holds in Canada at the sub-provincial level. The results of this thesis will therefore provide some indication as to what is actually happening in terms of growth.

1.3 Organization of this Thesis

The remainder of this thesis is organized in the following manner. Chapter 2 features a review of the pertinent theory and literature relating to this study. The theoretical model is presented in detail in Chapter 3. Next, in Chapter 4 the data are described including the variables employed in the regression analysis. Chapter 5 introduces the econometric model, gives an overview of the econometric process used and addresses a number of the potential econometric problems that may arise. In Chapter 6, the results of the econometric analysis are presented and discussed. Finally, the conclusions of the study are highlighted in Chapter 7.

Chapter 2: Literature Review

2.1 The Neoclassical Growth Model

Robert Solow first developed his growth model in 1956, but despite its age, it remains one of the most used models on growth to this day (Van Den Berg, 2001). Since Solow integrated the use of marginal concepts into his model, first purported by nineteenth-century neoclassical economists, it is frequently referred to as the neoclassical growth model (Van Den Berg, 2001). This model also provides much in the way of theoretical underpinnings for this thesis, as it is the source of convergence theory. Since one of the goals of this thesis is to explore convergence in income and human capital in Canada, it is useful to describe the neoclassical growth model in detail. To do so, I will follow the reasoning and notation of Van Den Berg (2001)[5], unless otherwise noted, to demonstrate Solow's model.

2.1.1 The Production Function

The neoclassical growth model starts out with a production function which consists of output (or income) *Y*, as a function of the quantity of capital, *K*; and labour, *L*, and knowledge (or education), *E*. Since knowledge is assumed to augment labour, the two factors enter the function multiplicatively. Together, they are referred to as effective labour. Formally:

$$Y = F(K, (L \cdot E)) = F(K, LE) \tag{1}$$

[5] Van Den Berg's (2001) description comes from Solow (1956) and Solow (1957).

Two key assumptions of this production function held by Solow are that it exhibits constant returns to scale (CRTS) and that there are positive but diminishing marginal returns to any single input. Formally CRTS is shown by:

$$cY = F(cK, cLE) \tag{2}$$

If one lets $c = 1/LE$, one can manipulate equation (2) to achieve a more useful form:

$$Y/LE = F(K/LE, 1) \tag{3}$$

or $$y = f(k) \tag{4}$$

Where: y represents Y/LE; K/LE is now defined as k and the function $f(k)$ replaces $F(K/LE, 1)$. Under this set up, the production function is now in per capita terms as y signifies output per effective worker; k is capital per unit of effective labour and $f(k)$ is the function in which per capita capital stock is converted to per capita output (Romer 2001). This form is rather useful, since economic growth is often examined per capita terms and is commonly regarded as the change in per capita output.

An important aspect of the production function in equation (4) is that it essentially embodies the supply side, or productive capacity of an economy. How much capital is present in the production function however, partly depends upon investment, and investment is restricted by people's willingness to save as opposed to consuming goods.

2.1.2 The Consumption Function

Solow constructed a consumption function to contend with the relationship between consumption, savings and investment. As such, Solow divided output or income into two categories, consumption goods and investment goods. To begin:

$$Y = C + I \tag{5}$$

Where: C is consumption and I represents investment. If one divides by LE as above:

$$y = c + i \tag{6}$$

Where: y again represents Y/LE, again giving us per capita output; c is C/LE, or consumption per worker; and I/LE is now defined as i, which is investment per worker.

Solow also assumed that consumption was a simplistic function of income as determined by the rate of savings (σ), possessing a value between 0 and 1. If one defines savings as S, then:

$$C = Y - S = (1 - \sigma)Y \tag{7}$$

In per capita terms:

$$c = y - s = (1 - \sigma)y \tag{8}$$

If one substitutes equation (8) into equation (6) and move the terms around, then:

$$i = \sigma y \tag{9}$$

Equation (9) allows us to see that per worker investment is equal to the share of per worker income saved. This means that the share of output that is saved is equivalent to the amount invested in productive capital. Productive capital is a generic form that can represent any number of different investments. For the purposes of this thesis productive capital will be considered to be one of two possible investments; human capital or physical capital investments. But for now, investments will simply be thought of as being made in productive capital.

2.1.3 Capital Stock, Population Growth and Technological Change

Solow stated that the stock of capital will increase as investment (savings) increases. He recognized in his model though, as also in the real world, that this capital will start to depreciate as time wears on. Thus it was assumed that a constant proportion of the existing stocks would depreciate at a constant rate, in each time period. This is denoted as δ (the depreciation rate).

Two other factors that affect the level of capital per effective worker k are population growth and technological change. Both of these factors are quite important to examine, since it has been contended that each factor is a potential source for economic growth. With regards to population growth, Solow assumed that the population within an economy grew at a constant rate, n. It was assumed that the population needs to be equipped with a base level of capital in order to be productive. Hence, for k to remain a constant when the size of the labour force (L) increases, investment (I) has to grow at the same pace as L. This means that investment needs to cover both the amount of capital that depreciates and the amount needed to equip new entrants into the labour force.

Similar to population growth, technology was assumed to grow at a fixed rate of z. Technology is assumed to make the labour force more productive. As such, more capital is required by the labour force to match the increase in productivity as enabled by the new technology. Thus, for k to remain constant, investment has to equal the amount of capital necessary to match the gains in the labour force's ability to produce from technological advances. From this and above, it can be gathered that the direction of change in k is subject to whether the amount invested per worker is greater than the sum of the depreciation per worker, the level of extra capital needed for each new labourer and the necessary capital to keep up with technological advances.

When combined, depreciation, population growth and technological advancement constitute the capital stock requirements of the economy, since each of these rates consumes an amount of capital. Formally:

$$\Delta K = I - \delta K - nK - zK \tag{10}$$

And in per worker terms:

$$\begin{aligned} \Delta k &= i - \delta k - nk - zk \\ &= \sigma f(k) - (\delta + n + z)k \end{aligned} \tag{11}$$

2.1.4 Solow Growth Model Steady State

Regarding equation (11), if savings (or $\sigma f(k)$) are larger than the needs of the capital stock (or $(\delta + n + z)k$), k will increase. On the other hand, if the capital stock requirements surpass savings, then k will decrease. When Δk is equal to zero, that is $\sigma f(k)$ is equal to $(\delta + n + z)k$, the amount of capital stock available exactly offsets the capital requirements for production to occur. Therefore, k will neither increase nor decrease. The capital stock has reached a steady state. Visually, this can be observed in Figure 1.

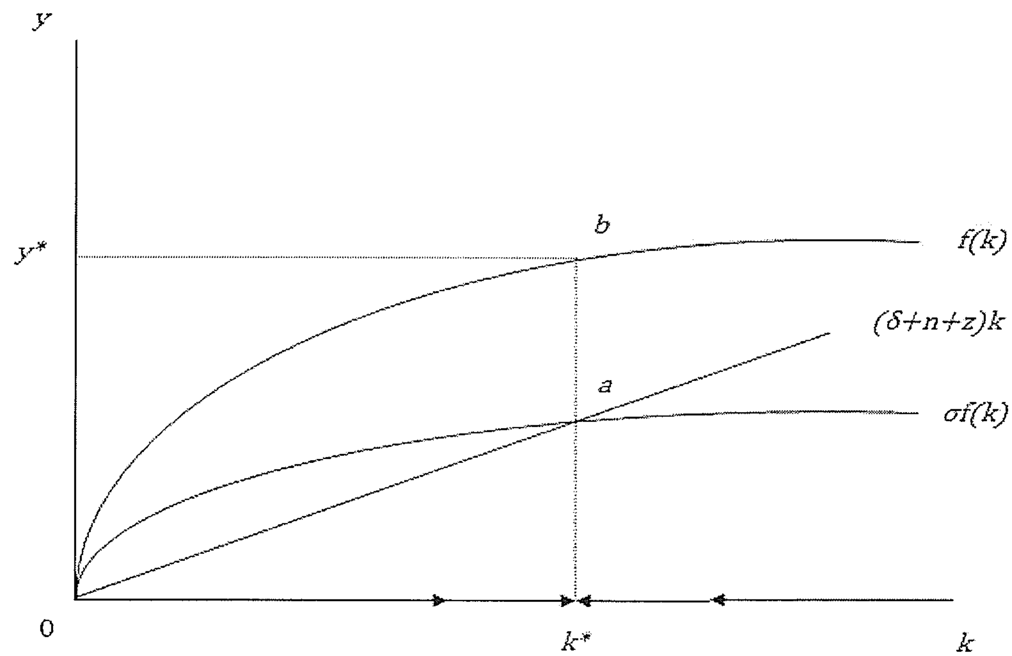

Figure 1. Neoclassical Growth Model Steady State

With a concave production function (demonstrating the positive, but diminishing returns to capital), constant population growth, knowledge acquisition and depreciation rates, there is some level of capital at which actual investments are perfectly offset by the needs of rising labour productivity, labour size and capital depreciation. This level of capital, k^*, is what is also referred to as the steady-state. Subsequently, output or income also reaches a steady-state level, y^*, at k^*.

As Figure 1 shows, in situations where there are high levels of capital stocks, (to the right of k^*), depreciation and the necessary capital needed to equip the labour force and maintain their productively would be much larger than the gains made from the capital invested. Therefore, capital investment and output would eventually decline until the steady state is reached. Conversely, when low levels of capital are invested (to the left of k^*), the gains made from the investment would outpace the needs of the labour force and the losses from depreciation. Thus, capital investment would increase until the steady state is reached.

From the model's tendency to arrive at the steady state, it can be seen that Solow's model predicts what is known as convergence. In economic growth literature, convergence refers to the process by which standards of living become similar across countries (Van Den Berg, 2001). In practice, economies are thought to be converging if the economies with lower starting per capita incomes are growing at a rate that is faster than the economies with larger starting per capita incomes. That is, if conditions of fixed savings rate, growth in population, knowledge and depreciation are maintained, economies with lower levels of capital stocks should grow faster than economies with higher levels of capital stocks; eventually converging at the steady-state.

If the above conditions of fixed savings, growth and depreciation are not maintained, then economies will not necessarily converge to the same steady-state, but rather their own steady-state level as determined by conditions found within the economy. From this, the conditional convergence hypothesis was developed. Generally speaking, conditional convergence refers to the convergence of economies that is 'conditional' on these economies having the same characteristics. The Solow model is said to predict conditional convergence amongst differing economies since Solow's convergence will only be seen if the economies' rates of saving, population growth rates, depreciation rates and accumulated levels of technology are the same (or accounted for in empirical analysis).

It should be noted that there is no distinction made between whether the term convergence refers to convergence in incomes or convergence towards the steady-state level of per capita capital stock, k^*. This is because they essentially mean the same thing. When two economies converge at k^*, they will both reach the same y^*, as shown in Figure 1. Since they are both at y^*, their incomes will be the same. Hence, when economies converge at k^*, their incomes will also converge or if their incomes converge, the economies will have reached k^*. As a point of clarification for this thesis however, convergence will considered in terms of its practical definition for income. This is unless the context of the discussion pertains to human capital. In this case convergence will refer to economies with lower starting per capita levels of human capital are increasing their human capital stocks at a rate that is faster than economies with higher starting per capita human capital stocks.

2.2 Additions to the Neoclassical Growth Model

Over the years, a number of authors have made several additions to Solow's original growth model. These addendums have aided in modeling an economy more realistically and paved the way for better economic insight into growth. Three such avenues that shall now be highlighted, as they are important for the purposes of this thesis, are endogenous savings, endogenous human capital (knowledge) investment and an open economy in the neoclassical growth model.

2.2.1 Endogenous Savings

Shortly after the neoclassical growth model came into existence, there was a push from economists to endogenize the savings rate (Van Den Berg, 2001). The reason for this is that the assumed fixed savings rate in Solow's model cannot account for variation in saving rates over time or across nations. Canada, for example, saved of 25 percent of its GDP in 1980 (Word Bank, 1998), which later fell to 21 percent in 1999 (World Bank, 2000). In comparison, Korea had a savings rate of 24 percent (of its GDP) and Jordan saved negative 8 percent of its GDP in 1980 (World Bank, 1998). In 1999, their respective rates of saving grew to 34 percent and 6 percent (World Bank, 2000). By extension, the fixed savings rate assumption of the neoclassical growth model does not allow individuals or firms to save at different rates, in order to achieve their differing individual goals. However, by endogenizing the savings rate, the savings rate is allowed to vary, thus accounting the potential variation discussed above. One such model of endogenous savings is the Cass-Koopmans-Ramsey (CKR) model. To elaborate on this model, Van Den Berg's (2001) explanation and intuition will be followed.

The CKR model follows most of Solow's model assumptions; however there are a few key distinctions. The first is that it drops the assumption that savings occur at a fixed rate. Instead, an inter-temporal savings function is put in place of σ. This allows the model to account for an agent's preferences between present day consumption and future consumption. This makes it possible to find the economy's equilibrium savings rate, along with the steady state levels of capital (k^*) and output (y^*).

Another distinction from the Solow model is that agents seek to maximize their utility over the long-term, but future utility is discounted, meaning that current consumption is preferred to equal future consumption. Romer (2001) explains that this means an infinitely-lived agent would consider utility generated from current consumption against future consumption and examine their discount rate to the return on capital. This allows them to find their preferred path of consumption and the necessary savings required to achieve it, thereby endogenizing savings. Van Den Berg (2001) presents this mathematically as follows:

$$\Delta k = f(k) - c - (\delta + n)k \tag{12}$$

Where: all the variables are as they were defined before, but the variable c, consumption, has been added. With $c = (1 - \sigma)f(k)$, the model does not use the fixed parameter σ since savings are to be determined endogenously.

In the end, the CKR model results in the following steady state level of saving:

$$\sigma * = \alpha \left[\frac{n + \delta + z}{\delta + \rho + \varphi z}\right] \tag{13}$$

Where: σ^* indicates the steady-state savings rate, which is dependent upon fixed population growth, n, the depreciation rate, δ, and the rate of technological progress, z, divided by the depreciation rate, plus ρ, the discount rate, and technological progress that is adjusted by φ, the elasticity of inter-temporal substitution, all multiplied by α, the share of capital in production. Since the determinants of the steady state savings rate are parameters that can be assumed to be constant, in the long-run σ^* would also be a constant. However, that is only true if these parameters remain constant over the long run.

It should be noted though, that this model allows saving rates to vary between economies, which is important since different regions can have vastly different savings rates as discussed at the beginning of this section. This model finds a stable pattern of growth in which convergence is predicted to occur in the long-run. The speed at which convergence is reached, however can vary from region to region because of other characteristics in each region.

In 1992, Barro and Sali-i-Martin explored conditional convergence amongst the 48 contiguous states of the U.S. and 98 countries worldwide with an endogenous savings model. In their estimation, their model employed a log linearization of the transitional dynamics towards the steady state of capital and incorporated a means to measure the speed of convergence. For the U.S., Barro and Sala-i-Martin computed data from 1840 to 1998, while accounting for inconsistencies in the data, since data was only available for 29 states or territories in 1840, and 47 states in 1880. Data for all 48 states became available starting in 1900. When studying the 98 countries, data ranged from 1960 to 1985 and was sourced from the Summers-Heston dataset, which now comprises what is known as the Penn World Table[6].

Their empirical results found that convergence was occurring in the 48 contiguous states as poorer states were growing faster than richer states in per capita terms. When adjusting for regional differences and sectoral composition, they found that the speed or rate[7] of convergence was roughly two percent per year, regardless of whether they examined personal income or Gross State Product. Evidence of convergence was found for the 20 OECD countries as well as all 98 countries. This evidence was contingent upon Barro and Sala-i-Martin holding constant the ratio of government consumption to GDP and initial school enrolment rate variables, otherwise there was virtually no

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[6] The Penn World Table is an international database that contains information on national accounts and a host of other data for 167 countries for some or all of the years in the 1950 to 1998 time period covered (Penn World Table, 2008).

[7] The rate of convergence generally refers to the movement from the current or starting level income or output towards the steady-state level (Young, Higgins and Levy, 2008).

statistical evidence of convergence. The government consumption variable acted as a proxy for the rate of technological advancement and the enrolment variable was a proxy for the steady-state level of labour-augmenting knowledge stocks, according to Barro and Sala-i-Martin. With these variables, they were accounting for the neoclassical growth model's assumption of a fixed growth rate in technological change, and for the effects of the human capital stocks/knowledge-based economy on income convergence. Barro and Sala-i-Martin did not make an examination into human capital convergence in this publication however. Human capital convergence will be explored further in section 2.2.2 and throughout this thesis.

Coulombe and Lee (1995) provided a look at convergence from a Canadian perspective, in light of some of the more recent convergence studies in the U.S. Like Barro and Sala-i-Martin (1992), they made use of Solow's model to capture the rate of convergence at the provincial level. The data they utilized spanned 30 years, covering 1961 to 1991. After exploring four different concepts of per capita income (earned income, personal income, personal income minus government transfers, and personal disposable income) and two concepts of per capita output (Gross Provincial Product deflated by a national price index or by estimates of provincial implicit price indices), Coulombe and Lee found convergence in Canada. Notably, the pattern of convergence observed for per capita income and nominal Gross Provincial Product were similar to what other authors had observed for other countries. Specifically, the rates of convergence, or the movement from the current or starting level income or output towards the steady-state level, they observed ranged from 1.05 percent to 2.89 percent per year. The rate observed was dependent upon the measure of income or output that was used.

In a study published five years later, conditional convergence was again explored at the provincial level by Coulombe (2000). A unique innovation found in this paper is that the author viewed each province individually, to study their potential movements towards their own respective steady-states. Another novelty featured in this study was the inclusion of an urbanization variable in the model that allowed for robust estimates of the per capita income steady-state levels for each Canadian province. This also aided in capturing provincial agglomeration economies, as proposed by Krugman (1991), which vary from province to province due to the differing levels of urbanization. Agglomeration economies refer to the decrease in business costs that stems from a concentration of firms and labourers in a particular geographic area (Chatterjee, 2003). This reduction in costs generates incentives for labourers and firms to cluster in an area, despite the increase costs associated with increased congestion.

Coulombe's results suggest that each province is converging to its steady-state at a rate of roughly 5 percent per annum. This higher speed for convergence was explained to be the result of allowing each province to converge towards its own steady-state, rather than constraining them to a singular, national steady-state. Coulombe (2000) argues that this allowance brings the provincial steady-states closer to the initial situation found in each province and as such, they should move faster towards their respective steady-states as was observed.

A recently published Canadian study by James and Krieckhaus (2008) also examined conditional convergence at the national level as means of determining the best government policy for eliminating or reducing regional economic disparity. Given that they were making use of Coulombe and Tremblay's (2001)[8] data set, it was not surprising that convergence was found to have been occurring at the national level. The important finding however was that despite government transfers and equalization payments used as a means of curbing regional disparity, these transfer payments had little effect on long-term provincial economic growth rates. This strongly suggests that convergence was the real driver behind shrinking provincial economic disparities. As well, it was noted that provincial growth was highly correlated to national growth, suggesting policies for encouraging national growth should be the preferred means of inducing further provincial growth, so as to reduce or eliminate economic disparity amongst the provinces.

2.2.2 Endogenous Human Capital Investment

Human capital can be defined as the knowledge gained by individuals, which can arise from specific investments made in formal education, training and/or self learning (Van Den Berg, 2001). Human capital, or knowledge as discussed above, augments the labour force at an assumed fixed rate, in a similar manner to that of population growth and technological change. However, a fixed rate of growth in human capital does not explain why firms make investments in research and development or why individuals in the labour force acquire further training and education. It also fails to account for vastly differing levels of education and training that can be found amongst different countries and regions.

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[8] This paper is discussed later on in Section 2.3.3 as it presents an example of convergence under a free capital mobility frame work.

In a discussion on human capital investment and capital flows between nations, Lucas (1990) asked why convergence was not always observed. That is, why poorer countries or economies did not always catch up to the richer countries. Divergence was observed in poor countries by De Long (1988) and Romer (1987), and later by Chatterji and Dewhurst (1996), Pritchett (1997) and Siriopoulous and Asteriou (1998).

After exploring several avenues of altered assumptions for Solow's model, Lucas (1990) surmised that deficiencies in the labour force with respect to human capital could result in an underutilization of available capital in poorer regions. This would provide a disincentive for capital investment to flow into that country. Adding to this, rich countries with higher levels of human capital are able to utilize capital investment more efficiently, thereby creating an incentive to keep capital invested in the rich region. This finding furthered the sentiment that the neoclassical growth model had to account for the variance in human capital stocks.

A means to reconcile this issue is to endogenize human capital, or the knowledge variable, in Solow's model. Romer, in his 1990 theoretical paper, was among the first to do this. Romer started with the production function in Cobb-Douglas form:

$$Y = K^{\alpha}[A \cdot H]^{1-\alpha} \tag{14}$$

Where: Y and K are as previously defined; A represents "non-rival[9]" or publicly available knowledge and H being labour quality adjusting human capital or "rival[10]" or private

[9] A non-rival or public good is any good that is non-excludable or freely available to all and one person's consumption of that good does not diminish the capacity of another to consume that good (McConnell, Brue and Barbiero, 1999).

[10] A rival or private good is any good that is excludable as only those who pay for the good may possess it and one person's consumption of that good diminishes the ability of another to consume that good (McConnell, Brue, and Barbiero, 1999).

knowledge. These two aspects of the knowledge component represent the "on the job" training and the formal education that one can acquire. H is defined as:

$$H = L \cdot G(E) \tag{15}$$

Where: L and E are the same as in equation (1), but now education or knowledge is subject to a human capital allocation process, G. This allocation process in the following form:

$$G = e^{\Phi E}, \ \Phi > 0 \tag{16}$$

As such, each year of education would add a fixed percentage increase in output.

If one converts this to the familiar form that was followed from Van Den Berg (2001), in per capita terms:

$$Y/A \cdot H = F(K/A \cdot H, 1) \tag{17}$$

Equation (17) reduces to equation (4), but:

$$\Delta k = \sigma f(k) - \ (\delta + n + z + E)k \tag{18}$$

Here k will function as before, moving towards a steady state, but an important distinction exists. Growth can be affected by the differences in beginning human capital levels, as normally assumed, but also now by the allocation of human capital investment, which may vary from region to region.

Romer (1990) asserted from this theory that the levels of human capital in an economy would determine the growth rate for income and that an economy with a larger total stock of human capital would grow faster, in terms of income, than those with less human capital. As Romer (1990) states, this finding provides a compelling explanation for the strong growth rates in per capita income that was experienced in the developed world over the twentieth century, and why some members of the developing world during that time have not seen such growth. This corroborates Lucas's (1990) claims on human capital with regards to growth.

An important empirical paper examining Romer's (1990) findings was written by Mankiw, Romer and Weil (1992). They found strong evidence for convergence when accounting for human capital in the neoclassical growth model at rates consistent with other studies, such as Barro and Sala-i-Martin (1992) and later Coulombe and Lee (1995).

Goetz and Hu (1996) took a different approach to analysing convergence in the presence of endogenous human capital. Instead of using a single equation to find convergence, they employed a two-equation system featuring per capita income and human capital as the two dependent variables and endogenized each of them within the system. This model is examined further in section 2.4 and Chapter 3. Goetz and Hu (1996) noted that convergence was found in both income and human capital in their examination of southern US counties. They also concluded that the rate of convergence in income and the contribution of human capital are underestimated if the effects of human capital growth are ignored. This is important as it further supports the inclusion of human capital in a convergence study.

Brewin (2004), also explored convergence in light of endogenous human capital while using an endogenous system of equations approach, similar to Goetz and Hu (1996). His model, however also allowed for migration in the context of an open economy. This model will be examined in the chapter laying out the theoretical model.

2.2.3 Open Economy and the Neoclassical Growth Model

Solow's model, as it has been examined thus far, has not made any assertions with respect to the flow of factors across borders. This means that up to this point, the model has functioned under the assumption that the economy of interest is completely closed. In reality this is quite unrealistic, as factors like capital and technology flow from one place to another, crossing regional and international borders every day.

To account for this, Barro and Sala-i-Martin (1995) further developed the neoclassical growth model to include the impacts of a freely traded input on convergence. The movement or flow of people (who constitute the labour input) between regions, is particularly important in regional development. So to begin, Barro and Sala-i-Martin's introduction of migration (M) into Solow's model will be followed.

Since the labour force is now able to migrate to different regions, alterations in the supply of labour are created. Thus, the change in labour supply is assumed to be:

$$\Delta L = L \cdot (n \cdot m) \tag{19}$$

Where: L represents the labour force and n being the fixed growth rate of the home labour force, as before. The new variable, m, represents the net migration rate and is decided by the function: $m = M/L$. Combined, n and m capture the net growth in population. Migrants can thus affect the change in capital through:

$$\Delta K = I - \delta K - nK - zK - \vartheta M \tag{20}$$

Where: all variables are as they were presented previously, but ϑrepresents the capital per unit of labour that comes into the region with immigrants.

Dividing by $LE$to shift equation (20) into per capita terms:

$$\Delta k = \frac{\sigma f(k)}{k} - (\delta + n + z) - m[1 - \vartheta/k] \tag{21}$$

Similar to equations (11) and (18), when Δk is equal to zero, it is found that the economy has reached a steady state; but now migration can affect the level of per capita capital in an economy, depending upon the level of capital stocks (ϑ) possessed by the migrants. If in-migrants posses a level of ϑ that is greater than k, then Δk will be positively affected by migrants. Conversely, if in-migrants carry less capital than the per capita level that is already present in the destination economy (ϑ is less than k), then Δk will be negatively affected by migrants. The reverse of this is true for out-migration. Out-migrants who carry a level of ϑ that is greater than $k, \Delta k$ will be negatively affected; however if ϑ is less than $k, \Delta k$ will be positively affected. In the event that ϑ is equal to $k, \Delta k$ is solely determined by the levels of the other factors in the equation.

Many growth models regard human capital as a less mobile form of capital, such that income growth is set up as being only a function of starting human capital. A classic example of this is the model developed by Barro, Mankiw and Sala-i-Martin (1995)[11]. In simplistic terms, this model basically replaces k with h, thus:

$$y = f(h) \tag{22}$$

The economy behaves as before, but now output is a function of human capital (h) and the steady state level of output, $y*$, is found relative to the human capital steady state $h*$.

In the context of the open economy migration model that is being explored, this human capital-based model evolves in a manner that is much like Barro and Sala-i-Martin's (1995) model. The end result is:

$$\Delta h = \frac{\sigma f(h)}{h} - (\delta + n + z) - m[1 - \gamma/k] \tag{23}$$

[11] This thesis draws its inference of this model mainly from Brewin (2004).

Where: each of the variables are as they were described above; Δh signifies the change in human capital (similar to Δk describing the change in capital), and γ indicates the level of human capital possessed by migrants (replacing ϑ). Following the explanation that proceeds equation (21), the level of per capita human capital h could be affected, depending on the level human capital stocks possessed by migrants and whether migrants are entering or exiting the economy (Brewin 2004).

Coulombe and Tremblay (2001) present an empirical analysis of regional convergence in Canada based on an open economy growth model featuring partial capital mobility[12]. Although labour force mobility is not accounted for within the model, human capital accumulation is designed to be a driving force of growth within the economy. The speed of convergence in light of this was explored as well as to determine to what extent human capital affects growth.

Their findings suggested that, since 1951, the provinces have been converging towards the steady-state in per capita output and human capital at a rate somewhere between 1.4 percent and 3.5 percent annually. The key finding for Coulombe and Tremblay (2001) however, was that the effects of human capital accumulation were quite significant for Canada's regional economies. Human capital explained about 50 percent of the relative growth in per capita income and over 80 percent of the relative income levels across the country. Finally, despite the integrated financial networks and mobility of physical capital, based on their findings, they noted that physical capital did not appear

[12] Barro and Sala-i-Martin explain that in a truly open, free flowing capital market, the most patient economy (the economy with the lowest discount rate) would eventually own all the assets in the world. The other economies would over time mortgage all capital and labour earnings to consume in the present. In the end, convergence does not occur. This is quite contrary to the empirical evidence. Barro and Sala-i-Martin overcome this outcome by specifying that capital markets are only partially open, as some forms of capital cannot be used as collateral to borrow against.

to flow into poorer regions from realtively rich regions as dimishing returns to investment would predict. It was aruged that capital stayed in the richer areas due to a the lack of available human capital in the poorer region's labour force, making capital investments inefficiently utilized in the poorer areas. As such a better return was provided if capital were to be invested in richer areas if they had increasing human capital. This is consistent with with Lucas's (1990) and Romer's (1990) findings.

In a combination of the models used in Coulombe (2000) and Coulombe and Tremblay (2001), Coulombe (2003) conducted an analysis to verify if human capital and per capita income in each province converged to different long-run equilibrium points as determined by the differing levels of urbanization found across the country. Again, capital was allowed to operate in a partially open economy, however migration was not accounted for.

Coulombe (2003) had several noteable findings, the first of which being that convergence was occuring in both income and human capital in each respective Canadian province. It was noted that both per capita income and human capital were converging to higher steady states in provinces that had greater levels of urbanization. Additionally, it was discovered that even if a province had high levels of human capital, that province could remain relatively poor in the long-run. This suggests that human capital is necessary for economic prosperity, but human capital alone cannot bring about long-run wealth. However, human capital coupled with urbanization appeared to be a sufficient driver for long-run prosperity.

Brewin (2004) looked for convergence in both income and human capital in the presence of migration at the U.S. county level. An emphasis was also placed on identifying the factors that affect migration, income and human capital growth. The vehicle he used to complete his examination was a simultaneous equation model similar to that of Goetz and Hu (1996). The fundamental difference with Brewin's (2004) model was that it included structural equations for migration and for employment as well as the income and human capital equations featured in Goetz and Hu's (1996).

Brewin's (2004) analysis found convergence was occuring in both per capita income and human capital at the rural and urban levels, although at very slow rates for urban counties. It was surmised that the slow speed of convergence was likely due to the presence of agglomeration economies, as noted by Krugman (1991), in cities and/or because of migrants carrying high levels of human capital which would support the high capital stocks in high income areas. This would cause difficulties for the poor counties to catch up quickly, as Lucas (1990) had contended. Another important finding was that migration tended to speed up growth in income and human capital. This suggests migrants were carrying highlevels of human captial.

2.3 Factors Affecting Migration

Since migration plays an important role in the stocks of physical and human capital, it is necessary to examine a number of the aspects that affect migration. The choice to migrate is an important decision for any agent or household to make. As such, the migration decision can be influenced in a number of ways: including the characteristics of the agents themselves (and the barriers to migration they face), and the characteristics of their original location and their destination.

It is probable, and makes intuitive sense, that the migration decision process undertaken by the household is like a cost-benefit analysis (Goetz, 1999). As with any cost-benefit analysis, the benefits are measured against costs with the decision being based on whether the differential between the benefits and costs is positive or negative. In this case, the benefits gained from moving are weighed against the costs associated with moving. Ferguson (2005) elaborates that these costs and benefits would include both pecuniary and non-pecuniary factors. Examples of pecuniary factors include such things as earned income, living costs, and search and transaction costs for finding a new home and place of employment (Ferguson 2005). Non-pecuniary factors can consist of location relative to friends and family, climate and available entertainment options (Ferguson, 2005). These costs and benefits can be very heterogeneous from household to household, making the decision process unique among individual households.

2.3.1 Characteristics of Households that Influence the Migration Decision

In his survey of a number of migration models, Goetz (1999) discovered a number of characteristics pertaining to households which influenced the migration decision process. The first, out of the five characteristics that will be highlighted, is age. Age was consistently found to be an influence in migration. Despite the fact that retirement migration is an important and common phenomenon, migration probabilities generally decline as age increases (Goetz, 1999). This can be explained since, as time wears on, a person is liable to have made substantial investments in his or her current location. These investments would include physical (homes and property) and social capital (sense of belonging to the community, social networks, family and friends). Forgoing these investments would add significant costs to migrating, thereby making it less likely to happen. In contrast, younger people are less likely to have made large investments in their community, and thus face fewer costs when deciding to migrate.

The next characteristic is level of education. Goetz (1999) noted that households with greater levels of educational attainment had a higher propensity to migrate. This is as opposed to those with little education, who were much less likely to move. Goetz (1999) reasons that agents with higher levels of education (or human capital) tend to receive better returns for their investments when they move.

Thirdly, income is listed by Goetz (1999) as an influence on migration decisions. It has been noted that lower income households are more likely to migrate than richer ones. Intuitively, it would be thought that the reverse would be the case, but it can be argued that richer households may have higher costs to migrating than poor ones. This stems from the likelihood that more affluent households will have made significant investments in their current location, similar to older age cohorts as explained above. These investments would add sizeable costs to migration, since choosing to migrate would result in the forfeiture of these investments. The poor, like the younger cohorts discussed above, are not likely to have made similar sized investments, ergo they would face lower costs to migrating. Also, poor households may migrate more readily because there is a chance that through migration they might improve their economic conditions (Brewin, 2004).

Ethnicity is also listed as a factor. Non-white people in the U.S. have been found to migrate less often than white people. Goetz (1999) states that this result is likely due to a lack of access to information, and possibly limited available resources to expend on a move.

Lastly, marital status also can have an important influence on the migration choice. Households containing a married couple and perhaps children as well (since not all married couples have children or have children living at home), are less likely to move as they would face significant social costs when migrating, similar to what has been discussed already in this section.

2.3.2 Characteristics of Locations that Influence the Migration Decision

The two key characteristics linked to the original and target locations as described by Goetz (1999) are economic conditions and amenities. The economic conditions of the place of origin or destination exert an influence on the decision process in a similar manner as the income influence described in section 2.3.2. Regions with less favourable economic conditions may not be providing the desired opportunities for households to maximize their utility, thus providing an incentive to move to a new location in which a household may find better opportunities and better economic conditions. The reverse of this is that areas with favourable economic conditions would provide an incentive for potential migrants to stay, since the desired opportunities or aspects are present. Under good home conditions there is a lower probability of finding better conditions elsewhere.

Amenities[13] implicitly or explicitly can be defined as items that can be consumed by virtue of residency in a location. They may vary from place to place and level of

[13] Amenities can be divided into three subcategories; those being natural, historic or modern amenities. A natural amenity is derived from a location's geography (rivers, shoreline, hills, etc) or climate. Historic amenities are consumables made available from the presence of past infrastructure or events (monuments,

supply (Diamond, 1980). Their influence on the migration decision comes in the way of "pushing" migrants out or "pulling" migrants in. Unfavourable amenities, or *disamenities*, such as air pollution, high crime rate or crumbling infrastructure, create adverse living conditions, thereby creating an incentive for households to move away in hopes of finding better conditions. These factors act to "push" households out of a region. Desirable amenities, like mild winters, nearby health care facilities, etc, can make living conditions more favourable, therefore providing an enticement for households to move to that location; or "pull" households in.

In two separate papers, Roback (1982; 1988) theorized that agents would be willing to trade income for available amenities and thus would affect their allocation across space. Her results in each publication provided support for this theory. This means that amenity poor areas would be required to compensate the labour force with higher wages in order to attract agents to move into the area. Amenity rich areas could offer lower wages to workers, since the difference in wages would be made up for by the presence of desirable amenities. Both of these studies are explored in more detail in section 2.4.

2.3.3 Relevant Canadian Studies

Although the theoretical and empirical significance of amenities has been well documented and employed in U.S. migration studies, this has not been the case in Canada. Ferguson et al. (2007) noted that most Canada-based studies have not included

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buildings, battlegrounds, etc). A modern amenity is any consumable related to the presence of modern buildings, institutions or services (hospitals, police services, theatres, etc) (Bruekner, Thisse, Zenou 1999).

amenities in their analyses. Three exceptions are Day (1992), Ferguson et al. (2007) and Partridge et al. (2007).

Day (1992) sought to determine if interprovincial migration flows were affected by government spending and taxation policies. To achieve this, a model was designed where agents would decide to live in the province providing them the highest degree of utility. Annual provincial data on wages, income, government transfer payments and expenditures, migration and amenities, ranging from 1962 to 1981 were used for a generalized least squares (GLS) estimation of a migration model.

There were several notable findings made by Day (1992), the first of which was that the amenity measures that were used were all found to be significant. As well, the composite variable of government spending as a whole was found to be statistically significant, with a positive coefficient indicating that migration increased as provincial governments increased their expenditures. Increases in spending on health and education increased in-migration whereas increased spending on social service programs, like employment insurance or welfare, had the opposite effect. Day (1992) explains the reason behind this could be because increased social spending may indicate less desirable economic conditions, such as high long-term unemployment rates or higher levels of taxation.

Ferguson et al (2007) studied the determinants of rural and urban community population growth. Their contribution to the literature includes an examination of the effect of local amenities, agglomeration economies and other economic factors, (income, industry concentration, etc), on population change for both the total population and for five different age cohorts. The key objective was to determine if growth or contraction in population was a result of people following jobs or the result of people seeking quality of life improvements. The model used for their study was theoretically based on utility maximization being the central behavioural criterion of households. Empirically, a single equation was developed around the theoretical model, where population change was the dependent variable. The independent variables employed in their model consisted of several vectors of variable groupings or cohorts. These cohorts included amenity, economic, agglomeration, demographic, human capital, and social capital variables. Using ordinary least squares (OLS) to estimate the model, they found that urban and rural areas are influenced differently by amenity, economic and agglomeration variable cohorts. Specifically, economic factors explain the greatest amount of variation in population change for rural and urban settings. In urban centers, amenities contribute more to population change than agglomeration effects; whereas in rural communities the opposite is true.

Partridge et al (2007) examined the effect of agglomeration economies on population growth in Canada. They argued that in the U.S., migration was driven by amenities towards some rural regions. Their study evaluated whether amenities had a stronger influence than nearby cities on population growth. They referred the "engines of growth" hypothesis, where cities (the so-called "growth engines") act as the driver of population growth. To investigate this, the decrease in agglomeration effects for regions located farther away from urban centers was examined empirically using OLS.

Partridge et al (2007) found evidence that major urban centers in Canada do stimulate population growth in and around their locations. Rural communities and smaller urban cities were found to have benefited from being closer to a major center.

They argued the reason for this being that these areas had an increased regional attractiveness, in the eyes of migrants, due to their closer proximity to the higher order services and amenities found in major urban areas. This was in light of the fact that there could be other drivers for migration, including; agglomeration effects and external economies of scale. Like Ferguson et al. (2007), it was seen that that amenities were not as important in terms of explaining population flows within Canada, as compared to economic and agglomeration factors. As Partridge et al (2007) pointed out this is likely due to the fact that there is less variation in climate along the southern border of Canada, where the majority of Canadians reside.

2.4 Simultaneous Equation Models

Although many economists have explored convergence and population change using simple linear regressions, others have employed alternative methods. Of most relevance to this thesis is the use of simultaneous equation models based on simultaneous choice by agents to migrate or to invest in physical or human capital. When exploring income and human capital convergence, in the presence of migration, simultaneity could be present in any model.

Equations (21) and (23), found in section 2.2.3, provide support for a relationship between convergence and migration, and therefore between migration and income and migration and human capital. When agents migrate, they alter the physical and human capital stocks in the areas they migrate to, these stocks affect incomes, even while migrants are motivated to relocate, at least partially because of income differentials. This in effect, creates simultaneity in any model that examines migration and income and human capital growth. Analogous to how a supply and demand model sets both price and quantity concurrently, preferred migration destinations, and human and physical capital stocks are all set simultaneously through the agent's utility function.

The review of simultaneous equation models begins with Roback (1982). Her study explored the role that wages and rents played in the allocation of labourers across space, given the variation in amenities from location to location. Roback (1982) designed a simultaneous equations model, theoretically based on utility maximization. Generic and freely mobile workers seek out their preferred location, in which the bundle of wages, land and site specific available amenities they consume provides the highest utility. Over time as workers migrate, wages and rents for the given level of land and amenities adjust at each location until the point is reached where workers become indifferent to each location. Empirically, Roback (1982) was able to estimate amenity values for 98 U.S. cities, through the use of hedonic estimation. It was found that observed regional wage differentials could be explained to a great extent by local amenities. This provided further evidence to the theory that individuals are willing to trade wages for greater amenities.

Carlino and Mills (1987) sought to search out the determinants of interregional population and employment densities at the county level in the United States. Their model (which is developed in detail in Chapter 3) was based theoretically on household utility maximization and firm profit maximization. Both firms and households were allowed to migrate, and through the migration process, eventually profits and utility would be equalized over the entire country, such that neither firms nor agents had incentives to move in the long-run. On the basis of the work by Steinnes and Fisher

(1974), Carlino and Mills (1987) were able to analyze this empirically through the use of a simultaneous system of equations featuring endogenous population and total employment density. They also constructed a manufacturing employment density equation, and built another system of equations with population density. This was done since they were also interested in isolating the relationship between population and the manufacturing sector.

They found that for both population and total employment density, climate was an important determinant of growth. Differential regional growth (or decline) in the manufacturing sector was largely seen as being a result of the economic and demographic conditions found in each county. Similar results were observed for total employment; however regional differences not controlled for had a greater influence on total employment than manufacturing employment. Carlino and Mills (1987) also noted that for population density, variables that are affected by government policy (such as taxes, crime rates, etc) had very little impact on growth. It was also noted that both the endogenous population and employment variables were significant. This provided support for their use of a simultaneous equations system.

In another paper published in 1988, Roback again explored the role of wages, rents and amenities in the allocation of labourers across space. The model used for this publication was very similar to Roback (1982), featuring a system of equations based on migrant workers seeking to optimize their utility. The innovation for this paper however, was that she considered two distinct types of labourers comprising the workforce, rather than the previously assumed generic workers. The cost of living in different locations was also accounted for. She again found empirical support for her earlier findings that regional differences in earnings were explained by amenity differentials between locations, instead of cost of living differentials.

Goetz and Hu (1996) as discussed earlier in section 2.2.2, examined convergence, at the county level in the southern U.S., in human capital and income using a simultaneous equations model. Their income growth equation was based on Barro and Sala-i-Martin's (1995) work, but did not follow the traditional linear model that had often been used by the likes of Baumol (1986) and others. Goetz and Hu used a simultaneous equation model with income and human capital stocks as the two dependent variables.

Deller et al. (2001), in a highly cited academic paper, furthered the work of Carlino and Mills' (1987) economic growth model. As will be seen in Chapter 3, an income growth equation was included along with population and employment; extending the system from two to three equations. The intent of their research however differed from Carlino and Mills (1987). The main focus for Deller et al. (2001) was to increase academic understanding of the nature and degree of economic structural shifts in rural American counties, with the spotlight aimed at amenities.

Empirically, although their model was simultaneous in nature, only the reduced form equations of the structural model were estimated and reported. Deller et al. (2001) were only interested in isolating amenity measures and not the interactions between the endogenous variables of the system. The important story that came from Deller et al. (2001) was the creation of well organized and consistent amenity indices. This was a significant shift away from previous ad hoc-type descriptions of amenities in empirical work. No such indices exist as of yet, for Canadian data on amenities.

Brewin (2004) considered convergence in income and human capital growth, while allowing for migration to take place. His simultaneous system furthered the work of Carlino and Mills (1987), Goetz and Hu (1996), and Deller et al (2001). Brewin (2004) also made use of a switching equation to model population change. This was done by way of an added slope shifter variable. This dummy variable (1 for in-migration and 0 for out-migration) was multiplied by all the other regressors in the population change model which were reinserted into the equation. This allowed for the modeling of the effects that the other variables have on in-migration versus out-migration. Brewin (2004) thus reported the coefficients for the variables multiplied by the slope shifter as in-migration and the non-multiplied variables as out-migration. He concluded that out-migration was influenced differently by amenities, income and human capital than in-migration.

Monchuk (2007) studied the impacts of gambling on aggregate income, employment and population growth for a cross-section of Midwestern and Southern states in the U.S. Drawing inspiration from Carlino and Mills (1987) and Deller et al. (2001), Monchuck (2007) used a very similar growth model to determine that casinos in operation prior 1995 had no measureable impact on income or employment. Alternatively, casinos started after 1995 did have a positive effect on employment growth but a negative effect on income growth.

Monchuk (2007) approached this query in much the same way as Deller et al (2001), employing a seemingly unrelated regression (SUR) analysis to control for unobserved simultaneity amongst the growth equations in his model. Drawing from Barro and Sala-i-Martin and others, he employed a Cobb-Douglas functional form for his analysis. Although Monchuk (2007) was focused on the effects of a casino's presence, his model provides further support for the use of simultaneous equations in exploring growth.

Chapter 3: Theoretical Model

3.1 General Migration Model

In the previous chapter, models of income growth were developed including the persistent evidence for income convergence – even in the case of models that allowed for migration (see equation 21). Near the end of Chapter 2, the Carlino and Mills (1987) system of equations were used in several studies that incorporated multiple endogenous growth rates.

Equations (21) and (23) propose that population changes could affect total capital changes and human capital changes, which will affect income growth. Previous studies show that conditional convergence requires the inclusion of other variables in the income growth function prior to the test of convergence. Finally, in models of migration, researchers acknowledge that migration is one of several choices solved simultaneously. Therefore, migration needs to be estimated in a system of equations.

As a precursor to the overall theoretical model for this thesis, Carlino and Mills' (1987) approach to simultaneous employment and migration processes is started with.

The migration theory for this model begins with an assumed equilibrium where both households and firms are considered to be geographically mobile but regions have differing levels of natural amenities and living costs. The general conditions of this equilibrium are described by Carlino and Mills:

"Consumers maximize utility which depends on purchased goods and services, on locations relative to work places, and on spatially varying nonmarket amenities. A conventional budget constraint equates income to the sum of spending on goods and services. Local taxes reduce consumption expenditures and government services, and other amenities appear in utility functions. . . . Profit-maximizing firms produce goods and services, buying inputs and selling outputs in competitive markets. Production costs vary by location because of regional comparative advantage, transportation cost differentials, regional variation in labour supply (amenities affect labour supplied at given wage rates), agglomeration economies, and perhaps because of spatial variation in other government actions – land-use controls, state and local taxes, etc… Firms view themselves as producing under conditions of constant returns, but agglomeration economies exist which are modeled as parametric external economies of scale to firms. We assume that firms and households adjust to disequilibrium by distributed-lag adjustment equations. Firms enter and leave regions until profits are equalized among regions at competitive levels, and households migrate until utility levels are equalized at alternative locations." (Carlino and Mills 1987, p. 40)

3.2 Additional Theory

Carlino and Mills (1987) have laid out much of the groundwork for the theory that is being employed in this thesis. However, there are two areas it is necessary for this thesis to expand upon. Those areas are the simultaneous migration and investment decisions for agents and firms.

3.2.1 Migration Decision

The migration decision for the infinitely lived household or agent is predicated upon maximizing his or her utility function in the long-run. It is assumed that an agent would consider the expected utility derived from different regions versus the utility they obtain in their current community and accounting for the cost of migrating (Ferguson 2005). Should the gains in utility derived from the new region be greater than their current utility and the added moving costs, the agent will migrate to the new region. Conversely, if no gains in utility are made, then the household will not choose to migrate.

Over time, the agent will continually re-evaluate the migration decision as part of maximizing his or her utility. As this decision process plays out, Carlino and Mills (1987) tell us that utility levels will eventually (in the long-run) equalize across space, leaving every agent indifferent to all locations, due to the equalization of wage rates, relative to locations specific amenities.

The moving costs experienced by households could include a host of factors; including the search costs associated with finding a new home and place of employment, the costs of buying a new home, transporting physical possessions and social costs[14] (Ferguson, 2005).

3.2.2 Investment Decision

Carlino and Mills (1987) tell us that agent utility is a function of consumption. Consumption is subject to a budget constraint, but only household income is considered in this constraint. Recalling from section 2.1.2, if one rearranges the terms in equation (5) it is seen that consumption is constrained to income minus investment. Carlino and Mills (1987) did not account for investment, but for the purposes of this thesis, it is important to do so. Therefore, the level of consumption for an agent is assumed to be equal to their income less investments.

As noted previously, Solow surmised that investments were only made in a generic, unspecified form of capital, referred to as productive capital. Here, an important distinction is made, in that this thesis divides Solow's productive capital into two

[14] This subset of costs can include such things as finding and developing new relationships, and cultural/community networks, while leaving established networks and relationships behind (Ferguson 2005).

subcategories: human capital and physical capital. Human capital investment is assumed to be made in formal education[15] (university, college or any other educational institution). Physical capital is assumed to be any tangible good that the agent can invest in. Examples include capital goods such as land, or machinery. Both of these investment types generate income for the agent in the long-run.

Agents who have made investments in either form of capital experience future gains in income. Human capital investments enable agents the ability to command higher wages (thus generating higher income) from firms that choose to hire those who have made such an investment. Physical capital investments generate increased future income for the agent through rental fees paid to the agent from firms who wish to lease the physical capital from the agent.

Assuming an endogenous investment choice (discussed in section 2.2.1) on the part of the agent, rather than a fixed savings rate, the investment decision is determined in the following way. The investment is made as an inter-temporal trade off to consumption. Agents compare the utility gained from current consumption to future consumption, while comparing their discount rate on future capital returns gained from investing in either form of capital. From this comparison, agents determine their preferred path of consumption and its corresponding investment path that that is required in order to achieve their maximum utility. The preferred path is the one which provides the highest amount of utility to the consumer over the long-run.

Firms choose to either hire agents who have invested in human capital (and pay them a higher wage) or rent physical capital from agents for a fee. The basis for the firm

[15] Although this assumption does not adequately encompass the complexity of the definition for human capital (see Chapter 2), it is an assumption that is consistent with the literature. This is further discussed in Chapter 4.

decision process is whether or not profits are increased from their current levels. Since acquiring either form of capital creates a cost to the firm, the firm will evaluate if the increase in productivity generated by either investment (or combination thereof), outstrips the increase in costs – i.e. increases profits. Solow's diminishing marginal returns to production are also in effect for firms as they are for agents.

3.3 Foundation Models

Carlino and Mills (1987) chose to focus on the steady-state levels of population (P) and employment (E) in their model. Under their equilibrium framework, Carlino and Mills endogenized each variable in a two-equation system that allowed other, exogenous variables to affect these two variables. They believed that a number of the observed variables that they classified as exogenous might be solved simultaneously under the given framework. However, due to identification problems and a lack of knowledge on potential variable interactions, they assumed that these other variables were determined outside of their model.

Carlino and Mills (1987) assumed that the model could be solved simultaneously as they had developed it, yielding the following:

$$E* = f(P, X_E) \tag{24}$$

$$P* = f(E, X_P) \tag{25}$$

Where: $E*$ and $P*$ represent the steady-state levels of employment and population, respectively; and X_E and X_P embody vectors of exogenous variables that affect employment and population respectively.

At the steady-state in Carlino and Mills' model, population and employment levels no longer change. This is because through migration, based on theoretical outlay quoted above, firm profits and agent utility have become equalized across space thus no longer providing any incentive for the firm or agent to move. This therefore puts the population level at steady or unchanging state. Additionally, with no migration and firm profits are equal to zero, the supply and demand for labour will not vary as firms do not have any incentive to hire any more or less labourers (since profits are maximized) and labourers gain nothing by moving. Therefore, the level of employment will remain in an unchanging or steady state. As will be shown below, beginning levels of the exogenous variables can be used to estimate the change in the endogenous dependent variables if it is assumed (as Carlino and Mills did) that the endogenous variables adjust towards their equilibrium at differing rates of change.

Deller et al (2001) later expanded on this model by adding income as a third dependent variable. In Carlino and Mills (1987), starting income entered their model as an exogenous variable. The change in income or growth in income levels was ignored. Deller et al (2001) however, being concerned with income's role in regional growth, added it as a third equation in the simultaneous system.

Brewin (2004) included human capital in the model. He used Goetz and Hu's (1996) finding that human capital had an influence on income growth. Since education levels were included exogenously in Deller et al's model, Brewin was thus able to append human capital to that model. A key deviation seen in the model being used in this thesis is that the forerunners of this model all included employment rate as a dependent variable, whereas this model does not. The grounds for this change are that employment and income are believed to be highly related to one another. The basis for this is Blanchflower and Oswald's (1996) wage curve, which empirically demonstrated a negative and significant relationship between unemployment and wages.

Building on Carlino and Mills (1987), the formal equilibrium or steady-state assumptions for this thesis are:

$$P* = f(Y, H, X_P) \tag{26}$$

$$Y* = f(P, H, X_Y) \tag{27}$$

$$H* = f(P, Y, X_H) \tag{28}$$

Where: $P*$, $Y*$ and $H*$ represents the steady-state levels of population, income and human capital. X_P, X_Y, and X_H are vectors of exogenous factors for each equation, which pertain to population, income or human capital.

The steady-state of this study's model reflects the levels of population, income and human capital that no longer change. In similar fashion to the steady-state described for Carlino and Mills' model, by the simultaneous migration and investment decision processes and the theoretical grounds of Carlino and Mills, profits and utility have become equalized (and therefore maximized) across locations. From this, there no longer remains any incentive for firms or agents to move, thus putting the population level at a steady-state. Natural population increase will not affect the steady-state since agents are assumed to be unable to produce any offspring.

Income and human capital also reach a steady-state due to their association with utility. As described earlier in this chapter, utility is assumed to be a function of consumption, which is a function of income and investments (human capital being one of them). Because utility has become equalized across space and is no longer changing, this implies that income and human capital will no longer change, due to the optimization of the agent utility function through the simultaneous migration and investment decision processes. Since agents no longer move, and investment decisions have been capitalized on in the long-run, income will not change and human capital levels will not change since there no longer remains any incentive to invest.

Holding all of Carlino and Mills' assumptions and including Deller et al and Brewin's additions and the additions made in this thesis, each key choice variable is written as a function of the other choices, initial endowments and an adjustment process.

Brewin (2004) explains that labour pools, human capital stocks, and incomes all adjust at different rates because of the varying processes involved in migration, education, innovation and acquisition of employment. In the case of population changes (P), the means for adjustment result in a current migration rate that is a function of the relative degrees of the vectors of factors in different regions. The decision of whether to move from one region to another is then dependent upon changing incomes, and human capital and the variables that alter migration exogenously.

At this juncture, the model describes the long-run equilibrium. In this state, the model would suggest that people would have already moved to their optimal location (Carlino and Mills, 1987). Since people are still migrating within Canada, it is reasonable to assume that from the theoretical long-run or infinitely lived agent perspective, the steady-state has not been reached.

One explanation for this current disequilibrium could be positive shocks to economic factors or amenities (disamenities) that pull (push) people towards (away from) a certain location. The resulting disequilibrium plays out over the long-term through an adjustment process that moves towards equilibrium. An allowance for this within the model is made through the incorporation of a distributed-lag adjustment within the model.

Being guided by Deller et al (2001) and maintaining the equilibrium conditions set out above, equations (26) – (28) can be regarded linearly as:

$$P* = \alpha_{0P} + \alpha_{1P}Y* + \alpha_{2P}H* + \Sigma\alpha_{iP}X_P \quad (29)$$

$$Y* = \alpha_{0Y} + \alpha_{1Y}P* + \alpha_{2Y}H* + \Sigma\alpha_{iY}X_Y \quad (30)$$

$$H* = \alpha_{0H} + \alpha_{1H}P* + \alpha_{2H}Y* + \Sigma\alpha_{iH}X_H \quad (31)$$

Where: $\sum_{i=3}^{n}\beta_{iP,J,H}X_{iP,Y,H} = \beta_{3P,Y,H}X_{3P,Y,H} + \beta_{4P,Y,H}X_{4P,Y,H} + \dots + \beta_{nP,Y,H}X_{nP,Y,H}$. α_{0P}, α_{0Y} and α_{0H} are the intercept terms for the dependent variables, with each α_{iP}, α_{iY} and α_{iH} representing a parameter.

To incorporate the adjustment process into the model, partial adjustment equations are added; resulting in:

$$\Delta P = P_t - P_{t-1} = \lambda_P(P* - P_{t-1}) \quad (32)$$

$$\Delta Y = Y_t - Y_{t-1} = \lambda_Y(Y* - Y_{t-1}) \quad (33)$$

$$\Delta H = H_t - H_{t-1} = \lambda_H(H* - H_{t-1}) \quad (34)$$

Where: each λ specifies the rate of adjustment to period t levels from period $t-1$ levels for population, income and human capital, which are considered to be positive. Δ signifies the change in the dependent variable, with P_{t-1}, Y_{t-1}, and H_{t-1} being the initial conditions for population, income and human capital (Deller et al., 2001).

By substituting equations (29) – (31) into (32) – (34) and then rearranging the terms, a linear depiction of the model can be shown (Deller et al., 2001):

$$\Delta P = \beta_{0P} + \beta_{1P}\Delta Y + \beta_{2P}\Delta H + \beta_{3P}P_{t-1} + \beta_{4P}Y_{t-1} + \beta_{5P}H_{t-1} + \Sigma\beta_{iP}X_{iP} \quad (35)$$

$$\Delta Y = \beta_{0Y} + \beta_{1Y}\Delta P + \beta_{2P}\Delta H + \beta_{3Y}Y_{t-1} + \beta_{4Y}P_{t-1} + \beta_{5Y}H_{t-1} + \Sigma\beta_{iY}X_{iY} \quad (36)$$

$$\Delta H = \beta_{0H} + \beta_{1H}\Delta P + \beta_{2H}\Delta Y + \beta_{3H}H_{t-1} + +\beta_{4H}P_{t-1} + \beta_{5H}Y_{t-1} \ \Sigma\beta_{iH}X_{iH} \quad (37)$$

Where: $\sum_{i=6}^{n} \beta_{iP,J,H}X_{iP,Y,H} = \beta_{6P,Y,H}X_{6P,Y,H} + \beta_{7P,Y,H}X_{7P,Y,H} + \dots + \beta_{nP,Y,H}X_{nP,Y,H}$

Here, it is seen that the change in population, income and human capital are functions of the change in the other dependent variables, the initial starting conditions of each dependent variable and a host of related exogenous variables. These exogenous variables consist of several variable groupings, including economic, demographic, location, typology (indicating community type – that is whether the community is a rural or urban community), agglomeration, education, and amenity cohorts.

Deller et al. (2001) point out that in this situation, the rate of adjustment coefficients (λ_P, λ_Y and λ_H) has been embedded in the linear coefficient parameters β_{iP}, β_{iY} and β_{iH}. This is a result of the adjustment coefficients becoming multiplicative with the original parameter coefficients (such as α_{iP}) during the substitution process. For simplicity, these multiplicative terms have been replaced by the new coefficient terms β_{iP}, β_{iY} and β_{iH}, which capture the effects of both the adjustment parameter and the original parameter on each variable. This system of equations provides an opportunity to model the short-term adjustments (ΔP, ΔY and ΔH) towards the long-term steady states of $P*$, $Y*$ and $H*$ respectively (Deller et al., 2001).

Equation (35) is the model for population change. As per the earlier discussion in this chapter on migration, it is necessary to include population change in the system in order to account for its effect on stocks of human capital and income change. This model depicts change in population as a proxy for migration and will be discussed further in Chapter 4. It also should be noted that although population change is related to convergence, this model does not provide any answers in determining if support for convergence exists. Those answers are found in the income growth model and human capital growth model.

Equation (36) is the income growth function, with the human capital growth function being equation (37). Should a negative sign be discovered for the parameter estimate of the starting income variable in equation (36) and for the parameter estimate of the starting human capital variable in equation (37), these findings would provide evidence to support convergence in incomes and in human capital. If this is indeed the case, this thesis provides further support for the previous work by Coloumbe and his co-authors, as well as the work of Barro and Sala-i-Martin, Goetz and Hu, and Brewin.

Like Deller et al. and Brewin, this study now has a simultaneous framework available with which an exploration of convergence can be made by estimating the parameter coefficients of the model. Although this model has not made any significant departures from its progenitors, there are two noted differences that provide a level of uniqueness to this model. The first is that this model will be estimated using Canadian data. All other studies that have utilized this model, or a version thereof, have used U.S. data sets.

Secondly, there is evidence from Brewin (2004) that the adjustment process from the beginning state to the long-run equilibrium (denoted by λ) is different for urban versus rural areas. In Brewin's (2004) income growth model, this difference in adjustment was modeled by creating an adjustment typology variable from the multiplication of starting income by the county's typology dummy variable[16]. These variables were found to be significant, indicating that the convergence process was a function of the community's urbanization.

Since there are two community types (urban and rural) in this study, an account for this will be made in a similar fashion. What is new about this for this study is that it is believed that this alternative adjustment process can be extended to population change and human capital change. Thus, this study includes adjustment typology variables in the population change and human capital models, in addition to the income adjustment variable. Should these adjustment variables be found to be significant with a positive coefficient estimate, this would indicate that urban areas are not following the pattern of growth predicted by convergence. Should the coefficient sign prove to be negative, support is provided for Brewin's (2004) findings that urban communities are converging faster than their rural counterparts.

[16] Brewin (2004) was able to separate the county type into four categories, including: large urban (core), small urban, rural but adjacent to an urban county (rural-adjacent) and rural non-adjacent to an urban county (rural remote). The rural remote variable was omitted to avoid the dummy variable trap.

Chapter 4: Data

4.1 Data Source

The source of the data that are being utilized for this study is found in the Canada-Rural Economy Research Lab[17] (C-RERL) database. Ferguson (2005), who also made use of the data in the C-RERL database in his migration study, explains that the data possessed by C-RERL originate from a myriad of sources. These sources include: Statistics Canada's Census of Population dataset; Desktop Mapping Technology Incorporated Spatial's (DMTI Spatial) Enhanced Points of Interest database; Elections Canada; Natural Resources Canada, Environment Canada, and Canadian Centre for Justice Statistics (Ferguson, 2005). Employing a vast amount of data that are sourced from many different agencies can present a challenge when not all of the data are tabulated in consistent units like Census Consolidated Subdivisions (CCS) (Ferguson, 2005). Fortunately, the C-RERL has expertly compiled these data into the CCS measure. As such, the data used for this study were drawn from the C-RERL database.

The C-RERL database is comprised of a wealth of information on natural and modern amenities, physical geography, population and demographics, education, employment, income and housing. This array is also allotted in five-year intervals, spanning a total of 25 years; beginning in 1981 and ending in 2006. These years, and each of the five-year intervals, coincide with the population censuses conducted by Statistics Canada.

[17] C-RERL is a research facility located within the University of Saskatchewan. Their dedicated purpose is to explore and analyze rural Canada's economy, quality of life and environment.

Since adjustments in the three dependent variables of interest occur at a slow pace, a longer duration of time is preferred for analysis. It would be preferable to use the entire range of the database; however this is not possible for this study. The reason for this is that a number of key variables, including information on income and human capital, are not available over the full 25 years in consistent units. This study will examine the available data over the 1986 to 2001 time period, since this is the longest, consistent time frame for the C-RERL database. This timeline may not be as preferable as a more current time period; however, it is similar to Ferguson et al. (2007) and Brewin (2004) and therefore should provide an interesting comparison to both of these studies.

4.2 The Unit of Observation

As mentioned above, one of the sources of originality for this thesis is the dataset that is employed. All previous Canadian studies regarding convergence have been conducted at the national or provincial level. This study however, is fortunate to have growth data at the sub-provincial level. Much like similar U.S. studies, the benefit of being able to explore the larger degrees of variability in income, education and amenities that exist at the "local" level than at the provincial or state levels is gained.

Following the lead of Ferguson (2005) and Partridge et al (2007), the sub-provincial unit of observation for this study is the CCS. As with Ferguson (2005) and Partridge et al. (2007), a CCS will constitute a community or location.

A census subdivision is defined as an area that is a municipality or county (e.g. rural municipality, town, or city) or any equivalent area (e.g. Native reserve or unorganized area) from a statistical reporting perspective (Ferguson, 2005)[18]. A CCS refers to a grouping of adjacent census subdivisions; the smaller, more "urban" (hamlets, villages, etc) census subdivisions are consolidated with the larger and more rural, surrounding census subdivision (Ferguson, 2005)[19]. This leads to the creation of a measurable geographic unit (although the physical dimensions can vary greatly) that is somewhat comparable to an US county.

There is another distinct advantage to utilizing the CCS unit of observation. With more than 2600 CCS located within Canada, a finely detailed analysis can be conducted as compared to American regional growth studies that focus on the 3000 plus county level observations (Partridge et al., 2007). The reason for this is that the U.S. has a population that is nearly ten times that of a Canada's (Partridge et al., 2007).

Theoretically, the best and most interesting unit to study would be the household itself. Regrettably, household data are not made available and has thus been tabulated by C-RERL at the various geographic and socio-economic levels for each CCS (Ferguson, 2005).

4.3 Specific Variables

A total of 41 variables (38 of which are considered to be exogenous) will be utilized in the simultaneous equation model. These variables were selected mainly from the work completed by Ferguson (2005), and the research of Goetz and Hu (1996), and Brewin (2004) and their simultaneous equations models. Since Ferguson's study also

[18] Ferguson (2005) adapted this definition from "1996 Census Dictionary – Final Edition" by Statistics Canada. The 1996 definition is used since the boundaries for our unit of measure is held constant to 1996 geographic measurements, just as Ferguson (2005) did.
[19] See previous footnote.

utilized the C-RERL database, many of the variable explanations are drawn from his work.

Following the lead of Ferguson (2005), in the ensuing subsections, each variable is presented, allowing for a brief discussion on what the variable is believed to be a measure of. As well, any important calculations or adjustments made by the author to create the variable will also be presented. It should be noted that, aside from the three dependent variables, all variables used are measured at their 1986 levels, unless stated otherwise.

4.3.1 Population Change

The first of the three endogenous variables present in this study's model is net population change. This variable acts as the measure of the overall percentage change in the number of people dwelling in a given community (CCS) over the 1986 – 2001 time line. This variable acts a proxy for net-migration, since this thesis is unable to employ a true net-migration variable. Region specific data on out-migration are not available; therefore net-migration cannot be calculated (Ferguson, 2005).

C-RERL's database provided data on 1986 and 2001 population levels; however these numbers have not been adjusted for births or deaths occurring in each CCS. Without making this adjustment, births essentially would be counted as in-migration and deaths would appear to be out-migration in the data (Ferguson, 2005). Since on average, births outstrip deaths in Canada, using the raw population numbers would serve to inflate net in-migration and deflate net out-migration numbers[20]. Thus, by accounting for births and deaths, natural increase of the population is assumed to be separated out of the data. This thereby enables the population change variable to capture population movement alone (as a proxy for true migration), rather than migration and natural increase simultaneously.

To make this modification to the population data, provincial crude birth rates (CBR) and age-specific death rates[21] (ASDR) were used to compute the net rate of natural increase per person (NR) for each CCS. These rates are calculated by Statistics Canada as being the number of births or deaths per 1000 persons in a year. Therefore, to arrive at the rate of natural increase per person, the difference of these rates must be divided by 1000. More formally:

$$NR = (CBR - ASDR)/1000 \qquad (38)$$

The calculated per person rate of natural increase was then used to compute annual estimates of CCS population up to 2001 as follows:

$$Est.1987\ Pop. = 1986\ Pop \cdot (1 + NR) \qquad (39)$$

$$Est.1988\ Pop. = Est.1987\ Pop \cdot (1 + NR)$$

$$\downarrow$$

$$Est.2001\ Pop = Est.2000\ Pop \cdot (1 + NR)$$

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[20] On average this would be true; however it is noted that on a CCS by CCS basis this will not always hold. It would be preferable for our study to account for actual births and deaths by CCS, but this data is not in our possession. As such it is assumed that each CCS follows the average birth and age-standardized death rates for the province in which it resides.

[21] An age-standardized death rate (ASDR) is defined as a weighted average of the age-specific death rates (per 1000 persons), in which the age distribution of a standard population is used as the weights (Statistics Canada, 1997). The 1991 population was used as the standard population by Statistics Canada. The purpose of using an ASDR is that it allows for comparisons to be completed between different time periods and across differing areas which have different age cohort distributions (Ferguson, 2005).

Finally, the estimated 2001 population was subtracted from the actual 2001 population to get the net adjusted change in population. This number was then divided by the 1986 population to convert it to percentage change. As Ferguson (2005) states, using percentage change enables us to account for any differences in scale between CCSs.

4.3.2 Income Change

The dependent variable for the income growth equation is income change. In similar fashion to population change, this variable provides information on the percent change in income levels over the time period used in this study. This variable was arrived at by subtracting 1986 per capita income for individuals 15 years of age and older from the 2001 per capita income for individuals 15 years old and up and then dividing the difference by the 1986 measure.

Per capita income is used since it has been the traditional metric in past models concerned with exploring income convergence. Additionally, it serves as an indication of the wages paid to the average or representative household that that this study has been concerned with. It is argued that it is with this income that the household uses for either consumption or investment in one of the two forms of capital discussed. Again percent change is used to remove scale.

4.3.3 Human Capital Change

The final endogenous variable is human capital change. This variable describes the percentage change in the levels of human capital over the course the 15 years that this study is examining. Human capital change was computed in the same manner as income change, such that the number of people aged 15 years and older with a university degree in 1986 was subtracted from the number of people 15 years of age and older with a university degree in 2001. The difference was then divided by 1986 number to convert it into the desired unit of percent change.

The decision was made to use the attainment of a university degree as the measure of human capital for several reasons. As stated in Chapter 2, human capital is any kind of knowledge gained by agents from education, training and/or personal experiences. Thus, simply using completed university education as the sole measure of human capital does seem rather meagre in comparison to the diversity and complexity of human capital; nevertheless this has been the common metric in past studies (Brewin, 2004). Other measures, like years of experience or innovativeness are often difficult to measure for purposes such as the ones found in this thesis, or they are correlated with other factors in the model.

It may have been possible to create some kind of weighted measure of completed university education with other forms of completed post-secondary education (an example would trade school education). This would enable us to account for other kinds of formal education in which Canadians have invested in, unfortunately though data on this were not available from C-RERL and thus not computed. It is likely that this information could be available from other sources, like Statistics Canada, but it is not in the CCS unit of measure. This would require the use of geographic information system (GIS) software to compile the data into the proper unit of measure (CCS), which is not available for this thesis.

Deller et al. (2001) used high school education as their measure for human capital, but this arguably, is not the most preferred means to gauge human capital. It has been stated that human capital investment comes at a trade-off to consumption, meaning that there is a monetary cost[22] associated with it. Agents who are engaged in acquiring a high school education are not directly responsible for paying for that education, since it is publically[23] provided. Finally, as Brewin (2004) states, it is widely accepted that a university education offers a substantial increase in future income over a high school education. It is claimed that because of this, it provides a better fit for this study's supposition that agents invest in human capital to receive a return and a greater ability to consume in the future consumption.

4.3.4 Location Variables

Canada is the second largest country in the world in terms of its physical geography. As any Canadian would tell you, there is a noticeable variation between regions as one travels from east to west. Hence, it is important to account for the regional variation between differing CCSs.

Location is a qualitative observation, thus three location/regional dummy variables for three of the four major provincial regions of Canada are used. They include Atlantic Canada, indicating that the CCS is located in one of the three Maritime Provinces (Newfoundland-Labrador, Nova Scotia, New Brunswick and Prince Edward Island), Quebec and Ontario. The other major provincial region is the group of the four

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[22] This monetary cost would also include the opportunity costs associated with acquiring a university education.

[23] The author is ignoring the possibility of private school education, which quite often has significant tuition fees associated with it.

western provinces of Manitoba, Saskatchewan, Alberta and British Columbia. This dummy variable was omitted to avoid the dummy variable trap. The three Canadian territories have been omitted as, like previous Canadian convergence studies, this study is only concerned with the ten Canadian provinces.

As will be seen by the end of this chapter, a large number of variables are employed in this model. The driver for this is that it is important in convergence studies (as per convergence theory) to control for potential variation between the observations. The number of exogenous variables utilised in this study are used to achieve this aim. As such, the different levels of amenities, employment, and so on that may occur in different regions should be accounted for by the specific exogenous variables. This fact would appear to make the inclusion of regional dummy variables a redundant exercise. However, the inclusion of the regional variables is still theoretically important. This is because these dummy variables can control for differences between observations that cannot be explained the other exogenous variables, but are consistent within the different regions. An example of this would be, as Ferguson (2005) notes, the possibility of the predominance of the French language in Quebec having a different influence on agent decisions as compared to the other regions which predominately speak English.

4.3.5 Adjustment Typology Variables

As described in Chapter 3, adjustment typology variables are included to account for the possible differing long-run adjustment processes (or growth pattern) that may occur between rural and urban communities in Canada. The 1986 starting population is multiplied by an urban/rural dummy to create the population adjustment variable. Initial human capital is multiplied by the same urban/rural dummy to derive the human capital adjustment indicator. Finally, 1986 starting income is multiplied by the urban/rural dummy to arrive at the income adjustment indicator.

4.3.6 Demographic Variables

Several demographic variables are included. These variables examine the variation in age distributions and ethnicity of the population within each CCS (Ferguson 2005). In total, four such variables were computed from the C-RERL database. The two age demographic variables are the percentage of the population that is young and the percentage of the population that are elderly. The young person variable included members of the 1986 population that were aged 0 to 19 years of age. The old person variable represents those aged 65 or more in 1986. The remaining two variables indicate the level of ethnicity in each CCS, since the presence of different cultures in varying degrees may result in different choice behaviour by agents (Ferguson, 2005). Therefore it is important to control for this possible factor. The two variables used as measures are the percentage of population that immigrated to Canada within the last 15 years and the percentage of the population that is Native Canadian.

4.3.7 Agglomeration Variables

The agglomeration variables used were put in place to make an allowance for the effects of a population mass on the three endogenous variables. As noted by Ferguson (2005), the presence of a sizeable collection of people in or near to a CCS is likely to have an effect on the dependent variables. This is because larger populations create larger markets for business, investment and employment and possible agglomeration economies are generated as well. In addition to this, increased costs due greater congestion, infrastructure and environmental demands for space and waste disposal also occur.

Three agglomeration variables are employed in the regression analysis. The first is the 1986 initial or starting population of each CCS. According to the theory employed in this thesis, (see Chapter 3) initial conditions form a key component in the long-run process or adjustment towards the equilibrium state. The distance from a CCS to the nearest urban CCS with population of 100,000 or greater and the total population of all adjacent CCSs of each CCS are also included.

A straight-forward urban/rural dummy indicating whether a CCS is an urban or rural community is not included in the analysis. The reason for this is that including the aforementioned adjustment variables and the distance to an urban center variable serve to convey more information than the urban/rural dummy. Therefore, including this dummy is redundant and likely would cause multicollinearity problems in the model.

4.3.8 Economic Variables

Economic factors comprise the second-largest variable cohort in this study. As this group's name implies, these variables provide information on the financial conditions that exist in each CCS. The first economic variable considered, which is of great importance to a convergence study, is initial or starting per capita income. This variable gives an indication of the starting period income that is available to agents in a particular region to use for either consumption or investment in any type of capital. Income is considered to be the sum of wages plus the returns generated from investments made into capital. The other income-related variable is a poverty indicator as measured by the percentage of the population that earns less than the national median income. This variable provides an indication of the effects of a larger concentration of people who live on lower incomes, or are impoverished, on the dependent variables.

The remaining economic variables all pertain to employment within each CCS. The employment rate measures the percentage of the population who are gainfully employed. The percentage of agents in a CCS who are employed in the agricultural industry is included and similarly, the percentage of the population that is engaged in other primary industry and the percentage of agents who are self-employed are also included. The rationale for separating these industries in gauging employment effects on the dependent variables is twofold. First, these industries are important sources of business and commerce in Canada. Secondly, a number of CCSs are believed to be heavily reliant on these industries as their main economic driver. Therefore, it is important to control for these affects and their variation across regions since, as mentioned above, it is important to do so in convergence studies.

The industry concentration levels present in each CCS is accounted for by the inclusion of the Herfindahl Index[24] measure found in the C-RERL database. As it is evaluated, a higher score indicates a higher level of industry concentration in an area, meaning that a greater number of people are employed by a smaller number of industries (Ferguson, 2005). It is thought that level of industry concentration will have significant impact on population change, income and human capital growth in the model being used

[24] This is actually an average Herindahl Index for all industries weighted by the size of the industry for each CCS. It helps identify "company towns" with concentration in both firm and industries.

in this study. This is due to Ferguson's (2005) findings that a high industry concentration had a negative effect on population change at the CCS level. He argued that because of this, communities with a diversified business atmosphere (lower index scores) may be able to attract more migrants because of the higher number alternative employment opportunities available should one industry experience a downturn.

By extension, lower industry concentration levels would likely mean that higher incomes will be present in an area because of the greater level of opportunities available to agents when in the presence of a broader number of firms present. Greater levels of human capital are also believed to be associated with diversified economic climate. This is the result of the greater employment opportunities driving agents to make investments in human capital in order to capitalize on those opportunities and earn a higher wage to increase their income and consumption. The reverse of this reasoning would be true in the case of higher industry concentration rates.

Lastly, a variable measuring the distance to the nearest "national highway"[25] from the center of each CCS is included. This variable serves as indication of the level of access the CCS has to trade with other cities and provinces (Ferguson, 2005). It could be argued however that this variable might represent a modern amenity as well. This is because access to greater transportation routes could provide greater access to other amenities and the like, rather than commercial activity. However, this thesis will follow Ferguson's lead and treat the national highway variable as an economic variable.

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[25] Transport Canada defines a national highway as a roadway that aids inter-provincial and international commerce and travel by connecting a major population or commercial center with other major populations or commercial centers or a major port of entry into the United States (Transport Canada 2004). Examples include the TransCanada Highway, and the Yellowhead Highway.

4.3.8 Education Variables

The following variables provide measures of the levels of education or human capital within each CCS. Starting human capital measures the percentage of the population that is 15 years and older with a completed university education. This variable, like starting income, is theoretically important for a convergence study as outlined in Chapter 3. Additionally, the percentage of the population 15 years and up that has not completed high school and the percentage of the population 15 years of age plus that have some university education but not completed it (SOMUNI) are included to capture their effects. Note high school education only has been left out as a category to prevent collinearity.

4.3.9 Amenity Variables

Amenities, as discussed earlier, are consumables that can create favourable or unfavourable living conditions for agents within a CCS. Theory and empirical evidence point clearly to their importance in both income and population change and therefore amenities need to be accounted for. It should be noted that there is not a theoretical reason for amenities to have an effect on human capital; however it is argued here that certain modern amenities could influence the decision of an agent to invest in human capital. For example: the presence of an acute care hospital could motivate an agent to invest in human capital, in order to capture the higher wages (and thus increased future income and consumption) that are available to agents from positions found in that hospital.

In terms of modern amenities, nine such variables were included in this analysis. The first two were the violent crime rate and property crime rate per 100,000 people in each CCS. Although these variables are important to consider in the growth model, this study acknowledges two sources of potential error in employing the crime rates found in the C-RERL database. First, it appears that these crime rates were recorded in C-RERL for the year 1991. This may only be five years ahead of the beginning of the time period, but crime levels over time could easily change. If the 1991 rates do not accurately reflect the initial period, this could cause inaccuracies in the results. The 1986 crime rates are likely to be available from additional sources; however GIS software would be required to compute this data into the proper CCS unit of measure. As stated above, GIS software is unfortunately beyond the means of this study. It is simply argued here that the rates found in C-RERL reflect the 1986 crime levels.

Secondly, Ferguson (2005) explains that the data for the crime rates were not originally available for each individual CCS, especially for rural CCSs. To overcome this, Ferguson (2005) adjusted provincial crime rates by subtracting the number of crimes already accounted for (since they could be assigned to a specific CCS) in each province from the total number of crimes committed at the provincial level. Crime rates were then re-calculated and assigned to the CCSs that lacked observations (Ferguson 2005). Because of this, attenuation bias could be introduced into the analysis from measurement error, since the provincial averages assigned to CCSs lacking specific data may not be an accurate representation of the true crime rate (Ferguson, 2005). Attenuation bias refers to a downward bias in the estimated parameter coefficients towards zero (Greene, 1993).

However, like Ferguson (2005), the author holds that it is reasonable to assume that rural areas have fairly uniform crime rates as derived from the adjusted provincial crime rates.

The remaining modern amenity variables consist of distance measures in each CCS to the specific amenity of interest. This includes the distance to a police station, distance to an acute care hospital, distance to a large acute care hospital[26], distance to a golf course, the distance to a ski hill, distance to a university and distance to a religious institution. These variables were selected based on Ferguson's (2005) exploratory regressions to find the best cohort of amenities for his study. For this study, generally the more robust amenities from Ferguson's study are employed in this thesis's model. Ferguson (2005) notes that using a distance measure is thought to be a reasonable proxy for access to the amenity, despite the two shortcomings that could bias the coefficient estimates.

The problems with using a distance measure for amenities, as well the distance to an urban center and national highway variables, arise out the fact that the distances are measured from the center of the CCS to the amenity location. First of all, this may not properly represent the location of the majority of people in each CCS reside and many amenities will be located where the majority of the people live (Ferguson, 2005). This means that the distance estimates could be incorrect with regard to actual travel times faced by residents wishing to consume those amenities. In addition, each measurement is a direct linear measurement, which may not correctly estimate actual travel times to the amenity. This is because direct linear routes may not exist or are impeded by physical barriers or traffic congestion (Ferguson, 2005).

[26] A large acute care hospital has 200 or more available beds for patients in need of health care.

Finally, several natural amenity variables were included to capture the positive (or negative) effects that agents derived from the natural environment in each CCS. A total of six measures capturing climatic and topographical phenomena make up this last sub-cohort of variables.

For topographical variables, a dummy variable indicating the presence or adjacency to any body of water in each CCS encapsulates the effects of lakes, coastlines, and other bodies of water that resulted in the land cover by water being greater zero percent (Ferguson, 2005). The presence of forest is captured by the percentage of forest cover. Hills and mountainous terrain providing picturesque scenery and alternative recreation are also considered through the use the standard deviation of CCS elevation. Ferguson (2005) contends that the standard deviation of the elevation reveals the degree of rugged terrain and variation in the scenery. Since terrain indices do not yet exist in Canada, it is believed that this is the next best measure available for use.

To capture climatic effects, the average hours of sunshine in January, average July humidity and the average amount of snowfall for each CCS are used. Other weather amenities are available through C-RERL; however they have been omitted due to concern over their correlation with other climate variables.[27]

Common statistical descriptors for the variables used in this study are featured in Table 1.

[27] Average January temperature and average precipitation were regressed against average hours of January sunshine and July humidity respectively. In both cases, it was found that their correlation coefficients (R^2 values) were greater than 0.8, indicating a strong level of correlation.

Table 1. Summary of Variable Statistics

Variable	Mean	Standard Deviation	Max	Min	Observations
Population Change (%)	-0.0300	0.2891	5.7040	-0.8980	2414
Income Change (%)	0.8544	0.2711	2.4947	-0.2071	2414
Human Capital Change (%)	1.4737	3.1519	32.3333	-1.0000	2414
Starting Population (# of People)	10323.8152	51522.3797	1728005.0000	290.0000	2414
Starting Income ($)	12368.7353	2892.7816	24338.0000	4253.0000	2414
Starting Human Capital (%)	0.0449	0.0324	0.2426	0.0000	2414
Regional Dummy (Atlantic)	0.1437	0.3509	1.0000	0.0000	2414
Regional Dummy (Quebec)	0.4163	0.4931	1.0000	0.0000	2414
Regional Dummy (Ontario)	0.2051	0.4038	1.0000	0.0000	2414
Adjustment-Typology Population (# of People)	8324.7370	51800.1130	1728005.0000	0.0000	2414
Adjustment-Typology Income ($)	2385.0290	5702.4751	24338.0000	0.0000	2414
Adjustment-Typology Human Capital (%)	0.0118	0.0314	0.2404	0.0000	2414
Percentage of Young People (%)	0.3208	0.0505	0.5587	0.0645	2414
Percentage of Elderly People (%)	0.1079	0.0482	0.3285	0.0000	2414
Percentage of Native People (%)	0.0313	0.0911	0.9906	0.0000	2414
Percentage of Immigrants (%)	0.0104	0.0165	0.1658	0.0000	2414
Surrounding Population (# of People)	847255.6089	1198862.3404	5311255.0000	2440.0000	2414
Dist. to Urban (km)	52.3406	51.2595	877.0440	0.0000	2414
Percent of Low Income Earners (%)	0.1855	0.0854	0.6176	0.0000	2414
Employment Rate (%)	0.5316	0.1147	0.8799	0.1406	2414
Percent Employed in Agriculture (%)	0.1576	0.1780	0.8472	0.0000	2414
Percent Employed in Primary Industry (%)	0.0416	0.0734	0.6083	0.0000	2414
Percent Self-Employed (%)	0.0687	0.0440	0.4231	0.0000	2414
Herfindahl Index (Ratio)	0.1952	0.0735	0.7070	0.1000	2414
Dist. National Highway (km)	38.9281	61.7617	1123.0078	0.0020	2414
Percent of People with No High School Dip. (%)	0.2938	0.0754	0.5814	0.0943	2414
Percent of People with Some University (%)	0.0558	0.0328	0.2074	0.0000	2414
Violent Crime Rate (# of Crimes per 100,000)	868.9695	489.5620	3772.8138	0.0000	2414
Property Crime Rate (# of Crimes per 100,000)	3637.5402	1371.6111	14609.4409	309.0000	2414
Dist. Police Station (km)	19.7965	18.3601	308.2550	0.0000	2414
Dist. Acute Care Hospital (km)	24.7477	32.0758	880.4470	0.2140	2414
Distance to Large Acute Care Hospital (km)	54.3565	68.0127	1132.2660	0.2590	2414
Distance to Golf Course (km)	20.7864	35.1839	872.1450	0.1740	2414
Distance to Skiing (km)	53.8035	50.1085	867.1960	0.3610	2414
Distance to University (km)	86.1280	83.3349	1145.0540	1.0300	2414
Distance to Religious Institution	10.0407	19.8947	583.1430	0.0000	2414
Water Body Dummy	0.4822	0.4998	1.0000	0.0000	2414
Percent Forest Cover (%)	54.2989	46.4093	100.0000	0.0000	2414
Standard Deviation of Elevation (m)	49.9269	79.6722	771.4070	-999.0000	2414
Average Snowfall (cm)	217.6683	91.6128	1471.1900	18.1100	2414
July Humidity (%)	58.4897	9.4659	93.9000	32.4200	2414
Hours of January Sunshine (hours)	91.0542	18.3765	122.9700	14.3300	2414

Units of measure for each variable is indicated in parentheses. E.g. ($)

Chapter 5: Econometric Estimation

5.1 Econometric Model

To estimate equations (35) – (37) empirically, it is necessary to make several functional amendments to them. Traditional econometric theory clearly states that one will never know what the true coefficients of any model are. This is because all possible data pertaining to the model and the model itself would have to be perfect in its ability to explain what it aims to describe are required to calculate the true coefficients. Both of these requirements are essentially impossible to fulfill.

By using econometrics however, one strives to make extremely good estimates of the true coefficients, and thus estimates of the coefficients in this study will be denoted as b instead of β (where β is the true coefficient) to reflect this fact. It is also necessary to now add a random component to the systematic portion of the theoretical model, in order to properly estimate it. This is the error term, denoted in the corresponding equation ase_P, e_Y or e_H respectively. With these additions, the econometric model is denoted as:

$$\Delta P = b_{0P} + b_{1P}\Delta Y + b_{2P}\Delta H + b_{3P}P_{t-1} + b_{4P}Y_{t-1} + b_{5P}H_{t-1} + \cdots$$
$$\Sigma b_{iP}X_P + e_P \qquad (40)$$

$$\Delta Y = b_{0Y} + b_{1Y}\Delta P + b_{2P}\Delta H + b_{3Y}Y_{t-1} + b_{4Y}P_{t-1} + b_{5Y}H_{t-1} + \cdots$$
$$\Sigma b_{iY}X_Y + e_Y \qquad (41)$$

$$\Delta H = b_{0H} + b_{1H}\Delta P + b_{2H}\Delta Y + b_{3H}H_{t-1} + b_{4Y}P_{t-1} + b_{5Y}Y_{t-1} + \cdots$$
$$\Sigma b_{iH}X_H + e_H \qquad (42)$$

Where: $\sum_{i=6}^{n} \beta_{iP,J,H}X_{iP,Y,H} = \beta_{6P,Y,H}X_{6P,Y,H} + \beta_{7P,Y,H}X_{7P,Y,H} + \ldots. + \beta_{nP,Y,H}X_{nP,Y,H}$

As with the theoretical model, all three equations in the econometric model are necessary for estimating the changes in population, income and human capital. This is because of the jointly dependent or endogenous variables present in each of the three equations, indicating that system is interdependent (Greene, 1993).

5.2 Econometric Problems

From the interdependence, there is in effect, a feedback between the endogenous variables and the error terms (Hill, Griffiths and Judge, 2001). The three random disturbances affect all of the endogenous variables. Under these circumstances, there is a correlation between the endogenous variables and the error terms. This violates the standard ordinary least squares or OLS assumption that the covariance between explanatory variables and the error term is nil. The proof of this is seen in deriving the covariance between one of the endogenous variables and an error term (see Hill, Griffiths and Judge, 2001 for the proof)

This correlation has a serious effect on two important and desirable properties of econometric estimation: unbiasedness and consistency. An unbiased estimator is characterized by having a sampling distribution mean equal to the parameter to be estimated (Kmenta, 1997). Essentially, if an infinite number of sample estimates were taken, the average of those estimates would equal the true parameter value.

A consistent estimate is regarded as such when its distribution becomes more centered on the parameter's true value as the sample increases to infinity (Kmenta, 1997). This characteristic affords us greater confidence in the estimates as sample size increases.

Due to the correlation between the error terms and the endogenous variables, these two properties are lost and a failure in OLS estimation subsequently occurs. This indicates that OLS estimates are now biased ($b \neq \beta$) and inconsistent ($b \neq \beta$ as $N \rightarrow \infty$). Again, see Hill, Griffiths and Judge (2001) for the proof of this.

5.2.1 Identification Problem

Another hurdle that exists when dealing with an endogenous system of equations is what is known as the identification problem. The identification problem, at a very basic level, refers to whether or not the unknowns within a model can be determined. Kmenta (1997) explains that there has to be a proper correspondence between the restricted and unrestricted parameters. Specifically, the number of unrestricted parameters has to either equal or exceed the number of restricted paramerters, for the model to be identified. Only when the model is shown to be identified, can it be estimated consistently. However, if the number of unrestricted parameters is less than the number of restricted parameters, then the model is said to be unidentified. In this situation, the parameters cannot be estimated with consistency, since there can be infinite solutions to underindentified parmeters (Kmenta 1997).

Hill, Griffiths and Judge (2001) provide us with a necessary condition for identification.

> "In a system of M simutaneous equations, which jointly determine the values of M endogenous variables, at least M - 1 variables must be absent from an equation for estimation of its parameters to be possible" (Hill, Griffiths and Judge, 2001, p. 310).

In the model, there are three simultaneous equations and therefore, two variables must be omitted from each equation to satisfy the above condition. This is achieved by including only the directly-related adjustment-typology variable in each structural equation. In other words, the income adjustment-typology variable is only found in the income growth model and so on. This allows the parameters to be identified

5.2.2 Measurement Error

In section 4.3.9, the possibility of measurement error being introduced from the distance to amenity variables was discussed. There is however, another source of measurement error in this study's dataset. Ferguson (2005) explains that Statistics Canada, as a matter of practice, randomly rounds off population numbers obtained in their censuses to five persons. Hence, population data in C-RERL also features this random rounding off. This affects the population change, starting population, percent young and percent old variables.

In the case of the endogenous population change variable, Ferguson (2005) argues that this random measurement error will not bias coefficient estimates; however it will generate larger standard errors and thus, lower t-statistics. For exogenous variables, the estimated coefficients will be biased toward zero. The degree of which, is dependent upon how much variability there is in the measurement error itself (Greene, 1993). In addition to this, since this study's model features multiple regressors, this problem extends beyond just the poorly measured variables. The result of this is that other parameter estimates in the model will be biased as well, albeit the direction cannot be determined (Greene, 1993).

A common correction for this issue is the use of instrumental variables. In this situation, another variable that is highly correlated with the metric of interest to this study, but uncorrelated with the measurement error, is put in place of the original variable. This practice, as Greene (1993) describes in detail, corrects for the bias created and ensures consistent estimates. For the purposes of this study, it will be assumed that the data to be employed, which has been used in published journal articles by Ferguson et al. (2007) and Partridge et al. (2007), are the best data available for the purposes of this thesis.

5.2.3 Spatial Dependence

Spatial dependence in the model may arise due to linkages between neighbouring CCSs. These cross-border relationships can stem from a variety of sources. Economic growth or recession in one area often flows into neighbouring areas, often due to similar industries and/or resource bases, like agriculture or forestry (Brewin, 2004). Employment gains in one region may be in a sense "cashed in" on by other regions through commuters who live in one CCS, but work in another CCS. Also, since agents do not always necessarily conduct business and commercial transactions solely in their home region, gains in wealth in one region can have positive effects on neighbouring CCSs.

These possible spatial relationships between CCSs can cause a correlation known as spatial autocorrelation. Spatial autocorrelation is caused by a variation between observations that is not independent from one observation to the next, and as such the disturbances will be correlated across space (Greene, 1993). The result is that the asymptotic variances become inflated and thus the estimates would be inconsistent, causing statistical inference to become invalid (Kmenta, 1997).

To correct for this, a common procedure is to perform a weighted regression (commonly known as weighted least squares or WLS). In WLS, the various instruments employed are weighted by either a known or an estimated weighting matrix that accounts for the differences in variation between observations (Kmenta, 1997). This corrects for the correlation in regression analysis, thus providing proper statistical results – see Kmenta (1997) for a detailed review of this solution for autocorrelation.

In order to create the required weighting matrix system to perform a WLS regression in this study, GIS software is required to map the distances between the CCSs in order to calculate the constituents of the weighting matrix. But, this requirement moves beyond the means of this study. This study does however address this issue to a certain degree in the model with several of the variables, those being the CCS surrounding population and the distance based measures provided by C-RERL. It is assumed that any spatial dependence in the system of equations is limited to just the effects of the surrounding population and the distance from an urban center.

5.2.4 Omitted Observations

Another practice held by Statistics Canada is the suppression of certain data. That is, for CCSs with fewer than 250 inhabitants, certain information gathered by the statistical agency is veiled to address accuracy and/or privacy concerns (Ferguson, 2005). In C-RERL, these data (on things such as income and employment) have been entered as zeros in their respective categories. As well, a number of data points in C-RERL were found to be inexplicably entered blanks in the database.

These suppressed or blank observations are unfortunately not useful for this study. Ferguson (2005) faced this situation as well. His decision was to delete these observations from his dataset on the basis that the small populations were normally spread over large geographical areas that would likely have added further measurement error to his model. This argument holds for the case of this thesis and it is added that regressing variables with values of zero for certain observations that are most certainly not zero (take income for example) would be detrimental to the results and interpretation. Because of this, a modicum of efficiency will be lost. By discarding observations from a dataset, the information that they provide about the covariation between regressors and the dependent variable is lost (Greene, 1993).

Greene (1993) poses that aggregating the data into appropriate groups[28] (based on type, association, etc) and then performing a regression on the group means provides an avenue for offsetting this loss of efficiency. However, a trade-off is made in which the parameter estimates would become less efficient, since individual CCS information is lost in the group formation (Greene, 1993). Since this study is very much interested in the individual CCSs, this solution would not help the cause of this thesis. Therefore, this study will hold to Ferguson's (2005) approach and delete the missing observations from the dataset.

All told, 193 observations were deleted from the dataset, leaving a total of 2414 CCSs for estimation. Of this, 90 CCSs were removed due to having no information

[28] An example of this would be if a person had yield data on all the different varieties of wheat, flax and canola, but then aggregated these data into three groups based on type. That being wheat, flax and canola since each different variety is a type of wheat or flax or canola.

entered about them, 97 more CCSs were deleted because of suppressed information and lastly, all six CCSs from the Canadian territories were dropped as well. The territories were discarded because, like previous authors, this study is only concerned with the ten provinces of Canada. Ferguson (2005) adds that the territories may be subject to accuracy issues, providing another reason for their removal.

5.3 Three-Stage Least Squares

In the literature that has been reviewed, a common method employed to estimate similar growth models has been two-stage least squares (2SLS). Although this estimation method deals with the biasness and inconsistency discussed above, the generated coefficient estimates are not asymptotically efficient (Kmenta, 1997). This arises because 2SLS does not pay any attention to the correlation of the error terms across the equations. In effect, if this correlation between the differing structural equations is ignored, all of the available information about each equation is not put to use, preventing the attainment of asymptotic efficiency. This is especially important if one or more equations in the system are over-identified[29], since the "extra" variables omitted still convey information through the cross-correlations of the error terms that is lost under single-equation techniques.

As Kmenta (1997) explains, the lack of efficiency can be overcome by simultaneously estimating all of the equations in the system. One such method of simultaneous estimation is three-stage least squares or 3SLS. What makes 3SLS so useful is that asymptotic efficiency is gained and the coefficient estimates it produces are

[29] Over-identification refers to an equation that has greater than M-1 variables omitted from the equation.

in fact consistent estimates[30]. As a result of the consistency in estimation, estimates from 3SLS can be reported with a degree of confidence. Even though, as it was explained above, a degree of efficiency has been lost from deleting missing observations, this study is making a concerted effort to make the most efficient estimates possible, which has not been a focal point in past research.

3SLS entails OLS estimation of each endogenous variable as a function of all of the exogenous variables, followed by the use of the estimates derived for the endogenous variables in a second round of regressions. Specifically, both the exogenous and fitted or predicted values for the endogenous variables are used as explanatory variables in OLS estimation. Finally, in the third stage the OLS estimates and the residuals from the second round OLS estimation are then used to estimate the variances and covariances of the structural error terms using Aitken or generalized least squares estimation (GLS) (Kmenta, 1997). The resulting variable coefficients after the third round of regressions are the estimates that will be reported in Chapter 6.

To demonstrate 3SLS more formally, Kmenta (1997) and his notation will be followed. Assuming a general form for this study's model such that:

$$y_1 = Y_1\beta_1 + X_1\gamma_1 + u_1 \tag{43}$$

$$y_2 = Y_2\beta_2 + X_2\gamma_2 + u_2$$

$$\downarrow$$

$$y_G = Y_G\beta_G + X_G\gamma_G + u_G$$

Where: each y is a vector representing the endogenous variable; Y_G is a matrix of the right-hand side endogenous variables, whose coefficients are represented by the matrix

[30] It should be noted that 2SLS produces consistent estimates as well.

β_G; X_G is the matrix of exogenous variables, with coefficients found in the matrix γ_G; and u_G represents the vector matrix of disturbances found in each equation.

For the sake of simplicity, only the sub-equation featuring y_1 in equation (43) will be regarded. It is important to point out that the following discussion applies to all of the equations in the model simultaneously. The matrix Y_1 can be separated to give us:

$$Y_1 = [y_2 \quad y_3 \cdots \quad y_G] \tag{44}$$

Where: each of the ys represent a vector of the other endogenous variables in the system. Their reduced form equations are:

$$y_2 = X\pi_2 + v_2 \tag{43}$$

$$y_3 = X\pi_3 + v_3$$

$$\downarrow$$

$$y_G = X\pi_G + v_G$$

Where: X is a matrix of all the exogenous variables within the system; each π signifies a vector of the corresponding reduced form coefficients; and each of the vs is a vector of the reduced form errors. If one lets:

$$V_1 = [v_2 \quad v_3 \cdots \quad v_G] \tag{46}$$

and

$$Y_1 - V_1 = [X\pi_2 \quad X\pi_3 \ldots \quad X\pi_G] \tag{47}$$

then equation (43) can be written as:

$$y_1 = (Y_1 - V_1)\beta_1 + X_1\gamma_1 + (u_1 + V_1\beta_1) \qquad 48)$$

Since $(Y_1 - V_1)$ depends solely upon X, and does not include any disturbances, it is therefore uncorrelated with the error term $(u_1 + V_1\beta_1)$. This is importance since, as it was shown above, the estimation of the equations with OLS broke down and caused significant problems due to variable correlation with the error terms. Equation (48) allows us to apply OLS, resulting in consistent estimates, since the issue of correlation has been resolved. Unfortunately there is a problem with equation (48), and it is that $(Y_1 - V_1)$ is unobservable.

To manoeuvre past this problem, one can substitute in the reduced form least squares residuals for V_1. This is the first stage of 3SLS as stated above. Formally:

$$Y_1 - \hat{V}_1 = \hat{Y}_1 = [X\hat{\pi}_2 \quad X\hat{\pi}_3 \ldots \quad X\hat{\pi}_G] \tag{49}$$

Where: estimations are denoted by the hat (ˆ) accent. Now since:

$$\text{plim}(Y_1 - \hat{V}_1) = [X\pi_2 \quad X\pi_3 \ldots \quad X\pi_G] = (Y_1 - V_1) \tag{50}$$

It is observed that $(Y_1 - \hat{V}_1)$ and $(u_1 + V_1\beta_1)$ are asymptotically uncorrelated. Substituting in $\hat{Y}_1$ for Y_1 and $(u_1 + V_1\beta_1)$ for u_1 (creating $u_1 *$) in equation (43) equates:

$$y_1 = \hat{Y}_1 \beta_1 + X_1\gamma_1 + u_1 * \tag{51}$$

OLS can now be applied to equation (51). This is the second stage of 3SLS.

At this point, the system of equations can be viewed as such:

$$y_1 = \hat{Y}_1 \beta_1 + X_1\gamma_1 + u_1 * \tag{51a}$$

$$y_2 = \hat{Y}_2 \beta_2 + X_2\gamma_2 + u_2 *$$

$$\downarrow$$

$$y_G = \hat{Y}_G \beta_G + X_G\gamma_G + u_G *$$

Equation (51a) can be rewritten in a more compact form such that:

$$y = \hat{Z}\alpha + u * \tag{51b}$$

Where: $\hat{Z} = [\hat{Y} \quad X]$ and $\alpha = [\begin{smallmatrix}\beta \\ \gamma\end{smallmatrix}]$. Now, one can apply GLS to equation (51b), which is the final stage of 3SLS. This yields:

$$\ddot{\alpha} = \left(\hat{Z}'\hat{\Omega}^{-1}\hat{Z}\right)^{-1}\left(\hat{Z}'\hat{\Omega}^{-1}y\right) \tag{52}$$

Where: the three dot accent on α represents the GLS estimates of the coefficients and $\hat{\Omega}$ signifies the calculated variance-covariance matrix of the disturbances in the model. Finally combining equation (52) with equation (51b) allows us to obtain consistent coefficient estimates resulting in:

$$y = \hat{Z}\ddot{\alpha} + u* \tag{53}$$

or less compactly:

$$y_1 = \hat{Y}_1 \hat{\beta}_1 + X_1\hat{\gamma}_1 + u_1 * \tag{54}$$

$$y_2 = \hat{Y}_2 \hat{\beta}_2 + X_2\hat{\gamma}_2 + u_2 *$$

$$\downarrow$$

$$y_G = \hat{Y}_G \hat{\beta}_G + X_G\hat{\gamma}_G + u_G *$$

Equation (54) represents the general form of the 3SLS estimates that will be used in the next chapter.

Chapter 6: Results and Discussion

6.1 Estimation

Equations (40) to (42) were estimated using the 3SLS technique that was described in the previous chapter. To compute the 3SLS estimation, the statistical analysis software, SAS version 9.1[31] was utilized.

It is important to note the removal of several variables from certain equations. In the human capital growth model, the relationship between topographical and climatic variables is difficult to perceive. Therefore, like Brewin (2004), the author believes this provides grounds for their removal from the model featured in equation (42). As briefly theorized in Chapter 4 however, there may be a relationship between modern amenities and human capital growth. Thus, the modern amenities have not been removed from equation (42). Importantly, with the removal of the six natural amenities, equation (42) is now over-identified, providing further justification for the use of 3SLS.

6.2 Population Change Model

The results of the 3SLS estimation for the population change equation are shown in Table 2. There are a number of notable results generated. The first result is that the change in per capita income and starting income level variables both possess negative coefficients that are significant at the five percent level. This indicates that higher starting levels of income and positive income growth led to a decrease in CCS population.

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[31] The author would like to express his appreciation and thanks to John Schoffner and the University of Manitoba for the use of the SAS software.

Table 2. Estimated Population Change Model with Endogenous Income Change and Human Capital Change

Variable	Estimate	Standard Error	t-Value	P-Value
Intercept	4.2763**	1.9846	2.1500	0.0313
Income Change ($)	-3.1376**	1.3642	-2.3000	0.0215
Human Capital Change (%)	0.0484**	0.0190	2.5500	0.0109
Starting Population (# of People)	-7.47E-06	6.30E-06	-1.1900	0.2356
Starting Income ($)	-0.0002**	0.0001	-2.3400	0.0192
Starting Human Capital (%)	8.4451***	2.7689	3.0500	0.0023
Regional Dummy (Atlantic)	0.2019*	0.1145	1.7600	0.0781
Regional Dummy (PQ)	0.2374*	0.1347	1.7600	0.0782
Regional Dummy (ON)	0.6271**	0.2673	2.3500	0.0191
Adjustment-Typology Population (# of People)	5.87E-06	6.05E-06	0.9700	0.3322
Percentage of Young People (%)	-1.1981**	0.4659	-2.5700	0.0102
Percentage of Elderly People (%)	-2.7433**	1.2151	-2.2600	0.0241
Percentage of Native People (%)	-0.1368	0.3133	-0.4400	0.6624
Percentage of Immigrants (%)	2.1144	1.5219	1.3900	0.1649
Surrounding Population (# of People)	1.26E-07***	2.81E-08	4.4700	<.0001
Distance to Urban (km)	0.0002	0.0004	0.5500	0.5851
Percentage of Low Income Earners (%)	0.2359	0.1999	1.1800	0.2381
Employment Rate (%)	1.0136***	0.3154	3.2100	0.0013
Percent Employed in Agriculture (%)	-0.4328***	0.1267	-3.4200	0.0006
Percent Employed in Primary Industry (%)	-0.4577***	0.1736	-2.6400	0.0084
Percent Self-Employed (%)	-0.0472	0.3396	-0.1400	0.8895
Herfindahl Index (Industry Concentration Ratio)	-1.6023***	0.5269	-3.0400	0.0024
Dist. National Highway	0.0001	0.0003	0.5000	0.6146
Percent of People with No High School Dip. (%)	1.5139**	0.6242	2.4300	0.0154
Percentage of People with Some University (%)	2.1884**	1.0622	2.0600	0.0395
Violent Crime Rate (Crimes per 100,000 People)	-0.0003**	0.0001	-2.0600	0.0394
Property Crime Rate (Crimes per 100,000 People)	0.0001***	3.60E-05	2.7100	0.0067
Distance to a Police Station (km)	-0.0006	0.0008	-0.7300	0.4639
Distance to an Acute Care Hospital (km)	0.0008**	0.0004	2.1400	0.0324
Distance to a Large Acute Care Hospital (km)	-0.0007**	0.0003	-2.2200	0.0264
Distance to a Golf Course (km)	-0.0030**	0.0014	-2.1500	0.0320
Distance to Skiing	-0.0003	0.0004	-0.7900	0.4303
Distance to a University (km)	0.0009*	0.0005	1.7300	0.0836
Distance to a Religious Institution (km)	0.0072***	0.0025	2.8300	0.0047
Water Body Dummy	0.0982**	0.0400	2.4600	0.0141
Percent Forest Cover (%)	-0.0002	0.0004	-0.4400	0.6618
Standard Deviation of Elevation (m)	2.00E-05	0.0002	0.1200	0.9012
Average Snowfall (cm)	-0.0005*	0.0003	-1.7600	0.0793
July Humidity (%)	0.0024	0.0019	1.3100	0.1910
Hours of January Sunshine (hours)	0.0022*	0.0012	1.8600	0.0627

Units of measure for each variable are indicated in parentheses. E.g. ($)

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

This result is quite surprising as it was expected that these coefficient signs would be the opposite. This expectation stems from Goetz's (1999) findings in the U.S. migration literature that mobility tended to decrease with wealth, causing less out-migration. Additionally wealthy areas were seen to have attracted greater levels of in-migration, as agents in other areas were thought to be entering the area in order to capture some of the higher levels of wealth.

There is not a solid explanation for this finding in this study's analysis. Ferguson (2005) also had a similar result in his study. He contended that, based on Roback's (1982 and 1988) amenity theory, amenities drove large in-migration in periods of time prior to the one featured in this study. This caused a surplus in the supply of labour which, ceteris paribus, pushed wage rates down. In effect, people traded income for amenities as Roback predicts people will do. This perhaps could be occurring in this study's model as well. Support for this argument may be found in the generally, theoretically correct estimated coefficient signs on the amenity variables, but it is not known if this amenity argument truly explains these results.

The positive and significant coefficient on human capital change shows that migrants typically possess higher human capital investments. This is in line with the theory posed that the more educated an agent becomes, the more mobile they become. The positive and significant starting human capital variable along with this would appear to suggest that areas rich in human capital tend to attract agents.

The three regional dummy variables were all seen to be significant with positive effects on population change. Recalling the discussion on these variables in Chapter 4, these results point out that there is a strong likelihood of having left out relevant variables from this model. This is because the effects of the omitted variables are being captured by the regional dummies, even after controlling for a number of exogenous factors that would control for regional differences across Canada.

The adjustment typology variable, although positive, was not significant. This indicates that the temporal adjustment towards the long-run equilibrium population base did not differ between urban and rural CCSs, statistically speaking. Having a high starting population also was found to provide no significant effect on population change.

The coefficient for the percentage of the population that is young was observed to have had a negative and significant effect on population change. Goetz (1999) noted in his literature review that young people had a greater propensity to migrate than other age cohorts. The result seen in this thesis would appear to be consistent with the literature in the U.S.; however, it cannot be this cannot be known for certain if this reasoning is the cause for higher proportions of young people having a negative effect on population change. The other significant demographic variable was the percent of the population over 65. Although an effort was made to address births and deaths in the data to separate out the effects of natural population change, it could be that the mortality rate among the older cohort is significantly higher than the provincial averages that were assumed. A higher number of deaths not accounted for could appear as out-migration, thus creating the negative effect on population change. The variables for the percent of the population that was Native or has immigrated within the last 15 years were not significant.

Of the remaining two agglomeration variables, only surrounding population was significant. Its coefficient estimate was found to be positive at the one percent level. This is consistent with Ferguson's (2005) finding. The significance of the surrounding population variable also indicates that there is a degree of spatial dependence within this study's model.

All of the employment variables that were used, except for the percent of the population that is self-employed, were very significant and possess signs that are consistent with Ferguson's (2005) model. The measure for the industry concentration level within each CCS was significant and negative. Distance to a national highway and the poverty indicator were both insignificant.

The percentage of the population without a high school diploma and the percentage with some but not a completed university education both had positive signs and their effects on population change were statistically significant. This is a surprising result, given the similar trend seen for university graduates, which served as the measure of human capital in a CCS.

Like Brewin (2004) argued for his observation on crime rates and population change, the strange positive coefficient on property crime rate (but not violent crime rate) could be a problem with causality. With more people moving into a CCS, there probability of criminal activity is likely to increase which can be the result of a number of factors. Those factors may include the greater chance of criminals moving into an area as the number of migrants entering an area increase, and greater population numbers means there could be a larger market present for criminal activity.

The other modern amenities also yielded some interesting results. The distance to golf courses had a negative sign, like Ferguson (2005), but was significant as opposed to the distance to ski runs, which was insignificant. The distance to police stations was also insignificant, which is somewhat surprising since both crime measures were significant at the five percent level. This may suggest the presence of multicollinearity in the model. The distance to acute care hospitals and religious centers both surprisingly had a positive effect on population change. This is curious since these two amenities are all considered to be desirable to live close to.

For the distance to large hospitals, the theoretically correct negative sign stems from the fact that most of these institutions are located in cities or towns whose area is large enough to encapsulate the entire geographical area of the CCS. Thus, the distance measure in this case would provide an accurate representation of access to the amenity. Finally, similar to Ferguson's (2005) distance to college variable, the distance to university instrument was found to be significant and positive.

For natural amenities, the presence of a body of water, the average annual snowfall and the hours of January sunshine were significant. Each of these amenity variables had coefficients consistent with amenity theory, as January sunshine and the presence of a body of water were both positive, and average annual snowfall was negative. The remaining natural amenities did not appear to have the expected signs, except for the terrain measure; however their coefficients were all not statistically different than zero.

6.3 Income Growth Model

Table 3 presents the results for the income growth model. All told, 17 of the 39 variables that were analysed, including the intercept term, were found to have had a significant effect on income growth.

Table 3. Estimated Income Growth Model with Endogenous Population Change and Human Capital Change

Variable	Estimate	Standard Error	t-Value	P-Value
Intercept	1.3974***	0.1548	9.0300	<.0001
Population Change (%)	-0.0889	0.4083	-0.2200	0.8276
Human Capital Change (%)	0.0186**	0.0085	2.1900	0.0284
Starting Population (# of People)	-3.97E-07*	2.37E-07	-1.6700	0.0944
Starting Income ($)	-0.0001***	4.02E-06	-19.0000	<.0001
Starting Human Capital (%)	2.7032***	0.5517	4.9000	<.0001
Regional Dummy (Atlantic)	0.0533	0.0375	1.4200	0.1553
Regional Dummy (Quebec)	0.0647	0.0433	1.4900	0.1355
Regional Dummy (Ontario)	0.1833***	0.0399	4.5900	<.0001
Adjustment-Typology Income ($)	7.50E-07	1.30E-06	0.5800	0.5644
Percentage of Young People (%)	-0.2502	0.2787	-0.9000	0.3693
Percentage of Elderly People (%)	-0.7927***	0.2207	-3.5900	0.0003
Percentage of Native People (%)	-0.1639	0.2224	-0.7400	0.4613
Percentage of Immigrants (%)	0.5849	0.4402	1.3300	0.1841
Surrounding Population (# of People)	2.55E-08	2.66E-08	0.9600	0.3374
Distance to Urban (km)	0.0001	0.0002	0.3800	0.7029
Percentage of Low Income Earners (%)	0.0794	0.0866	0.9200	0.3591
Employment Rate (%)	0.2437	0.1737	1.4000	0.1606
Percent Employed in Agriculture (%)	-0.0605	0.1509	-0.4000	0.6886
Percent Employed in Primary Industry (%)	-0.0573	0.1643	-0.3500	0.7275
Percent Self-Employed (%)	-0.1159	0.2182	-0.5300	0.5954
Herfindahl Index (Industry Concentration Ratio)	-0.4651***	0.1547	-3.0100	0.0027
Dist. National Highway	2.50E-05	0.0001	0.1800	0.8542
Percent of People with No High School Dip. (%)	0.4438***	0.1268	3.5000	0.0005
Percentage of People with Some University (%)	0.5643*	0.3116	1.8100	0.0703
Violent Crime Rate (Crimes per 100,000 People)	-0.0001***	2.30E-05	-3.8800	0.0001
Property Crime Rate (Crimes per 100,000 People)	2.50E-05**	1.10E-05	2.1800	0.0293
Distance to a Police Station (km)	-3.00E-05	0.0005	-0.0700	0.9471
Distance to an Acute Care Hospital (km)	0.0002	0.0002	1.1500	0.2519
Distance to a Large Acute Care Hospital (km)	-0.0001	0.0003	-0.4200	0.6770
Distance to a Golf Course (km)	-0.0010***	0.0003	-3.2800	0.0010
Distance to Skiing	-0.0001	0.0002	-0.4300	0.6692
Distance to a University (km)	0.0004**	0.0002	2.3200	0.0204
Distance to a Religious Institution (km)	0.0018**	0.0009	2.0800	0.0373
Water Body Dummy	0.0210	0.0192	1.1000	0.2725
Percent Forest Cover (%)	-0.0002	0.0003	-0.6900	0.4886
Standard Deviation of Elevation (m)	-1.00E-05	0.0001	-0.1500	0.8819
Average Snowfall (cm)	-0.0002**	0.0001	-2.2200	0.0264
July Humidity (%)	0.0010	0.0007	1.3600	0.1739
Hours of January Sunshine (hours)	0.0007**	0.0003	2.2200	0.0266

Units of measure for each variable is indicated in parentheses. E.g. ($)

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

The first observation noted is that population change had a negative but insignificant coefficient. What this indicates is that migrants are more than likely carrying sufficient capital levels with them to offset their needs in the economy, thus not changing per capita income. This is confirmed by following Brewin (2004) (as suggested by Barro and Sala-i-Martin), and regressing the income model without including population change. The result, seen in Appendix A, was that starting income remained completely unchanged from the results in Table 2, indicative of sufficient capital possession.

Human capital change did affect income change positively as did, starting human capital level. These variables mentioned confirm the belief that human capital investment generates returns that increase per capita income. The percent of the population without a high school diploma or a completed university education were also significant and positively signed.

A key finding pertinent to this study is that starting income levels were negative and strongly significant. This means that growth in incomes was slower for rich CCSs as compared to poor CCSs, ceteris paribus. Convergence theory states that income growth should be faster for low income regions than for high income regions. The results support this conclusion.

Unlike Brewin's (2004) findings, the income adjustment-typology variable that was employed in this study, although positive, was not significant. This means that the convergence process towards the long-run equilibrium state does not vary between urban and rural CCSs, from a statistical perspective.

The agglomeration variables were all insignificant, save starting population which featured a negative coefficient. The negative sign on starting population is very surprising, especially considering that positive economic effects are generated from economies of scale. However, this result is consistent with this study's results for starting income on population change in section 6.2, and as such, should not be such a surprise should Ferguson's (2005) explanation be correct for this study.

All three of the regional dummies had positive signs for their coefficient estimates, but only the Ontario dummy was actually significant. This indicates that there are likely factors that are specific to income growth in Ontario that have been left out of the model. This is since the Ontario regional dummy variable has picked up the effects of those omitted variables.

Only one of the demographic variables was found to be significant, that being the percent of the population that is considered old. Its coefficient is negative stating that higher populations of people 65 and older were detrimental to income growth. Brewin (2004) found this to be positive, suggesting that retirees often help generate greater incomes from increased demands in the service industry. Brewin's argument may still hold, but only if wealthy, retired Canadians are moving out of Canada and taking their pension incomes and increased service demands with them.

None of the other economic variables, save the industry concentration measure, had any kind of significant effect on income growth. The industry concentration variable's effect was seen to be negative and significant at the one percent level. This is consistent with the argument presented in Chapter 4 that a diversified economy generates higher incomes than a highly concentrated economy that leans heavily on the rise and fall of only one or two industries.

Both crime rate measures were significant factors in income change, albeit their signs differed. Roback's contention that people will surrender income for amenities may provide support for the finding that incomes were lower in neighbourhoods with less crime. It may be possible for the positive coefficient estimate for property crime rate that regions with higher incomes provided greater incentive to thieves, and other offenders to commit crimes since those regions could have greater and more valuable asset stocks.. Of the remaining modern amenity measures, only the distance to golf courses, the distance to universities and the distance to religious institutions were significant and held the same signs as found in the population model.

In terms of the natural amenity measures, only the average annual snowfall and average hours of sunshine in January variables were significant. Their signs were positive, which is inconsistent with amenity theory as it pertains to incomes. This seems to provide further evidence to support Ferguson's (2005) contention that amenities have been capitalized in the wage rate.

6.4 Human Capital Growth Model

The final results for 34 variables featured in the human capital growth model are presented below in Table 4.

Table 4. Estimated Human Capital Growth Model with Endogenous Income Change and Population Change

Variable	Estimate	Standard Error	t-Value	P-Value
Intercept	-1.5272	4.4638	-0.3400	0.7323
Population Change (%)	6.9521***	2.2408	3.1000	0.0019
Income Change (%)	3.7570	2.7395	1.3700	0.1704
Starting Population (# of People)	4.39E-06**	2.16E-06	2.0300	0.0421
Starting Income ($)	0.0003*	0.0002	1.6700	0.0944
Starting Human Capital (%)	-63.4391***	5.9878	-10.5900	<.0001
Regional Dummy (Atlantic)	0.4169	0.4343	0.9600	0.3372
Regional Dummy (Quebec)	0.7139	0.5323	1.3400	0.1800
Regional Dummy (Ontario)	-0.1931	0.6297	-0.3100	0.7591
Adjustment-Typology Human Capital (%)	14.8626***	3.3133	4.4900	<.0001
Percentage of Young People (%)	1.3938	2.7348	0.5100	0.6103
Percentage of Elderly People (%)	0.1528	3.4422	0.0400	0.9646
Percentage of Native People (%)	-2.3608	1.5623	-1.5100	0.1309
Percentage of Immigrants (%)	14.3115**	5.6633	2.5300	0.0116
Surrounding Population (# of People)	-6.57E-07***	1.61E-07	-4.0900	<.0001
Distance to Urban (km)	0.0001	0.0026	0.0600	0.9554
Percentage of Low Income Earners (%)	-1.7538	1.1678	-1.5000	0.1333
Employment Rate (%)	-4.6774***	1.4927	-3.1300	0.0017
Percent Employed in Agriculture (%)	5.0673***	1.1918	4.2500	<.0001
Percent Employed in Primary Industry (%)	1.6961	1.3055	1.3000	0.1940
Percent Self-Employed (%)	-2.7233	1.9761	-1.3800	0.1683
Herfindahl Index (Industry Concentration Ratio)	8.2324***	1.7555	4.6900	<.0001
Dist. National Highway	-0.0029*	0.0017	-1.7300	0.0846
Percent of People with No High School Dip. (%)	-2.2578	1.9986	-1.1300	0.2587
Percentage of People with Some University (%)	4.9903	3.9087	1.2800	0.2018
Violent Crime Rate (Crimes per 100,000 People)	-0.0001	0.0004	-0.1500	0.8794
Property Crime Rate (Crimes per 100,000 People)	-0.0002*	0.0001	-1.9300	0.0533
Distance to a Police Station (km)	0.0061	0.0053	1.1500	0.2487
Distance to an Acute Care Hospital (km)	-0.0054**	0.0021	-2.5100	0.0121
Distance to a Large Acute Care Hospital (km)	0.0043*	0.0024	1.7700	0.0768
Distance to a Golf Course (km)	0.0054	0.0047	1.1500	0.2490
Distance to Skiing	-0.0026	0.0021	-1.2100	0.2273
Distance to a University (km)	-0.0015	0.0016	-0.9200	0.3560
Distance to a Religious Institution (km)	-0.0146	0.0093	-1.5700	0.1175

Units of measure for each variable is indicated in parentheses. E.g. ($)

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

As with this study's previous findings for population change and income growth, there a number of interesting and surprising results for the human capital growth model.

The first was that population change had a positive and highly significant effect on the dependent variable. This may provide support for the claim that migrants tend to carry significant human capital stocks.

Starting income level is significant and positive though, indicating that when more wealth is initially available to agents, they will make greater investments into human capital. Change in income was found to have a positive coefficient, which is consistent with this thesis's previous results and what would have been expected. However, it was not significant. This is a curious result as it was thought that as income increased, more investment would be made by agents into human capital. Nonetheless, this is not the case according the results.

A very important result found was that starting human capital possessed a negative and very significant coefficient. This supports the convergence hypothesis for human capital that areas with relatively large human capital stocks do not grow as fast as areas with relatively low human capital stocks, ceteris paribus.

However, this finding is only true for rural CCSs, as the adjustment-typology variable was found to have had a highly significant and positive effect on human capital growth. This outcome provides support for the theory that, in the case of human capital, there is a different pattern of growth occurring between rural and urban areas. Since the estimated coefficient is positive, this indicates that faster growth in human capital stocks occurs when higher starting levels of human capital are present in urban CCSs. This is growth pattern is counter to convergence theory which predicts the reverse this observation. Therefore, convergence in human capital growth is not supported in urban settings in Canada. This is somewhat confirmed by starting population, which had a positive and significant coefficient. This particular finding may indicate the occurrence of some "brain drain"[32] or human capital flight from lesser populated rural CCSs to higher populated urban CCSs.

A surprising find was that surrounding population was negative and highly significant. One would expect that through knowledge spillovers and other agglomeration effects, as discussed by Krugman (1991), higher surrounding populations would lead to greater human capital growth. It is possible that higher populated surrounding regions tend to draw in agents who have invested in human capital.

Each of the three regional dummy variables was not significant, indicating that these regions are not any further ahead of the omitted western region in terms of human capital growth. Additionally, three of the four demographic variables were insignificant as well. The percent of the population that has immigrated in the 15 years prior to the time period examined in this thesis was significant.

Another area of surprising results is seen when regarding the employment-type variables. First, employment rate was seen to be quite significant and negative. According to Goetz and Hu (1996), citing Cohn and Hughes (1994), increased employment should have a positive impact on human capital, although their 2SLS model found a result similar to this study. It is speculated that, since investing in a university education requires a significant time commitment, it is possible that high employment rates may indicate a lack of available time to invest in human capital.

The industry concentration measure was also positive and significant for the human capital growth model. This is surprising since a higher Herfindahl Index score

[32] Van Den Berg (2001) defines brain drain as the phenomenon seen when professional and university-educated people leave their native (and often developing) region, where they received their training, for more developed regions in order to capture better economic and political conditions.

indicates a greater level of industry concentration. It would be expected that this would cause lower growth in human capital, since a less concentrated employment environment should encourage more human capital investment. That is since there are more employment opportunities available in an economically diverse area, which was argued in Chapter 4 to be a potential driver for human capital investment, since agents would have incentive to invest in order to capitalize on the available opportunities. However, this result makes sense when regarding convergence theory. A higher industry concentration in an area likely means that there is less human capital to begin with, meaning that growth in human capital for a concentrated area would be faster than a more diverse area. A similar result and subsequent explanation is also seen for the variable measuring the percentage of agents employed in agriculture.

The distance to a national highway variable is significant at the ten percent level and is negative. Since a national highway is said to connect important regions of population and business, this is congruent with the findings reported above for starting population and the adjustment-typology variables.

Including the percent of the population that has not obtained a high school diploma or completed a university degree, did not provide any significant results, but their signs are as could be expected. Agents with some but not completed university education did have a positive effect on human capital as it is possible that those agents eventually did complete their degrees. This is likely due to these agents having lower costs to investment in human capital, since they already have attained a portion of their investment. The negative sign on the no high school variable is consistent with the fact that agents who do not complete their secondary education, generally are unable to attend university and thus cannot invest in human capital as it has been defined.

Of the crime rate indicators, only property crime rate was significant. The results show that an increase in property crimes led to a decline in human capital growth over the time period this study. The other modern amenity variables that were kept in this growth model were found to be mostly insignificant. The two hospital indicators were the only amenities that were significant. Their signs however, are consistent, given the shortcomings of the acute care hospital distance measures discussed previously, and the fact that large hospitals tend to be found in larger, often urban centers, when considering this study's findings on starting population levels, population change and the adjustment-typolgy variable.

Chapter 7: Conclusions

7.1 Review

In this study, it was purposed to test if convergence in income and human capital has been occurring at the sub-provincial level in Canada. After reviewing the neoclassical growth model, a survey of the relevant literature and academic studies on this topic were presented. The theoretical model was then developed in detail and using a simultaneous system based on the arguments of past authors who contend that per capita income and human capital are simultaneously affected by migration and by each other. Next, information on the data and the variables used in this study was offered, followed by a discussion on the econometrics pertinent to the empirical model. The empirical model was then estimated using a three stage least squares regression process that accounts for the simultaneity that is argued to exist within this study's model. Finally, the results of regression analysis were presented in Chapter 6 and discussed. The conclusions for the findings are presented below.

7.1.1 Income Convergence

A major finding of this thesis is that as a whole, convergence in per capita incomes was occurring at the consolidated census subdivision or community level, conditional on varying characteristics of the area. Confirmation for this finding arises from the negative and significant coefficient on the starting income variable in the income growth model. This is consistent with Bollman's (1999) observation that low income communities had higher growth rates than higher income communities over a similar time frame as the 1986-2001 period utilized in this study. Additionally, this conclusion is consistent with the findings of Coloumbe and his co-authors, and James and Krieckhaus (2008), who found convergence at the provincial level.

It was also found that convergence process for per capita income did not appear to be statistically different between rural and urban CCSs. This is quite different than what Brewin (2004) found in a similar study on U.S. counties.

7.1.2 Human Capital Convergence

The second major finding derived from the results of the analysis was that, again accounting for many different characteristics, convergence was occurring in human capital growth over the time period of this study. The result is also congruent with the findings of Brewin (2004) and Goetz and Hu (1996) that convergence in human capital growth was taking place amongst American counties. This provides further evidence for the argument that the characteristic of diminishing returns also applies to human capital as it does to physical capital.

Importantly, the adjustment-typology variable was found to be significant for human capital growth, indicating that growth in human capital in urban CCSs does not follow the pattern of convergence. This confirms the theory that Brewin's (2004) finding of differing income adjustment among urban and rural counties is applicable to other forms of capital. It is probably that this result arises out of the effects of agglomeration economies from knowledge spillovers as argued by Krugman (1991).

7.1.3 Effect of Migration on Income and Human Capital Growth

The affect of migration on income growth was found to be insignificant in this study's model. Ceteris paribus, the simple supply of labour should drive down per capita income. It would be expected that migration would play a key role in income growth because of this; however, this was not the case. The findings of this thesis suggest that migrants possess enough capital stocks (either physical or human capital) to cover their capital requirements.

In terms of human capital growth, migrants had a measurable and positive effect. This strongly suggests that migrants tend to carry significant human capital stocks. It could be that the human capital carried by migrants is an important driver in offsetting the increased capital needs they create in their destination economy, causing the lack of overall significance of migrants as seen in the income growth model.

7.1.4 Effect of Amenities

The theory pertaining to amenities from Roback (1982; 1988) suggests that the high levels of amenities would help drive in-migration and be at a trade-off to income. In the population change model, this was confirmed. On the other hand, the findings were somewhat mixed for the income growth model, since the presence of the two significant natural amenities caused effects that are in opposition to the theory. This might be due to amenities being capitalized into housing prices that were not available for this study as Ferguson (2005) has argued.

7.1.5 Endogenous Model

In evaluating the simultaneous system used in this thesis, it is noted that human capital change was significant in both the migration and income growth models. Population change was not significant in income growth, but did play a measurable role in the human capital growth model. Lastly, income change as was noted above was not significant in the human capital growth model, but was a significant factor in population change. Given these observations, it can be concluded that employing a simultaneous system based on the work of Monchuk (2007), Brewin (2004), Deller et al. (2001), Goetz and Hu (1996) and Carlino and Mills (1987) is justified. This also points out that the use of the three stage least squares process to estimate the model was appropriate.

7.2 Policy Implications

This study focused on exploring convergence in income and human capital, while accounting for the presence of migration. Within these three areas, several interesting policy implications are seen.

There is a perception held by some in Canada, particularly in rural areas, that inducing net in-migration would lead economic (income) growth within a community. Based on the results, this study found that when people or agents moved into an area, they did not appear to cause any direct increase in income growth. Migrants however, did have a significant and beneficial effect on human capital growth at community level. Human capital growth itself had measurably positive effect on income growth. Thus, through human capital, migrants appear to be having an indirect effect income growth.

From a policy stand point, policies that encourage in-migration in communities as means for growth are likely to only be beneficial to income growth should the migrants attracted by such policies possess significant human capital stocks and are part of the workforce. This would seem to imply that these policies should be focused on creating employment opportunities that attract and retain the educated.

In terms of education or human capital, the integral finding of convergence in rural areas for this capital stock might provide support for success in any past and present policies put in place that are directed at increasing rural education levels. However, proponents of such policies would be well-advised to know that the apparent success of such policies does not constitute a corresponding growth in incomes. That is of course, should such policies become a decided means to stimulate income growth in rural areas.

Although it was found that increases in human capital had a positive effect on income growth, nothing can be said as to whether or not the agents that successfully invested in human capital remained in the communities from which they originate. There is possible support in this thesis and in the literature that those who have invested in human capital tend to be more migratory. Hence, simply increasing education rates along would not guarantee income growth in rural communities if that was the policy goal. Achieving such a goal would also require providing employment opportunities to retain agents with high human capital stocks, especially when considering that the benefits to agents from human capital stem from increased wages.

Since convergence in incomes was observed in this study, there appears to be an opportunity for capital investments to be made in poorer communities to take advantage of their faster rates of growth in income. How those investments are made is not for this study to decide however, as that is best left with those whose capital is at stake. For policy makers wishing to encourage greater investment and capital flows into poorer communities, it is important for them to consider the arguments of Romer (1990) and Lucas (1990) that in order for investment into poorer communities to be effectively utilized, the labour force that is present must possess a large enough quantity of human capital stocks. Therefore, it is again vital that policy works to promote employment opportunities and job retention for those who possess significant human stocks.

7.2 Limitations of this Study

Although important results were seen in this thesis, it is necessary to note that there are several areas of caution associated with this study's findings. There are a number of potential sources for measurement error within the dataset, as have been discussed in earlier chapters. Therefore, it is quite possible that the results suffer from a degree of biasness, stemming from this issue. Bias in the estimates may also have arisen from spatial dependence amongst the CCSs that this study is not able to account for. An example of this would be gains in employment in one CCS creating beneficial economic effects in neighbouring CCSs because of commuters.

A total of 41 variables were used in the analysis completed. There is however, support for the argument that there are a number of other variables that warrant inclusion in the model. This support arises from the significance of several of the regional dummy variables after controlling for a broad number of factors that would account for regional differences. Examples of possible omitted variables would include such things as housing prices, land values, and social capital factors, like participation in community clubs or volunteer activities and so on. Unfortunately, these kinds of variables were not available for this study through the C-RERL database. Omitting relevant variables in econometric analysis would also result in biasing the results.

Conversely, having utilized a large number of variables, some of them may in fact be irrelevant for this study. The problem associated with irrelevant variables is that it inflates the calculated standard errors and increases the probably of committing errors when conducting hypothesis tests.

Finally, the observations that were purposefully omitted due to their lack of information, or questionable accuracy, may have downgraded the efficiency of this study's analysis. This would cause the variance estimates to become inflated, thus statistical inference may not be completely valid.

7.3 Avenues for Future Research

There are several areas in which this study could be expanded upon in the future. The first is that this study covered a 15-year time period, spanning from 1986 to 2001. Since Statistics Canada completes a major population census every five years, longer time frames could be employed for studies of this sort, as new data become available. This would be especially advantageous since it can take long periods of time for population, income and human capital and other economic and development changes to occur.

It is likely that not all of the variables employed in this study have a linear relationship with income, human capital and population change as has been assumed. As advancements in the theory pertaining to growth models are developed, it may be possible to take advantage of nonlinear versions of the simultaneous system that has been used in this study. This could lead to more robust findings and a better understanding of economic growth in the future.

As noted, human capital growth in urban communities did not appear to be following the pattern of growth that is predicted by convergence. What the actual pattern in urban areas is however cannot be delineated by this study. This raises interesting questions as to whether or not this pattern can be predicted and what the true drivers of this pattern of growth are. Future research into this finding could lead to a better understanding of human capital growth, which in turn would aid in beneficial policy development for economic growth.

Finally, the use of geographic information system software could also be implemented in Canadian studies on this topic. This software could be used to determine the level of and account for spatial dependency amongst different regions or communities, as well enable the use of host of variables that are otherwise difficult measure.

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Appendix A

Table 5. Estimated Income Growth Model with Endogenous Human Capital Change Only

Variable	Estimate	Standard Error	t-Value	P-Value
Intercept	1.4195	0.1338	10.6100	<.0001
Human Capital Change (%)	0.0165	0.0084	1.9600	0.0507
Starting Population (# of People)	-3.51E-07	1.08E-07	-3.2500	0.0012
Starting Income ($)	-0.0001	3.97E-06	-19.2100	<.0001
Starting Human Capital (%)	2.5420	0.4750	5.3500	<.0001
Regional Dummy (Atlantic)	0.0520	0.0343	1.5200	0.1290
Regional Dummy (Quebec)	0.0638	0.0395	1.6100	0.1065
Regional Dummy (Ontario)	0.1796	0.0294	6.1000	<.0001
Adjustment-Typology Income ($)	1.04E-06	1.16E-06	0.9000	0.3675
Percentage of Young People (%)	-0.2083	0.1602	-1.3000	0.1935
Percentage of Elderly People (%)	-0.7775	0.1837	-4.2300	<.0001
Percentage of Native People (%)	-0.2082	0.0738	-2.8200	0.0048
Percentage of Immigrants (%)	0.6115	0.4312	1.4200	0.1563
Surrounding Population (# of People)	1.95E-08	5.85E-09	3.3300	0.0009
Distance to Urban (km)	0.0001	0.0002	0.4200	0.6726
Percentage of Low Income Earners (%)	0.0772	0.0853	0.9000	0.3659
Employment Rate (%)	0.2082	0.0911	2.2800	0.0225
Percent Employed in Agriculture (%)	-0.0243	0.0630	-0.3900	0.7002
Percent Employed in Primary Industry (%)	-0.0276	0.0779	-0.3500	0.7229
Percent Self-Employed (%)	-0.1557	0.1189	-1.3100	0.1905
Herfindahl Index (Industry Concentration Ratio)	-0.4299	0.1056	-4.0700	<.0001
Dist. National Highway	0.0000	0.0001	0.0900	0.9298
Percent of People with No High School Dip. (%)	0.4294	0.1031	4.1600	<.0001
Percentage of People with Some University (%)	0.5468	0.2477	2.2100	0.0274
Violent Crime Rate (Crimes per 100,000 People)	-0.0001	2.20E-05	-3.9800	<.0001
Property Crime Rate (Crimes per 100,000 People)	2.30E-05	6.02E-06	3.8100	0.0001
Distance to a Police Station (km)	2.50E-05	0.0004	0.0700	0.9474
Distance to an Acute Care Hospital (km)	0.0002	0.0002	1.1700	0.2408
Distance to a Large Acute Care Hospital (km)	-0.0001	0.0001	-0.4100	0.6834
Distance to a Golf Course (km)	-0.0010	0.0003	-3.3100	0.0010
Distance to Skiing	-0.0001	0.0002	-0.4500	0.6518
Distance to a University (km)	0.0004	0.0001	3.5600	0.0004
Distance to a Religious Institution (km)	0.0017	0.0004	3.8200	0.0001
Water Body Dummy	0.0183	0.0106	1.7400	0.0828
Percent Forest Cover (%)	-0.0002	0.0002	-1.3700	0.1713
Standard Deviation of Elevation (m)	-2.00E-05	0.0001	-0.2400	0.8142
Average Snowfall (cm)	-0.0002	0.0001	-2.4600	0.0139
July Humidity (%)	0.0011	0.0006	1.7100	0.0878
Hours of January Sunshine (hours)	0.0007	0.0003	2.2700	0.0235