Conditional Labor Productivity Convergence in Canada

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The purpose of this paper is to investigate the determinants of labor productivity growth at the provincial level in Canada over the 1966-92 period. The model considers differences in the initial level of labor productivity, human capital characteristics, private and public investments, and industry mix as explanatory variables in determining productivity growth. The main results are the following. The rate of human capital accumulation (its effect becomes more significant once the effects of inter-provincial migration are accounted for) and public investment (excluding government investment on non-residential construction) are positively correlated with productivity growth while the initial level of productivity and government consumption are negatively correlated with productivity growth. On the other hand, private investment is not significantly correlated with provincial productivity growth reflecting the high degree of private capital mobility between regions in Canada. Relatively slow convergence we observe in Canada appears, in part, to be due to differences in the industry mix across provinces. (*JEL* Classifications: O51, R11)

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I. Introduction

A number of research empirical papers provide an understanding of the growth process. Most of these papers rely on cross-country data to test convergence within the framework of Solow's neoclassical growth model. Mankiw, Romer and Weil (1992) and Knight, Loayza and Villanueva (1993), extending a simple neoclassical growth model to include a proxy for human capital, suggest that human capital is significant in explaining cross-country variation in growth. Even within a large sample of countries, different countries tend to converge to the same level of productivity once differences in human capital are controlled for, thereby suggesting that poor countries need to develop their human capital before they have any chance of catching-up to the productivity levels of rich countries.

There also have been some empirical studies focusing on regional convergence. These are becoming increasingly important since many industrialized countries face difficulty financing regional distribution and stabilization programs. Barro and Sala-i-Martin (1992a, c) analyze unconditional convergence for the United States. Holtz-Eakin (1993b) extends their analysis to test conditional convergence in the United States. He finds that, in addition to the initial level of output per worker, both physical and human capital accumulation, the rates of labor force growth, technological progress, and depreciation are significantly correlated with growth in output per worker.[1]

[1]There are other regional studies focusing on the U.S. states. Carlino and Voith (1992) use a labor demand equation to analyze the determinants of aggregate productivity for the U.S. states. They find that differences in aggregate state productivity can be attributed to human capital characteristics, investment in infrastructure, metropolitan structure, a state's industrial structure and other state-specific effects. Helms (1985) study suggests that increases in state and local taxes significantly retard economic growth when the revenue is used to fund transfer payments. However, when the revenue is used instead to finance public services (such as educating, highways, and public health and safety), the negative influence of tax may be outweighed by the value of services. Moreover, Mofidi and Stone (1990) report similar findings. On the other hand, Holtz-Eakin (1993a) does not find additional benefits to private output stemming from investing in state and local government capital. Canto and Webb (1983) use a neoclassical model with mobile and immobile factors to highlight the importance of both state and federal fiscal policies in determining the overall economic performance of a region.

In addition, there have been a number of recent studies focused on regional growth in Canada. Coulombe and Lee (1995) focus on regional disparities in Canada over the 1961-91 period, and conclude that there is evidence of convergence in Canada for different measures of per capita income and output. Lee and Coulombe (1995) extend this analysis and suggest that labor productivities converges faster than per capita incomes in Canada. Helliwell (1994) discusses the role of migration on convergence. He finds that both interprovincial and international migration have been directed toward the richer provinces. Surprisingly, there has been no empirical analysis that considers the effects of human capital, private and public investment, migration and industrial structure on productivity growth and convergence in Canada. However, determining the factors that are pertinent to regional productivity growth and convergence are particularly important for policymakers, since these factors can guide them to allocate scarce resources more effectively. The purpose of this paper is to determine these factors.

The paper finds that there is a significant negative relationship between the initial level of productivity and productivity growth suggesting that there is a tendency for convergence in Canada. This convergence process becomes faster once the determinants of steady state output across provinces are controlled for. Private investment is not significantly correlated with productivity growth, indicating high degree of capital mobility causing the rate of return on private capital to be equalized across provinces. On the other hand, public investment excluding government investment in non-residential construction is positively correlated with productivity growth. A proxy for human capital becomes more significant once the inter-provincial migration factor is added as an extra explanatory variable, suggesting that migrants tend to carry some human capital with them. The ratio of government consumption to output is negatively correlated with productivity growth.

The rest of the paper is organized as follows. The following section sets up the model. Section III discusses the data and empirical results. The last section draws conclusions.

II. The Model

A simple neoclassical model only considers two inputs, namely capital and labor in the production function. However, recent empirical studies (e.g. Carlino and Voith, 1992; Holtz-Eakin, 1992a) suggest that we need to consider other factors such as human capital and different industrial structures in understanding the growth process. Therefore, we use an extended version of the neoclassical model to account for differences in various types of investment and industrial structures. We first introduce an extended neoclassical model and then describe its steady state. The dynamics outside the steady state are described last.

A. Augmented Neoclassical Model

The behavior of public sector capital can be different from that of private sector capital in the economy.[2] We, therefore, extend the Mankiw, Romer, and Weil model (1992) to include public sector capital by assuming the following Cobb-Douglas production function at time t:[3]

$$Y_t = H_t^{\gamma} K_t^{\alpha} G_t^{\beta} (A_t L_t)^{1-\gamma-\alpha-\beta} \tag{1}$$

where Y_t is real output, H_t is the stock of human capital, K_t is the private stock of physical capital, G_t is the public stock of physical capital,[4] L_t is raw labor, and A_t is labor-augmenting technology. The production function implicitly assumes decreasing returns to private inputs unless public capital expands at the same rate.

A_t and L_t are assumed to grow at constant rates, m and n, respectively:

$$A_t = A_0 e^{mt} \tag{2}$$
$$L_t = L_0 e^{nt}. \tag{3}$$

$A_t L_t$ denotes the effective labor force which grows at a rate $m + n$. Each variable is divided by effective labor in order to facilitate our analysis. Let lower case letters with a hat represent quantities per effective unit of labor. Then rewriting production function (1) in terms

[2]See Aschauer (1989) and Barro and Sala-i-Martin (1992b).

[3]Although this framework is initially developed to explain economic growth for a closed economy, it is widely used for analyzing cross-country, cross-regional differences in economic growth. The framework is rich enough to explain both convergence and divergence depending on whether countries/regions are assumed to be at the same steady state or different steady states. See Holtz-Eakin (1993a, 1993b), Lee (1996a) and Mankiw (1995).

[4]Externalities associated with public capital is not explicitly introduced in the model. However, a significantly high rates of return to public capital would suggest the presence of externalities.

of the effective labor force yields the following:

$$\hat{y}_t = \hat{h}_t^{\gamma} \hat{k}_t^{\alpha} \hat{g}_t^{\beta}. \tag{4}$$

We assume that the savings ratios are exogenously determined either by savers' preferences or by government policy. Therefore, human, private and public capital per effective unit of labor are accumulated according to the following expressions:

$$\dot{\hat{h}}_t = s_h \hat{y}_t - (m + n + \delta)\hat{h}_t \tag{5}$$
$$\dot{\hat{k}}_t = s_k \hat{y}_t - (m + n + \delta)\hat{k}_t \tag{6}$$
$$\dot{\hat{g}}_t = s_g \hat{y}_t - (m + n + \delta)\hat{g}_t, \tag{7}$$

where s_h, s_k and s_g are the fractions of income invested in human, private and public capital respectively. All three types of capital are assumed to depreciate at the same rate, δ. The term $(m + n + \delta)$ reflects capital requirement necessary to equip effective labor force growth.

B. The Steady State

Equations (5), (6) and (7) imply that the levels of human, private and public capital per effective unit of labor are constant in the steady state as shown by the following expressions:

$$\hat{h}^* = \left(\frac{s_k^{\alpha} s_g^{\beta} s_h^{1-\alpha-\beta}}{m + n + \delta} \right)^{\frac{1}{(1-\gamma-\alpha-\beta)}} \tag{8}$$

$$\hat{k}^* = \left(\frac{s_k^{1-\beta-\gamma} s_g^{\beta} s_h^{\gamma}}{m + n + \delta} \right)^{\frac{1}{(1-\gamma-\alpha-\beta)}} \tag{9}$$

$$\hat{g}^* = \left(\frac{s_k^{\alpha} s_g^{1-\alpha-\gamma} s_h^{\gamma}}{m + n + \delta} \right)^{\frac{1}{(1-\gamma-\alpha-\beta)}}. \tag{10}$$

Substituting equations (8), (9) and (10) into production function (4) yields the steady state value of effective-labor productivity:

$$\hat{y}^* = \left(\frac{1}{m + n + \delta} \right)^{\frac{(\gamma+\alpha+\beta)}{(1-\gamma-\alpha-\beta)}} s_h \frac{\gamma}{(1-\gamma-\alpha-\beta)} s_k \frac{\alpha}{(1-\gamma-\alpha-\beta)} s_g \frac{\beta}{s(1-\gamma-\alpha-\beta)} \tag{11}$$

In reality, we do not observe output per effective unit of labor. The model, however, can be expressed in terms of output per worker to predict the steady state level of output. Let y denote output per worker, then combining equations (2) and (11) yields:

$$\ln y_t^* = -\left(\frac{\gamma+\alpha+\beta}{1-\gamma-\alpha-\beta}\right)\ln(m+n+\delta) + \left(\frac{\gamma}{1-\gamma-\alpha-\beta}\right)\ln s_h$$
$$+\left(\frac{\alpha}{1-\gamma-\alpha-\beta}\right)\ln s_k + \left(\frac{\beta}{1-\gamma-\alpha-\beta}\right)\ln s_g + \ln A_0 + mt \ldots \tag{12}$$

C. Transitions to the Steady State

Expression (12) implicitly assumes that the economy is at steady state. However, in the presence of random shocks and various government policies, it is more likely the economy would be out of steady state. Therefore, in order to describe dynamics outside steady state, we need to assume that the economy is sufficiently close to but not at steady state. We can then approximate transitional dynamics around the steady state by log-linearizing output around it, yielding the following result:

$$\frac{d \ln \hat{y}_t}{dt} = \lambda(\ln \hat{y}^* - \ln \hat{y}_t), \tag{13}$$

where $\lambda = (1 - \gamma - \alpha - \beta)(m + n + \delta)$.[5] The parameter λ indicates the speed of convergence: how fast output per effective labor is approaching its steady state.

In order to estimate expression (13), we integrate equation (13) from t_0 to $t_0 + T$:

$$\ln \hat{y}_{t_0+T} = (1 - e^{-\lambda T}) \ln \hat{y}^* + e^{-\lambda T} \ln \hat{y}_{t_0}. \tag{14}$$

Transforming equation (14) into observable output per worker and substituting equation (12) into the resulting expression produces the following:

$$\frac{1}{T}\ln\left(\frac{y_{t_0+T}}{y_{t_0}}\right) = -\left(\frac{1-e^{-\lambda t}}{T}\right)\ln y_{t_0} - \left(\frac{1-e^{-\lambda T}}{T}\right)\left(\frac{\gamma+\alpha+\beta}{1-\gamma-\alpha-\beta}\right)\ln(m+n+\delta)$$
$$+\left(\frac{1-e^{-\lambda T}}{T}\right)\left(\frac{\gamma}{1-\gamma-\alpha-\beta}\right)\ln s_h$$
$$+\left(\frac{1-e^{-\lambda T}}{T}\right)\left(\frac{\alpha}{1-\gamma-\alpha-\beta}\right)\ln s_k \tag{15}$$

[5]This relationship is derived by linearizing the natural logarithm of output per effective worker around the steady state using a Taylor series approximation. The derivation is available from the author upon request.

$$+\left(\frac{1-e^{-\lambda T}}{T}\right)\left(\frac{\beta}{1-\gamma-\alpha-\beta}\right)\ln s_g+\left(\frac{1-e^{-\lambda T}}{T}\right)\ln A_{t_0}+m.$$

III. Empirical Analysis

This section presents the estimated models and describes the data. Following the description of the data, empirical results are discussed.

A. *Econometric Specification*

Since Canada is composed of ten provinces, an analysis using cross-sectional data will result in a severe degrees of freedom problem. In order to eliminate this problem, we create a sample of pooled cross-section and time series data by dividing provincial data series from 1968 to 1992 into three sub-periods: 1968-76, 1976-84, 1984-92. Therefore, equation (15) is re-expressed as the following with the addition of an error term, $\mu_{i,t}$:

$$\frac{1}{T}\ln\left(\frac{y_{i,t_0+T}}{y_{i,t_0}}\right)=\theta_0+\theta_1\ln y_{i,t_0}+\theta_2\ln(m+n_{i,t}+\delta_{i,t})+\theta_3\ln s_{h,i,t} \\ +\theta_4\ln s_{k,i,t}+\theta_5\ln s_{g,i,t}+\theta_6\ln A_{i,t_0}+\mu_{i,t}, \tag{16}$$

where, $i=1,\ \dots,\ 10$; $t=1,2,3$ and $T=8$. Therefore, t here refers to each sub-period.

Mobility of factors across provinces is crucial for understanding the dynamics of regional growth in Canada. Therefore, equation (16) is modified to consider the open economy aspects by replacing savings rates s_h, s_k and s_g with respective investment rates Φ^h, Φ^k and Φ^g. At the same time, we allow regional differences in industrial structure as in Barro and Sala-i-Martin (1992a, c) and Carlino and Voith (1992).[6] Thus, equation (16) is modified as:

$$\frac{1}{T}\ln\left(\frac{y_{i,t_0+T}}{y_{i,t_0}}\right)=\phi_0+\phi_1\ln y_{i,t_0}+\phi_2\ln(m+n_{i,t}+\delta_{i,t})+\phi_3\ln\Phi^h_{i,t} \\ +\phi_4\ln\Phi^k_{i,t}+\phi_5\ln\Phi^g_{i,t}+\sum_{j=6}^{8}\phi_j\ln x_{i,j,t}+\varepsilon_{i,t}. \tag{17}$$

[6]Mankiw *et al.*(1991) point out the possibility of permanent differences in production functions causing a correlation between different $A(0)$'s and the initial level of productivity. Allowing regional differences in the industry mix would reduce this possibility.

B. Data

Equations (17) is estimated using a sample of ten cross-section and three time series data obtained from dividing annual observations from 1968 to 1992 into three sub-periods. The data for each sub-period are averages of 8 years. The following discussion briefly explains variables used in the paper, and more detailed explanations are given in the Appendix.

The dependent variable used is the annual average change in productivity (real GPP per worker)[7] over the eight-year subperiod.

The model is initially estimated using OLS. However, a series of heteroskedasticity tests rejects the null hypothesis of homoskedasticity at the 5% level of significance. Therefore, White's (1980) heteroskedastic-consistent covariance matrix was used to correct the estimates of unknown form of heteroskedasticity. The initial level of productivity ($y_{i,0}$) used in estimating equation (18) is the level of real GPP per worker in the first year of each sub-period. The next explanatory variable is the natural logarithm of the sum of labor-augmented technical progress (0.02), the average growth rate of employment and the depreciation rate for the capital stock.[8] The human capital investment rate is proxied by the percentage of the working-age population in university ($\Phi^h_{i,t}$). It is approximated by multiplying the gross enrollment rate in university by the fraction of working-age population that is supposed to be in university (aged 15-24).[9] The next set of The next set of explanatory variables used is the natural logarithm of the average ratios of four different real investments to real investments to real GPP: the ratio of private sector investment[10] to GPP ($\Phi^k_{i,t}$); the ratio of public sector investment[11] to

[7]The Conference Board's estimates of provincial implicit price indices are used to calculate real GPP in order to capture regional differences in output prices.

[8]The depreciation rate was calculated based on the capital stock excluding residential capital stock since it is not publicly available. This, however, is not likely to change the results significantly.

[9]Using the average fraction of working-age population in high school does not alter the basic results. See Mankiw (1995) and Mankiw, Romer and Weil (1992) for some of the shortcomings associated with these proxies for measuring the human capital investment rate.

[10]Private sector investments refers to the investment undertaken in the provinces.

[11]Institutions and government departments are defined as the public sector in this paper. Defense related spending is not included. Public sector investment

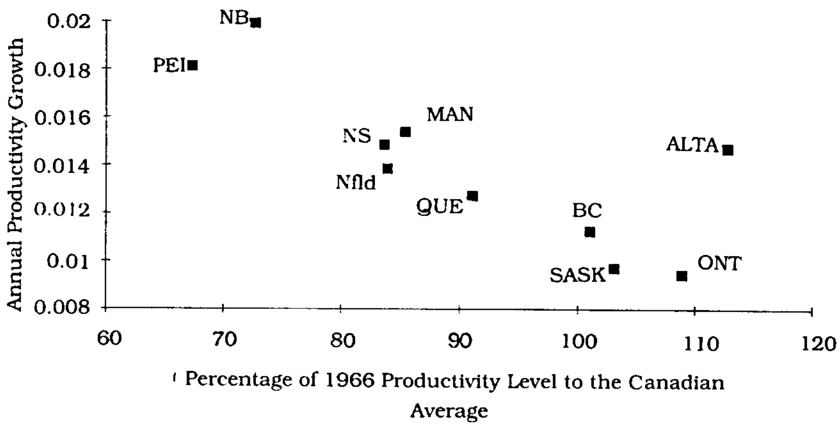

FIGURE 1

GROWTH RATE VERSUS INITIAL LEVEL OF PRODUCTIVITY

GPP ($\Phi^{g}_{i,t}$) and further decomposing this ratio into the ratios of public investment excluding government investment in non-residential construction[12] to GPP ($\Phi^{g-if}_{i,t}$) and government investment in non-residential construction to GPP ($\Phi^{if}_{i,t}$). In addition, the natural logarithm of the ratios of real government consumption to real GPP ($gc_{i,t}/y_{i,t}$) and taxes to real GPP ($tax_{i,t}/y_{i,t}$) are also considered.

In order to account for differences in resource endowments and industrial structure, the natural logarithm of the average ratios of three sectors' GPP to real GPP ($x^{j}_{i,t}$) are used: the primary, manufacturing and construction sectors.

Lastly, the net inter-provincial migration rate ($mr_{i,t}$) is used to consider the effects of migration on the convergence process.

C. Empirical Results

Equation (15) predicts that economies that begin with a lower level of productivity will grow faster during their transition path to the steady state. Figure 1 confirms this process since the plot of the annual growth rate and the initial level of productivity results in a negative slope. Figure 2 provides further evidence of this convergence process where

includes capital expenditures on machinery and equipment, building construction and engineering construction by the three levels of government (federal, provincial and municipal governments).

[12]Government investment in non-residential construction includes spending on highways, bridges and office buildings.

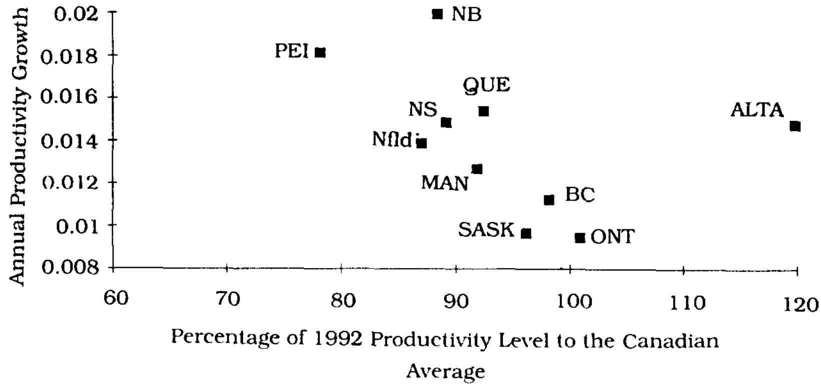

FIGURE 2

GROWTH RATE VERSUS TERMINAL LEVEL OF PRODUCTIVITY

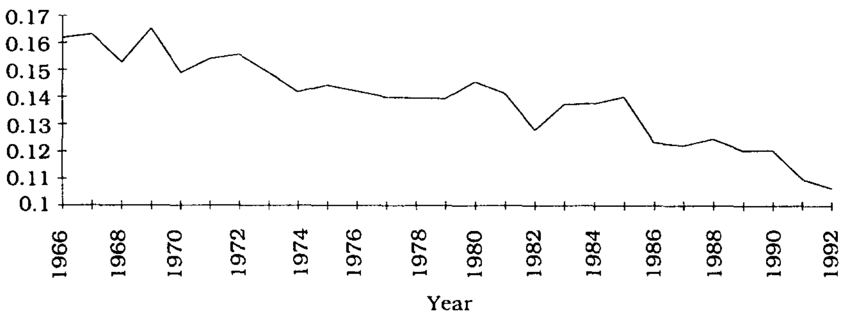

FIGURE 3

DISPERSION OF GPP PER WORKER

the slope becomes steeper when the annual growth rate is plotted against the terminal level of productivity. But the slope does not become perfectly vertical in Figure 2 and there are three possible ways to interpret this. First, the convergence process may not be over, and Canada may be still in the process of moving towards the steady state. Second, it is possible that each province has different steady states, suggesting that all provinces will not reach the same level of productivity in the future. Third, each province's productivity growth is endogenously determined by interactions among different types of capital and government policies. However, this possibility is not pursued any further in this paper since it is beyond the scope of this paper. Interestingly, the dispersion of productivity (measured by the unweighted cross-sectional standard deviation of the logarithm of output per work-

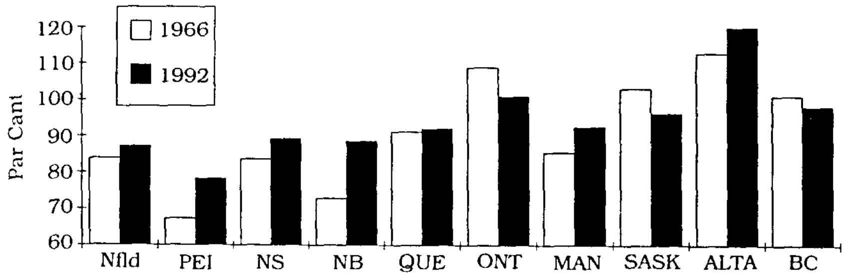

FIGURE 4
GPP PER WORKER AS A PERCENTAGE OF THE CANADIAN AVERAGE

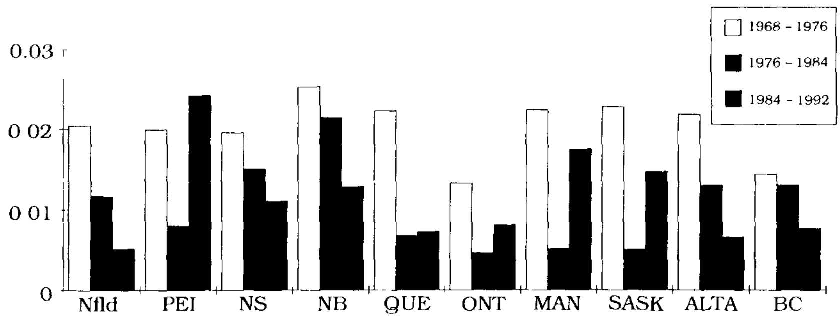

FIGURE 5
ANNUAL GPP PER WORKER GROWTH

er in each year) declined rather steadily over the years as shown in Figure 3. This steady decline has reduced the productivity gaps between the provinces. but productivity did not equalize among provinces by 1992 as shown in Figure 4.

The empirical results presented in this paper reflect variations in productivity growth across regions as well as over the three sub-periods, as shown in Figure 5, since variables in the analysis are not defined as logarithmic deviations from the Canadian average.[13] It is important to understand the relationship between productivity growth and associated factors across regions as well as over time since each will yield different information that may have different policy implications.

According to the results in Table 1, the initial level of productivity is always significant suggesting that there is a partial adjustment towards

[13]However. basic results do not change when logarithmic deviations from the Canadian average data are used.

TABLE 1

REGRESSIONS OF GROWTH IN ECONOMIC VARIABLE (1968-1992)

	(1)	(2)	(3)	(4)	(5)	(6)
Constant	0.0967*	0.195**	0.193**	0.288**	0.226**	0.296**
	(0.0172)	(0.0583)	(0.0545)	(0.0785)	(0.0594)	(0.0861)
$\ln(y_{i,0})$	-0.0240**	-0.0308**	-0.0321**	-0.0399**	-0.0463**	-0.0510**
	(0.00494)	(0.00812)	(0.00758)	(0.00929)	(0.0117)	(0.0122)
$\ln(0.02+n_{i,t}+\delta_{i,t})$		-0.00253	-0.00490	0.00913	-0.00708	0.00388
		(0.00849)	(0.00867)	(0.0109)	(0.00836)	(0.0122)
$\ln(\Phi^{h}_{i,t})$		0.00810*	0.00395	0.0117*	0.110*	0.0163**
		(0.00526)	(0.00578)	(0.00681)	(0.00708)	(0.00816)
$\ln(\Phi^{k}_{i,t})$		-0.00609	-0.00724	-0.00416	-0.00769	-0.00528
		(0.00809)	(0.00739)	(0.00840)	(0.00655)	(0.00790)
$\ln(\Phi^{g}_{i,t})$		0.00189				
		(0.00572)				
$\ln(\Phi^{g,y}_{i,t})$			0.00778**	0.00470	0.00575*	0.00358
			(0.00323)	(0.00349)	(0.00328)	(0.00361)
$\ln(\Phi^{y}_{i,t})$			-0.00628**	-0.00320	-0.00302	-0.000960
			(0.00355)	(0.00352)	(0.00382)	(0.00383)
$\ln(gc_{i,t}/y_{i,t})$					-0.0121*	-0.0110*
					(0.00767)	(0.00763)
$\ln(x^{primary}_{i,t})$		0.0121**	0.0148**	0.0144**	0.0115**	0.0115**
		(0.00299)	(0.00254)	(0.00225)	(0.00307)	(0.00290)
$\ln(x^{manu}_{i,t})$		0.0135**	0.0167**	0.0180**	0.0125**	0.0139**
		(0.00361)	(0.00337)	(0.00363)	(0.00408)	(0.00461)
$\ln(x^{const}_{i,t})$		0.00418	0.00160	0.00514	0.00395	0.00646**
		(0.0102)	(0.00940)	(0.00854)	(0.00878)	(0.00825)
$mr_{i,t}$				-0.000391*		-0.000300
				(0.000259)		(0.000279)
Implied λ	0.0266*	0.0354**	0.0371**	0.0481**	0.0578**	0.0655**
	(0.00611)	(0.0108)	(0.0102)	(0.0151)	(0.0185)	(0.0206)
Adj R^2	0.40	0.47	0.50	0.49	0.51	0.49
$\hat{\sigma}$	0.0051	0.0048	0.0047	0.0048	0.0047	0.0048
Reset(4)	0.753	1.359	0.809	0.652	0.356	0.427

Note: Corrected for heteroskedasticity using White's heteroskedastic-consistent covariance matrix estimation. Numbers in the parentheses indicate standard errors. We reject the null hypothesis of omitted variables according to the Ramsey Specification Test Statistics at the 5% level so significance

*: significant at 10 percent level

**: significant at 5 percent level based on a one-tailed test.

the steady states In regression (1), the initial productivity level appears as the only right-hand-side variable. It is highly significant and explains 40 percent of the variation in productivity growth. According to regression (1), the estimated value for the speed of convergence is 0.0266 per year, implying that the economy moves halfway to the steady state in about 26 years.

Regression (2) includes a proxy for the ratio of human capital investment to GPP, the log of the business and non-business investment shares and different industrial output shares. The human capital measure is positively correlated with productivity growth[14] but other investment shares are not significantly correlated with productivity growth. Primary and manufacturing output shares are also positively correlated with productivity growth. The speed of convergence increases from 0.0266 to 0.0354, once we control for differences in investment shares and industrial structures across provinces. Decomposing the non-business investment share into a non-business investment share excluding government investment in non-residential construction and a government investment share in non-residential construction as shown in regression (3) does not change the basic results other than that the non-business investment share excluding government investment in non-residential construction is significant. Regressions (5) and (6) show that government consumption is negatively correlated with productivity growth. The empirical results pertaining to each variable are discussed in greater detail below.

Initially, the model was estimated without taking account of inter-provincial migration. That is, the speed of convergence in regressions (1), (2), (3) and (5) implicitly includes the impact of inter-provincial migration. In order to filter out the effects of this migration, the migration rate is added to regressions (3) and (5). The addition of the migration rate as a regressor causes the coefficient on human capital proxy in regressions (3) and (5) to become much more significant as shown by corresponding *t*-ratios in regressions (4) and (6) and increases the speed of convergence. This suggests that the impact of human capital measure on productivity growth is greater once the inter-provincial migration factor is taken into account. The reason is that highly educated migrants may move from low productivity to high productivity provinces, lured by higher standards of living and higher wages, thereby slowing down the convergence process.[15] This suggests that we

[14]This proxy becomes much more significant when regressions are performed using data based on deviations from the Canadian average.

[15]In other words, regressions (3) and (5) have lower speeds of convergence compared to those in regressions (4) and (6) where the role of migration is explicitly controlled.

need to explore a step beyond a simple neoclassical model.[16]

There is no significant relationship between the private investment share and productivity growth. This, in turn, suggests that the marginal productivity of physical capital decreases rapidly, probably due to the high degree of private capital mobility in Canada. Thomas (1993) shows that there is no positive relationship between regional personal savings and private investment in Canada.[17] This, in turn, suggests that the flow of private savings from rich to poor regions in Canada dampens the effects of regional disparities caused by regional differences in savings. Furthermore, the relationship may reflect the hypothesis that rich regions generate higher savings but these savings are likely to be redistributed across the provinces. Thus, capital inflows from rich to poor regions are partly responsible for the convergence process. In any case, an increase in the saving rate in one region does not necessarily translate into a higher investment rate for that region since its effect may spill over to other regions due to the high degree of private capital mobility.

Public investment excluding government investment in non-residential construction is positively correlated with productivity growth in regressions (3) and (5). Since there exist large disparities in government savings, transfers tend to reduce the disparities causing public investment to be more equally distributed than public savings, thereby reducing regional disparities.[18] The effects of capital mobility and transfers tend to dampen regional disparities caused by differences in regional savings. However, private capital flows from rich to poor regions may also have been induced by government policies such as tax concessions and subsidies and therefore do not necessarily reflect an outcome of an efficient economy.[19]

[16]This is contrary to a simple neoclassical growth framework which predicts that exogenous in-migration will have a negative effect on growth per worker and that the addition of the migration rate as a regressor will lower the speed of convergence, since workers are motivated to move from low-wage to high-wage area.

[17]In contrast to the significant positive relationship in savings and investment across countries.

[18]Indeed, Thomas finds a negative relationship between government savings and investment.

[19]Interestingly, investment is significantly correlated with output per worker in cross-country studies such as in Mankiw, N., Romer D., and Weil, D.N. (1992) and Knight, M., Loayza, N , and Villanueva, D. (1993).

Regression (5) considers the effects of adding the share of government consumption[20] to output. It is negatively correlated with productivity growth. Although not shown here, the share of taxes in output is not significantly correlated with productivity growth. This may be due to the fact that the government budget is not balanced each year and inefficiencies created by government are more accurately depicted by government consumption than by taxes. At the same time, taxes can be used to finance growth-enhancing programs, thereby cancelling distortions created by higher taxes.

Obviously regional differences in industrial structure impose a restriction on how fast convergence takes place in Canada. The model is not rich enough to explain detailed regional differences in industrial structure, but the empirical results indicate that these differences do play a significant role in regional growth as shown by significant coefficients for the industry variables especially those for primary and manufacturing. Perhaps, a brief discussion on regional differences in industrial structure for Canada could be helpful for understanding the issue. British Columbia is heavily dependent on logging and forestry whereas both Alberta and Saskatchewan rely on the petroleum and agriculture industries. Manitoba is another province where agriculture is an important industry. Ontario and Quebec have always been known as the manufacturing center of Canada and Atlantic provinces depend on fishery.

D. Comparisons with Other Estimated Results

Table 2 presents the estimates of equation (18) with the restriction of constant returns to scale imposed. The restriction is not rejected at the 5% level of significance for all regressions. This, in turn, suggests that there are constant returns to scale and diminishing returns to each input. Table 3 reports the speed of convergence and elasticities of investment implied by the coefficients presented in Table 2 in order to compare our results with those obtained from the cross-country and U.S. states studies as shown in Table 4. The estimates of γ (0.213, 0.217) from regressions (11) and (12) are fairly close to those for three different samples of countries (0.23) but lower than the estimate for the U.S. states (0.33).

The estimated elasticity of output with respect to capital decreases as

[20]This does not include transfer payments and interest payments on the public debt.

TABLE 2

RESTRICTED REGRESSIONS OF GROWTH ON ECONOMIC VARIABLES (1968-1992)

	(7)	(8)	(9)	(10)	(11)	(12)
Constant	0.0967*	0.192**	0.208**	0.223**	0.228**	0.234**
	(0.0172)	(0.0503)	(0.0438)	(0.0355)	(0.0427)	(0.0365)
$\ln(y_{i,0})$	−0.0240**	−0.0305**	−0.0335**	−0.0345**	−0.0468**	−0.0460**
	(0.00494)	(0.00770)	(0.00669)	(0.00603)	(0.00982)	(0.0102)
$\ln(0.02+n_{i,t}+\delta_{i,t})$		−0.00299	−0.00269	−0.000347	−0.00680	−0.00528
		(0.00674)	(0.00679)	(0.00605)	(0.00688)	(0.00600)
$\ln(\Phi^{h}_{i,t})$		0.00784*	0.00555	0.00629*	0.0113**	0.0111**
		(0.00488)	(0.00486)	(0.00446)	(0.00539)	(0.00552)
$\ln(\Phi^{k}_{i,t})$		−0.00650	−0.00532	−0.00696	−0.00742	−0.00799
		(0.00794)	(0.00818)	(0.00722)	(0.00737)	(0.00674)
$\ln(\Phi^{g}_{i,t})$		0.00163				
		(0.00554)				
$\ln(\Phi^{g\text{-}if}_{i,t})$			0.00744**	0.00671**	0.00567**	0.00549**
			(0.00294)	(0.00296)	(0.00296)	(0.00293)
$\ln(\Phi^{if}_{i,t})$			−0.00498**	−0.00569**	−0.00277	−0.00333
			(0.00357)	(0.00350)	(0.00353)	(0.00358)
$\ln(gc_{i,t}/y_{i,t})$					−0.0123*	−0.0111*
					(0.00735)	(0.00782)
$\ln(x^{primary}_{i,t})$		0.0121**	0.0144**	0.0148**	0.0113**	0.0118**
		(0.00296)	(0.00250)	(0.00238)	(0.00295)	(0.00304)
$\ln(x^{manu}_{i,t})$		0.0134**	0.0165**	0.0173**	0.0124**	0.0131**
		(0.00363)	(0.00345)	(0.00341)	(0.00391)	(0.00439)
$\ln(x^{const}_{i,t})$		0.00460	0.00181	0.00374	0.00379	0.00512
		(0.0103)	(0.0102)	(0.00880)	(0.00933)	(0.00833)
$mr_{i,t}$				−0.000158		−0.0000751
				(0.000128)		(0.000134)
Adj. R^2	0.40	0.49	0.52	0.51	0.53	0.51
σ	0.0051	0.0047	0.0047	0.0047	0.0045	0.0046
Wald Test		0.017	0.59	0.98	0.013	0.73
Reset(4)	0.753	1.290	1.150	0.687	0.361	0.425

Note: Same as in Table 1.

the sample becomes similar in terms of preferences, technology and institutions (from 0.48 to 0.29). However for Canada, the estimate of the elasticity of output for private capital is not statistically significant and the estimated elasticity of output for public capital excluding government investment in non-residential construction is between 0.11 and 0.19. This suggests that there is not much variation in private investment across Canadian provinces.

The estimated speed of unconditional convergence is 2.7 per cent per

TABLE 3
IMPLIED SPEED OF CONVERGENCE AND ELASTICITIES FROM RESTRICTED REGRESSIONS IN TABLE 2

	(7)	(8)	(9)	(10)	(11)	(12)
Implied γ		0.138*	0.101	0.113*	0.217*	0.213*
		(0.0669)	(0.0777)	(0.0711)	(0.0716)	(0.0714)
Implied α		−0.114	−0.0972	−0.125	−0.143	−0.153
		(0.136)	(0.147)	(0.130)	(0.137)	(0.123)
Implied β		0.0286				
		(0.102)				
Implied $\beta^{g\text{-}if}$			0.136*	0.120**	0.189**	0.105*
			(0.0729)	(0.0669)	(0.0727)	(0.0721)
Implied β^{if}			−0.0910*	−0.102*	−0.0532	−0.0637
			(0.0593)	(0.0611)	(0.0694)	(0.0732)
Implied λ	0.0266**	0.0349**	0.0399**	0.0404**	0.0586**	0.0574**
	(0.00611)	(0.0107)	(0.00914)	(0.00833)	(0.0157)	(0.0161)

TABLE 4
COMPARISON OF CROSS-COUNTRY AND CROSS-STATE ELASTICITIES AND THE SPEED OF CONVERGENCE

	Implied β	Implied α+β	Implied λ
U.S. states[(1)]			0.0222
			(0.0065)
U.S. states[(2)]	0.333	0.288	0.0450
	(0.0216)	(0.0267)	(0.0021)
OECD[(3)]	0.23	0.38	0.0206
	(0.11)	(0.13)	(0.0020)
Intermediate 78 countries[(3)]	0.23	0.44	0.0186
	(0.05)	(0.07)	(0.0019)
Non-oil 98 countries[(3)]	0.23	0.48	0.0142
	(0.05)	(0.07)	(0.0019)

Notes: 1. Barro and Sala-i-Martin (1992), p. 237. The sectoral composition variable is included in the estimation. The estimated results are over the 1963-86 period.
2. Holtz-Eakin (1993), p. 435. Controlled for initial income, variations in resource endowments, and urban area. The estimated results are for the 1973-86 period. The speed of convergence is calculated using the estimated parameters and data for 1986, p. 437.
3. Mankiw, Romer and Weil (1992), p. 429. The estimated results are for the 1960-85 period. Differences in the industry mix are not considered.

year for Canada. This is fairly close to 2.2 per cent per year obtained by Barro and Sala-i-Martin (1992) for the U.S. states as shown in Table 4[21] Once we include human and physical investment, and different industry mix, the estimates of speed of convergence are between 4.0 and 5.7 per cent per year. The estimates are fairly close to the one for the U.S. states (4.5 per cent) but lower than those other countries (between 1.4 and 2.1 per cent). There are at least two reasons why the estimates of Canada's conditional speed of convergence are higher than those for cross-country convergence. First, our estimates account for differences in the industry mix while the estimates of cross-country convergence do not take account of these differences. Second, the estimated elasticity of output with respect to physical capital is 0.19,[22] suggesting that diminishing returns to physical capital set in much quicker in Canada than in the United States or other countries due to high inter-provincial capital flows. This, in turn, causes a higher convergence speed. In any case, from these comparisons, we conclude that the speed of conditional convergence increases as the economies become similar, that is, the speed of convergence is faster with-in country than cross-country.

IV. Conclusion

Our main empirical results are:

C1. The relationship between the growth rate of output per worker and the initial level of output per worker is significantly negative.

C2. Regional differences in productivity growth are significantly related to differences in the industry mix.

C3. A proxy for human capital is positively associated with productivity growth. This relationship becomes much more significant when differences in inter-provincial migration are allowed for.

C4. Both private and public investment rates are not significantly related to productivity growth. This suggests that capital mobility in Canada reduces disparities caused by differences in savings across provinces.

[21]There are some differences between the two estimates. We focus on GPP per worker whereas Barro and Sala-i-Martin focused on GSP per capita.

[22]This is taking the highest number in Table 3, from regression(11). The elasticity of output with respect to private capital is not significantly different from zero.

C5. Public investment excluding government investment in non-residential construction is positively correlated with productivity growth.
C6. Government consumption is negatively related with productivity growth while taxes are not.

Given that industrial structure is slow to change and there is already high capital mobility across regions in Canada, human capital accumulation is the only factor that is likely reduce regional disparities in Canada. However, highly educated migrants may move from poor regions to rich regions where there are more opportunities thereby slowing down the convergence process. Therefore the federal government not only need to invest in human capital to benefit the country as a whole, but poor regions also need to work to attain and attract highly educated workers. The literature also suggests that the social rate of return to investment on education is higher than the private rate of return.

Appendix: Data Definitions and Sources

List of Variables and Parameters

Variable	Definition	Source
$GPPM_{i,t}$	Gross provincial product at market price	1966-1992 CANSIM (D31544, D31558, D31572, D31586, D31600, D31614, D31628, D31642, D31656, D44000, D31530)
$IT_{i,t}$	Indirect taxes net of subsidies	1966-1992 CANSIM (D12547, D12549, D12551, D12553, D12555, D12557, D12559, D12561, D12563, D12565, D20008)
$YN_{i,t}$	Gross provincial product at factor cost = $(GPPM_{i,t} - IT_{i,t})$	1966-1992
$P_{i,t}$	GPP Deflators for provinces GDP Deflators for Canada	1966-1992: Conference Board 1966-1992: CANSIM (D20556)
$Y_{i,t}$	GPP at factor cost in 1986$	1966-1992

	$= (YN_{i,t}/P_{i,t})$	
$N_{i,t}$	Employment 15 years and over	1966-1992 CANSIM (D768890, D769857, D768616, D769890, D769839, D769902, D769946, D769967, D769988, D769920, D767888)
$y_{i,t}$	GPP at factor cost per worker $= (Y_{i,t}/N_{i,t})$	1966-1992
$n_{i,t}$	Employment growth $= (N_{i,t} - N_{i,t-1})/N_{i,t-1}$	1966-1992
$POP15_{i,t}$	Population 15 years and over	1966-1992 CANSIM (D768787, D769855, D768606, D769889, D769837, D769900, D769944, D769965, D769986, D769918, D767867)
$UD_{i,t}$	Gross university enrollment rate	1961, 1971, 1975-1991 Statistics Canada Catalogue 93-110, 93-328, and 71-529
$H_{i,t}$	$= UD_{i,t}$	1961, 1971, 1975-1991
	$= UD_{i,t_0} + (T-t)\dfrac{UD_{i,T} - UD_{i,t_0}}{T - t_0}$	1962-1970, 1972-1974
$\Phi^h_{i,t}$	Proportion of working age population in university $= H_{i,t}*(POP(15_{i,t} - 24_{i,t})/N_{i,t})$	1966-1992
$IN_{i,t}^{res}$	Gross business investment in residential construction in current prices	1966-1970 CANSIM (D31733, D31755, D31773, D31799, D31821, D31843, D31865, D31887, D31909, D44025, D31711)
$IN_{i,t}^{nres}$	Gross business investment in non-residential construction in current prices	1966-1970 Statistics Canada, Unpublished Data
$I_{i,t}^{nres}$	Gross business investment in non-residential construction at 1986 prices	1966-1970 Statistics Canada, Unpublished Data

$I_{i,t}^{res}$	Gross business investment in residential construction at 1986 prices $= IN_{i,t}^{res}/(IN_{i,t}^{nres}/I_{i,t}^{nres})$	1966-1970 1971-1992 CANSIM (D44511, D44529, D44547, D44565, D44583, D44601, D44619, D44637, D44655, D44673, D44493)
$I_{i,t}^{k\text{-}res}$	Gross business investment excluding residential construction at 1986 prices	1966-1992 Statistics Canada, Unpublished Data
$I_{i,t}^{k}$	Gross business investment at 1986 prices $= I_{i,t}^{k\text{-}res} + I_{i,t}^{res}$	1966-1992
$I_{i,t}^{g}$	Gross non-business investment at 1986 prices	1966-1992 Statistics Canada, Unpublished Data
$I_{i,t}^{g\text{-}if}$	Gross non-business investment excluding government non-residential construction at 1986 prices	1966-1992 Statistics Canada, Unpublished Data
$I_{i,t}^{if}$	Gross government investment in non-residential construction at 1986 prices	1966-1992 Statistics Canada, Unpublished Data
$\Phi_{i,t}^{k}$	Ratio of business investment to output at 1986 prices $= I_{i,t}^{k}/Y_{i,t}$	1966-1992
$\Phi_{i,t}^{g}$	Ratio of non-business investment to output at 1986 prices $= I_{i,t}^{g}/Y_{i,t}$	1966-1992
$\Phi_{i,t}^{g\text{-}if}$	Ratio of non-business investment excluding government investment in non-residential construction to output $= I_{i,t}^{g\text{-}if}/Y_{i,t}$	1966-1992

$\Phi^{if}_{i,t}$	Ratio of government investment in non-residential construction to output $= I^{if}_{i,t}/Y_{i,t}$	1966-1992
$K^{k\text{-}res}_{i,t}$	Capital stock for the business sector excluding residential construction at 1986 prices	1966-1992 Statistics Canada, Unpublished Data
$K^{g}_{i,t}$	Capital stock for the non-business sector at 1986 prices	1966-1992 Statistics Canada, Unpublished Data
$\delta_{i,t}$	Depreciation rate $= \left(\frac{K^{k-res}_{i,t}}{K^{k-res}_{i,t}+K^{g}_{i,t}}\right)\left(\frac{I^{k-res}_{i,t}-(K^{k-res}_{i,t}-K^{k-res}_{i,t-1})}{K^{k-res}_{i,t-1}}\right) + \left(\frac{K^{g}_{i,t}}{K^{k-res}_{i,t}+K^{g}_{i,t}}\right)\left(\frac{I^{g}_{i,t}-(K^{g}_{i,t}-K^{g}_{i,t-1})}{K^{g}_{i,t-1}}\right)$	1966-1992
$CPI_{i,t}$	Consumer price index Provinces Canada	1966-1992 Conference Board CANSIM (D484000)
$GC_{i,t}$	Government current expenditureon goods and services in current prices	1966-1992 CANSIM (D31724, D31746, D31768, D31790, D31812, D31834, D31856, D31878, D31900, D44018, D31702)
$gc_{i,t}/y_{i,t}$	Ratio of government consumption to output $= (GC_{i,t}/CPI_{i,t})/Y_{i,t}$	1966-1992
$VA^{j}_{i,t}$	Value added for jth industry in current prices	1966-1970 Statistics Canada Catalogue 61-202
$YN^{forestry}_{i,t}$	GDP at factor cost for forestry in current prices	1971-1980 Statistics Canada Catalogue 15-203
$YN^{mining}_{i,t}$	GDP at factor cost for mining in current prices	1971-1983 Statistics Canada Catalogue 15-203

$Y^j_{i,t}$	GDP at factor cost for *j*th industry at 1986 prices	1971-1991 Statistics Canada Catalogue 61-202 Statistics Canada Catalogue 15-203
$x^{agric}_{i,t}$		Ratio of agricultural output to
GPP		
	$= VA^{agric}_{i,t}/YN_{i,t}$	1966-1970
	$= Y^{agric}_{i,t}/Y_{i,t}$	1971-1991
$x^{forestry}_{i,t}$	Ratio of forestry output to GPP	
	$= VA^{forestry}_{i,t}/YN_{i,t}$	1966-1970
	$= YN^{forestry}_{i,t}/YN_{i,t}$	1971-1980
	$= Y^{forestry}_{i,t}/Y_{i,t}$	1980-1991
$x^{mining}_{i,t}$	Ratio of mining output to GPP	
	$= VA^{mining}_{i,t}/YN_{i,t}$	1966-1970
	$= YN^{mining}_{i,t}/YN_{i,t}$	1971-1983
	$= Y^{mining}_{i,t}/Y_{i,t}$	1984-1991
$x^{pri}_{i,t}$	Ratio of primary output to GPP	
	$= x^{agric}_{i,t} + x^{forestry}_{i,t} + x^{mining}_{i,t}$	1966-1991
$x^{cons}_{i,t}$	Ratio of construction output to GPP	
	$= YN^{cons}_{i,t}/Y_{i,t}$	1966-1970
	$= Y^{cons}_{i,t}/Y_{i,t}$	1971-1991
$PDT_{i,t}$	Personal Direct Tax	1966-1992 CANSIM (D12601, D12619, D12637, D12655, D12673, D12691, D12709, D12727, D12745, D12763, D11132)
$CDT_{i,t}$	Corporate Direct Tax	1966-1992 CANSIM (D12602, D12620, D12638, D12656, D12674, D12692, D12710, D12728, D12746, D12764, D11133)

$NR_{i,t}$	Non-residential Tax	1966-1992 CANSIM (D12603, D12621, D12639, D12657, D12675, D12693, D12711, D12729, D12747, D12765, D11134)
$IT_{i,t}$	Indirect Tax	1966-1992 CANSIM (D12604, D12622, D12640, D12658, D12676, D12694, D12712, D12730, D12748, D12766, D11135)
$tax_{i,t}/y_{i,t}$	Ratio of tax to output at 1986 prices $= \{(PDT_{i,t} + CDT_{i,t} + NR_{i,t} + IT_{i,t})/CPI_{i,t}\}/Y_{i,t}$	1966-1992
$mr_{i,t}$	Net migration per 1000 of population	1966-1992 CANSIM (D122704-D122713)

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