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Abstract

We apply modern growth accounting based on the semi-endogenous growth theory of Jones (2002) to determine the sources of Canadian economic growth between 1981–2013. This framework allows us to distinguish between transition dynamics and steady-state growth, and quantify their respective contributions. We find that over 80% of the total average growth rate of output per worker of 1.24 percentage points has been due to transitional factors. Among these, the bulk of the contribution is attributed to domestic human capital growth driven by educational attainment, and global research and development (R&D) intensity. These two factors have been the primary sources of Canadian economic growth. The growth in capital-output ratio contributed a small share of 0.14 percentage points suggesting a limited role of capital accumulation. The steady-state growth over is attributed to population growth indicating modest scale effects of about 16% of the total average growth. Our results highlight that the future of Canadian productivity growth and the standard of living are closely tied to sustained growth in both domestic human capital and global R&D intensity.

JEL classification: O47, O51

Key words: Modern Growth Accounting, Economic Growth

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1 Introduction

What are the sources of Canadian economic growth? Previous research has used the traditional growth accounting framework that originated with Solow (1957) to answer this question.[1] Surprisingly, however, accounting framework based on the modern growth theory, such as that proposed in Jones (2002), has not yet been applied to determine the sources of Canadian economic growth.[2] The objective of our paper is to fill this gap. The key difference between the two approaches is that the former computes total factor productivity as a residual whereas the latter explains it in terms of underlying economic forces such as ideas-oriented research and development (R&D) and educational attainment.

The particular version of the modern growth theory that forms the basis of the accounting exercise is a semi-endogenous growth model. In this framework, total factor productivity is endogenous but long-run growth is driven by exogenous population growth (Jones (1995)). This feature offers two specific advantages. First, if the economy is growing along the balanced-growth path, then the model implies that all of growth is driven by exogenous population growth, which reflects growth in the effective number of world researchers generating productive ideas. This aspect allows us to distinguish between transition dynamics and steady-state growth, and quantify the contribution of each to growth. Second, we can also quantify the growth contributions of the forces mentioned above that have an endogenous effect on productivity.

Canadian output per hour grew at an average rate of 1.24 percentage points between 1981 and 2013 (Figure 1). We find that nearly 84% of the total average growth rate has been due to transitional factors, and attribute about 16% to steady-state growth. We also show that R&D intensity and educational attainment reflecting human capital growth have been the main transitional factors and the primary sources of growth. These two factors account for nearly 73.1% of the average growth in output per hour (that is, 0.90 percentage points of the 1.24 percentage points average growth in output per hour), with shares of R&D intensity and human capital growth of 33.09% and 40.01%, respectively. The contribution of capital accumulation is a little over 10%. Finally,

[1] See, for example, Kosempel and Carlaw (2003) and Baldwin et al. (2012).

[2] The empirical analysis in Jones (2002) is based on G-5 (France, West Germany, Japan, the United Kingdom, and the United States for 1950-1993 (43 years of data).

the contribution of steady-state growth attributed to population growth is 0.21 percentage points.

Our finding that transitional factors have had a dominant role in Canadian growth is similar to the results for the U.S. economy provided in Fernald and Jones (2014). There are, however, two notable differences. First, we find that the total contribution of educational attainment and research intensity is higher in U.S. economic growth relative to Canada, 79.61% versus 73.1%, respectively. Second, capital accumulation as reflected in capital-output growth has contributed relatively more to Canadian growth. In fact, in the U.S., the contribution of capital-output growth turns out to be negative (−7.12%) over 1981–2013 whereas in Canada it is about 11%.[3]

Despite the large role of transitional factors, the average growth rate of output per hour has been relatively stable over 1981–2013 (Figure 1). In this context the Canadian economy shares the well documented stylized fact of the U.S. growth experience. Over the past 150 years per capita real U.S. GDP has grown at a steady 2% per year (see Jones (2015)). Reconciling this stylized fact with theories of endogenous growth has been challenging because such theories predict that increases in human-capital investments, and ideas-oriented R&D should have permanent effects on growth rates. Indeed, for Canada, the evidence points to increases in both of these factors over the past decades so it is unlikely that the observed evidence indicates an economy moving along a balanced growth path. Indeed, our decomposition confirms that nearly a full percentage point of average growth since 1981 is due to transition factors. Following Jones (2002), we interpret the relatively large contribution of transition factors with a stable growth rate by distinguishing between a constant growth path and a balanced-growth path. Under the constant growth path hypothesis, all growth rates are constant but the allocations themselves need not be constant (capital stock and the stock of ideas). But unlike a balanced growth path, an economy need not remain on the constant growth path forever. This distinction helps reconcile why growth may appear to be constant (and potentially away from the steady state) if driven by transitional factors. The large shares in the growth of output per worker in Canada, due to increased educational attainment and dissemination of the stock of ideas from G-6 countries, are supportive of the constant growth hypothesis.

[3] Fernald and Jones (2014) find that capital-output growth has not contributed to growth over the 1950–2007 period.

Our results highlight that the future of Canadian productivity growth and the standard of living are closely tied to sustained growth in both domestic human capital and global R&D intensity.

The remainder of this paper is organized as follows. Section 2 describes the modern growth accounting framework. Section 3 describes the data and the growth accounting results. Section 4 presents the growth accounting results for the constant growth path decomposition. Section 5 concludes.

2 A semi-endogenous growth model

The modern growth accounting framework is based on the semi-endogenous growth theory proposed by Jones (1995) and Jones (2002).[4] Here we briefly describe an overview of the model and provide the key equations underlying the framework that we use in the later sections.

The world consist of J economies that differ in their endowments and allocations. Each economy, however, has the same production function. The only link between the economies is that they all share ideas. Production in each economy occurs using the common and cumulative stock of ideas, country-specific capital stock, and aggregate human capital. Capital stock is accumulated by foregoing consumption, and human capital is accumulated by foregoing time in the labour force. New ideas are created using the current stock of ideas and the effective world research effort. The resource constraint on labour dictates that total labour time (the time endowment of an individual is normalized to one) is divided between producing output, human capital, and ideas. Each economy is populated by an identical number of infinitely lived agents, and the population grows at a common and constant exogenous rate.

Production function: Output is produced using the production function

$$Y_{jt} = A_t^{\sigma} K_{jt}^{\alpha} H_{Yjt}^{1-\alpha}, \quad \sigma > 0,\ 0 < \alpha < 1,\ j = 1, ..., J \tag{1}$$

where Y_{jt} is output in country j, A_t is the common stock of ideas, K_{jt} is capital stock, and H_{Yjt} is the quantity of human capital.

Capital accumulation: New capital is produced via the capital accumulation process given

[4] See, also, Kortum (1997) and Segerstrom (1998).

by

$$\dot{K}_{jt} = s_{Kjt}Y_{jt} - dK_{jt}, \qquad K_{j0} > 0 \tag{2}$$

where s_{Kt} is investment rate and $0 < d < 1$ is the depreciation rate.

Human capital accumulation: The process of human capital accumulation is described as

$$H_{Yjt} = h_{jt}L_{Yjt} \tag{3}$$

$$h_{jt} = e^{\psi \ell_{hjt}}, \quad \psi > 0 \tag{4}$$

where h_{jt} is human capital per person, L_{Yjt} is the total labour employed in producing output, and ℓ_{hjt} is the amount of time an individual spends in accumulating human capital.

New ideas creation: The process of new ideas creation is described as

$$\dot{A}_t = \delta H_{At}^{\lambda} A_t^{\phi}, \qquad A_0 > 0,\ 0 < \lambda \leq 1,\ \phi < 1 \tag{5}$$

$$H_{At} = \sum_{j=1}^{J} h_{jt}^{\theta} L_{Ajt}, \quad \theta \geq 0 \tag{6}$$

where δ is a shift parameter, H_{At} is the effective world research effort and L_{Ajt} is the number of researchers in country j.[5]

Resource constraints and population growth: The labour force available for new ideas creation and output production is

$$L_{Ajt} + L_{Yjt} = L_{jt} = (1 - \ell_{hjt})N_t \tag{7}$$

$$N_t = N_0 e^{nt}, \qquad N_0 > 0,\ n > 0 \tag{8}$$

where L_{jt} denotes employment, N_t denotes the number of agents in each economy at time t which grows at a constant exogenous rate $n > 0$.

Re-writing the production function (1), and dropping the country subscript, we can obtain the key expression that forms the basis of the quantitative analysis as

$$y_t = \left(\frac{K_t}{Y_t}\right)^{\frac{\alpha}{1-\alpha}} \ell_{Y_t} h_t A_t^{\frac{\sigma}{1-\alpha}}, \quad \ell_{Y_t} \equiv L_{Yt}/L_t \tag{9}$$

[5]The parameter restriction in (5) $0 \leq \lambda < 1$ allows for the probability of duplication in research, and whether past discoveries have a positive ($\phi > 0$) or negative ($\phi < 0$) effect on current research productivity.

where $y_t \equiv Y_t/L_t$, output per person, K_t/Y_t is the capital-output ratio, and ℓ_{Y_t} is the fraction of the labour force that produces output. The economy characterized in equations (1) to (8) exhibits a stable balanced growth path along with the growth rate of output per worker, g_y is

$$g_y = \gamma n, \quad \gamma \equiv \frac{\sigma\lambda}{(1-\alpha)(1-\phi)} \tag{10}$$

Equation (10) shows a key implication of the semi-endogenous growth model that is different from endogenous growth models of Romer (1990), Grossman and Helpman (1991), and Aghion and Howitt (1992): Although productivity is endogenous, the long run growth rate depends on the exogenous population growth rate.

3 Accounting for Canadian growth

We apply the framework described in Section 2 to determine the sources of Canadian economic growth. Specifically, the production function in (9) forms the basis of the quantitative analysis, and we first describe the data required to implement the accounting exercise.

3.1 Data

Figures 1–4, show the data we use in the quantitative analysis. These data correspond to the variables in equation (9). We now describe each variable in more detail and also provide information on the parameters in (9).

3.1.1 GDP per hour

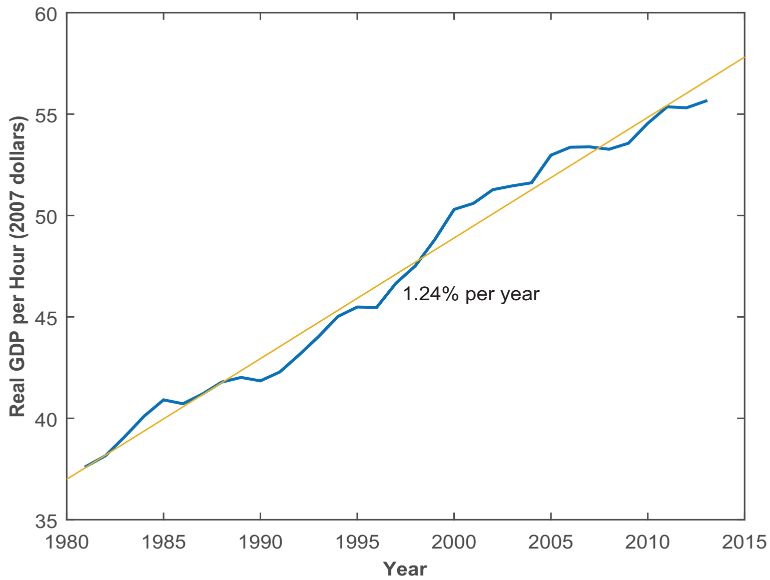
Canadian output per hour is the ratio of real GDP (2007 constant prices) to average annual hours worked.[6] Figure 1 shows a gradual trend up in GDP per hour.

3.1.2 Physical capital

Total physical capital includes flows and stocks of fixed non-residential capital, K^{NR}, flows and stocks of fixed residential capital, K^R, and net amount of durable goods, DG, owned by consumers

[6]Source: Real GDP is from CANSIM Table 384-0038 and hours data is from the OECD database.

Figure 1: Real GDP per hour (2007 dollars): 1981-2013



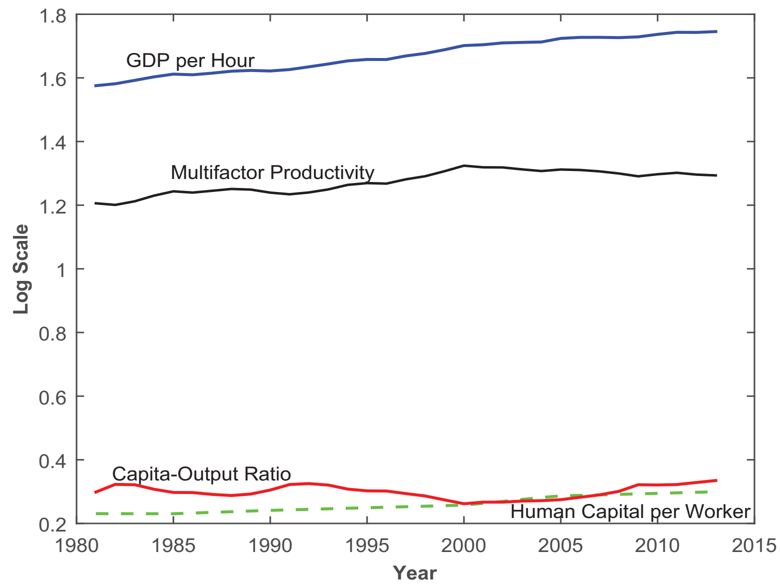
is $(1 - d_D)DG$.[7]

$$K_t = K_t^{NR} + K_t^{R} + (1 - d_D)DG \tag{11}$$

Statistics Canada defines non-residential capital stock as building and engineering construction, machinery and equipment, and intellectual property products. Residential capital stock is composed of renovations and new construction. Due to the lack of data related to depreciation rates of durable goods (d_D) for Canada, we used average depreciation rate of U.S. data over the same period which is equal to 16.2%. Figure 2 shows that the capital-output ratio slowly declines during the 1990s and then gradually increases during the 2000s.

[7] d_D shows depreciation rate of durable goods.

Figure 2: Factors of production in Canada : 1981-2013

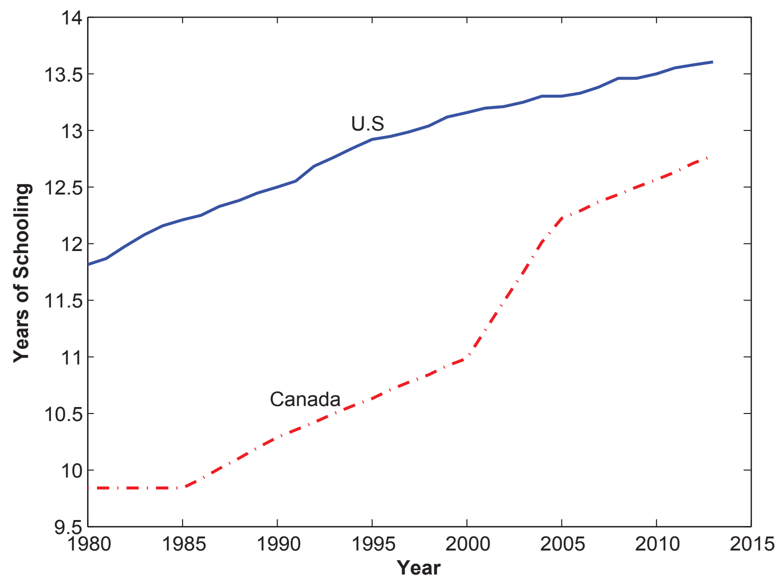


3.1.3 Human capital per person

OECD defines human capital as the "productive wealth embodied in labour, skills and knowledge". Human capital is usually estimated through education measures. Many authors have used formal education measures, like the level of educational attainment or enrolment rates, as a measure of the human capital, while others have employed indirect proxies as a way to identifying human capital (Prados de la Escosura and Rosés (2010)). Mankiw et al. (1992) employ the secondary school enrolment rate as a measure for investment rate in human capital. They, however, ignore primary and tertiary schooling and attainment of workforce, which is a source of bias in their measure. Klenow and Rodriguez-Clare (1997) and Jones (2002) use years of educational attainment using the Barro and Lee (2013) results, which includes primary, secondary, and tertiary schooling. In estimation of human capital we use two main factors: educational attainment (years of schooling) and economic rate of return to schooling.

i. Educational attainment (years of schooling): Since Barro and Lee data are available until 2010 in five-year intervals, we calculated the annual data of educational attainment using average growth of each interval dividing five. We predict data after 2010 using average growth of educational attainment. Figure 3 plots average educational attainment in Canada and U.S. for persons aged 25 and over, from 1981 to 2013. Educational attainment of Canada rises from a low of 9.84 years in 1981 to a high of 12.77 years in 2013. Although during this period Canada consistently experienced a lower rate of educational attainment compared to the U.S, it had a higher average growth rate, 0.79% compare to 0.43%.

Figure 3: Average Canadian educational attainment (aged 25 and over): 1981-2013



ii. Economic rate of return to schooling: Equation (4) is based on the literature of human capital where ψ is the economic rate of return to schooling. An additional year of schooling generates $100\psi\%$ growth in human capital. We take the estimated values of ψ from Trostel et al. (2002) and Coulombe and Tremblay (2006). Trostel et al. (2002) employed a Mincerian regression model (Mincer (1974)) and IV estimation using International Social Survey Programme Data for the period 1985-1995. This survey contains information about individual earnings, marital status, and education in a sample of employed individuals between 21-59 years old in the year of interview. The sample size for Canada includes 270 males and 318 females. Mincer (1974) modelled the natural logarithm of income (y_i) as a function of years of schooling (S_i) and the vector of observed attributes (X_i).[8]

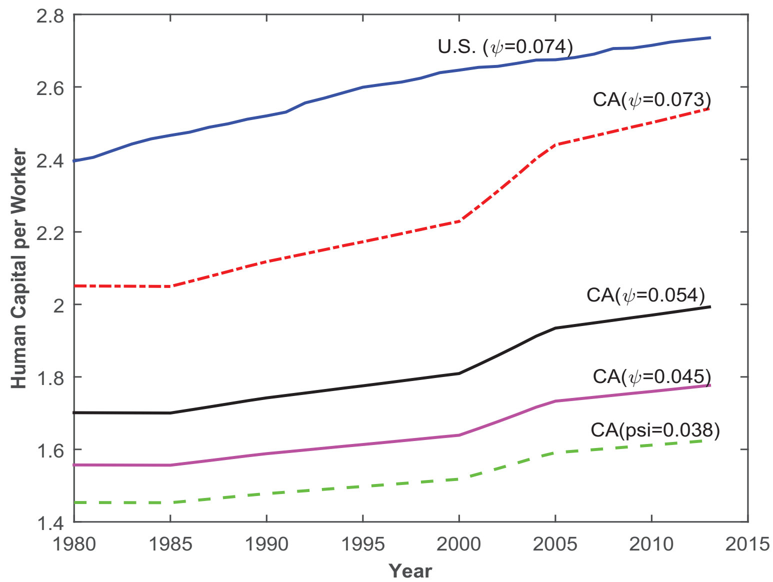
$$y_i = X_i\gamma + \psi S_i + u_i \tag{12}$$

For Canada, the estimated returns are 3.8 and 4.5 percent for males and females, respectively. For the U.S., the estimated returns are 7.4% and 9.6% for males and females, respectively. The rate of return to schooling for Canada is approximately half the U.S. equivalent. Trostel et al. (2002) claim that in general IV estimates are over 20 percent higher than OLS estimates. This point suggests that Canada's rate of return to schooling using IV should be approximately 0.054% .

Coulombe and Tremblay (2006) measured human capital by using different indicators, based on university attainment, literacy test scores, and years of schooling. They estimated macroeconomic rate of return of one additional year of education in Canada using IV estimations for period 1951-2001 of approximately 7.3%. They emphasize that their results are consistent with microeconomic Mincerian regression. Figure 4 shows human capital per worker using different rates of return to schooling for Canada and U.S. The rise of human capital per worker during this time is due to the rise in educational attainment.

[8]We note two criticisms of the Mincerian regression in estimating the rate of return to schooling. First, Manuelli and Seshadri (2014) estimate rate of return to schooling by entering 3 periods in their estimations: early childhood, schooling period and job training period. They argue that since in Mincerian regression only schooling period is considered, the rate of return to schooling is consequently underestimated. Second, Belzil and Hansen (2002) show that when the rate of return to schooling is a sequence of spline functions, the relationship between log earnings and schooling is convex while Mincerian equation is based on a linear relationship. For these reasons, Mincerian regression is not a perfect method in the estimation of rate of return to schooling but lack of data prevent us to use another method.

Figure 4: Human capital per worker: 1981-2013



3.1.4 Multifactor productivity

Following Jones (2002), we obtain multifactor productivity as a residual from (9) by imposing the normalization $\sigma = 1 - \alpha$. This measured multifactor productivity does not show any clear upward or downward trend over the entire sample 1981–2013 (see Figure 2).

To implement growth accounting we also need parameters α and γ. We assume that capital share parameter $\alpha = 1/3$, therefore $\frac{\alpha}{1-\alpha}$ is 0.5. We obtain parameter γ upon dividing growth rate of multifactor productivity by the growth rate of H_A (Jones (2002)). Using the results of Table 1 the baseline value of this parameter is $0.622/2.658 = 0.23401$ when $\psi = 0.054$.

3.2 Growth accounting

Using (9), and making the normalization that $\sigma = 1 - \alpha$, we can express the growth rate of output per person between *any two points*, denoted by hat (ˆ), as

$$\hat{y}_t = \frac{\alpha}{1-\alpha}(\hat{K}_t - \hat{Y}_t) + \hat{h}_t + \hat{\ell}_{Yt} + \hat{A}_t \qquad (13)$$

$$= \frac{\alpha}{1-\alpha}(\hat{K}_t - \hat{Y}_t) + \hat{h}_t + \hat{\ell}_{Yt} + \left(\hat{A}_t - \gamma n\right) + \gamma n \qquad (14)$$

Equation (14) adds and subtracts γn to highlight that if the economy growing along the steady state balanced growth path then almost all of the growth should be accounted for by γn. This result holds since all other hat terms on the right hand side of (14) are zero along the balanced growth path. Table 1 denotes growth rates of variables which we use in constructing the decomposition shown in (14).

TABLE 1: Average annual growth rates for Canada, 1981-2013

Growth rate of	Variable	Sample Value
Output per hour	$\dot{y}$	1.242
Capital-output ratio	$\dot{K} - \dot{Y}$	0.283
Share of labour in goods production	$\dot{l}_Y$	−0.018
G-5 + Canada labour force	$\dot{n}$	0.897
Human capital	$\dot{h}$	0.497 (0.054)
		0.349 (0.038)
		0.414 (0.045)
		0.672 (0.073)
Multifactor productivity	$\dot{A}$	0.622 (0.054)
		0.770 (0.038)
		0.705 (0.045)
		0.447 (0.073)
G-5 + Canada R&D labour	$\dot{H}_A$	2.658
Share of labour in R&D	$\dot{l}_A$	3.084

Notes: The Sample Value is in percentage points. The value in parenthesis is for parameter ψ.

3.3 Results

Table 2 shows the growth accounting results. The baseline results are highlighted in bold. First, the contribution of capital-output ratio is small 0.14 percentage points or about 11% of the total average growth in output per worker. Thus, the role of capital accumulation, the key mechanism in standard neoclassical growth theory, has been quite limited. The contribution of labour reallocation from producing goods to creating new ideas was even smaller and negative (about −0.01 percentage points).

TABLE 2: Accounting for Canada Growth, 1981-2013

			TRANSITION DYNAMICS				
		Output per Hour	Capital Intensity	Labour Reallocation	Educational Attainment	Excess Idea Growth	Steady-State Growth
ψ	γ	$\dot{y}$	$\frac{\alpha}{1-\alpha}(\hat{K}_t - \hat{Y}_t)$	$\hat{\ell}_{Yt}$	$\hat{h}_t$	$\hat{A}_t - \gamma n$	γn
0.054	**0.23401**	**1.242**	**0.141**	**−0.018**	**0.497**	**0.413**	**0.209**
		(100%)	**(11.35%)**	**(-1.44%)**	**(40.01%)**	**(33.25%)**	**(16.83%)**
0.038	0.28969	1.242	0.141	−0.018	0.349	0.511	0.259
		(100%)	(11.35%)	(-1.44%)	(28.10%)	(41.14%)	(20.85%)
0.045	0.26524	1.242	0.141	−0.018	0.414	0.467	0.238
		(100%)	(11.35%)	(-1.44%)	(33.33%)	(37.60%)	(19.3%)
0.073	0.16817	1.242	0.141	−0.018	0.672	0.296	0.151
		(100%)	(11.35%)	(-1.44%)	(54.11%)	(23.83%)	(12.15%)

Notes: This table reports the growth accounting decomposition corresponding to equation (14). The numbers in columns 2-7 are in percentage points. The numbers in parenthesis indicate percentages of the growth rate of output per hour.
The baseline results are shown in bold.

Second, increased educational attainment contributed to nearly half a percentage point or about 40% of the growth in output per worker. This suggests that human capital accumulation over the past three decades have had an important influence on long-run growth in Canada.

Third, largest share of the growth rate of output per hour is due to the increase in the stock of ideas produced by researchers in the G-6 countries. It accounts for 0.62 percentage points or over 50% of the growth rate of output per hour. The decomposition allows us to separate out the relative contribution of the increased growth in ideas relative to the steady state (the excess ideas growth) and that coming from the steady state growth. This former component is nearly 0.41 percentage points (or about 33% of the growth in output per worker). Depending upon the values of γ, the share ranges from 0.29 to 0.51 percentage points. The component of steady state growth itself is only 0.20 percentage points or about 17% of the growth rate of output per hour. This share is attributed to the growth in effective number of world researchers which is in turn driven by population growth (the scale effect). For the different values of γ, this steady state contribution ranges between 0.15 to 0.25 percentage points (i.e. under 21% of the total average growth in output per worker).

In summary, our findings suggests that the Canadian economy is not on a balanced growth path implied by the semi-endogenous growth theory. And importantly, that between 69%-78% of the growth in output per worker is attributed to educational attainment and the stock of ideas. We, therefore, conclude that the Canadian growth experience over the past 33 years is largely an outcome of transition dynamics due to increased educational attainment and the dissemination of the stock of ideas produced in G-6 countries.

4 The constant growth path decomposition

To reconcile the large contribution of accounted for by transitional factors to Canadian economic growth with the observed steady growth of 1.24% over the last 33 years, we apply the *constant growth path hypothesis* put forward by Jones (2002). The key expression for the production function that forms the basis of the quantitative analysis is

$$y_t = \left(\frac{K_t}{Y_t}\right)^{\frac{\alpha}{1-\alpha}} \ell_{Y_t} e^{\psi \ell_{h_t}} \nu \tilde{\ell}^{\gamma}_{A,t} \tilde{L_t}^{\gamma} \tag{15}$$

where $\nu = (\delta/g_A)^{\gamma/\lambda}$, g_A is the constant growth rate of A, and tilde ($\tilde{}$) denotes the aggregate for G-5 plus Canada.[9] The constant growth path is defined as a situation in which all growth is constant. A constant growth rate of output per worker can arise, for example, if each of the terms in equation (15) are growing at a constant rate. Unlike a balanced growth path, however, it does not represent a perpetual situation. We log-difference equation (15) and express the growth rate of output as

$$g_y = \frac{\alpha}{1-\alpha} g_k + g_{\ell_Y} + \psi \Delta \ell_h + \gamma g_{\ell_A} + \gamma n \tag{16}$$

[9] An assumption underlying equation (15) is that the skill level of the researchers in G-5 plus Canada is the same thus the weights, $h^{\theta}_{jt} = 1$ in equation (6), which gives that $\tilde{H}_{At} = \sum_{j=1}^{6} L_{Ajt} = \tilde{L}_{At} = \frac{\tilde{L}_{At}}{\tilde{L}_t}\tilde{L}_t = \tilde{\ell}_{At}\tilde{L}_t$, where $\tilde{L}$ and $\tilde{\ell}_A$ are the G-5 plus Canada employment and research intensity.

where the g_z denotes the constant growth rate of a particular variable z.

We base our growth accounting exercise on

$$g_y \approx \frac{\alpha}{1-\alpha} g_k + \psi \Delta \ell_h + \gamma g_{\ell_A} + \gamma n \tag{17}$$

There are two reasons: First, from section 3.3 (and as we show below in Table 3) we found that the labour reallocation from producing goods to producing ideas has a very small effect on the growth rate of output per hour. Second, equation (17) is the same as in Fernald and Jones (2014) which allows us to compare the results with those for the U.S. economy.

For the constant growth path decomposition we use the ratio of researchers engaged in R&D times one hundred divided by the total number of employment to measure research intensity. In the OECD statistics, total R&D personnel include three groups of employees: researchers, technicians and other support staff. The U.S data are available only for the number of researchers and we calculate research intensity just based on this group. In terms of research intensity, Canada had higher rate of research intensity after 2004 compare to the U.S. (Figure 5), however the proportion of GDP devoted to R&D has declined after 2004, and it is now lower than any other G5 country except U.K.

Figure 5: Research intensity: 1981-2013

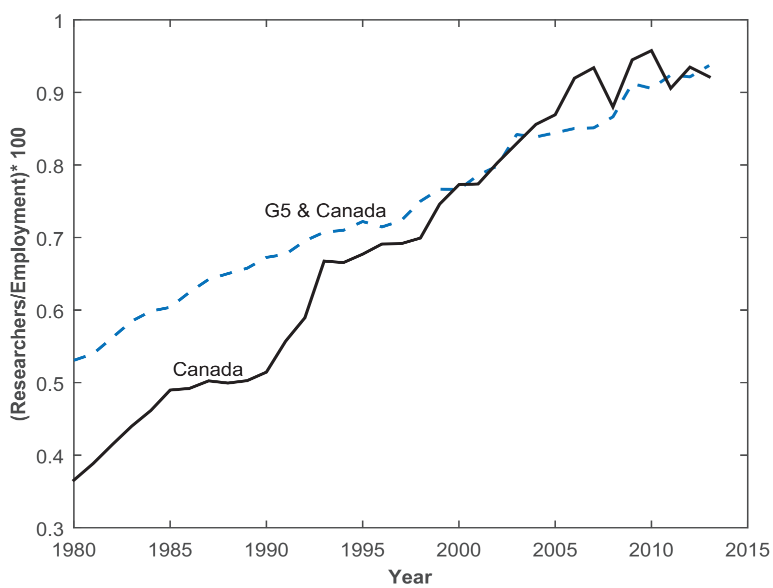
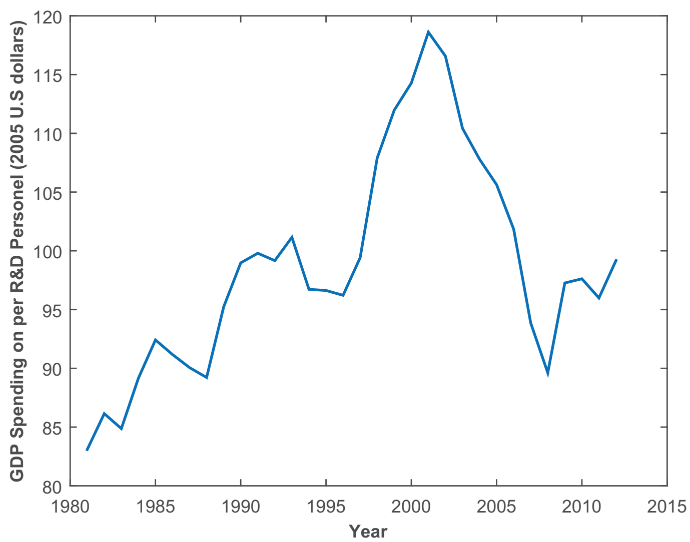


Figure 6 shows the trend of GDP per R&D personnel over 1981–2013. Between 2001 and 2008 this share declined sharply, with a slight recovery after 2008.

Figure 6: GDP per R&D personnel: 1981-2013



We use Merged R&D under two assumptions. First is that new ideas are disseminated between economies. In the calculation of research intensity we assume that the G6 countries are closest to the world technological frontier and contribute the most to creation of new ideas. In this case we assumed just G5 countries and Canada are the source of these new ideas. Second is that researchers are homogeneous, so we can set θ in equation (6) equal to zero (Jones (2002)). Since the number of researchers for Canada and U.S was not available for 2013, we defined it using annual average growth rate during 1981-2012, and used the same method to calculate total number of researchers in G5 countries plus Canada in 2013. During 1981-2013 research intensity in Canada increased by an average rate of 3.1% per year while U.S had an annual average rate of 1.8%. The number of researchers in G-5 countries plus Canada shows an average growth rate of 2.65 percent per year and the number of employees in these countries had a growth rate of 0.89% per year (see Table 1).

Finally, parameter γ is determined by the restriction that equation (16) holds which gives the value of 0.23.

4.1 Results

Table 3 presents the results. We find that transitional factors (human capital growth and R&D intensity) have been the primary source of Canadian economic growth over the 1981–2013 period.

TABLE 3: Constant growth path decomposition for Canada, 1981-2013

			TRANSITION DYNAMICS				
		Output per Hour	Capital Intensity	Labour Reallocation	Educational Attainment	G-6 R&D Intensity	Scale Effect of G-6 Labour Force
ψ	γ	g_y	$\frac{\alpha}{1-\alpha} g_k$	$\hat{\ell}_{Yt}$	$\psi \Delta \ell_h$	γg_{ℓ_A}	γn
0.054	**0.23481**	**1.242**	**0.141**	**-0.018**	**0.497**	**0.411**	**0.211**
		(100%)	**(11.35%)**	**(-1.44%)**	**(40.01%)**	**(33.09%)**	**(16.99%)**
0.038	0.29068	1.242	0.141	−0.018	0.349	0.509	0.261
		(100%)	(11.35%)	(-1.44%)	(28.10%)	(40.98%)	(21.01%)
0.045	0.26614	1.242	0.141	−0.018	0.414	0.466	0.239
		(100%)	(11.35%)	(-1.44%)	(33.33%)	(37.52%)	(19.24%)
0.073	0.16874	1.242	0.141	−0.018	0.672	0.296	0.151
		(100%)	(11.35%)	(-1.44%)	(54.11%)	(23.83%)	(12.15%)

Notes: G-6 is defined as G-5 plus Canada. The baseline results are shown in bold.

These factors account for nearly 73% of the growth in output per hour. That is, 0.90 percentage points of the 1.24 percentage point growth over 1981–2013. The compositional share of human capital growth and R&D intensity is 55% and 45%, respectively. Although these compositional shares vary somewhat depending upon the assumptions about the model parameters, the total contribution of transitional factors remains between 69%–78%. The contribution of population growth of countries generating ideas ranges between 12%–22%. Finally, the contribution of capital accumulation as in the neoclassical growth model is a little over 11%. Although the large role of transitional factors in Canadian growth is similar to the findings for the U.S. economy, there are some notable differences. For a proper comparison, we first re-do the calculations in Fernald and Jones (2014) for the 1981–2013 period. Table 4 shows the results.

TABLE 4: Constant growth path decomposition for the U.S. : 1981-2013

			TRANSITION DYNAMICS				
		Output per Hour	Capital Intensity	Labour Reallocation	Educational Attainment	G-6 R&D Intensity	Scale Effect of G-6 Labour Force
ψ	γ	g_y	$\frac{\alpha}{1-\alpha}g_k$	$\psi\Delta\ell_h$	γg_{ℓ_A}	γn	
0.074	0.51718	1.643	-0.117	-0.012	0.402	0.906	0.464
		(100%)	(-7.12%)	(-0.73%)	(24.47%)	(55.14%)	(28.24%)

Notes: From Fernald and Jones (2014), we assume α is equal to 0.32 for U.S.

We find that the contribution of transitional factors to U.S. economic growth is relatively higher than Canada, 79.61% versus 73.01%. On the other hand, the contribution of capital accumulation, as reflected in capital-output growth, is relatively higher in Canada. In fact, in the U.S. the contribution of capital-output growth turns out to be negative (-7.12%) whereas in Canada it is about 11%.[10]

5 Conclusion

Using the modern growth accounting framework of Jones (2002), we conduct an accounting exercise to determine the sources of Canadian economic growth over the 1981–2013 period. Our main finding is that over 80% of the 1.24 percentage point growth is due to transitional factors such as domestic human capital growth and global R&D intensity. The growth in capital-output ratio made a small contribution of 0.14 percentage points. We find that the constant growth path hypothesis put forth in Jones (2002) helps to reconcile the large contribution of transition dynamics with the relatively stable growth experienced in Canada since 1981. Our results highlight that the future of Canadian productivity growth and the standard of living are closely tied to sustained growth in both domestic human capital and global R&D intensity.

[10] Fernald and Jones (2014) find that capital-output growth did not contribute to growth over the 1950–2007 period. There are three main reasons why our results for U.S. differ somewhat from theirs. First, the time period is different. Second, our decomposition is based on G6 countries while theirs is based on G5 countries. Third, they used the BLS measure of labour composition instead of Mincerian return to education which grows more slowly.

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