

**An Examination of Hall and Jones and the Role of Social Infrastructure and  
Canadian Disparity**

**Susan Lee**

Major Paper submitted to the  
Faculty of Graduate and Postdoctoral Studies  
In partial fulfillment of the requirements  
For the MA degree in Economics

Department of Economics  
Faculty of Social Sciences  
University of Ottawa

© Susan Lee, Canada, 2008

## TABLE OF CONTENTS

LIST OF TABLES .....	iii
LIST OF FIGURES .....	iv
LEGEND .....	v
ACKNOWLEDGEMENTS .....	vi
ABSTRACT.....	vii
1. INTRODUCTION .....	1
2. THEORETICAL FRAMEWORK.....	5
2.1 THE SOLOW MODEL .....	5
2.2 THE AUGMENTED SOLOW MODEL .....	6
3. GROWTH ACCOUNTING.....	10
4. THE BASIC DATA SET .....	11
4.1 OUTPUT .....	12
4.2 LABOUR INPUT .....	12
4.3 PHYSICAL CAPITAL .....	13
4.4 HUMAN CAPITAL .....	14
4.5 PARAMETER $\alpha$ .....	15
5. RESULTS.....	16
5.1 DECOMPOSITION OF OUTPUT PER WORKER .....	16
5.2 SUCCESS MEASURES OF VARIATION.....	18
6. THE EXPANDED DATA SET .....	20
6.1 OUTPUT .....	21
6.2 HOURS WORKED .....	24
6.3 MEASURES OF CAPITAL ASSETS .....	25
6.4 MEASURES OF HUMAN CAPITAL .....	28
6.4.1 Years of Schooling.....	28
6.4.2 Rate of Return to Schooling .....	29
6.5 SHARE OF CAPITAL .....	30
7. CONCLUSION .....	33
APPENDIX – DATA SOURCES.....	36
BIBLIOGRAPHY .....	38

**LIST OF TABLES**

TABLE 1 – DECOMPOSITION OF OUTPUT PER WORKER: RATIOS TO ONTARIO VALUES ..... 16

TABLE 2 - SUCCESS MEASURES OF VARIATION ..... 20

TABLE 3 - DECOMPOSITION OF OUTPUT PER WORKER EXCLUDING NATURAL RESOURCES: RATIOS TO  
ONTARIO VALUES ..... 21

TABLE 4 - SUCCESS MEASURES OF VARIATION EXCLUDING NATURAL RESOURCES ..... 22

TABLE 5 - DECOMPOSITION OF OUTPUT PER WORKER BASED ON TOTAL GDP: RATIOS TO ONTARIO VALUES  
..... 23

TABLE 6 - SUCCESS MEASURES OF VARIATION BASED ON TOTAL GDP ..... 24

TABLE 7 - VALUES OF  $\alpha$  ..... 33

## LIST OF FIGURES

FIGURE 1 – TOTAL VALUE-ADDED PER WORKER .....	2
FIGURE 2 - DYNAMICS OF THE HUMAN-CAPITAL AUGMENTED SOLOW MODEL .....	9
FIGURE 3 - PRODUCTIVITY AND OUTPUT PER WORKER.....	18
FIGURE 4 - RETURNS TO SCHOOLING AND SUCCESS MEASURES.....	30
FIGURE 5 - SHARE OF CAPITAL AND SUCCESS MEASURES .....	31
FIGURE 6 - SHARE OF CAPITAL INCOME .....	32

## LEGEND

NAICS	North American Industry Classification System
AL	Alberta
BC	British Columbia
CEGEP	<i>Collège d'enseignement général et professionnel</i>
CPA	Canadian Productivity Accounts
GDP	Gross Domestic Product
LFS	Labour Force Survey
MB	Manitoba
NFLD	Newfoundland and Labrador
NB	New Brunswick
NS	Nova Scotia
ON	Ontario
PEA	Provincial Economic Accounts
PEI	Prince Edward Island
QC	Quebec
SK	Saskatchewan
SNA	System of National Accounts

## **ACKNOWLEDGEMENTS**

I am indebted to my advisor S. Coulombe for his suggestion to pursue the examination of Canadian income disparity within the context of Hall and Jones (1999) and for helpful discussions. I am grateful also to Mychele Gagnon and Jean-Pierre Maynard at Statistics Canada for providing me with unpublished provincial data. I am responsible for any remaining errors or omissions. All views expressed in the paper are my own.

## **ABSTRACT**

This paper draws from the study of Hall and Jones (1999) and investigates whether social infrastructure is the primary driver of differences in output per worker. Social infrastructure is relatively homogenous across Canada so evaluating income disparity within the context of Hall and Jones is an appealing area of study. I explore whether their results are robust using regional data for the Canadian provinces. My results hold up to Hall and Jones only when alternate measures are considered. I document that the relative importance of social infrastructure and factor inputs in explaining regional income disparity in Canada is quite sensitive to the measurement of capital stock and the share of profits in national income.

## 1. INTRODUCTION

Why do some economies perform better than others? Attempts to answer the old-age question have amassed into an extensive collection of theoretical and empirical work; so much so that many readers will glance over this paper. I re-ignite the debate by questioning the importance of social infrastructure in explaining differences in output per worker using data at the regional level.

This paper takes Hall and Jones (H&J, 1999) seriously<sup>1</sup>. Using cross-country data the authors show that only a modest share of the difference in output per worker is attributable to differences in capital accumulation. In particular, H&J find that output per worker in the five richest countries in their sample exceeded the five poorest by a factor of 31.7 (based on a geometric average), or a log difference of 3.5, with differences in the intensity of physical capital and human capital per worker contributing about 15 per cent and 23 per cent, respectively. Productivity<sup>2</sup>, which is measured residually here as usual, accounts for more than half of the difference. According to H&J, the primary driver of differences in capital inputs and productivity, and hence output per worker, is social infrastructure.

The findings of H&J (1999) provides for an interesting empirical study in a federation such as Canada. Social infrastructure is broadly homogenous across the provinces. This implicitly suggests that differences in capital intensity and human capital per worker should capture most of the variability in output per worker.

As Figure 1 illustrates, provincial differences in output per worker are fairly diverse in Canada. Value-added per worker is generally lower in the Atlantic provinces and has fallen somewhat relative to the 10-province average. Newfoundland and Labrador, however, has been able to raise its relative performance. In 1986, Newfoundland and Labrador ranked 7<sup>th</sup>

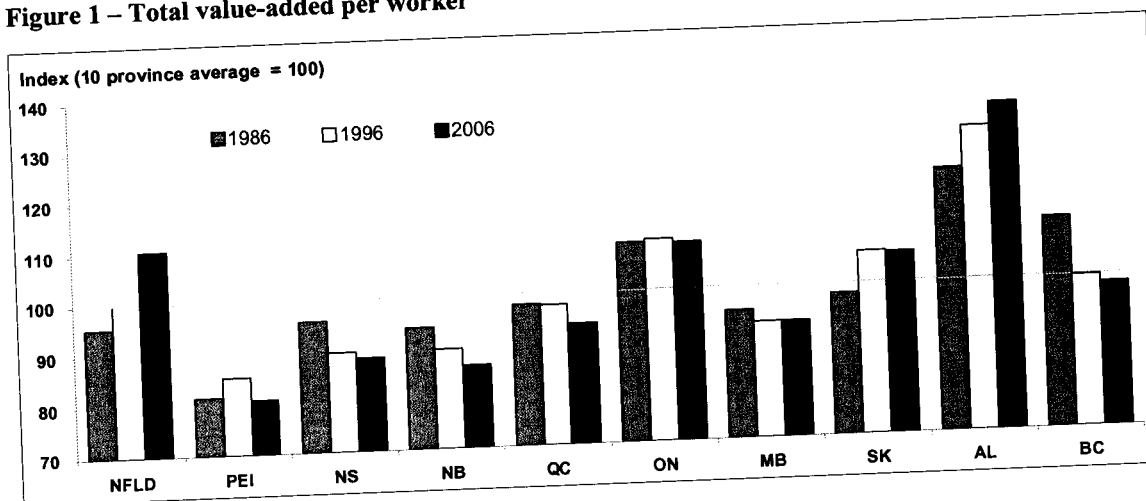
---

<sup>1</sup> This is a rewrite of the quote of Mankiw, Romer and Weil (1992, p. 407), "This paper takes Robert Solow seriously."

<sup>2</sup> The term "productivity" refers to total factor productivity. I use both terms interchangeably in the paper.

overall but in just a decade the province has moved to 2<sup>nd</sup> place<sup>3</sup>. Saskatchewan's relative performance has also risen while declining in British Columbia. Ontario and Alberta have historically higher levels of output per worker in Canada. The converse is true for Quebec and Manitoba. What accounts for the observed differences in output per worker? From the textbook Solow model to "new growth" theory, researchers turn to the proximate determinants of growth or go further and investigate the source of these proximate determinants<sup>4</sup>.

Figure 1 – Total value-added per worker<sup>5</sup>



Mankiw, Romer and Weil (1992) point to the sufficiency of factor inputs in explaining differences in output across countries. They find that the Solow model, broadened to include human capital, explains nearly 80 per cent of the cross-country variations in income per capita<sup>6</sup>. Christensen, Cummings, and Jorgenson (1981) reach similar conclusions using a

<sup>3</sup> Coulombe (2007) attributes the "catch-up" performance of Newfoundland and Labrador to the Hibernia offshore oil field which came into production in 1997 and later Terra Nova in 2002. The result is a temporary increase in Canadian regional disparity.

<sup>4</sup> The discussion that follows is not meant to be exhaustive. See Mankiw (1995) for a good overview of the main ideologies of economic growth. For a synthesis of cross-country empirical work, see Temple (1999).

<sup>5</sup> I discuss in detail the data in Section 4.

<sup>6</sup> Using three alternative vintages of the Penn World Table (PWT) data set and a longer sample period, Bernanke and Gurkaynak (2001) find slightly weaker fits of  $\bar{r}^2$ .

translog production function which allows for non-neutral efficiency differences<sup>7</sup>. Differences in output per capita in the G-7 countries (U.S, Canada, France, Germany, Italy, Japan, UK), Korea, and the Netherlands were more closely associated with differences in the levels of capital and labour inputs than total factor productivity. Factor accumulation is also found to be fundamental in explaining the post-war growth experience among East Asian countries (Young, 1995; Senhadji, 2000). These results, however, are inconclusive. H&J (1996, 1999), Klenow and Rodrigue-Clare (1997), and Caselli (2005) perform an exercise in growth accounting and observe that productivity or the Solow residual accounts for at least one-half of cross-country income differences. Here, standard neoclassical assumptions translate to lower contributions from factor inputs to differences in income. H&J and Klenow and Rodrigue-Clare also give higher emphasis to productivity differences because of varying assumptions about human capital and the endogeneity between productivity and factor inputs. According to Easterly and Levine (2001), “something else” besides factor accumulation accounts for the majority of cross-country income differences.

In an attempt to “chip-away” at the Solow residual, Caselli (2004) considers improvements in the measures of physical and human capital, the sectoral composition of output, and different functional forms. For the most part, productivity continues to play a prominent role in explaining income differences, but when technological differences are non-neutral and the elasticity of substitution between physical and human capital is sufficiently low, differences in factor inputs can explain the bulk of the variance in income across countries. Quality adjustments in physical capital could also eradicate the Solow residual if the different types of capital used in production are poor substitutes for one another.

H&J (1999) instead argue that social infrastructure is what ultimately drives differences in output per worker<sup>8</sup>. Here, social infrastructure is defined as the institutions and government policies that affect incentives to invest in productive activities, such as capital accumulation or technological innovation, and the diversion of rent-seeking activities. H&J use as their

---

<sup>7</sup> Caselli (2004) documents that poor countries use physical capital more efficiently than rich countries. Conversely, rich countries use human capital more efficiently.

<sup>8</sup> Easterly and Levine (2001) document that national policies more generally are linked strongly to steady-state levels of output and total factor productivity.

proxy of social infrastructure an equally-weighted index of anti-diversion policies and openness to trade variable for each country. Instrumental variables estimation shows that a 0.01 difference in social infrastructure is related to a 5.14 per cent difference in output per worker. This result is of course sensitive to the scale of the index chosen by the authors to measure social infrastructure. The variation of true social infrastructure, adjusted for measurement error, can account for a 25.2-fold difference in output per worker. If social infrastructure is instead exogenous, it implies a 38.4-fold difference in output per worker. Subsequent regressions of the relative contributions to output per worker from capital intensity, human capital per worker and the Solow residual on social infrastructure suggests that the observed variability of factor input accumulation can also be attributable to differences in social infrastructure.

Are H&J (1999) correct in their identification of social infrastructure as the primary determinant of differences in output per worker? I test their assertion and whether their results are robust using data for the Canadian provinces. By employing regional data from within a country, there is less susceptibility to omitted variable bias in the level of productivity, making Canada an ideal testing ground.

The remainder of the paper is organized as follows. In the next section, I introduce an extension of Solow's neoclassical model of growth which sets the theoretical framework for the growth accounting model. I take a static approach to growth accounting whereby the technique is applied across countries, or provinces in my case, rather than over time (Section 3). I describe in detail my basic data in Section 4. In Section 5, I present my results. The importance of social infrastructure in explaining provincial income differences seem to hold only when I consider complementary tests of variance. This calls into question the appropriateness of the model and the robustness of my result using alternative measures of income and factor inputs (Section 6). I find that the results are quite sensitive to the measurement of capital stock and the assumed value of  $\alpha$ . I conclude with some remarks in Section 7.

## 2. THEORETICAL FRAMEWORK

### 2.1 THE SOLOW MODEL

The Solow model, identified as such due to the originating author Robert Solow (1956), is the textbook model of neoclassical growth. The productive capacity of an economy is characterized by

- (i) constant returns to scale,

$$F(cK, cL) = cF(K, L); \quad \forall c \geq 0$$

- (ii) factor inputs exhibit positive and diminishing marginal returns,

$$\frac{\partial F}{\partial K} > 0; \quad \frac{\partial^2 F}{\partial K^2} < 0$$

$$\frac{\partial F}{\partial L} > 0; \quad \frac{\partial^2 F}{\partial L^2} < 0$$

and,

- (iii) the Inada conditions are met

$$\lim_{K \rightarrow 0} \left( \frac{\partial F}{\partial K} \right) = \lim_{L \rightarrow 0} \left( \frac{\partial F}{\partial L} \right) = \infty$$

$$\lim_{K \rightarrow \infty} \left( \frac{\partial F}{\partial K} \right) = \lim_{L \rightarrow \infty} \left( \frac{\partial F}{\partial L} \right) = 0$$

where  $F(\cdot)$  embodies the form of the production function, and  $K$  and  $L$  denotes the stock of capital and labour, respectively.

As with all theory though, Solow's model of long-run growth has some rigidity. For Solow's model to agree with Kaldor's stylized facts<sup>9</sup> of economic growth one must add technical progress to the production function. Equally important, empirical evidence has not held up favourably against Solow's predictions. In particular, the original Solow model is unable to explain the large variations in output per worker across countries. Mankiw, Romer and Weil (1992) shed some insight on these earlier findings and find that if capital is broadened to

---

<sup>9</sup> Kaldor found that:

- i. Income per worker is rising over time, and its growth rate does not tend to diminish.
- ii. Physical capital per worker grows over time.
- iii. The rate of return on capital is (nearly) constant through time and the wage rate is rising over time.
- iv. The capital-output ratio is (nearly) constant.
- v. The shares accruing to labour and capital in national income are (nearly) constant.
- vi. There are large disparities in income per worker across countries.

include human capital the Solow model can explain nearly 80 per cent of the cross-country variation in income per capita. As such, my framework focuses on the dynamics of the *human-capital augmented* Solow model and its conclusions<sup>10</sup>.

## 2.2 THE AUGMENTED SOLOW MODEL<sup>11</sup>

I assume an aggregate production function of the form Cobb-Douglas with Harrod-neutral technological progress<sup>12</sup>

$$[1] \quad Y = K^\alpha H^\beta (AL)^{1-\alpha-\beta}; \quad \alpha > 0, \beta > 0, \alpha + \beta < 0$$

where output,  $Y$ , can be raised through physical capital,  $K$ , human capital,  $H$ , or technological progress,  $A$ , which in effect, increases the efficiency of each unit of labour,  $L$ . All available labour input is utilized such that the supply of labour grows at the same exogenous rate  $n$  as population

$$L = L_0 e^{nt}$$

Technology is given by

$$A = A_0 e^{gt}$$

and grows at exogenous rate  $g$ .

Given constant returns to scale, I can divide the production function by  $AL$  so Equation 1 simplifies to

$$[2] \quad y = k^\alpha h^\beta$$

where  $y = Y/(AL)$ ,  $k = K/(AL)$ , and  $h = H/(AL)$ . Equation 2 states that in efficiency units, output per labour is a function of the physical capital-labour ratio and the human capital-

<sup>10</sup> The dynamics and predictions of the human-capital augmented Solow model are identical to the Solow model without human capital.

<sup>11</sup> This section draws from my lecture notes of Demers (September 30, 2003). See Bibliography for complete citation.

<sup>12</sup> There are three alternative ways to introduce technological progress into the production function: Harrod-neutral, Hicks-neutral or capital-augmenting. In general, technological progress must be Harrod-neutral to ensure that the dynamics of the Solow model settles to a steady state, however, in the special case of Cobb-Douglas, the specification of technological progress does not alter the results of the model.

labour ratio. Therefore, I turn to the derivation of the evolutions of  $k$  and  $h$  to extract the predictions of the model.

As with standard consumption models output can be either consumed or saved. Total savings is a fixed proportion of output,  $sY$ , and equal to total investment,  $I$ , whereby the marginal propensity to save,  $s$ , includes investment in physical and human capital. Investment in physical capital is defined as the sum of net investment – new additions to the stock of capital assets, *plus* replacement investment – the amount of capital investment required to maintain capital at its previous level due to the depreciation of existing capital assets. Therefore

$$s_K Y = \dot{K} - \delta K; \quad \delta > 0, 1 > s_K > 0$$

or

$$\dot{K} = s_K Y - \delta K$$

where the share of resources available for physical capital investment,  $s_K$ , and the depreciation rate,  $\delta$ , are fixed and exogenous, and the dot over the variable denotes its derivative with respect to time. In efficiency units, physical capital is given by

$$[3] \quad k = s_K y - \frac{\dot{K}}{AL}$$

The change in physical capital in efficiency units is found by taking the derivative of  $K/AL$  with respect to time. So

$$\begin{aligned} \dot{k} &= \frac{d(K/AL)}{dt} \\ &= \frac{\dot{K}}{AL} - (n+g)k \end{aligned}$$

Rearranging Equation 3 and substituting for  $\dot{K}/AL$ , I arrive at

$$[4] \quad \dot{k} = s_K y - (n+g+\delta)k$$

Similarly, human capital accumulation is given by

$$\dot{H} = s_H Y - \delta H; \quad \delta > 0, 1 > s_H > 0$$

or inefficiency units

$$[5] \quad \dot{h} = s_H y - (n + g + \delta)h$$

where  $s_H$  denotes the share of resources available for human capital investment, which is fixed and exogenous, and where the stock of human capital depreciates at the same rate as physical capital. Therefore, physical capital and human capital have the same production function. So what do Equations 4 and 5 reveal about the growth process? Capital per effective unit of labour, and thus output per effective unit of labour, depends on the difference between savings and replacement investment, which is now extended to include additions to capital due to population growth and technological progress. When savings exceeds replacement investment, capital increases. The converse is true when savings falls short of replacement investment. Therefore, regardless of the initial level of capital per effective unit of labour, a long-run equilibrium or steady-state (\*) is reached when

$$[6] \quad k^* = \left( \frac{s_k^{1-\beta} s_h^\beta}{n + g + \delta} \right)^{1/(1-\alpha-\beta)}$$

and

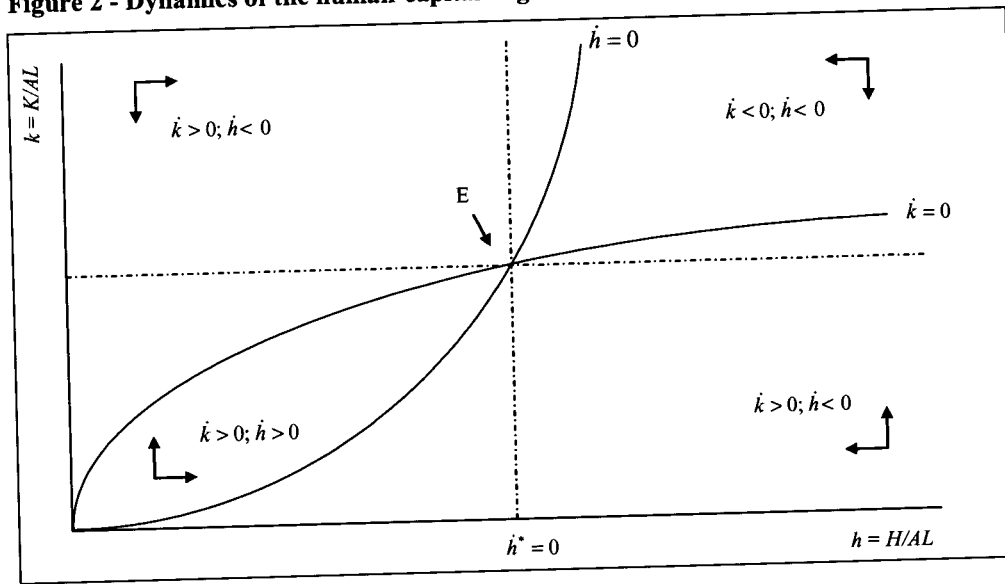
$$[7] \quad h^* = \left( \frac{s_k^\alpha s_h^{1-\alpha}}{n + g + \delta} \right)^{1/(1-\alpha-\beta)}$$

The evolution of  $k$  and  $h$  is found by taking the first and second derivatives of Equations 6 and 7. So

$$\begin{aligned} \frac{dk}{\partial h} &> 0; & \frac{d^2k}{\partial h^2} &< 0 \\ \frac{\partial h}{\partial k} &> 0; & \frac{d^2h}{\partial k^2} &> 0 \end{aligned}$$

Figure 2 illustrates their locus of points.

Figure 2 - Dynamics of the human-capital augmented Solow model



In this model, the economy will be globally stable (i.e. converge to pt E) since

$$\frac{dk}{dh} = \beta s_K k^\alpha h^{\beta-1} > 0$$

and

$$\frac{dh}{dh} = \alpha s_H k^{\alpha-1} h^\beta > 0$$

This means that no matter what the initial conditions are, the evolution of capital is such that the economy converges to a steady-state.

To assess the model's prediction on the long-run behavior of output per worker, I simply rearrange Equation 2 to get

$$[8] \quad \frac{Y}{L} = Ak^\alpha h^\beta$$

So variations in output per worker are a function of differences in capital inputs and technological change<sup>13</sup>.

<sup>13</sup> Since  $k^*$  and  $h^*$  are constant in the steady-state, sustainable increases in output per unit of labour is driven by productivity or technological progress only.

### 3. GROWTH ACCOUNTING

Solow (1957) presents what he describes as “an elementary way” (p. 312) to decompose the aggregate production function into factor inputs and technical change. Otherwise known as growth accounting, it is a technique that lends itself as a useful tool to empirically test models of neoclassical growth and to better understand the relative contribution of each factor input to economic growth. I make use of Solow’s growth accounting technique to develop my model here except the exercise is performed across provinces rather than over time<sup>14</sup>.

Following H&J (1999), I assume the provinces have identical Cobb-Douglas production technologies with competitive factor markets<sup>15</sup>. The productive capacity for each province,  $i$ , is given by

$$[9] \quad Y_i = K_i^\alpha (A_i H_i)^{(1-\alpha)}; \quad 1 > \alpha > 0$$

where  $Y$  is output,  $K$  and  $H$ , respectively, are the stocks of physical and human capital, and  $A$  is a labour-augmenting measure of productivity. Human capital is homogenous within a province. People accumulate human capital by spending time learning new skills through education. So

$$H_i = e^{\phi(S_i)} L_i; \quad \phi > 0$$

where  $S$  is years of schooling and  $\phi(S)$  is some piecewise linear function<sup>16</sup> that provides a measure of the efficiency of each unit of raw labour,  $L$ . Here, schooling increases the amount of input each unit of labour provides for production

<sup>14</sup> Across 135 countries, Easterly and Levine (2001) report a correlation of only 0.08 between income per capita growth in 1977-92 with 1960-1976. This suggests that the economies being studied are not in their respective steady-states, however, this does not pose a problem for growth accounting in levels.

<sup>15</sup> In competitive markets, factors are paid their marginal products. Thus

$$\begin{aligned} w = MP_L &= \frac{\partial Y}{\partial L} = (1-\alpha) \left(\frac{K}{L}\right)^\alpha (Ae^{\phi(S)})^{(1-\alpha)} \\ &= (1-\alpha) \frac{Y}{L} \end{aligned}$$

and

$$\begin{aligned} r = MP_K &= \frac{\partial Y}{\partial K} = \alpha \left(\frac{AH}{K}\right)^{1-\alpha} \\ &= \alpha \frac{Y}{K} \end{aligned}$$

where  $w$  is the real wage paid to labour and  $r$  is the real rental price paid to capital.

$$\frac{d \log(H)}{dS} = \phi$$

where  $\phi$  is equal to the rate of return to schooling from a Mincerian-wage regression. Note that if no time is devoted to education (i.e.  $S = 0$ ), then  $H = L$ .

I am interested in output per worker rather than output. I adhere to the algebraic manipulation of Romer (2001, p.138-139) and divide both sides of the production function by  $L$ , and then take logs to arrive at

$$[10] \quad \ln \frac{Y_i}{L_i} = \alpha \ln \frac{K_i}{L_i} + (1 - \alpha) \ln \frac{H_i}{L_i} + (1 - \alpha) \ln A_i$$

H&J (1999) point out that the impact on output per worker from a shock to  $A$  would be attributed to the pure effect of technical change *and* capital per worker. In order to separate the contributions from  $A$  from those generated by capital inputs alone, Romer explains that the authors subtract  $\alpha \ln(Y/L)$  from both sides of Equation 10, which simplifies to

$$[11] \quad \ln \frac{Y_i}{L_i} = \frac{\alpha}{(1 - \alpha)} \ln \frac{K_i}{Y_i} + \ln \frac{H_i}{L_i} + \ln A_i$$

As  $A$  is the only variable that is not directly measurable, I rewrite Equation 11 to solve for  $A$ , which is commonly referred to as a “measure of our ignorance”<sup>17</sup>.

#### 4. THE BASIC DATA SET

I introduce the basic data set for the provinces here. In an effort to abstract inadvertent differences in my results arising from the measurement of parameters and year of analysis, these variables approximate those of H&J (1999).

---

<sup>16</sup> This assumption draws from microeconomic evidence of diminishing returns to schooling and survey data reported in Psacharopoulos (1994).

<sup>17</sup> This term was coined by Stanford economist Moses Abramowitz.

#### 4.1 OUTPUT

Output estimates are drawn from the Provincial Economic Accounts (PEA), valued at market prices, and normalized to exclude natural resource endowments of a province. The closest approximation for the Canadian provinces is to subtract from Gross Domestic Product (GDP) the value-added share of output from North American Industry Classification System (NAICS) code 21, *Mining and Oil and Gas Extraction*<sup>18</sup>. H&J (1999) argue that this correction is necessary to control for the upward bias in productivity estimates in oil rich countries. They add that this adjustment does not change their empirical results, however, as I show later in the paper, my results are quite sensitive to the exclusion of the mining, oil, and gas sector and more generally primary industries. The non-uniformity of natural resource endowments across the provinces, especially oil and gas, is a factor in the result.

I use data on GDP reported in real dollars to isolate for volume differences from those attributable to differences in the price of goods among the provinces. Statistics Canada produces two such measures. The first is based on the Laspeyres method only and values quantities in 2002 dollars. The second is based on the chain fisher volume index, calculated as the geometric mean of the Laspeyres and Paasche indexes. While the latter estimates are superior and preferred by Statistics Canada, the non-additive nature of chain index estimates, which also increase as you diverge from the base year, leads me to use current dollars to calculate the natural resource share of each province. My study is otherwise carried out using PEA estimates in 2002 constant dollars.

#### 4.2 LABOUR INPUT

H&J (1999) explicitly identify hours worked as the preferred labour input variable, however, lack of available data for most countries direct their study in per worker terms. As a best approximation I use total employment for the population 15+ from the Labour Force Survey (LFS) and introduce hours worked in the next section.

---

<sup>18</sup> Data for NAICS code 21 is suppressed from 1984 to 1994 in PEI and from 1984 to 1996 in NFLD, NB, MB, and SK due to confidentiality. I make the naïve assumption that missing data points are negligible in magnitude. This assumption has the effect of attributing to output per worker, a larger contribution from the Solow residual or productivity.

### 4.3 PHYSICAL CAPITAL

H&J (1999) take national income and product accounts data from the Penn World Tables Mark 5.6 to construct a time series of fixed capital stock. Using all available data on investment the authors first estimate the initial level of capital stock and then apply the perpetual inventory method to determine the level of capital stock for 1988.

Following H&J (1999), I calculate the initial level of capital stock for each province as

$$K_t = \frac{I_t}{(g + \delta)}; \quad t = 0$$

where  $t = 0$  is the first year of available data on real investment,  $I$ , and  $g$  is the average geometric growth rate of investment from time,  $t = 0$  to 1970. The depreciation rate,  $\delta$ , is set equal to 6.0 per cent. I then apply the perpetual inventory method, which takes the existing level of capital stock less depreciation and discards, and adds to it, current net investment. Specifically, the net stock of real capital,  $K_t$ , is constructed according to the following expression

$$K_t = I_t + K_{t-1}(1 - \delta)$$

where  $t=1956$  to 2006 and the rate of depreciation is 6.0 per cent.

Investment, defined here from the perspective of expenditure-based output, consists of business gross capital formation and business investment in inventories. Investment figures from the PEA parallels the series used by H&J (1999), but is only available from 1981 onwards<sup>19</sup>. Therefore, I create a proxy measure for business investment by summing data on gross capital formation and inventories from alternate sources. In particular, I combine data on investment in residential capital<sup>20</sup> and unpublished data on fixed non-residential capital

---

<sup>19</sup> Provincial data prior to 1981 were not subject to the historical revision of 1997 which involved methodological, conceptual and statistical changes to various components of GDP, and do not incorporate revisions since then or changes that were adopted in the Canada's System of National Economic Accounts.

<sup>20</sup> Investment in fixed residential capital is not available by NAICS, but it is suitable to assume residential investment by government is negligible. I thank Étienne Saint-Pierre from Statistics Canada Investment and Capital Stock Division for his input.

from Statistics Canada<sup>21</sup>, which is available from 1941 and 1955, respectively, for gross capital formation. For business investment in inventories, I use available PEA estimates from 1981. For data points prior to 1981, I apply the provincial share of national business investment in inventories<sup>22</sup> using data published in the PEA historical issue. Since total provincial investment figures are benchmarked to the National Income and Expenditure Accounts, this enables me to create a relatively consistent time series beginning in 1961. The reader should note that by construction, earlier estimates of investment expenditures represent a diminishing share of the current level of capital stock<sup>23</sup>. As such, any erroneous measurement of business inventories should have little influence on my proxy for business investment, and thus the level of capital stock in 1988.

#### 4.4 HUMAN CAPITAL

Human capital is an abstract concept and therefore can not be measured directly. Instead it is measured via a proxy. H&J (1999) take as human capital the educational attainment for the population 25+ as reported in Barro and Lee (1993). Unfortunately I am unable to replicate Barro and Lee's approach to construct average years of schooling<sup>24</sup> for the provinces due to

<sup>21</sup> I thank Mychèle Gagnon from Statistics Canada Investment and Capital Stock Division for providing these unpublished estimates at my request.

<sup>22</sup> I thank Giovanni Salvatore from Statistics Canada Income and Expenditure Accounts Division for this suggestion. This approach far from ideal, but it is inferior to neglect changes in inventory investment given its close association with the business cycle.

<sup>23</sup> By recursion

$$\begin{aligned} K_t &= I_t + K_{t-2}(1-\delta)^2 \\ &= I_t + I_{t-1}(1-\delta) + I_{t-2}(1-\delta)^2 + K_{t-3}(1-\delta)^3 \\ &\vdots \\ &= I_t + I_{t-1}(1-\delta) + I_{t-2}(1-\delta)^2 + \dots + I_{t-n}(1-\delta)^n + K_{n+1}(1-\delta)^{n+1} \end{aligned}$$

which simplifies to

$$K_t = \sum_{p=0}^{t-1} I_{t-p}(1-\delta)^p + K_0(1-\delta)^t$$

<sup>24</sup> Specifically, Barro and Lee (1993) calculate average years of schooling as

$$\begin{aligned} \text{Average years of schooling} &= DUR_p \left( \frac{1}{2} h_{ip} + h_{cp} \right) + \left( DUR_p + DUR_{s1} \right) \cdot h_{is} + \left( DUR_p + DUR_{s1} + DUR_{s2} \right) \cdot h_{cs} \\ &+ \left( DUR_p + DUR_{s1} + DUR_{s2} + \frac{1}{2} DUR_h \right) \cdot h_{ih} + \left( DUR_p + DUR_{s1} + DUR_{s2} + DUR_h \right) \cdot h_{ch} \end{aligned}$$

where  $h$  is the share of the population for which  $j^{\text{th}}$  level of schooling is the highest attained:  $j = ip$  for incomplete primary,  $i$  for complete primary,  $is$  for the first cycle of secondary,  $cs$  for the second cycle of secondary,  $ih$  for incomplete higher, and  $ch$  for complete higher; and  $DUR_i$  is the duration in years of the  $i^{\text{th}}$

lack of detail contained in the Census of Canada Public Use Microdata Files for Individuals. As such, I use schooling data from the Census of Canada publication for the population 25+.

H&J (1999) take returns to schooling estimates from Psacharopoulos (1994). Analogous to the Mincerian rate of return in the Sub-Saharan Africa region,  $S$  below four years is set equal to 13.4 per cent,  $S$  between four and eight years to 10.1 per cent, equivalent to the world average, and  $S$  above eight years to 6.8 per cent, the average for OECD countries. I apply the same rates of return for the provinces and experiment with varying returns to schooling estimates in the next section.

#### 4.5 PARAMETER $\alpha$

The parameter  $\alpha$  in Equation 9 equals the share of income paid to capital<sup>25</sup>. I keep to H&J (1999) and use a benchmark value for  $\alpha$  of one-third based on the national income accounts in the U.S.

---

level of schooling based on the United Nations Educational, Scientific and Cultural Organization (UNESCO) classification:  $i = p$  for primary,  $s1$  for the first cycle of secondary,  $s2$  for the second cycle of secondary, and  $h$  for higher.

<sup>25</sup> National income is the sum of labour income and capital income

$$Y = wL + rK$$

so the share of capital income in total income is given by

$$[i] \quad r \frac{K}{Y}$$

Recall that factors are paid their marginal products or in the case of capital

$$r = MP_k$$

As such

$$[ii] \quad r = \alpha \frac{Y}{K}$$

Substitution of  $r$  from Equation *ii* into Equation *i* gives

$$r \frac{K}{Y} = \alpha \frac{Y}{K} \cdot \frac{K}{Y}$$

which simplifies to

$$r \frac{K}{Y} = \alpha$$

Therefore the share of income paid to capital,  $r \frac{K}{Y}$ , equals  $\alpha$ .

## 5. RESULTS

### 5.1 DECOMPOSITION OF OUTPUT PER WORKER

Table 1 presents, for the 10 Canadian provinces in 1988, the decomposition of output per worker into the contributions from capital intensity, human capital per worker, and productivity. Values are shown relative to a benchmark province, Ontario. Expressed in this manner I expect little variation in  $A$  across provinces and for all provinces to have a value of  $A$  close to one. As well, relative differences in inputs from the benchmark province should capture most of the differences in output per worker.

**Table 1 – Decomposition of output per worker: Ratios to Ontario values**

Province	Y/L	Contribution from		
		$(K/Y)^{\alpha/(1-\alpha)}$	H/L	A
British Columbia	1.015	1.008	1.015	0.992
Ontario	1.000	1.000	1.000	1.000
Alberta	0.954	1.343	1.019	0.697
Quebec	0.910	1.048	0.929	0.935
Newfoundland and Labrador	0.896	1.167	0.871	0.881
Manitoba	0.855	1.049	0.951	0.857
Nova Scotia	0.854	1.050	0.953	0.853
Saskatchewan	0.845	1.258	0.950	0.707
New Brunswick	0.844	1.018	0.916	0.905
Prince Edward Island	0.756	0.971	0.942	0.827
Average	0.893	1.091	0.955	0.866
Standard deviation	0.079	0.124	0.046	0.103
Correlation with Y/L (logs)	1.000	0.137	0.553	0.385
Correlation with A (logs)	0.385	-0.802	-0.056	1.000
2 richest (BC-ON) / 2 poorest (NB-PEI)	1.261	1.010	1.084	1.151

The mean and standard deviation of the contribution from productivity to differences in output per worker are shown in the bottom of Table 1. Since differences in social infrastructure in Canada are generally small, differences in productivity from that of Ontario should likewise be small. Respectively, the mean and standard deviation is 0.866 and 0.103. In comparison, H&J (1999) report a mean and standard deviation of 0.516 and 0.325, respectively, for their 127-country sample. This suggests that across Canada productivity, or implicitly social infrastructure, is comparatively close to that of Ontario and much less variable. In spite of this, the relative contributions from factor inputs and productivity by province lead to inconsistent results. According to the table, output per worker in British

Columbia is slightly higher than Ontario. Capital intensity is the same in the two provinces, but human capital per worker is slightly higher in British Columbia so productivity is the same as that in Ontario. The remaining provinces have lower levels of output per worker. Nova Scotia, New Brunswick, Prince Edward Island, Newfoundland and Labrador, Quebec, and Manitoba have higher physical capital intensity than Ontario, but educational attainment is lower. As such, productivity levels are slightly lower than that of Ontario. The results for Saskatchewan and Alberta, however, are counterintuitive. Output per worker in Saskatchewan is about 84 per cent of that in Ontario and in Alberta around 95 per cent. Despite the high capital intensity in both provinces about 35 percentage points of the difference in output per worker is attributable to lower productivity.

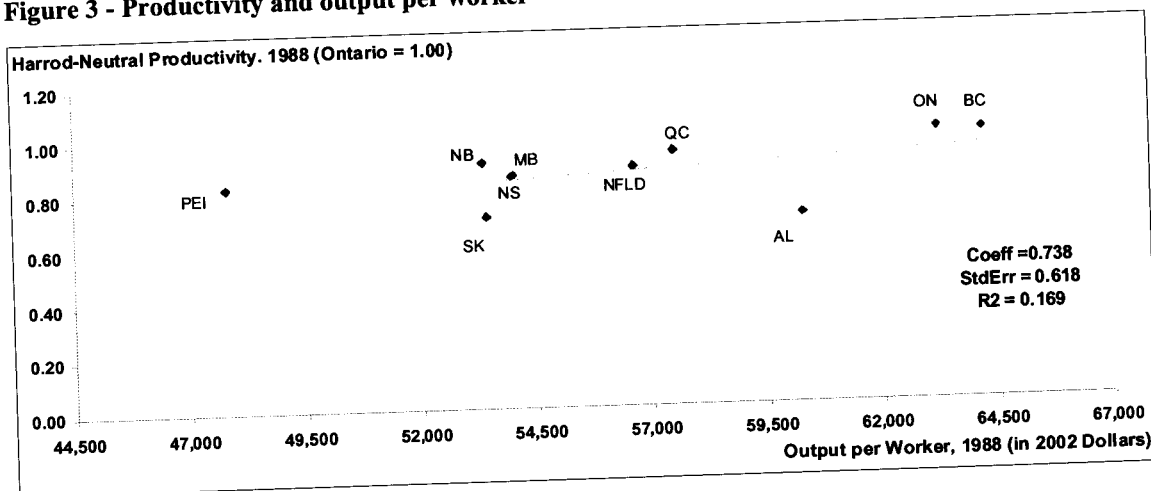
The bottom of Table 1 also compares output per worker in the two richest provinces (British Columbia and Ontario) with the two poorest provinces (New Brunswick and Prince Edward Island). Differences in capital intensity contributes a factor of 1.01 (or 4.9 per cent based on a log difference) and human capital per worker a factor of 1.084 (or 34.8 per cent)<sup>26</sup>. The factor from productivity is the largest at 1.151. If the provinces all had the same level of productivity, output per worker in British Columbia and Ontario would be just 9.5 per cent higher than New Brunswick and Prince Edward Island instead of 26.1 per cent. This indicates that differences in productivity are in fact sizeable. I repeat the analysis for 2002 and reach similar conclusions. For the same rich-poor provincial pair, capital intensity contributes a factor of 1.007, human capital a factor of 1.079, and productivity a factor of 1.139.

Figure 3 shows productivity levels (from Table 1) plotted against output per worker for the 10 provinces in 1988. Economic and institutional differences are certainly less pronounced in a federation such as Canada. If H&J (1999) are correct I expect the correlation between productivity and output per worker to be small. The correlation (in logs) is modest at 0.385. On the other hand, the coefficient of determination,  $R^2$ , is 16.9 per cent which suggests that only a small proportion of the total variance in output per worker is explained by productivity differences.

---

<sup>26</sup> I take the geometric average for calculations for the two rich-poor provincial pair.

Figure 3 - Productivity and output per worker



The cross-correlations are also a surprise (reported at the bottom of Table 1). The correlation between estimates of  $\ln(H/L)$  and  $\ln A$  is close to zero ( $\rho = -0.056$ ) and the correlation between estimates of  $[\alpha/(1-\alpha)]\ln(K/Y)$  and  $\ln A$  is negative ( $\rho = -0.802$ )! The correlation between the two capital terms is 0.072. There are two possible interpretations for these results. The contribution from capital accumulation could be overstated due to measurement error or more debatable, there are negative externalities to capital and the factors that affect capital accumulation beyond social infrastructure are also important. Overall, the results for the Canadian provinces appear suspect.

### 5.2 SUCCESS MEASURES OF VARIATION

I follow Caselli (2004) to assist with the deliberation of my findings above and consider two supplementary measures of success, where success agrees with the premise of H&J (1999). The measures compare the observed variation between factor inputs against the observed variation in output per worker. The first measure of success is based on the general formula for variance decomposition; the second is an inter-percentile differential. In the words of Caselli, they answer the question, "What would the dispersion of income be if all countries had the same A" (p.10)? The form of the question is quite ideal for the purpose of assessing the merit of social infrastructure in explaining provincial income differences in Canada.

For the variance decomposition I first take Equation 9 and express capital as a share of labour rather than output to isolate the influence  $A$  has on  $Y$ . So

$$[12] \quad \frac{Y}{L} = A^{(1-\alpha)} \left(\frac{K}{L}\right)^\alpha \left(\frac{H}{L}\right)^{(1-\alpha)}$$

or

$$\frac{Y}{L} = A^{(1-\alpha)} X$$

where  $X$  is a composite of the two capital intensities. I then take the variance of Equation 12 to arrive at

$$[13] \quad \text{var}[\log(y)] = \text{var}[(1-\alpha)\log(A)] + \text{var}[\log(X)] + 2\text{cov}[(1-\alpha)\log(A), \log(X)]$$

If social infrastructure drives productivity differences, then for the Canadian provinces

$$\text{var}[\log(A)] = \text{cov}[(1-\alpha)\log(A), \log(X)] = 0$$

and Equation 13 simplifies to<sup>27</sup>

$$[14] \quad \text{success}_1 = \frac{\text{var}[\log(X)]}{\text{var}[\log(y)]}$$

If  $\text{success}_1$  equals one, the variation in factor inputs can explain all of the variance in output per worker, and thus provides support for H&J (1999).

The inter-percentile differential arises from percentile ratios commonly used in literature that analyze income inequality. Percentile ratios measure the extent of dispersion by directly comparing the “haves” – the upper cut-off value of the observations at some  $p^{\text{th}}$  percentile – against the “have nots” – the lower cut-off value of observations at some  $p^{\text{th}}$  percentile. The reader should note that while percentile ratio has the advantage of minimizing measurement error arising from outliers at the very top or very bottom of the distribution, it only looks at two distinct data points so care must be taken when interpreting the ratios, particularly in small samples where the distribution is more likely to be skewed and it becomes less compelling as a measure of dispersion.

---

<sup>27</sup> Klenow and Rodriguez-Clare (2001) instead split the covariance term equally to  $\ln(X)$  and  $\ln(A)$ .

I use a 90/10 percentile dispersion ratio to determine the extent to which the observed variation between factor inputs explains the observed variation in output per worker. So

$$[15] \quad success_2 = \frac{y_{KH}^{90} / y_{KH}^{10}}{y^{90} / y^{10}}$$

where  $y^p$  is the value of the  $p^{th}$  percentile. The value of  $success_2$  has the same interpretation as  $success_1$ .

I report my results in Table 2. The fraction of variance explained by observed endowments for  $success_1$  is 0.966. For  $success_2$ , it is 1.003. Therefore by either measure the variation in factor inputs can basically explain all of the variation in output per worker. The results also support *a priori* the relative homogeneity of social infrastructure across Canada.

**Table 2 - Success measures of variation**

var[log(y)]	0.007	( $y_{90} / y_{10}$ )	1.199
var[log( $y_{KH}$ )]	0.007	( $y_{90KH} / y_{10KH}$ )	1.203
success <sub>1</sub>	0.966	success <sub>2</sub>	1.003

I argue against the robustness of the basic data set used by H&J (1999) and show in the next section that my results using the decomposition framework are quite sensitive to the measurement of parameters.

## 6. THE EXPANDED DATA SET

This section conducts a number of robustness checks. In particular, I discuss some of the assumptions and data quality issues of the basic data set and experiment with alternate measures of the parameters to test the sensitivity of my results and debunk some of the counterintuitive findings noted in the previous section.

## 6.1 OUTPUT

The motivation of H&J (1999) to exclude from GDP value added in the mining industry is subject to question. If the underlying rationale for this adjustment is correct it should extend to all industries with abundant natural resources. More importantly, any normalization to output should also apply to factors of production generally. I examine the sensitivity of my results to the former point only due to the lack of available data on educational attainment by North American Industry Classification System (NAICS).

As a proxy for the natural resource endowments of a province, I combine NAICS code 21, *Mining and Oil and Gas Extraction*, and NAICS code 11, *Agriculture, Forestry, Fishing and Hunting*. The results based on the decomposition framework are presented in Table 3.

**Table 3 - Decomposition of output per worker excluding natural resources: Ratios to Ontario values**

	Y/L	Contribution from		
		$(K/Y)^{\alpha/(1-\alpha)}$	H/L	A
Ontario	1.000	1.000	1.000	1.000
British Columbia	0.978	1.028	1.015	0.938
Alberta	0.921	1.366	1.019	0.662
Quebec	0.902	1.052	0.929	0.924
Newfoundland and Labrador	0.877	1.179	0.871	0.854
Manitoba	0.834	1.062	0.951	0.826
Nova Scotia	0.831	1.065	0.953	0.819
New Brunswick	0.821	1.032	0.916	0.867
Saskatchewan	0.776	1.313	0.950	0.622
Prince Edward Island	0.699	1.010	0.942	0.735
Average	0.864	1.111	0.955	0.825
Standard deviation	0.091	0.131	0.046	0.121
Correlation with Y/L (logs)	1.000	-0.038	0.457	0.588
Correlation with A (logs)	0.588	-0.780	-0.046	1.000
2 richest/poorest (BC-ON/NB-PEI)	1.306	0.993	1.084	1.213

There are several observations worth noting. First, the correlation between the observed values of  $\ln(Y/L)$  and the residual values of  $\ln A$  is substantial ( $\rho=0.588$ ). Second, the average and standard deviation of the contribution from productivity differences to output per worker indicate comparatively greater differences in social infrastructure among the 10 provinces. Third, differences in productivity contribute even more to income differences. The difference in output per worker for the same rich-poor provincial pair (i.e. BC and NB-

PEI) rises to 1.306 (1.261 in 2002). Productivity contributes a factor of 1.213 (1.379 in 2002) while differences in capital intensity contributes a factor of 0.993 (0.847 in 2002). On a log scale this translates to a contribution from productivity differences of 72.4 per cent! Here, output per worker in the two rich provinces would be only 7.7 per cent higher than the two poor provinces with no difference in total factor productivity.

I summarize the success measures in Table 4.  $Success_1$  falls to 0.661 (0.591 in 2002) and  $success_2$  to 0.943 (0.981 in 2002). Altogether, the exclusion of natural resources from the analysis results in even less support for H&J (1999).

**Table 4 - Success measures of variation excluding natural resources**

$var[\log(y)]$	0.010	$(y^{90} / y^{10})$	1.276
$var[\log(y_{KH})]$	0.007	$(y^{90}_{KH} / y^{10}_{KH})$	1.203
$success_1$	0.661	$success_2$	0.943

The reason for this is straight forward. Certainly provinces differ in terms of their natural endowments. This is reflected in part by the importance of the natural resources sector to provincial GDP, particularly for Alberta and Saskatchewan<sup>28</sup>. Apart from differences in industry-mix, some sectors are also intrinsically more or less productive than other industrial sectors<sup>29 30</sup>. For example, relative to Ontario, Saskatchewan and Alberta enjoy productivity advantages in the *Natural Resources*<sup>31</sup> and *Agriculture, Fishing and Trapping* sectors that largely offset its poor relative performance elsewhere (Baldwin, Maynard, Sabourin, and Zietsma, 2001; Sabourin and Zietsma, 2001). *Ceteris paribus*, the exclusion of value-added GDP from the natural resource sectors translate to lower output per worker. At the same time, the capital intensity of provinces with abundant natural resources rises relative to that

<sup>28</sup> Beine and Coulombe (2003) capture the degree of dependency of an economy on natural resources using a ratio of primary production to manufacturing output (PM ratio). For Saskatchewan and Alberta, the PM ratio values were 2.06 and 1.14, respectively.

<sup>29</sup> While it is true that the industrial structure of a region or country can play a role in accounting for differences in labour productivity, Baldwin, Maynard, Sabourin, Zietsma (2001) document that real productivity differences of specific industry sectors are generally more important than industry-mix differences in explaining differences in business sector productivity across provinces.

<sup>30</sup> Caselli (2004) analyzes efficiency differences between the agriculture and non-agriculture sectors and finds that the sectoral composition of a country accounts for only a small fraction of the overall variation in efficiency.

<sup>31</sup> Here, the natural resources sector includes the forestry, mining, and oil and gas industries only.

of Ontario. The net effect places productivity differences further from the benchmark province of Ontario as it removes the 'real' influence of differences in productivity from the analysis. Therefore, unlike the finding of H&J (1999), my results are quite sensitive to the exclusion of natural resources.

In light of the anomalies noted above I set as my baseline case the results based on total GDP, found in Tables 5 and 6. The conclusions stand essentially unchanged from Section 5. Productivity differences still contribute the largest factor to differences in output per worker between the two richest provinces and two poorest provinces. In this instance, differences in productivity account for 45.2 per cent of income differences. For the success measures,  $success_1$  falls to 0.440 and  $success_2$  to 0.941 where the considerable decline in  $success_1$  is attributable in large part to the performance of value-added GDP from the oil and gas sector in Alberta.

**Table 5 - Decomposition of output per worker based on total GDP: Ratios to Ontario values**

	Y/L	Contribution from		
		$(K/Y)^{\alpha/(1-\alpha)}$	H/L	A
Alberta	1.165	1.215	1.019	0.941
British Columbia	1.036	0.998	1.015	1.023
Ontario	1.000	1.000	1.000	1.000
Quebec	0.904	1.051	0.929	0.926
Newfoundland and Labrador	0.881	1.177	0.871	0.859
Manitoba	0.840	1.058	0.951	0.836
Nova Scotia	0.840	1.059	0.953	0.831
Saskatchewan	0.831	1.269	0.950	0.689
New Brunswick	0.830	1.027	0.916	0.882
Prince Edward Island	0.743	0.979	0.942	0.806
Average	0.907	1.083	0.955	0.879
Standard deviation	0.125	0.101	0.046	0.098
Correlation with Y/L (logs)	1.000	0.205	0.672	0.703
Correlation with A (logs)	0.703	-0.492	0.454	1.000
2 richest (AL-BC) / 2 poorest (NB-PEI)	1.399	1.099	1.094	1.164

In subsequent analyses, I focus on the estimates of the rich-poor provincial pair and highlight supplementary statistics where appropriate. The reader should note that Alberta now replaces Ontario as one of the rich provinces. I rely also on  $success_1$  and  $success_2$  as complementary measures of success.

**Table 6 - Success measures of variation based on total GDP**

var[log(y)]	0.016	(y <sub>90</sub> / y <sub>10</sub> )	1.277
var[log(y <sub>KH</sub> )]	0.007	(y <sub>90KH</sub> / y <sub>10KH</sub> )	1.203
success <sub>1</sub>	0.440	SUCCESS <sub>2</sub>	0.941

## 6.2 HOURS WORKED

The most accepted labour input variable for measuring differences in productivity is hours worked per employed person. There are several motivations for using hours worked rather than employment. First, estimates of employment do not necessarily capture changes in labour required for production. For example, firms may reduce the number of hours worked rather than layoff workers during periods of lower demand resulting in estimation bias of true labour usage. Second, conventional measures of employment do not capture the decline in the volume of work arising from holidays, vacation, sick leave and other types of leave.

Statistics Canada collects monthly data on actual hours worked by way of the Labour Force Survey (LFS). Here, annual figures are simply the 12-month average of actual hours worked by all persons who were employed during the reference week. A more accurate measure of actual hours worked, and one that is consistent with the System of National Accounts (SNA) and the International Labour Organization (ILO), is data from the Canadian Productivity Accounts (CPA). Here, estimates of hours worked during the 12 reference weeks of the LFS year are interpolated for the other weeks of the year. Adjustments are then made to add back in hours lost due to statutory holidays and sporadic events (e.g. strikes, Ontario's power outage in 2003), and to account for the day of the week in which each year begins and ends. The CPA also adjusts data on employment to account for multiple-job holders, workers absent from work without pay during the reference week and excluded LFS persons to arrive at a measure of the volume of hours worked.

I use unpublished data for the volume of hours worked provided by the Productivity Measures Division at Statistics Canada<sup>32 33</sup>. With it, output per worker in the two rich provinces (Alberta and British Columbia) is 1.427 times higher than output per worker in the two poor provinces (New Brunswick and Prince Edward Island), a small increase from the baseline value and all of which is attributable to  $A$ <sup>34</sup>. The two success measures are consistent with this result;  $success_1=0.406$  and  $success_2=0.905$ . So while the volume of hours worked is in principle a better measure of labour input than employment, the change in the results are minimal.

### 6.3 MEASURES OF CAPITAL ASSETS

By construction, there is inherent flexibility in using the perpetual inventory method to generate capital stock estimates. Variances can arise from the initial level of capital stock, gross investment in fixed capital and the depreciation profile<sup>35</sup>. Such flexibility can have an impact on the level of capital stock in any given period and thus affect residual estimates of productivity. This is particularly true in poor countries. For example, Caselli (2004) finds that the choice of the initial level of capital stock has very small persistence, but it is negatively correlated with income per capita. Since poor countries are less likely to satisfy the steady-state condition that motivates the initial capital stock estimate most used by researchers (i.e.  $K_i = I_i / (g + \delta)$ ), it is probable that the initial level of capital is systemically overestimated. Not only does this bias downward the variability of capital stock estimates across countries, it overstates the true correlation between output per worker and productivity<sup>36</sup>.

<sup>32</sup> I thank Jean-Pierre Maynard from Statistics Canada Productivity Measures Division for providing these estimates at my request. Public data is available from 1997 onwards only.

<sup>33</sup> The reader should be aware that the annual provincial program of the CPA is experimental. As such, statistics may lead to erroneous inferences or interpretations.

<sup>34</sup> Differences in productivity contribute a factor of 1.187 (or 48.1 per cent).

<sup>35</sup> At the same time, it can increase the likelihood of measurement error.

<sup>36</sup> To illustrate the latter point, suppose for each country  $i$ , output per worker (in logs),  $y_i$ , is given by the following simple linear equation

$$y_i = \beta \left( k_i + \frac{\tilde{a}}{k_i} \right) + A_i$$

where  $\beta$  is some constant,  $A$  is the error term, and  $\tilde{a}$  is some constant that provides a measure of the systemic overestimation of true capital stock per worker,  $k$ ; all right-hand side variables are independent. If  $\tilde{a} > 0$ ,

The Investment and Capital Stock Division at Statistics Canada produces unpublished estimates of net capital stock by province also based on the perpetual inventory method<sup>37</sup>. These estimates, however, are less likely to suffer from measurement error relative to a cross-country data set. Data used to construct the capital stock series are taken primarily from the Capital and Repair Expenditures survey. The stock of physical assets includes building construction, engineering construction and machinery and equipment (and excludes investment in land and inventories). Three separate estimates of capital stock are produced by Statistics Canada based on varying assumptions about the rate of depreciation – straight-line, geometric and hyperbolic<sup>38</sup>. The straight-line depreciation method deducts a constant amount each year such that at the end of the estimated service life the asset is no longer available for use, or in other words, its marginal product is zero. With the hyperbolic method, depreciation increases as the asset ages. Here, machinery and equipment is assumed to depreciate more quickly than structures as the former is more likely to adopt efficiency improvements. Lastly, the geometric depreciation method takes into account retirements such that efficiency falls by a constant rate<sup>39</sup>.

The results using any of Statistics Canada's estimates of capital stock are encouraging. For the rich-poor provincial pair, the contribution from productivity to differences in output per worker falls dramatically to a factor of just 1.019 (or 5.8 per cent) for the hyperbolic method, 1.026 (or 7.7 per cent) for straight-line, and 1.022 (or 6.6 per cent) for the geometric method. The majority of the income gap is attributable to differences in the accumulation of capital inputs. Physical capital explains between 65.5 per cent and 67.4 per cent and human capital for the remainder. The success measures corroborate these results.  $Success_1$  increases considerably from the baseline case to between 0.890 and 0.941; the inter-percentile ratios decline slightly from the baseline values to between 0.923 and 0.929.

---

capital is systemically overestimated. The upward bias in the measurement of capital, which is more probable in poor countries, lowers  $A$  such that the correlation between  $y$  and  $A$  is overstated.

<sup>37</sup> I thank Mychèle Gagnon from Statistics Canada Investment and Capital Stock Division for providing the provincial estimates at my request.

<sup>38</sup> Retirements are assumed to be normally distributed and truncated so that all retirements occur between 50 per cent and 150 per cent of its average survey-based useful service life.

<sup>39</sup> Here, depreciation rates equal the declining balance rate divided by mean service life.

The manner in which Statistics Canada treats capital retirements can partly explain these results. According to Coulombe (2000), the truncated pattern for the retirement of capital assets results in higher aggregate effective depreciation rates and an underestimation of the level of capital stock. In effect it increases the variability of capital stock estimates given variability in net investment flows. His analysis show that over the 1961-1997 period, the standard deviation of the growth rate of capital stock in the business sector rose by 1.89 per cent based on the truncated method of depreciation versus 1.10 per cent using comparable U.S figures from the Bureau of Labor Statistics. This translates to a sizeable difference in variability of 54 per cent. Nonetheless, it is evident that the results are quite sensitive to the measurement of capital stock.

Before proceeding to the parameter of human capital, a couple of inadequacies regarding capital stock estimates deserve discussion. The first is related to capital utilization. According to Paquet and Robidoux (2001), only when adjustments are made for varying capacity utilization rates do Canada's market structure exhibit constant returns to scale and perfect competition. It seems appropriate then to weigh the provincial stock of capital by capacity utilization rates to agree with the assumptions of my model. Statistics Canada publishes quarterly estimates of industrial capacity utilization rates, but it is only available at the national level. The second caveat focuses on the concept of productive capital stock itself. The net stock of capital assets is constructed using acquisition prices as weights, a measure of wealth and thus unsuitable for analyses that utilize a production function. The alternate is a volume index of capital services where an asset of a particular vintage is weighted by the rental price<sup>40</sup>. The use of rental prices also better accounts for changes in the quality of capital since for a given required rate of return, the rental price is higher for higher rates of depreciation. In principle, capital services are a preferred measure due to its consistency with the flow concept of measuring input and output. A study by Harchaoui and Takhani (2002) finds that between 1981 and 2002 the composition of capital in the business sector using the volume index of capital services grew 70 per cent more than the traditional

---

<sup>40</sup> The rental price of capital takes into account opportunity cost, the change in market value of an asset, and depreciation.

wealth measure. The difference is substantial. Unfortunately, Statistics Canada does not produce a volume index of capital services by province to assess the impact on my results.

## 6.4 MEASURES OF HUMAN CAPITAL

### 6.4.1 Years of Schooling

Recall that my basic data set uses average years of schooling for the population 25+ to proxy the stock of human capital. One can easily argue that the stock of human capital should be based on potential workers such as the labour force rather than the population as a whole. Further, a well-known short coming of using years of schooling is that it does not take into account the quality of education, length of school day or year. Statutory education requirements and the relative homogeneity in education systems in Canada, however, mitigate some of these concerns<sup>41</sup>. Caselli (2004) also documents using various measures of schooling quality (i.e. student-teacher ratios, per student government spending, student test scores, and the stock human capital of previous generations) that “broadening” the measure of human capital translates trivially to the explanatory power of factor inputs. As such, I assess the former point only.

I use the Census of Canada statistics on schooling, tabulated by age group, and interpolate the average years of schooling for the population 15 to 64<sup>42</sup>. This yields  $\text{success}_1=0.417$  and  $\text{success}_2=0.939$ . At the same time, the factor from human capital declines to 1.071 from 1.094 for the rich-poor provincial pair. By either measure an improvement in the measure of educational attainment worsens the results relative to the baseline case. The reason for this is higher levels of schooling attainment among the younger cohorts of the population, most notably in the Atlantic provinces and Quebec. Thus enlarging the sample to include the population aged 15-24 reduces the education gap across provinces and lowers the relative dispersion in human capital.

---

<sup>41</sup> Education falls under provincial jurisdiction in Canada so some differences across education systems can still exist. For example, the duration of compulsory education varies by province. As another example, secondary school ends after 11 years of education in Quebec. High school graduates must then obtain a diploma from a Collège d'enseignement général et professionnel (CEGEP) to further their post-secondary education.

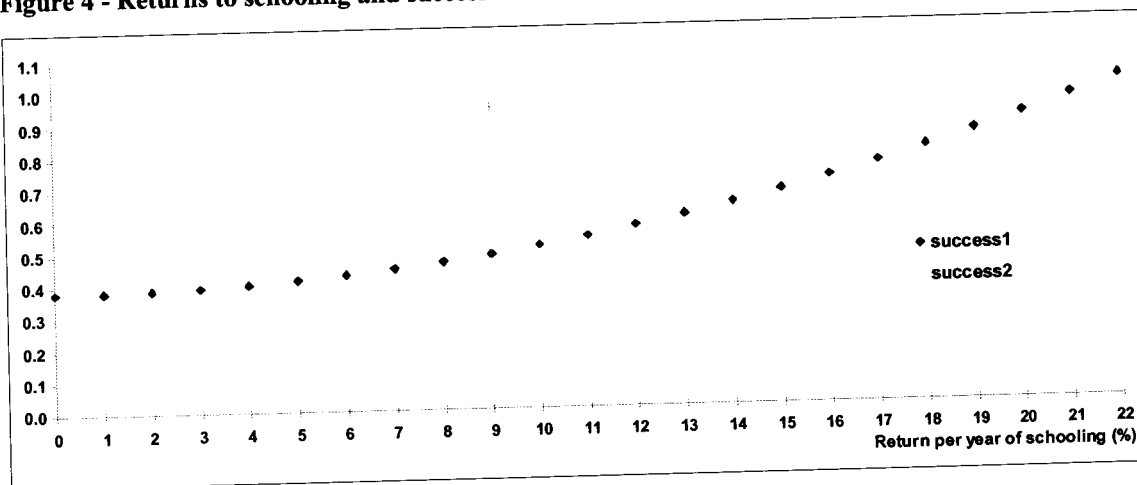
<sup>42</sup> One might consider using the percentage of males or the population of both sexes who have achieved at least one university degree (Coulombe, 2003 )

#### 6.4.2 *Rate of Return to Schooling*

Since Hall and Jones' 1999 study, Psacharopoulos (2004) has updated his cross-country survey on returns to schooling estimates to include new and updated figures found in the literature. The negative relationship between returns to schooling estimates and the stage of economic development continues to hold. The latest survey report a return to schooling for the Sub-Sahara Africa region of 11.7 per cent, down 1.7 percentage points from his 1994 study, while the return for OECD countries has risen to 7.5 per cent from 6.8 per cent. The world-average rate of return to schooling stands at 9.7 per cent. Unsurprisingly, applying these revised estimates has only a small effect on the baseline values. For the rich-poor provincial pair, differences in human capital per worker and productivity, contribute factors of 1.071 and 1.189, respectively, to the difference in output per worker. For the success measures,  $success_1=0.417$  and  $success_2=0.939$ .

I augment my analysis by testing the general sensitivity of my results to the parameters of the function  $\phi(S)$  except here I assume a constant rate of return to schooling for ease of analysis. Figure 5 plots  $success_1$  and  $success_2$  as functions of  $\phi(S)$ . The line in the chart represents the Mincerian-based rate of return to schooling estimate for Canada of 8.9 per cent as reported by Psacharopoulos (2004). According to the chart, the rate of return to schooling would have to be around 20 per cent for both success measures to uphold the finding of H&J (1999).

Figure 4 - Returns to schooling and success measures



There is general consensus that positive externalities to human capital exists in terms of the flow of knowledge and ideas to the general population. This implies that the social rate of return will be larger than the total rate of return. Moreover, the private rate of return to human capital is higher for Canada because both the federal and provincial levels of government subsidize education<sup>43</sup>. It seems, then, that this may be a suitable area for further study.

### 6.5 Share of Capital

The parameter  $\alpha$  in Equation 9 equals the elasticity of output with respect to capital. In a growth accounting framework it captures the contribution of capital to differences in output per worker. My assumption that the Cobb-Douglas production function has constant returns to scale implies that the value of  $\alpha$  and the accuracy with which it is measured can alter the relative importance of factor inputs and the Solow residual in explaining differences in output per worker.

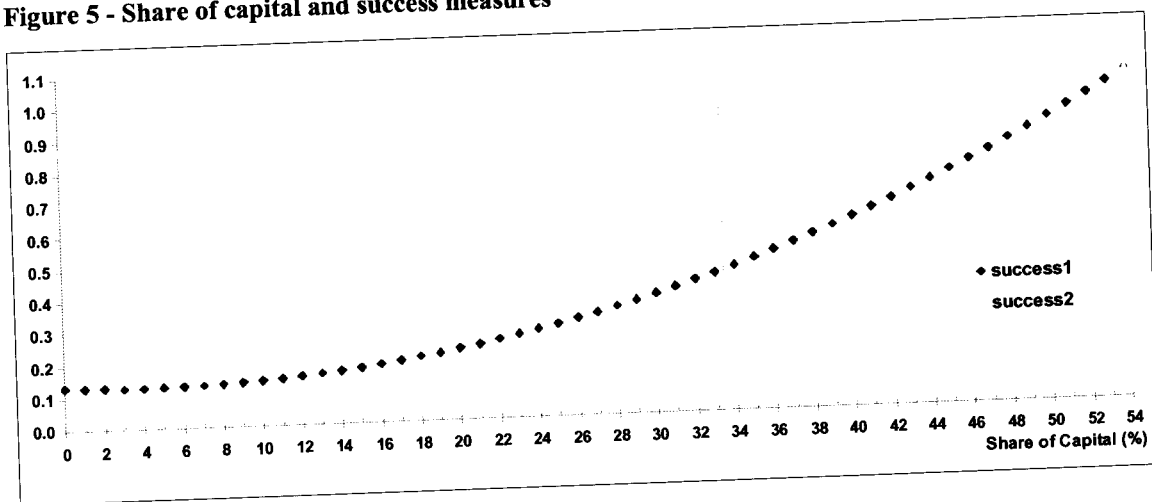
By construction, increasing the contribution of capital to income differences necessarily decreases the contribution from human capital and total factor productivity. Since capital is

<sup>43</sup> For example, see Vaillancourt (1995).

more variable across the provinces than human capital, one can exploit the variability of capital by assuming higher values of  $\alpha$  and thus increase the explanatory power of factor inputs on the observed variation in output per worker.

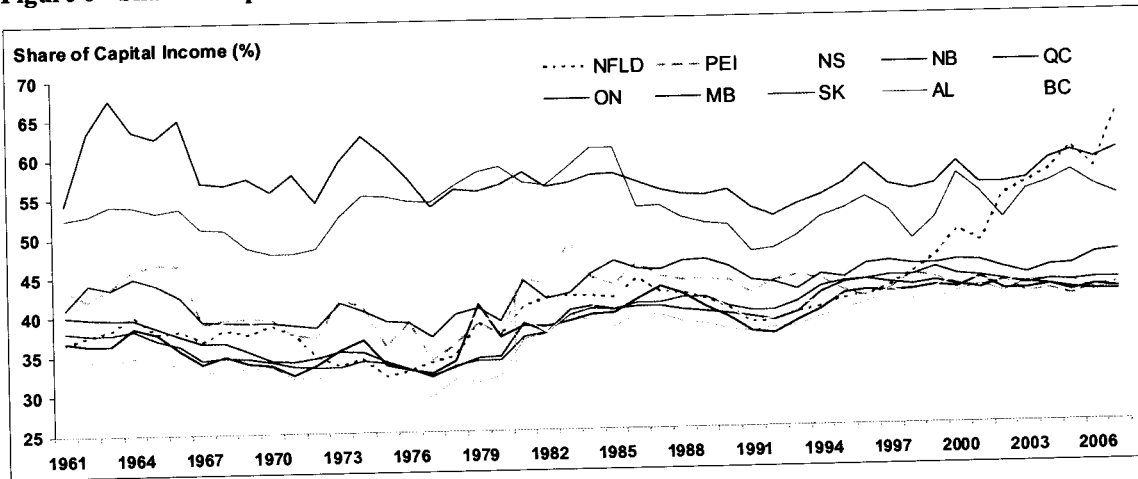
Figure 6 plots the sensitivity of varying assumptions for the value of  $\alpha$  on the measures of success. As the value of  $\alpha$  increases both measures of success approach one. Further, the inter-percentile ratio is relatively more sensitive to  $\alpha$ . For example, if the capital share is 40 per cent,  $\text{success}_2$  increases from the baseline value of 0.440 to 0.596 while  $\text{success}_1$  increases to 0.969 from 0.941. At a capital share of 50 per cent,  $\text{success}_1=0.890$  and  $\text{success}_2=1.012$ . Moreover, my analysis using the decomposition framework reveals that if  $\alpha$  is 0.4, the contribution to differences in output per worker from productivity declines from 45.2 per cent in the baseline case to 35.7 per cent, and to 16.8 per cent when  $\alpha$  equals 0.5. Therefore the accuracy of the estimate for  $\alpha$  is indisputably important.

Figure 5 - Share of capital and success measures



To get a value for  $\alpha$ , one can use data on profits as a share of total income or estimate it residually using wage income. Figure 6 shows the capital income share for the 10 provinces using data on wages, salaries and supplementary income from the Provincial Economic Accounts. The series are based on basic prices from 1981 onward and on factor cost prior to 1981; the line in the chart corresponds to the break in the series.

Figure 6 - Share of capital income



A visual inspection of Figure 6 illustrates that while factor shares are approximately stationary<sup>44</sup> it is higher than my assumption of one-third. Further, there is substantial inter-provincial variation in the share of capital income so my assumption about identical Cobb-Douglas production technologies across the provinces is easily arguable.

Table 7 reports the average values of  $\alpha$  for the 10 provinces between 1981 and 2007. The share of capital income ranges from a low of 39.7 in Nova Scotia to a high 55.9 in Saskatchewan. While these values are notably higher than one-third, they are not implausible. According to Senhadji (2000), among industrialized countries the average value for  $\alpha$  is 0.64. Here, he estimates the parameters of the production function using the Fully Modified (FM) estimator, which takes into account serial correlation and the possible endogeneity of the explanatory variables.

<sup>44</sup> This observation agrees with the steady-state condition.

**Table 7 - Values of  $\alpha$**

<u>Province</u>	<u><math>\alpha</math></u>
Newfoundland and Labrador	45.6
Prince Edward Island	43.2
Nova Scotia	39.7
New Brunswick	40.6
Quebec	41.6
Ontario	41.0
Manitoba	44.7
Saskatchewan	55.9
Alberta	53.4
British Columbia	41.7

There are several reasons why factor shares may differ among the 10 provinces. As I note above, provinces may have different forms of production technologies though this is highly unlikely in my sample. Second, factor markets are not perfectly competitive such that there are differences in the marginal product of capital or the real rental rate of capital. Third and a more promising area for further investigation is that  $\alpha$  is poorly measured. Gollin (2004) argues that despite common practice to use employee compensation as a measure of labour income, it is conceptually different from labour income. He finds that when self-employment income is accounted for in employee compensation, differences in income shares across countries tend to be approximately constant. In all, there is indication that the measurement of  $\alpha$  has a notable effect on the results.

## 7. CONCLUSION

Across countries, income differences exist. This is also true at the regional level. According to H&J (1999), social infrastructure is *the* fundamental determinant of differences in capital accumulation, productivity, and thus output per worker. Indeed, it is hard to think that social infrastructure would not be a factor influencing income differences. At the regional level, the importance of social infrastructure in explaining income disparity is a unique story altogether.

My empirical analysis based on the decomposition framework of H&J (1999) and a comparable data set for the Canadian provinces suggests that productivity differences account for a substantial amount of the difference in output per worker. The contribution from productivity is around 60 per cent when comparing the income gap between the two rich provinces and the two poor provinces. Given that social infrastructure is relatively homogenous across Canada, the results are questionable. I make the case that the data set of H&J is far from ideal. A sensitivity analysis reveals that the relative importance of capital inputs and productivity is influenced by the measurement of select parameters of the model. My results hold up to H&J only when official estimates of capital stock from Statistics Canada are used. Here, the differences in output per worker between the two rich provinces and two poor provinces can be explained almost entirely by differences in the accumulation of physical and human capital. The contribution from productivity is in the range of only 5.8 per cent to 7.7 per cent.

My analyses also indicate that the decomposition framework is less feasible for evaluating the merits of social infrastructure in explaining income differences at the regional level. With limited exceptions, complementary tests of variation reveals that the dispersion in physical and human capital accumulation can explain the bulk of observed differences in output per worker. Unexpectedly, this finding also holds true for the basic data set. It may follow that when differences in social infrastructure are small or more generally, when differences in the primary determinant of the Solow residual are small, the decomposition framework can lead to erroneous conclusions so alternative approaches should be considered.

Overall, my results do not imply that social infrastructure should be overruled as a key determinant of income disparity in Canada. A more detailed investigation on the calculation of certain model parameters, however, would be useful. Based on the outcomes of my experiment with alternate parameter measurement, further study and analyses on the estimate of  $\alpha$  is one priority area. A second area of value may be the consideration of alternate measures and assumptions for the accumulation of human capital stock, especially since education is highly subsidized in Canada and falls within provincial jurisdiction. On

the whole, I view this paper as a starting point for future empirical work. A fiery debate will likely ensue going forward.

## APPENDIX – DATA SOURCES

- Statistics Canada. n.d. *Table 030-0002 - Flows and stocks of fixed residential capital, annual (dollars) (table)*, CANSIM (database). Using E-STAT (distributor). Version updated June 30, 2007. [http://estat.statcan.ca.proxy.bib.uottawa.ca/cgi-win/cnsmcgi.exe?Lang=E&ESTATFile=EStat\English\CII\\_1\\_E.htm&RootDir=ESTAT/](http://estat.statcan.ca.proxy.bib.uottawa.ca/cgi-win/cnsmcgi.exe?Lang=E&ESTATFile=EStat\English\CII_1_E.htm&RootDir=ESTAT/) (accessed June 17, 2008).
- Statistics Canada. n.d. *Table 282-0008 - Labour force survey estimates (LFS), by North American Industry Classification System (NAICS), sex and age group, annual (persons unless otherwise noted) (table)*. CANSIM (database). Using E-STAT (distributor). Version updated June 30, 2007. [http://estat.statcan.ca.proxy.bib.uottawa.ca/cgi-win/CNSMCGI.EXE?CANSIMFILE=EStat\English\CII\\_1\\_E.htm](http://estat.statcan.ca.proxy.bib.uottawa.ca/cgi-win/CNSMCGI.EXE?CANSIMFILE=EStat\English\CII_1_E.htm) (accessed June 5, 2008).
- Statistics Canada. n.d. *Table 282-0028 - Labour force survey estimates (LFS), by total and average usual and actual hours worked, main or all jobs, type of work, sex and age group, annual (table)*, CANSIM (database). Using E-STAT (distributor). Version updated July 7, 2008. [http://estat.statcan.ca.proxy.bib.uottawa.ca/cgi-win/cnsmcgi.exe?Lang=E&ESTATFile=EStat\English\CII\\_1\\_E.htm&RootDir=ESTAT/](http://estat.statcan.ca.proxy.bib.uottawa.ca/cgi-win/cnsmcgi.exe?Lang=E&ESTATFile=EStat\English\CII_1_E.htm&RootDir=ESTAT/) (accessed August 18, 2008).
- Statistics Canada. n.d. *Table 283-0009 - Labour statistics consistent with the System of National Accounts, by job category and North American Industry Classification System (NAICS), annual (table)*. CANSIM (database). Using E-STAT (distributor). Version updated June 30, 2007. [http://estat.statcan.ca.proxy.bib.uottawa.ca/cgi-win/CNSMCGI.EXE?CANSIMFILE=EStat\English\CII\\_1\\_E.htm](http://estat.statcan.ca.proxy.bib.uottawa.ca/cgi-win/CNSMCGI.EXE?CANSIMFILE=EStat\English\CII_1_E.htm) (accessed August 21, 2008).
- Statistics Canada. n.d. *Table 379-0025 Gross Domestic Product (GDP) at basic prices, by North American Industry Classification System (NAICS) and province, annual (dollars) (table)*. CANSIM (database). Using E-STAT (distributor). Version updated July 7, 2008. <http://datacenter2.chass.utoronto.ca.proxy.bib.uottawa.ca/cansim2/index.jsp> (accessed August 13, 2008).
- Statistics Canada. n.d. *Table 380-0017 - Gross Domestic Product (GDP), expenditure-based, annual (dollars unless otherwise noted) (table)*. CANSIM (database). Using E-STAT (distributor). Version updated June 30, 2007. [http://estat.statcan.ca.proxy.bib.uottawa.ca/cgi-win/CNSMCGI.EXE?CANSIMFILE=EStat\English\CII\\_1\\_E.htm](http://estat.statcan.ca.proxy.bib.uottawa.ca/cgi-win/CNSMCGI.EXE?CANSIMFILE=EStat\English\CII_1_E.htm) (accessed June 26, 2008).

Statistics Canada. n.d. *Table 384-0001 - Gross Domestic Product (GDP), income-based, provincial economic accounts, annual (dollars)* (table), CANSIM (database). Using E-STAT (distributor). Version updated July 7, 2008.  
[http://estat.statcan.ca.proxy.bib.uottawa.ca/cgi-win/cnsmcgi.exe?Lang=E&ESTATFile=EStat\English\CII\\_1\\_E.htm&RootDir=ESTAT/](http://estat.statcan.ca.proxy.bib.uottawa.ca/cgi-win/cnsmcgi.exe?Lang=E&ESTATFile=EStat\English\CII_1_E.htm&RootDir=ESTAT/)  
(accessed September 20, 2008).

Statistics Canada. n.d. *Table 384-0002 - Gross Domestic Product (GDP), expenditure-based, provincial economic accounts, annual (dollars)* (table). CANSIM (database). Using E-STAT (distributor). Version updated July 7, 2008.  
<http://datacenter2.chass.utoronto.ca.proxy.bib.uottawa.ca/cansim2/index.jsp> (accessed August 13, 2008).

Statistics Canada. n.d. *Table 384-0014 - Provincial Gross Domestic Product (GDP), income-based, annual (dollars)* (table), CANSIM (database). Using E-STAT (distributor). Version updated July 7, 2008.  
[http://estat.statcan.ca.proxy.bib.uottawa.ca/cgi-win/cnsmcgi.exe?Lang=E&ESTATFile=EStat\English\CII\\_1\\_E.htm&RootDir=ESTAT/](http://estat.statcan.ca.proxy.bib.uottawa.ca/cgi-win/cnsmcgi.exe?Lang=E&ESTATFile=EStat\English\CII_1_E.htm&RootDir=ESTAT/)  
(accessed September 20, 2008).

Statistics Canada. *Flows and Stocks of Fixed Non-Residential Capital, Provinces, annual (dollars)*. Special Request. (Received June 19, 2008)

Statistics Canada. *Hours Worked for All Jobs, Labour Statistics Consistent with the System of National Accounts (SNA), Provinces, annual (hours)*. Special Request. (Received September 10, 2008)

Statistics Canada. 1988. *Provincial economic accounts : historical issue, 1961-1986*. Statistics Canada Catalogue no. 13-213S. Ottawa. 465 p.

Statistics Canada. 1989. *Schooling and Major Field of Study*. Statistics Canada Catalogue no. 93-110-XPB. Ottawa. 731 p. Nation Series, 1986 Census.

Statistics Canada. 2004. *Total, Average and Median Years of Schooling (9), Age Groups (13B) and Sex (3) for Population 15 Years and Over, for Canada, Provinces, Territories, Census Metropolitan Areas and Census Agglomerations, 1991 to 2001 Censuses - 20% Sample Data (table)*. Topic-based Tabulations: *Education in Canada: School Attendance and Levels of Schooling*. Statistics Canada Catalogue no. 97F0017XCB2001008. Ottawa. March 25. <http://www12.statcan.ca/english/census01/products/standard/themes/index.cfm> (accessed June 8, 2008).

## BIBLIOGRAPHY

- Baldwin, John R., Maynard, Jean-Pierre, Sabourin, David and Zietsma, Danielle. 2001. *Differences in Interprovincial Productivity Levels*. Statistics Canada Catalogue no. 11F0019. Ottawa. 37 p. Analytical Studies Branch Research Paper Series, no. 180. (Retrieved March 17, 2004, from <http://www.statcan.ca/english/research/11F0019MIE/11F0019MIE2001180.pdf>).
- Barro, Robert J., and Lee, Jongwha. 1993. International Comparisons of Educational Attainment. *Journal of Monetary Economics*, 32, 363-394. (Retrieved March 29, 2004, from Elsevier SD Backfile Economics database).
- Barro, Robert J., and Lee, Jongwha. 2000. International Data on Educational Attainment Updates and Implications. *NBER Working Paper Series*, Working Paper 7911. (Retrieved March 29, 2004, from <http://www.nber.org/papers/w7911>).
- Beine, Michel and Coulombe, Serge. 2003. Regional Perspectives on Dollarization in Canada. *Journal of Regional Science*, 43, 541-569. (Retrieved October 9, 2008, from Scholars Portal database).
- Bernanke, Ben S. and Gurkaynak, Refet S. 2001. Is Growth Exogenous? Taking Mankiw, Romer, and Weil Seriously, *NBER Working Paper Series*, Working Paper 8365. (Retrieved December 30, 2004, from <http://www.princeton.edu/~bernanke/exogenous.pdf>).
- Caselli, Francesco. 2004. *Accounting for Cross-Country Income Differences*. (Retrieved June 5, 2008, from <http://personal.lse.ac.uk/CASELLIF/papers/handbook.pdf>).
- Coulombe, Serge. 2000. *Three Suggestions to Improve Multi-Factor Productivity Measurement in Canadian Manufacturing*. CSLS Conference on the Canada-U.S. Manufacturing Productivity Gap, January 21-22, 2000, Ottawa, Ontario, Canada. (Retrieved September 14, 2008, from <http://www.csls.ca/events/jan2000/Coulombe.pdf>).
- Coulombe, Serge. 2003. Human Capital, Urbanization and Canadian Provincial Growth. *Regional Studies*, 37 (3), 239-250.
- Demers, Michel. *Introduction of Human Capital in the Solow Model*. Lecture. ECON5500 Theory of Economic Development. Carleton University, Ottawa. 30 September 2003.
- Easterly, William and Levine, Ross. 2001. It's Not Factor Accumulation: Stylized Facts and Growth Models. (Retrieved October, 20, 2008, from <http://www.nyu.edu/fas/institute/dri/Easterly/File/its%20not%20factor%20accumulation.pdf>).

- Girard, Andrée, Maynard, Jean-Pierre and Tanguay, Marc. 2006. *Producing Hours Worked for the SNA in order to Measure Productivity: the Canadian Experience*. Statistics Canada Catalogue no. 15-206-XIE. Ottawa. 17 p. The Canadian Productivity Review, no. 4. (Retrieved August 18, 2008, from <http://www.statcan.ca/english/research/15-206-XIE/15-206-XIE2006004.pdf>).
- Gollin, Douglas. 2002. Getting Income Shares Right. *Journal of Political Economy*, 110, 458-474. (Retrieved January 3, 2005, from JSTOR database).
- Hall, Robert E., and Jones, Charles I. 1996. The Productivity of Nations. *NBER Working Paper 5812*. (Retrieved November 19, 2006, from <http://www.nber.org/papers/w5812>).
- Hall, Robert E., and Jones, Charles I. 1999. Why do some Countries Produce so much more Output per Worker than Others? *The Quarterly Journal of Economics*, 114, 83-116. (Retrieved July 23, 2004, from JSTOR database).
- Harchaoui, Tarek and Tarkhani, Faouzi. 2001. *A Comprehensive Revision of Statistics Canada's Estimates of Capital Input for the Productivity Accounts*. Statistics Canada. Ottawa. 12 p. Microeconomic Analysis Division. (Retrieved September 22, 2008, from <http://www.statcan.ca/english/concepts/15-204/note.pdf>).
- Klenow, Peter J. and Rodriguez-Clare, Andres. 2001. The Neoclassical Revival in Growth Economics: Has It Gone Too Far? *NBER Macroeconomics Annual*, 12, 73-103. (Retrieved December 15, 2004, from JSTOR database).
- Mankiw, Gregory N. 1995. The Growth of Nations. *Brookings Papers on Economic Activity*, 1995 (1), 275-326. (Retrieved September 2, 2004, from JSTOR database).
- Mankiw, Gregory N., Romer, David and Weil, David N. 1992. A Contribution to the Empirics of Economic Growth. *The Quarterly Journal of Economics*, 107, 407-437. (Retrieved December 30, 2004, from JSTOR database).
- Maynard, Jean-Pierre. 2005. *Annual Measure of the Volume of Work Consistent with the SNA: the Canadian Experience*. Statistics Canada Catalogue no. 11F0026MIE. Ottawa. 30 p. Economic Analysis methodology paper series: National Accounts, no. 5. (Retrieved September 12, 2008, from <http://www.statcan.ca/english/research/11F0026MIE/11F0026MIE2005005.pdf>).
- Paquet, Alain and Robidoux, Benoit. 2001. Issues on the measurement of the Solow residual and the testing of its exogeneity: Evidence for Canada. *Journal of Monetary Economics*, 47, 595-612. (Retrieved August 28, 2004, from Elsevier SD Backfile Economics database).
- Psacharopoulos, George. 1994. Returns to Investment in Education: A Global Update. *World Development*, 22, 1325-1343. (Retrieved March 29, 2004, from Elsevier SD Backfile Economics database).

- Psacharopoulos, George. 2002. Returns to Investment in Education - A Further Update. *The World Bank, Policy Research Working Paper, no. 1814*. (Retrieved September 23, 2008, from [http://siteresources.worldbank.org/EDUCATION/Resources/278200-1099079877269/547664-1099079934475/547667-1135281504040>Returns\\_Investment\\_Edu.pdf](http://siteresources.worldbank.org/EDUCATION/Resources/278200-1099079877269/547664-1099079934475/547667-1135281504040>Returns_Investment_Edu.pdf)).
- Romer, David. 2001. *Advanced Macroeconomics* (2<sup>nd</sup> ed). New York: Mc-Graw-Hill/Irwin.
- Senhadji, Abdelhak. 2000. Sources of Economic Growth: An Extensive Growth Accounting Exercise. *IMF Staff Papers*, 47, 129-158. (Retrieved July 17, 2004, from JSTOR database).
- Solow, Robert M. 1956. A Contribution to the Theory of Economic Growth. *The Quarterly Journal of Economics*, 70, 65-94. (Retrieved January 30, 2005, from JSTOR database).
- Solow, Robert M. 1957. Technical Change and the Aggregate Production Function. *Review of Economics and Statistics*, 39, 312-320. (Retrieved July 17, 2004, from JSTOR database).
- Statistics Canada. 1988. *Provincial economic accounts : historical issue, 1961-1986*. Statistics Canada Catalogue no. 13-213S. Ottawa. 465 p.
- Statistics Canada. 1989. *Schooling and Major Field of Study*. Statistics Canada Catalogue no. 93-110-XPB. Ottawa. 731 p. Nation Series, 1986 Census.
- Statistics Canada. 2001. *Investment flows and Capital Stocks – Methodology 2001* Statistics Canada. Ottawa. 31p. Investment and Capital Stock Division. (Retrieved May 17, 2004, from [http://www.statcan.ca/english/sdds/document/2820\\_D1\\_T9\\_V1\\_B.pdf](http://www.statcan.ca/english/sdds/document/2820_D1_T9_V1_B.pdf)).
- Statistics Canada. 2006. *How to Cite Statistics Canada Products*. Statistics Canada Catalogue no. 12-591-XWE. Ottawa. Version updated March 31. Ottawa. <http://www.statcan.ca.proxy.bib.uottawa.ca/english/freepub/12-591-XIE/12-591-XIE2006001.htm>.
- Summers, Robert and Heston, Alan. 1991. The Penn World Tables (Mark 5): An Expanded Set of International Comparisons, 1950-1988. *The Quarterly Journal of Economics*, 106, 327-369. (Retrieved April 9, 2005, from JSTOR database).
- Temple, Jonathan. 1999. The New Growth Evidence. *Journal of Economic Literature*, 37, 112-156. (Retrieved October 28, 2008, from JSTOR database).
- Vaillancourt, Francois. 1995. The Private and Total Returns to Education in Canada, 1985. *The Canadian Journal of Economics*, 28, 532-554. (Retrieved February 24, 2004, from JSTOR database).

Young, Alwyn. 1995. The Tyranny of Numbers: Confronting the Statistical Realities of the East Asian Growth Experience. *The Quarterly Journal of Economics*, 110, 641-680. (Retrieved July 25, 2004, from JSTOR database).

Zietsma, Danielle and Sabourin, David. 2001. Interprovincial Productivity Differences. *Canadian Economic Observer*. Vol. 14, no. 8. Statistics Canada Catalogue no. 11-010-XPB. p. 3.1-3.10. (Retrieved July 17, 2004, from ProQuest database).