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## Different paths? Human capital prices, wages and inequality in Canada and the US

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**Different Paths? Human Capital Prices,  
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US**

**by**

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# Different Paths? Human Capital Prices, Wages and Inequality in Canada and the US <sup>\*</sup>

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## **Abstract**

In the last three decades, Canada and the US showed different paths in per capita GDP growth, skill premiums and inequality. Both firm and worker productivity differences play a role and have different policy implications, but are difficult to distinguish. To examine separate firm and worker productivity effects, human capital prices and quantities are estimated using the methods developed in Bowlus and Robinson (2012). The quantities reflect worker productivity while the prices tend to reflect firm productivity. In the US there was faster growth and a much more rapid rise in skill premia and inequality. This was primarily due to different paths for the relative price paid to rent high skilled human capital in the two countries, rather than differences in relative quantities of human capital supplied by the typical high skilled worker. Worker productivity increased for high skilled workers, but decreased for low skilled workers over the 1980-2000 period.

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# 1 Introduction

In the last three decades, Canada and the US showed different paths for a number of measures related to the standard of living. These include measures of average wages, skill premiums, and inequality, as well as various labour productivity measures.<sup>1</sup> In this paper we examine the role of cross country differences in the evolution of (1) the amount of human capital supplied by average skilled and unskilled workers, and (2) the prices paid by firms for human capital, in explaining these different paths. From a policy point of view, it is important to distinguish between quantities of human capital supplied, and the prices paid by firms for human capital. The policy implications for different evolution of the quantities relate to education and training policy, including, more broadly, the incentives to invest in human capital. The policy implications for different evolution of prices for the human capital of skilled and unskilled workers relate more to policies to increase firm productivity.

The distinction between prices and quantities of human capital is central to drawing out the policy implications, but is made difficult by the fact that human capital is not directly measurable. At the aggregate level, assessing the contribution of human capital to output, living standards and growth has been studied extensively in the past literature. However, there remain serious conceptual and measurement problems, especially for international comparisons and for secular analyses over several decades. Since human capital is not directly measurable, a variety of approaches to measurement have been taken in the literature. Most of these are based on what in the original human capital models are more appropriately interpreted as inputs into the human capital production function rather than the output, such as years of schooling. A refinement of this takes into account work experience - usually in the form of some measure of total accumulated time at work and some demographic characteristics. For international comparisons, in the absence of measures at a more detailed level, a common procedure is to compare the fraction of the relevant populations with various levels of education.<sup>2</sup> However, for a variety of important contexts, it is widely recognized

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<sup>1</sup>The *Centre for the Study of Living Standards* using a variety of measures documents a marked decline in relative standard of living for Canada between 1980 and the mid 1990s; for example, using GDP per capita, Canada's level fell from over 90% relative to the US in 1981 to 80% in 1996. (The data are available in Chart 1 and Table 3 at <http://www.csls.ca/data/ict.asp>.)

<sup>2</sup>For example, the OECD report comparisons of a such a measure, designated A1, which the publication characterizes as "traditionally used to proxy the stock of human capital" *Education at a Glance - OECD Indicators*, OECD 1998, p. 7. However, this can result in misleading conclusions. According to the latter measure, Canada has higher per capita human capital than the United States. However, the US has a higher fraction of the population with a university degree. If this measure was used instead of the fraction with post-secondary education the ranking would be reversed.

that a better measure of human capital is needed.<sup>3</sup>

The structure of the paper is as follows. Section 2 outlines a simple framework to distinguish between productivity differences due to “better” workers and those due to “better firms”, and to link these differences to differences in wages, human capital quantities and prices, and measures of labour productivity. Identification of the “better” worker and “better firm” effects is done by separately identifying human capital *prices*, that reflect firm productivity, and *quantities*, that reflect worker productivity, from individual level wage data. A major cross country difference in the relative price paths is a much larger drop in the university price relative to the price for lower skilled workers in Canada compared to the US. The influential “canonical model,” which is the workhorse model for explaining the time path of the skill premium, is incorporated into the framework to facilitate discussion of this.

The standard approach to measurement of human capital when workers may vary in both “quality” (human capital type) and “quantity” is labor force composition adjustment within type. This, for example, is the approach taken in the canonical model where total skill supplies are computed as composition adjusted quantities for two skills using education, experience and sex as the relevant composition cells. However, there is increasing evidence that important cohort effects over the last three or four decades caused the simple composition adjusted wages and hours to be relative poor proxies for the true skill prices and quantities over this period. In this paper we estimate skill prices and quantities for the two countries based on the methods of Bowlus and Robinson (2012), hereafter BR, that account for the cohort effects.

Section 3 describes the data sources and presents estimates of the human capital price series, for four “types” of human capital, based on BR, for the two countries. The major difference between the countries is the much larger relative decline in Canada, especially from 1980 to 2000, in the prices for university graduates compared to the lowest education groups. Comparing university with high school graduates, Canada and the US have roughly similar drops for the high school and some college

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<sup>3</sup>The issue of internationally comparable human capital measures that takes into account quality variation across country has received a great deal of attention. Barro and Lee (1993, 1996), for example, constructed measures of schooling years, designed to be internationally comparable, but stressed that the measure of years did not take into account quality differences. Hanushek and Kim (1995) and Hanushek and Kimko (2000) use international test score data to address the issue of schooling and labor force quality. Coulombe, Tremblay and Marchand (2004) utilize data from the International Adult Literacy Survey, and argue that human capital measures based on these data are superior to years of schooling measures normally used in international growth regressions. However, this literature pays little attention to the issue of quality variation over time within countries, or to the identification or interpretation problems that occur if human capital is heterogeneous.

prices, but the US has a much smaller drop in the university price, producing a skill price increase in the US, but not in Canada. Even more extreme is when university is compared with dropouts where, since US dropouts experience a much larger fall in the price than Canadian dropouts, there is a relative skill price decrease in Canada compared to a relative price increase in the US.

Cross country price path differences account for the part of the relative wage path differences due to prices. That leaves the relative wage path differences due to differences in the path of per worker (hour) efficiency units of human capital within skill or education group. Section 4 compares the paths of wages and per worker efficiency units supplied across countries for all age and education groups separately. Canadian university graduates did worse in terms of wages relative to US university graduates. This was not because the amount of human capital (worker productivity) of the typical Canadian university graduate deteriorated markedly relative to the average US university graduate, but rather because the (high) skill price in Canada fell relative to the price in the US. Another notable feature is the difference for the lower education groups, especially older dropouts, that do much better in Canada.

An important part of the increased inequality in the US is the large increase in the university wage premium, primarily for young university graduates, that occurred from the late 1970s to the mid 1990s. Section 5 compares the path of the university premium for young males in the two countries and shows that the much smaller increase in the premium for Canada is primarily due to the difference in the price path rather than to worker productivity differences. There was an increase in per worker efficiency units for young university graduates relative to high school graduates in both countries, but this translated into a larger wage premium increase for the US because of a larger relative price increase. Section 5 also shows increases in per worker efficiency units for young university graduates relative to high school graduates in both countries played major roles in determining the increases in the university premiums.

The path of per worker efficiency units of human capital within skill or education group is determined by the human capital investment profiles of the various cohorts of workers in the two countries. Section 6 examines cohort effects in the two countries as they are reflected in the life-cycle human capital profiles of young Canadian and US university cohorts. Life-cycle human capital profiles by birth cohort are estimated, and the cross country differences are interpreted for both countries within the framework of BR.

Section 7 presents estimates of the aggregate labour input in the two countries. The high corre-

lation in the BR price series for the different types of labor in the US suggest that, for the purposes of aggregate productivity analysis, a homogeneous human capital model may be a useful approximation. The estimated price series in Section 3 suggest that the same may be true for Canada. In BR, using a homogeneous human capital model with a single price series to obtain estimates of the true aggregate labor input, the role of MFP growth in the growth of output in the US was reduced to a negligible role. In Section 7, the analysis is repeated for Canada and a comparison made. The results show that as for the US, standard composition adjusted hours methods under count the increase in the aggregate labor input because they cannot account for important cohort effects. The cohort effects are included in the total efficiency units of labour measure using estimates of human capital prices obtained by the flat spot method. This provides a general method for obtaining human capital quantities, adjusting for cohort effects, from wage data. However, Section 7 also discusses other evidence from alternative approaches using test scores and job skills measures that support the importance of cohort effects and the patterns obtained from the BR approach. The under count in the true labour input results in an over-estimate of the growth in MFP. The results for Canada are qualitatively the same as for the US, though the extent of the under count of the aggregate labor input is smaller. As a result the gap in MFP growth between the two countries is reduced. Section 8 concludes.

## 2 Worker and Firm Productivity: A Simple Framework

In a homogeneous human capital model, the hourly wage of a worker is the product of the price of a worker efficiency unit of labour, and the quantity the efficiency units supplied by the worker per hour.<sup>4</sup> The average worker in a country is paid more if they supply more efficiency units per hour, but also if the price is higher. We are interested in a cross country (or across time, within country) comparison of average hourly wages, but seek to decompose any differences into those due to (on average) better workers (higher efficiency units of labour supplied per hour) and those due to (on average) better firms, which is reflected in a higher price of efficiency units.

For simplicity, assume that the single product  $X$  is produced in each country (or time period within a country) and that firms take as given a constant world price,  $p$ , for  $X$  and  $r$  for the capital

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<sup>4</sup>The price is equivalent to the human capital rental rate where the capital is measured in units that yield one efficiency unit per hour as the service flow.



input,  $K$ .<sup>5</sup> To further simplify, suppose we have a Leontief production function, with inputs of worker efficiency units,  $Y$ , and capital,  $K$ , and parameters,  $a$  and  $b$ :

$$X = \min[aY, bK]. \quad (1)$$

Assume all workers in a country or time period are the same and initialize the measure  $Y$  in units of hours of these workers,  $N$ , i.e.  $Y = N$ . The price ( $\lambda$ ) of  $Y$  in this case is simply the hourly wage,  $w$ . With cost minimizing firms,  $a = \frac{X}{Y} = \frac{X}{N}$ . So this production function parameter directly corresponds to the standard “labour productivity” measure, corresponding to output per worker hour. In that case, normalizing  $p = 1$ , gives:

$$MC = \frac{w}{a} + \frac{r}{b} = 1 \Rightarrow w = \lambda = a(1 - \frac{r}{b}).$$

## 2.1 Differences in Firm Productivity

If firms are more productive in country 1, than in country 2, then by definition they have a production function with larger values of  $a$ , or  $b$  or both. A country (or time period) with a higher  $a$  or  $b$  will have higher wages:

$$\frac{\partial w}{\partial a} = \frac{\partial \lambda}{\partial a} = (1 - \frac{r}{b}) > 0, \text{ and } \frac{\partial w}{\partial b} = \frac{\partial \lambda}{\partial b} = \frac{ar}{b^2} > 0.$$

Differences in  $a$  also correspond to differences in the “labour productivity” measure  $\frac{X}{N} = a$ . An economy with more productive firms in the form of a higher value for  $a$ , has higher labour productivity, as well as higher wages. An economy with more productive firms in the form of the same value for  $a$  but a higher value for  $b$ , has higher wages. However, in the case of the simple Leontief production function, this will not result in a higher labour productivity measure. If differences in firm productivity are restricted to “neutral technological differences,” keeping the ratio  $a/b$  the same, then the wage labour productivity measure always move together. Better firms result in a higher “labour productivity.”

Overall, an economy with higher productivity firms (higher  $a$  or  $b$ ) has a higher  $\lambda$  which is the source of higher wages. The “labour productivity” is higher even though there is no difference in the human capital of the workers. That is, the “labour productivity” measure is a measure of firm, not worker, productivity.

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<sup>5</sup> $X$  is traded and  $K$  is mobile.

## 2.2 Differences in “Worker Productivity”

What about an economy with more educated workers - workers with more human capital, or more “productive workers.” What does this mean? It does not mean higher  $a$ , since that is just the technology parameter that corresponds to the productivity of the firms. Suppose we keep the labour input homogeneous, and define more productive workers as those with a higher level of human capital providing a higher number of efficiency units of labour input per worker hour. The input,  $Y$ , in the production function (1) is thus  $Y = \beta N$ , where  $\beta$  converts worker hours into efficiency units. A country with more productive workers (workers with more human capital) has a higher  $\beta$ .

The price of  $Y$  is now  $\frac{w}{\beta}$  where  $w$  is the hourly wage rate as before. So:

$$MC = \left( \frac{\lambda}{a} + \frac{r}{b} \right) = \left( \frac{w}{a\beta} + \frac{r}{b} \right) = 1 \Rightarrow \lambda = a \left( 1 - \frac{r}{b} \right), \text{ and } w = a \left( 1 - \frac{r}{b} \right) \beta = \lambda(a, b)\beta.$$

The labour productivity measure,  $\frac{X}{N}$  now depends on both worker and firm productivity:

$$\frac{X}{Y} = a = \frac{X}{\beta N} \Rightarrow \frac{X}{N} = a\beta.$$

Thus, an economy with more productive workers (higher  $\beta$ ) has both a higher measured labour productivity and higher hourly wages. However, in this case the source of the higher wages is not a higher  $\lambda$ , due to better firms, but rather higher  $\beta$  due to better workers, with the same firms (same  $a$  and  $b$ ) and the same price,  $\lambda$ . In this simple Leontief framework with homogeneous human capital, firm productivity, as captured by the technology parameter,  $a$ , and worker productivity, as captured by the human capital measure  $\beta$ , play identical roles in determining wage rates and measured labour productivity.

Workers of different education (and/or experience) level vary in their human capital. Allowing for two levels we can distinguish between high skilled,  $N_H$ , and low skilled,  $N_L$ , worker hours. In this homogeneous human capital framework, total hours are given by the sum of low skill and high skill hours,  $N = N_L + N_H$ , efficiency units of high skill hours and low skill hours are given by  $H = \beta_H N_H$  and  $L = \beta_L N_L$ , respectively, and total efficiency units of labour are given by  $Y = H + L = [s_L \beta_L + (1 - s_L) \beta_H] N$ , where  $s_L = \frac{N_L}{N}$  and  $\beta_H > \beta_L$ . In this case the labour productivity measure,  $\frac{X}{N}$  now depends on both worker and firm productivity,  $\beta_L, \beta_H$ , and  $a$ , and on the share of unskilled workers:

$$\frac{X}{N} = a[s_L \beta_L + (1 - s_L) \beta_H].$$

Average wages, like the labour productivity measure, depends on both worker and firm productivity and on the share of unskilled workers:

$$w = \lambda(a, b)[s_L\beta_L + (1 - s_L)\beta_H].$$

Wages for both high and low skilled workers depend on their worker productivity ( $\beta_H, \beta_L$ ) and firm productivity ( $a, b$ ):

$$w_L = \underbrace{\lambda(a, b)}_{\text{"firm"}} \underbrace{\beta_L}_{\text{"worker"}} \quad \text{and} \quad w_H = \underbrace{\lambda(a, b)}_{\text{"firm"}} \underbrace{\beta_H}_{\text{"worker"}}.$$

The skill premium depends only on the difference in the efficiency units supplied by high skilled compared to low skilled workers, i.e.  $\frac{w_H}{w_L} = \frac{\beta_H}{\beta_L}$ .

### 2.3 Heterogeneous Human Capital: the Canonical Model and the Skill Premium

A marked difference between Canada and the US has been the path of the skill premium over the last three or four decades, and the consequences for income inequality. The homogeneous human capital model allows for changes in the skill premium, but only through changes in the relative efficiency units supplied by high and low skilled workers,  $\frac{\beta_H}{\beta_L}$ . A larger increase in the skill premium for the US compared to Canada from this source would relate mainly to differential education or training policies or environments in the two countries that resulted in an increase in efficiency units supplied per hour by a high skilled worker compared to a low skilled worker in the US relative to Canada.

An important potential alternative source for the different path of the skill premium is a different rate of skill biased technological change (SBTC) across the countries. SBTC is the centerpiece of the “canonical model” of wages and employment, but requires imperfect substitutability between high and low skilled workers to have an effect on the skill premium.<sup>6</sup> We incorporate this into our simple framework by redefining the efficiency units of labour input,  $Y$ , in equation (1), as a constant elasticity of substitution (CES) aggregate of high and low skill efficiency units. This corresponds to the production function in the standard representation of the canonical model:

$$Y = A[\alpha_L L^{\frac{\sigma-1}{\sigma}} + \alpha_H H^{\frac{\sigma-1}{\sigma}}]^{\frac{\sigma}{\sigma-1}}, \quad (2)$$

where  $L$  is the total (efficiency unit) input of low skill and  $H$  is the total (efficiency unit) input of high skill, as before, and  $\sigma$  is the elasticity of substitution between them. This may be regarded as

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<sup>6</sup>See, for example, Autor, Katz and Kearney (2008), Acemoglu and Autor (2011).

an intermediate output that enters the final production function (1), or simply as a CES aggregate of high and low skill efficiency units to replace the previous perfect substitutability aggregate,  $Y = H + L$ . SBTC is captured by changes over time in  $\alpha_L$  and  $\alpha_H$ , and general firm productivity effects in producing  $Y$  are captured by  $A$ .

Profit maximizing intermediate firms that sell  $Y$  in a competitive market to final goods firms at price  $\lambda$ , set  $\lambda(\partial Y/\partial H) = \lambda_H$  and  $\lambda(\partial Y/\partial L) = \lambda_L$ , where  $\lambda_H$  and  $\lambda_L$ , respectively, are the prices for high and low skill efficiency units of labour. Wages are now given by:

$$w_L = \lambda(a, b)A \left( \left( \frac{L}{H} \right)^{-\frac{1}{\sigma}} \alpha_L \left( \frac{L}{H} \right)^{\frac{\sigma-1}{\sigma}} + \alpha_H \right)^{-\sigma} \beta_L = \underbrace{\lambda_L(a, b, A, \alpha_L, \alpha_H, L/H)}_{\text{"firm"}} \underbrace{\beta_L}_{\text{"worker"}},$$

and:

$$w_H = \underbrace{\lambda_H(a, b, A, \alpha_L, \alpha_H, H/L)}_{\text{"firm"}} \underbrace{\beta_H}_{\text{"worker"}}$$

As before, the wages for high and low skill are determined by both worker productivity ( $\beta_H$  and  $\beta_L$ ) and firm productivity, but firm productivity is now represented by both the parameters in the final output production function,  $a$  and  $b$ , and the parameter  $A$  in the intermediate production function. In addition, wages now also depend on the relative supply of high and low skill,  $\frac{H}{L}$ , and the production function parameters representing SBTC,  $\alpha_L$  and  $\alpha_H$ . The path of wages for high and low skill across country or across time may differ if the paths of worker productivity, firm productivity or relative skill supply are different.

With either intermediate firms producing  $Y$  or final goods ( $X$ ) firms producing their own labour input,  $Y$ , cost minimization implies:

$$\frac{\partial Y/\partial H}{\partial Y/\partial L} = \left( \frac{\alpha_H}{\alpha_L} \right) \left( \frac{H}{L} \right)^{\frac{-1}{\sigma}} = \frac{\lambda_H}{\lambda_L} = \frac{w_H/\beta_H}{w_L/\beta_L}.$$

This yields the well known skill premium equation from the canonical model in terms of skill prices and efficiency units quantities:

$$\ln w = \ln(\lambda_H/\lambda_L) = \ln(\alpha_H/\alpha_L) - \frac{1}{\sigma} \ln(H/L). \quad (3)$$

Since  $\ln(\lambda_H/\lambda_L) = \ln(w_H/w_L) - \ln(\beta_H/\beta_L)$ , and  $\ln(H/L) = \ln(\beta_H/\beta_L) + \ln(N_H/N_L)$ , following Bowlus *et al* (2016) we can re-write the skill premium equation in terms of hourly wages and

quantities of hours as:<sup>7</sup>

$$\ln(w_H/w_L) = \ln(\alpha_H/\alpha_L) + \frac{\sigma-1}{\sigma}\ln(\beta_H/\beta_L) - \frac{1}{\sigma}\ln(N_H/N_L). \quad (4)$$

From equation (4) the path of the wage premium may vary across countries because of differences in: (1) SBTC ( $\ln(\alpha_H/\alpha_L)$ ), (2) relative high skilled hours supply ( $\ln(N_H/N_L)$ ), (3) relative high skill “quality” ( $\ln(\beta_H/\beta_L)$ ), and (4) the elasticity of substitution,  $\sigma$ .

In the simple framework above where  $\lambda_L$ ,  $\lambda_H$  and  $\lambda$  depend only on the firm productivity parameters,  $a, b$ , and  $A$ , separating the quantity of efficiency units supplied by the average high and low skilled worker,  $\beta_H$  and  $\beta_L$  and their prices,  $\lambda_L$  and  $\lambda_H$  is equivalent to separating the firm and worker productivity changes. More generally,  $\lambda_t$  depends on  $p$  and  $r$ , which may change over time, and in a more complex model, the industrial mix may be different across time for a country, or vary across countries. In this case, while the path of the  $\beta$ ’s still measure the changes in worker productivity, the path of the  $\lambda$ ’s will not reflect solely firm productivity changes. Nevertheless, from a policy point of view the distinction is of major importance. Differences in the  $\beta$ ’s have implications for education and training policies and more generally the incentives to invest in human capital in the country, while differences in  $\lambda$ ’s likely have implications for firm productivity.

## 2.4 Identifying Human Capital Prices and Quantities from Wages

Wages for low skill and high skill, in period  $t$ , are given by:

$$w_{Lt} = \lambda_{Lt}\beta_{Lt} \text{ and } w_{Ht} = \lambda_{Ht}\beta_{Ht}.$$

We observe the wage but not the components, so in general there is an identification problem. Standard implementation of the canonical model implicitly solves the identification problem by assuming that the per worker hour quantities of human capital associated with any observed education-age-gender cell are the same over time, that the cells can be assigned to two human capital types based on observed education, and that efficiency units hold within each human capital type. This permits the identification of changes in the price from changes in the (cell) composition adjusted wage.<sup>8</sup>

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<sup>7</sup>Bowlus *et al.* (2016) refer to equation (4) as the augmented canonical model.

<sup>8</sup>The fixed relationship between the quantities of efficiency units for each cell within a human capital type is estimated by the relationship between the cell wages within type, averaged over the whole period, and these are then used as weights to weight the cell hours.

However, constancy of the per worker hour cell quantities is a very strong assumption for an analysis covering several decades. It assumes no selection effects on average quantities of human capital supplied by education group even though there have been large increases in the fraction of successive birth cohorts choosing higher levels of education. It rules out within cell per worker hour human capital increases that might be expected for females in cohorts with greater life-cycle labor force attachment.<sup>9</sup> It also rules out technological change in human capital production functions. Since major quality improvements due to technological change have been found for capital inputs such as computers, it is surprising that they have not been considered for the labor input. BR argue that technological improvement in human capital production functions produces workers of a given observed type, such as college graduates, that can do more, in the same sense as more recent computers can do more, especially at higher levels as knowledge advances.<sup>10</sup> There is, in fact, increasing evidence that the constant cell quantities assumption behind the composition adjustment approach is a poor one for an analysis covering the last three or four decades during which there were large cohort changes in education level and female participation, as well as potentially significant changes in human capital production functions.<sup>11</sup>

In BR a method for identifying prices and quantities without the assumption of constant per worker hour cell quantities is developed and implemented on U.S. data. The framework uses a fixed number of “types” of human capital, indicated by education group, as in the composition adjustment approach, but allows quantities within type to change over time. This introduces cohort or vintage effects, but represents a parsimonious specification of vintage effects since it maintains a constant number of human capital types and prices. BR use a “flat spot” approach to identification. In their framework, the optimal human capital investment path for each human capital type has a range towards the end of the working life where efficiency units are constant. This offers a strategy for identification. Under the assumption of competitive markets for human capital, given two periods in which a worker’s efficiency units are equal (a “flat spot”), the change in log prices across periods is given by the change in log wages.<sup>12</sup> Thus, given two samples of individuals in their flat spots

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<sup>9</sup>See Bowlus and Robinson (2016) for estimates of strong cohort effects for females over the period of changing participation.

<sup>10</sup>See BR for further discussion of the vintage issue. BR assume technological progress for the college graduate production function, embodying the advancement of knowledge. However, for lower education groups technology changes could be positive or negative. See Green and Riddell (2013), and Barrett and Riddell (2016) for evidence on this.

<sup>11</sup>See Carneiro and Lee (2011), Hendricks and Schoellman (2014), Bowlus and Robinson (2016).

<sup>12</sup>A “flat spot” approach to identification based on human capital theory was first proposed in Heckman, Lochner

for which the mean log (supplied) efficiency units are equal across periods, the change in log prices across periods can be estimated by the change in mean log wages:

$$Mean[\ln E_{t,i}] = Mean[\ln E_{t+1,i}] \Rightarrow Mean[\ln w_{t+1,i}] - Mean[\ln w_{t,i}] = \ln \lambda_{t+1} - \ln \lambda_t. \quad (5)$$

### 3 Skill Prices for Canada and the US

Price series for four types of human capital, defined by education group, are estimated for Canada and the US and the paths of the price series are compared.

#### 3.1 Identification for Cross Country Comparison

For the purposes of cross country comparison, the methods of BR can be used separately for each country,  $j$ , to compare the separate *time paths* of the prices,  $\lambda_{jt}$ , and quantities,  $\beta_{jt}$ , but not the levels. Given a normalization on the BR price series by skill type for the US, this implies corresponding quantity series for human capital, given the wage series. The same methodology of BR is used to construct equivalent price series for Canada, and a normalization of the Canadian price series implies quantity series for Canada. However, this identification, unfortunately, does not extend to cross country comparisons in the quantities or prices, due to the same fundamental identification problem in human capital models. We may observe, for example, the wage of a university graduate of the same age in both countries, but we do not observe the separate price and quantity components.<sup>13</sup>

Our analysis, therefore, aims primarily to provide evidence on whether *changes* in wage (or labour productivity) patterns within and across Canada and the US are due to *changes* in worker productivity or quality ( $\beta$ ) or to *changes* in firm productivity ( $\lambda$ ). For example, it is possible to ask: do the relative wage patterns for university graduates in the two countries imply that the quality of US university graduates (per capita quantity of efficiency units) increased at a faster pace than those of Canada, or that they simply experienced a more rapid rise in the price. Thus, many interesting questions relating to the relative paths of standard of living, of inequality and the skill premium,

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and Taber (1998).

<sup>13</sup>The identification strategy embodied in Equation (5) is based on finding samples where the quantities are the same so the relative prices can be inferred from the relative wages. One possibility for cross country comparisons would be to follow migrants across the two countries at an age when the migrants were in their flat spot region. However, this is likely to involve very small samples (migrants tend to be young) and, more importantly, there is a large body of evidence documenting the fact that migrants are highly selected. Thus, international comparisons of levels continue to face formidable measurement challenges. This same problem occurs for composition adjustment methods where the ratio between the per worker hour quantities in each country for at least one cell is required for a comparison of levels.

and of the aggregate labor input and productivity can be addressed without direct comparability of the levels.

### 3.2 Data Sources

The data source for the price series for the US is the annual March series from the Current Population Survey (MCPS). The MCPS records annual labor incomes for the year preceding the survey. In BR, data from the March files for 1964 to 2009 were used to construct the price series for earnings years 1963 to 2008 for four types of human capital defined by their education group: high school dropouts, high school graduates, some college and university graduates. In this paper the price series is extended to 2014. Two main issues for obtaining a consistent series from the MCPS are a break in the education group definitions in 1991 and time varying top-coding and allocation methods. The education break in the MCPS at the level of the four education groups is studied Jaeger (1992) using data over a period of overlap in the definitions and he provides evidence useful for constructing consistent series. How issues of consistency over time for education and earnings are dealt with are discussed in detail in BR.

Construction of the price series for Canada is more complicated and cannot be done for the same extended period. In order to construct price series using the flat spot method it is necessary to observe earnings for a cohort over reasonably adjacent time periods. In addition, it is necessary that the education groups are defined in a consistent way across the adjacent time periods. Finally, relatively large sample sizes are required for the data set to provide reasonable sample sizes in the flat spot regions for each of the education groups. In this paper price series for Canada are constructed using two large data sets for two periods in which the definition of the education groups is consistent within period, and for which an earnings measure is available. The first is the Canadian Census data for the earnings years 1980, 1985, 1990, 1995 and 2000. The second is the pooled monthly Labour Force Surveys (LFS) for 1997-2015.

The switch from the Canadian Census to the LFS after 2000 is primarily because of a major break in the education groups between the 2000 and 2005 and the dropping of the census long form after 2005 which introduced major comparability issues for 2010 earnings year data from the Census. The LFS has the additional benefit of allowing the construction of an annual price series to compare with the US annual price series from the MCPS. The census data for Canada come from the Statistics Canada Research Data Centre (RDC) confidential census files for 1981, 1986, 1991, 1996, 2001 and



2006. Canada has held a census every five years since 1971. In all years except 1976 the census contains measures of total wage and salary earnings and total weeks worked in the previous year, as in the MCPS for the US. There is no measure of usual hours in the previous year, but it is possible to identify which individuals were working mainly full time in the previous year.

The education categories in the Canadian censuses for 1981-2001 are based on grades attended and degrees and diplomas received, like the United States surveys after January 1992, and are consistent over time. The detailed categories in the “highest level of schooling” variable can be divided into four groups that broadly correspond to Jaeger’s four groups for the United States. A consistent education series can be constructed for four education groups in the Canadian censuses for 1981-2001 that correspond to the four groups in the US data. The closest, almost exact, correspondence is for the university graduates group, particularly after the relatively minor US break in 1991 when it is possible to know whether the individual actually received a BA degree or higher.

The correspondence is less exact for the groups below BA. The Census documentation makes it clear that “highest level of schooling” should not be interpreted in a strict hierarchical sense because of the difficulties of ranking various forms of “post-secondary” education categories. The Census also records the highest grade attended whether or not this was the highest level of schooling. Examination of this, together with the highest level of schooling shows a strong pattern of “leap-frogging” in the highest level of schooling variable based on the post-secondary information. That is, for example, there is a substantial number of individuals whose highest grade was as low as 5-8 that, on the highest level of schooling variable, rank above individuals who graduated from high school. This leap-frogging is due to the receipt of post-secondary certificates below the university degree level. Thus, some caution is needed in cross country comparison at the level of the education groups below a BA.

The main disadvantage with the Census is that it does not provide an annual series.<sup>14</sup> However, an annual series is available from the LFS starting in 1997.<sup>15</sup> The education definitions in the LFS are consistent throughout the 1997-2015 period, but differ somewhat from the definitions in the

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<sup>14</sup>The closest equivalent repeated cross section data source to the MCPS for Canada is the Survey of Consumer Finances (SCF). This survey, started in 1972, and held every second year became annual from 1982 to 1998 except 1984 and represents an annual survey measuring previous years earnings in a way similar to the MCPS. Unfortunately, there are several major problems in the SCF, especially of comparability over time, that are less of an issue in the MCPS. (See the Appendix for more detail.) Gu et. al. (2002) argue that for consistency over time the census education measures are preferable to the SCF measures and use the census for the Statistics Canada series on a composition adjusted labour input series for 1961-2000.

<sup>15</sup>Unfortunately, the monthly LFS did not begin to collect earnings data until 1997.

Canadian census. Four education groups, similar to the groups defined for the Canadian census and for the US MCPS, are constructed from the LFS data to match the earlier period as closely as possible. The closest match occurs for university graduates where the measures are almost the same. Frequencies for the four education groups in the 1981 census and in the monthly LFS for 1981 are very close for the two highest levels of education and quite close for the two lowest groups. However, the match is far from perfect and some caution is, therefore, warranted in interpreting estimated prices and quantities across the two data sources for Canada.

### 3.3 Estimated Price Series for Canada and the US

The most important problem to be solved in estimating the price series via the flat spot method is the choice of the flat spot regions in supplied efficiency units for the four education groups. The estimated price series using this method are sensitive to the location of the flat spot, primarily for college graduates. BR provide a framework for choosing the flat spot and estimate annual price series for four skill types for the US, rather than two skill types as in the framework of Section 3 and in the standard implementation of the canonical model. Broadly speaking, the university (BA degree or higher) price may be associated with the high skill price,  $\lambda_H$ , and the other prices with disaggregated versions of the low skill price,  $\lambda_L$ . Alternatively, as in the canonical model literature, the high skill group may include part of the some college group.<sup>16</sup>

Figure 1 presents the annual price series for the US for 1963-2015, normalized to one in 1975, for the four types of human capital or skills: high school dropouts, high school graduates, some college and university graduates. The price series in Figure 1 is an extension of Figure 3 in BR to 2015. This is the preferred price series for the US, based on median wages, largely to avoid problems due to time varying top-coding and allocation procedures in the US data.<sup>17</sup> A striking feature of Figure

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<sup>16</sup>The main assumption employed in using wage data to estimate the prices is that workers are paid their marginal product in each period. Biases for some groups could arise from contract wages and time varying incentive effects, as well as the problem of time varying top-coding and allocated values procedures. The standard literature associating relative wages with relative skill prices has discussed a number of these problems, including the complications arising from changing non-wage benefits, union rents and other influences on relative wages. Both composition adjustment approaches and BR use observed wages and are subject to these problems. Possible non-random participation due to retirement is perhaps a more specific concern for flat spot estimates. However, the use of flat spot regions not too close to retirement, and the supplementary confirmation from an alternative method (discussed in the web Appendix to BR) that uses a younger age group, goes some way to minimize this problem.

<sup>17</sup>The simplest application of the estimation methodology constructs the price series using mean log wage differences  $\text{Mean}[\ln w_{t+1,i}] - \text{Mean}[\ln w_{t,i}]$  for observations in the flat spot range. However, in practice the chosen benchmark series in BR uses median wages. The primary reason for preferring medians for the US price series is the time varying treatment of top-coding and allocated values in the MCPS. However, the basic pattern of the estimated price series is robust to alternative wage measures, sample restrictions and estimation methods. See the Web Appendix of BR for

1 is the close correspondence in the series for such diverse education groups as high school dropouts and university graduates. Over short intervals, there is some movement in relative prices, but any gaps tend to disappear quite quickly. All four groups are closely related most of the time except for the pattern of the dropouts tending to suffer larger price declines in recessions, though these are recovered within a few years.

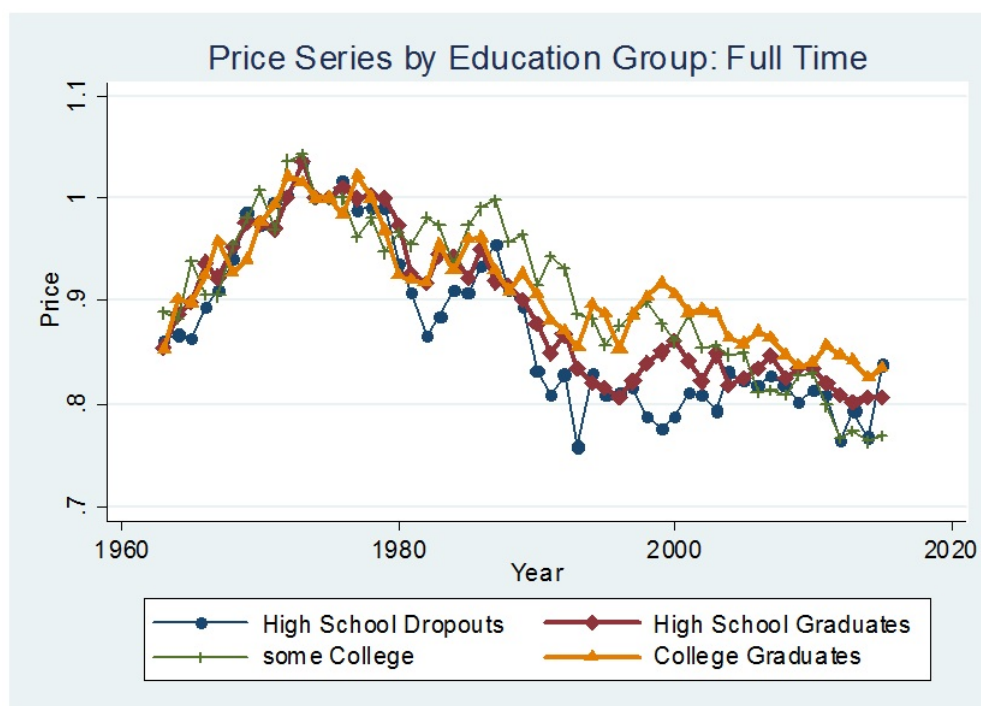


Figure 1: US Price Series 1963-2015

The sample sizes for Canada are larger, but the data set for the 1980 - 2000 period, rather than being annual as in the MCPS, is every five years. A flat spot method, corresponding as closely as possible to the method used for the US, was applied to the Canadian census data set for the 1980-2000 period by following the same five year cohort group across adjacent five year censuses, such that in both censuses the age range of the cohort group remains within the same ten year flat more details. The series based on medians are not affected by time varying top-coding, but series based on average log wages are. However, as long as top-coding and the switch to replacement values in the mid 1990s are appropriately dealt with the series based on average log wages are very similar to those based on medians. See Bowlus, Bozkurt, Lochner and Robinson (2016) for a full analysis.

spot used for the US. In order to assess any systematic differences that might occur from using five year rather than one year intervals that would complicate Canada-US price series comparisons, the price series for the US were recomputed using the same MCPS data, but restricting the data to five year intervals. The results were quite similar.

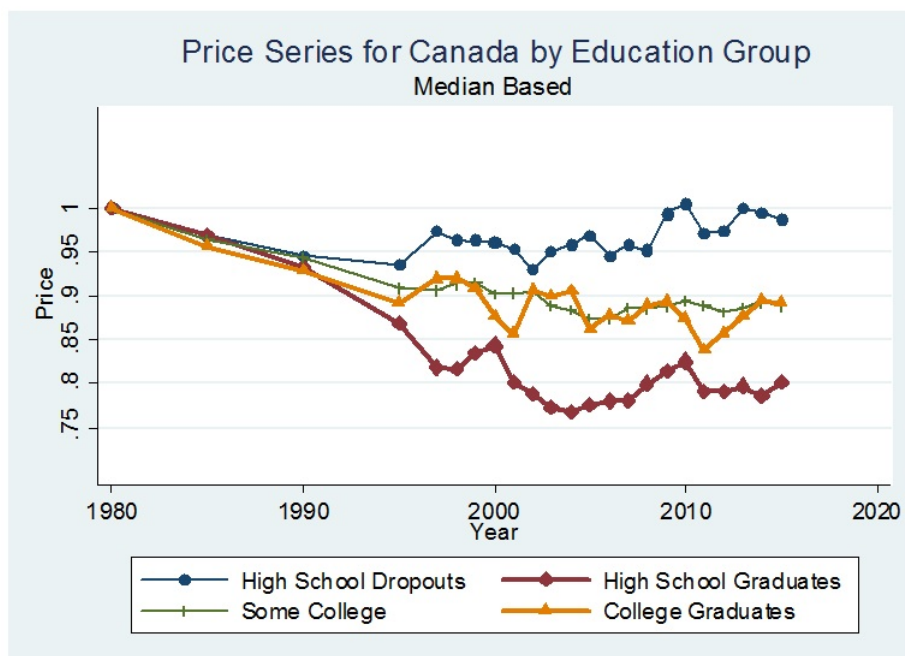


Figure 2: Canadian (Median Based) Price Series 1980-2015

The Canadian series is extended beyond 2000 by using the same procedure that BR applied to the MCPS to the Canadian monthly LFS, with the same flat spot regions. The LFS series for 1997-2015 is spliced to the Canadian census series for 1980-2000 by normalizing the LFS series to the values of the census series in the overlap earnings year, 2000. The Canadian series are consistent within the 1980-2000 period of the census data, and within the 1997-2015 period of the LFS, but there is a potential break between the series for the education groups below university graduates.

Figure 2 plots the price series for Canada for the period 1980-2015 using medians for all years. The prices all decline by similar amounts until 1995. There is some deviation after 1995, though by

2000 all but the dropouts have converged again to similar values. High school graduates appear to be substantially affected by the early 2000s recession, though by 2010 their price series is again close to the some college and university groups. Dropouts are the exception. There is some decline in the early 2000s recession, but they recover much earlier and are then roughly constant throughout the remaining period.

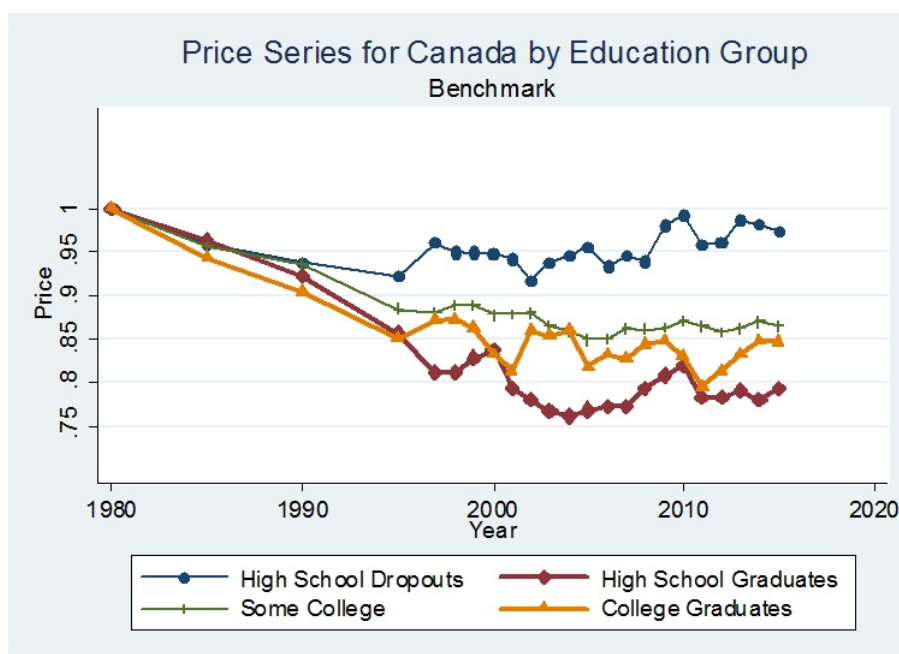


Figure 3: Canadian Benchmark Price Series 1980-2015

As noted above, very similar price series are produced using either medians or average log wages in the US data provided the problems of time varying top-coding and allocation methods are dealt with. The Canadian series estimated from annual LFS data for 1997-2015 also are essentially the same whether median or average log wages are used except for the dropout group where they begin to separate in the mid 2000s. However, the series using Census data are sensitive to the use of medians or average log wages for the higher education groups. For all groups there is a decline in the price from 1980, but the median series shows a smaller decline, especially for the higher

education groups. The difference is minor for the lower education groups.

While the Census education group break between 2000 and 2005 affects the education groups below a BA degree, for the university group we can compare the census price change from 2000 to 2005 with the LFS. If we smooth the LFS series with a 3 year moving average and compare the census and LFS changes between 2000 and 2005, a simple average of the median and average log based price series from the census is very close to the estimated change from the LFS. A “benchmark” Canadian series is constructed that takes a simple average of the median and log based series from the census period and splices this with the median based series from the LFS. For all but the university group this is very similar to the series that uses medians throughout. The benchmark series is plotted in Figure 3.

A direct comparison between the US and Canada is shown in Figure 4, which includes both the benchmark and the median series for Canada. There are relatively large declines in the price for the groups below university in both countries in the 1980-1995 period, and then prices tend to level off, except for some college in the US. The major difference between the countries is the much larger relative decline in Canada, especially from 1980 to 2000, in the price for university graduates compared to the lowest education groups. Comparing university with high school graduates, Canada and the US have roughly similar drops for the high school price for the 1980 to 1995 period, but the US has a much smaller drop in the university price, producing a relative skill price increase in the US, but not in Canada. The high school price for Canada also appears to be more affected by the early 2000s recession. Even more extreme is the comparison with dropouts where, since US dropouts experience a much larger fall in the price than Canadian dropouts, there is a relative skill price decrease in Canada compared to a relative skill price increase in the US.

### 3.4 Interpretation of the Different Price Paths Across Countries

In the simple framework of Section 3, prices for the low and high skills,  $\lambda_L$  and  $\lambda_H$ , depend on the firms’ productivity parameters,  $a$ ,  $b$ , and  $A$ , the SBTC terms,  $\alpha_L$  and  $\alpha_H$ , and the relative skill supply,  $H/L$ . In the presence of SBTC and an increase in the relative skill supply,  $H/L$ , the effect on  $\lambda_L$  and  $\lambda_H$  is ambiguous. For  $\lambda_H$ , the increase in  $H/L$  has a negative effect, and can account for a small price decline in the university price in the US, even in the presence of SBTC. For  $\lambda_L$  the increase in  $H/L$  has a positive effect, but this could be outweighed by SBTC. A decline in firm productivity would exert a downward effect on both prices. The strong secular increase in  $H/L$  also

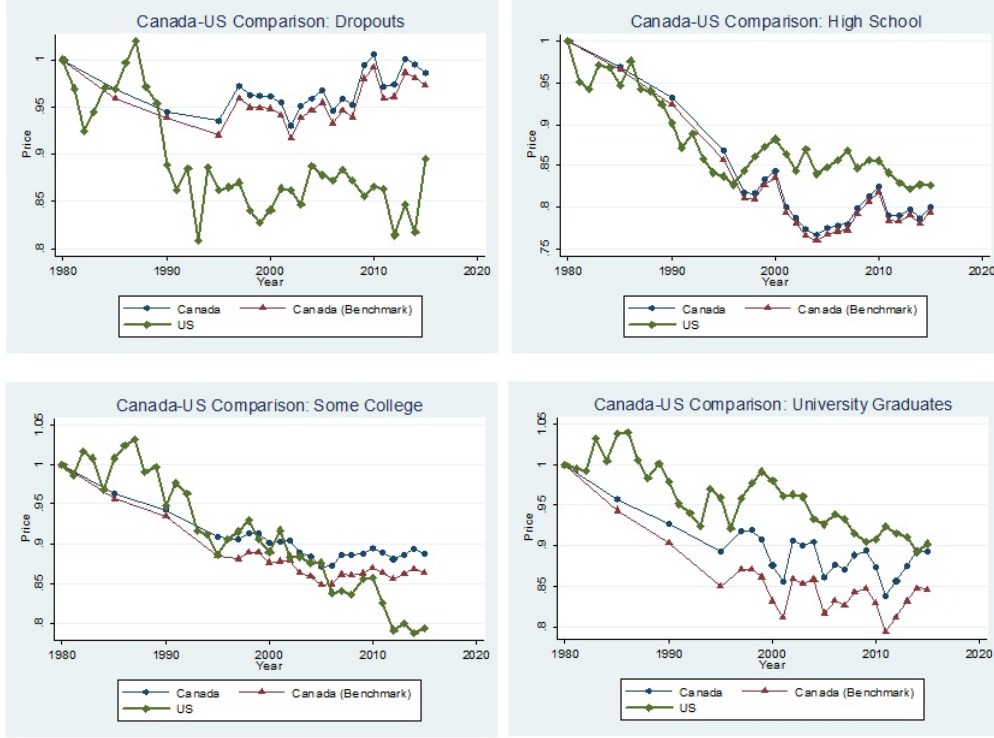


Figure 4: Canada-US Price Series Comparison 1980-2015

increases the total “labour” input,  $Y$ . In the framework of Section 3,  $r$  is assumed constant and  $K$  is assumed to adjust to any increase in  $Y$ , but if the continuous adjustment to the continuous increase in  $Y$  always follows with a lag, there could be a decline in  $\lambda$  as the adjustment takes place.<sup>18</sup>

In the canonical model equation (3), the path of relative skill prices depends on changes over time in SBTC and relative skill supplies. One significant difference between the two countries over this period that is relevant for the path of relative skill supplies is the large difference in the skill pattern of immigration. The implications of this difference for relative wages were recently analyzed in Borjas and Aydemir (2007) within the framework of the standard canonical model. Borjas and Aydemir (2007) estimate the effects of the relatively large scale “immigration shocks” to both countries in the 1980-2000 period. They show a large negative wage effect for university educated workers in Canada, but not in the US due to the very different pattern, by education, in the increased supply

<sup>18</sup>This is the same phenomenon as in the immigration literature where the long run effect on wages is zero when capital adjusts, but wages are depressed in the short run.

of university educated workers through immigration. Indeed, the direction and magnitudes of the effects reported in Table 4 in Borjas and Aydemir (2007) are close to the price differences shown in Figure 4.

Card and Lemieux (2001) present some cross country evidence on SBTC for the earlier period using a version of the canonical model with imperfect substitution across age groups within skill. While the parameters for the US and the UK were quite similar and estimated with some precision, it was not possible to obtain precise estimates for Canada.<sup>19</sup> Green and Sand (2015) argue that boom periods in the natural resources sector in Canada play an important role in shifting relative demand for low skilled workers. Relative demand shifts in the standard canonical model come from SBTC. The model does not explicitly have different output sectors. However, relative demand shifts of the type discussed in Green and Sand (2015) may show up as SBTC differences in Canada compared to the US and may account for some of the difference in the path of the skill premium.<sup>20</sup>

## 4 Cross Country Comparison of the Paths of Wages and Efficiency Units by Age and Education Group

Given the price paths,  $\lambda_H$  and  $\lambda_L$ , we can now decompose the wage paths,  $w_H$  and  $w_L$ , into price and quantity components. The cross country price path differences account for the part of the wage path differences due to prices. That leaves the cross country wage path differences due to differences in the path of per worker (hour) efficiency units of human capital within skill or education group, i.e. in the  $\beta_H$  and  $\beta_L$ . As noted in Section 3, for each country the price and efficiency units series are identified up to a normalization specific to each country. For our comparative analysis, the normalization sets the price of each type of human capital in each country equal to one in 1980. This implicitly normalizes efficiency units supplied, on average, for workers from cohort  $c$  with experience  $s$  for each type of human capital to the wage of that type of worker in 1980. Within country, this normalization is innocuous and allows the identification of changes, relative to 1980 levels, in prices and quantities for each of the four human capital types, and therefore of changes in relative prices

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<sup>19</sup>Bowlus *et al* (2016) show that implementation of the canonical model with prices and quantities of the type used in this paper that incorporate cohort effects yield a much better fit for the out of sample predictions of the original simple canonical model and do not require imperfect substitutability across age groups. In principle estimates of SBTC for Canada and the US using these prices and quantities could be compared, but the data limitations for Canada make this difficult. The number of data points is reduced relative to the approach in Card and Lemieux (2001) because there are no separate prices by age. See Bowlus *et al* (2016) for more details and for SBTC estimates for the US.

<sup>20</sup>Green and Sand (2015) also note important institutional differences between the two countries that can affect the path of relative wages. We discuss these in Section 6 below.



or quantities across skill levels. Across countries, however, the normalization is not innocuous. As discussed in Section 3, the relative skill price across countries for any human capital type in 1980 is not identified. This rules out comparison of levels of efficiency units across countries, but still allows for the identification of relative changes in efficiency units across countries.

The pattern of wages and per worker efficiency units supplied by males for all four human capital types and for young and older workers are presented in Tables 1 and 2, respectively. Table 1 presents estimates of wages for the median worker by age and skill type for the period of consistent education coding in the Canadian Census, 1980-2000. Two important features stand out. First, university graduates do much better in the US. In Canada, both young and old university graduates experienced a substantial decline in median wages over the 1980-2000 period. In contrast, for the US there is relatively little change except for the 7.66% increase for the young group. Second, for some college, high school graduates and dropouts in both countries there are large declines in median wages that are often very similar across countries, but older workers in Canada for all three below university groups have much less of a decline.<sup>21</sup>

Table 2 reports the time path for efficiency units for the median worker in the same four education groups by age for both countries implied by the price series in Figures 1 and 3 and the median wages in Table 1. Efficiency units for young university graduates increase by similar amounts in both countries. Thus, in terms of the productivity of young Canadian university graduates, as measured by their efficiency units, there is no substantial decline relative to the US. In terms of median wages, young university graduates in Canada suffer a decline in median wages compared to increased median wages for their US counterparts because of the larger price decline that they face for university level human capital in Canada that is not offset by their similarly increased efficiency units.

Older male university graduates in both countries show efficiency units increases, somewhat larger for Canada. In the US there is a very small decline in median wages while for Canada the decline is larger. For the US the wage decline is small because the price decline was relatively small, requiring only a relatively small increase in efficiency units to largely offset it. For Canada the price decline was large, and the efficiency units increase was not enough to offset it. The lower wages are again a consequence of the larger price decline for university level human capital in Canada.

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<sup>21</sup>Note that the Canadian dropouts at both ages are much closer in earnings to high school graduates than in the US: young dropout earnings are about 93% of the high school graduates earnings using the 1981-2001 census education codes (about 88% using the 2006 codes) compared to only about 78% in the US. For the old it is about 86-90% in Canada compared to about 75% in the US.

	Dropouts		High School		Some College		University	
	Canada	US	Canada	US	Canada	US	Canada	US
Younger (26-30)								
1980	10.74	6.82	11.51	8.75	12.32	8.98	13.42	9.85
1985	10.09	5.81	11.04	7.95	11.48	8.86	13.16	10.58
1990	9.36	5.16	10.33	7.17	11.00	8.09	12.77	9.81
1995	8.26	4.73	9.47	6.56	10.10	7.10	11.73	9.46
2000	8.62	5.08	9.10	6.98	10.21	8.12	12.71	10.61
% Change								
1980-2000	-19.75	-25.47	-20.93	-20.25	-17.11	-9.54	-5.29	7.66
Older (46-60)								
1980	11.93	8.75	13.90	11.67	14.53	12.32	20.85	15.70
1985	11.82	8.04	13.74	11.17	14.40	12.72	19.87	16.09
1990	11.42	7.36	13.49	10.30	14.35	11.77	19.51	15.65
1995	11.29	6.31	12.84	9.46	14.29	11.04	19.05	14.91
2000	11.36	6.42	12.54	9.31	14.36	10.89	18.67	15.36
% Change								
1980-2000	-4.78	-26.63	-9.74	-20.25	-1.19	-11.64	-10.44	-2.16

Table 1: Median Wages for Males by Age and Skill Type

In both countries there is an increase in both young and old high skill worker productivity, but the effect on wages is reduced or offset by the decrease in the price. Overall for high skill wages the cross country differences are largely driven by price differences, reflecting some combination of cross country differences in the path of firm productivity parameters, relative skill supplies and SBTC. There is little role for differences in the path of worker productivity differences.

For the younger workers efficiency units in the non-university groups generally decline. The Canadian dropouts and some college do worse relative to the US, but Canadian high school graduates do better relative to the US. The most notable cross country difference is for older workers. For all groups in the US except university graduates, the efficiency units for older workers show almost the same pattern as for the younger group. Dropouts and high school graduates show large declines and some college is stable. However, for Canada the older workers do much better than the young for all non-university education groups. For dropouts efficiency units are roughly constant, while they increase substantially for both high school graduates and some college. The age differences are very marked. For example, for dropouts the young group has a decrease of 14%, compared to an increase of 2% for the older group; and for high school graduates while efficiency units fall by 5% for the

	Dropouts		High School		Some College		University	
	Canada	US	Canada	US	Canada	US	Canada	US
Younger (26-30)								
1980	10.74	6.82	11.51	8.75	12.32	8.98	13.42	9.85
1985	10.45	5.98	11.44	8.18	12.00	8.76	13.94	10.45
1990	9.92	5.78	11.19	7.92	11.76	8.22	14.14	10.17
1995	9.00	5.48	11.06	7.80	11.42	7.79	13.78	10.10
2000	9.23	6.07	10.89	7.94	11.64	8.88	15.28	11.01
% Change								
1980-2000	-14.02	-10.90	-5.40	-9.31	-5.48	-1.07	13.83	11.70
Older (46-60)								
1980	11.93	8.75	13.90	11.67	14.53	12.32	20.85	15.70
1985	12.25	8.28	14.24	11.51	15.06	12.58	21.05	15.88
1990	12.11	8.24	14.61	11.37	15.33	11.96	21.60	16.24
1995	12.32	7.31	15.00	11.24	16.16	12.12	22.40	15.92
2000	12.17	7.68	15.01	10.58	16.37	11.91	22.44	15.93
% Change								
1980-2000	2.02	-12.28	7.97	-9.31	12.68	-3.36	7.64	1.51

Table 2: Median Efficiency Units for Males by Age and Skill Type

young group, they increase by 8% for the older group.

Overall, there is considerable evidence of some worker productivity decline for the low skill groups, especially dropouts and high school graduates. This is true for both age groups in the US, but only for the young group in Canada. Unlike for the high skill group, this worker productivity decline among the low skilled was an important component of the wage decline, and reinforced the negative price effect.

The pattern of efficiency units for the older non-university groups in Canada is something of a puzzle. This raises the possibility that institutional differences across countries, in particular the much larger presence of unions and the public sector in Canada may have resulted in the downward wage adjustment for the non-university groups due to SBTC happening more for the younger workers with older workers partially protected by less flexible union and public sector contracts. If this occurs and influences the flat spot estimates which come from the older workers, then the estimated price series for the non-university groups experiencing decreased demand will be upward biased.

## 5 University Wage Premium and Inequality Paths: Relative Price and Quantity Decomposition

Comparing wages for university graduates relative to high school graduates in the US in Table 1 shows the well documented increase in the US skill premium. The large increase in the university premium in the US from the late 1970s to the mid 1990s was a major part of the overall increase in inequality in this period for the US. This increase was driven in part by an increase in the relative price for university graduate human capital. Unlike the US, the price for university graduates in Canada did not increase relative to that of the lower education groups, suggesting that this different relative price path may be important in explaining inequality differences.

### 5.1 The University Wage Premium for Young Males

Card and Lemieux (2001) showed the increased university premium for males in the US, interpreted as the skill premium in the standard implementation of the canonical model, was largely confined to younger workers. In BR this increasing “skill” premium for the younger male university graduates in the US, documented in Card and Lemieux (2001), was decomposed into price and per worker quantity effects. Figure 5 reproduces this decomposition and shows that price and quantity both had an effect in increasing this measure of inequality. The rapid increase in the university premium for young males from 1980 to the mid 1990s was in part due to a significant increase in the relative price, though the majority of the increase was due to a large increase in the per worker efficiency units for high skill workers relative to low skill workers. That is, different trends in high and low skill worker productivity were most important.

The analysis is repeated here for Canada and compared to the US. First, the Canadian census data are used to examine the important 1980-2000 period.<sup>22</sup> Table 3 shows the well documented much larger increase in the relative wages of university graduates in the US compared to Canada, especially up to 1995. For the entire period, 1980-2000, in the US the log gap increased by .3001, while in Canada the increase is only .1804 log points. Up to 1995 there is an even starker difference of .2476 for the US compared to only .0606 for Canada.

In both countries the source of the increased university wage premium for young males is predominantly the increased  $\beta_H$  relative to  $\beta_L$ , i.e. high skill efficiency units supplied by the average

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<sup>22</sup>The Canadian Census uses a consistent definition of both high school and university graduates throughout 1980-2000.

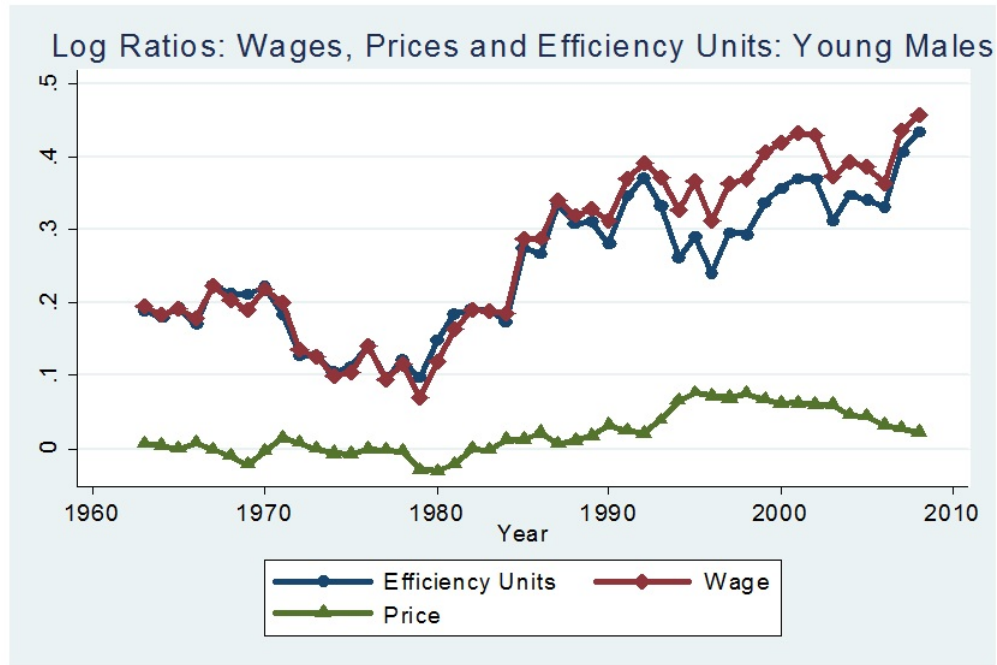


Figure 5: Decomposition of the US University Premium

university graduate compared to low skill efficiency units supplied by the average high school graduate. For the US .0917 of the .3001 increase is due to price, and for Canada, none is due to price. In fact, the relative growth in per worker efficiency units supplied by university graduates is only a little behind the growth for the US (.1852 vs .2084). Thus, over the 1980-2000 period the productivity (human capital) of Canadian male university graduates relative to high school graduates improved at a similar rate to that of US male university graduates, but their relative wages grew more slowly because they received a lower relative price for their human capital, consistent with the “immigration shock” differences across countries to the relative supply of university human capital. In summary, the slower increase in inequality between young university and high school graduates in Canada relative to the US is due to the absence of any relative price increase in Canada.

Figure 5 shows that the relative price increase stopped in the US in the mid 1990s and was no longer a source of increasing inequality between college graduates and high school graduates. A

Log Relative University/High School Ratios  
Younger Workers: 26-30

	Canada			United States		
	Wage	Quantity	Price	Wage	Quantity	Price
1980	0.1535	0.1535	0.0000	0.1186	0.1186	0.0000
1985	0.1761	0.1980	-0.0218	0.2869	0.2441	0.0428
1990	0.2121	0.2334	-0.0213	0.3130	0.2506	0.0624
1995	0.2141	0.2206	-0.0064	0.3662	0.2592	0.1070
2000	0.3339	0.3387	-0.0047	0.4187	0.3270	0.0917

Table 3: Decomposition of the University Premium: Canada and the US

comparison for the period after 2000, when there is a break in the education coding in the Canadian census, can be made using a measure of hourly earnings from the LFS for the 1997-2015 period in which the education definitions are constant. A similar weekly earnings measure is available in the Merged Outgoing Rotation Groups (MORG) data from the US Current Population Survey which also has similar consistent education measures.

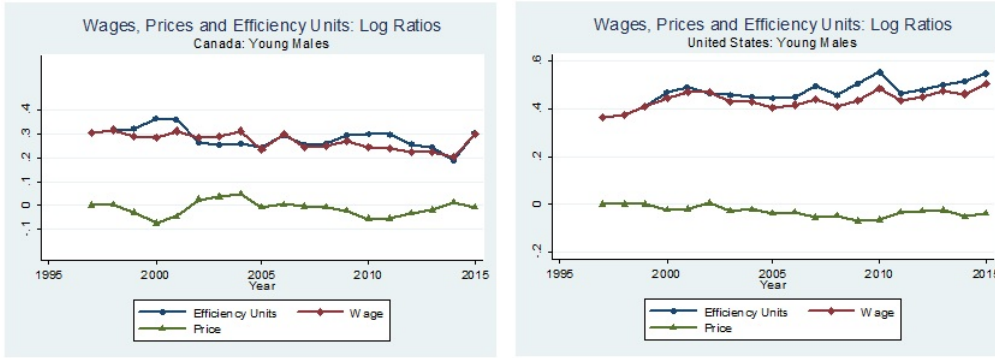


Figure 6: Decomposition of the University Premium 1997-2015

Figure 6 plots the decomposition of the relative wages for young male university graduates into relative price and quantity components for the 1997-2015 period using the LFS for Canada and the MORG for the US. The relative price paths are much more similar for the two countries after 2000. The large relative price increase for university graduates in the US for the earlier 1980-2000 period (Table 3) compared to university graduates in Canada is absent for the 2000-2015 period.

The university wage premium continues to increase in the US, but at a much slower rate than for the 1980-1995 period. Differences in the path of relative prices in the two countries is no longer the main driver of differences in relative wages of university graduates.

## 6 Cohort Effects

Figure 5 and Table 3 show the large increase in the relative per capita efficiency units supplied by young university graduates compared to young high school graduates as a driving force of skill premium increase in both countries. This pattern of cohort effects can be interpreted within the human capital framework of BR and the extension in Bowlus and Robinson (2016). The production of human capital in each country is assumed to be the result of optimal investments in human capital over the life-cycle, subject to the constraints imposed by the relevant environments in each country. The latter may reflect possibly different education and taxation systems, as well as potentially different time paths in the prices for the different types of human capital.

BR uses a combination and extension of the discrete time Ben-Porath based models used in Heckman, Lochner and Taber (1998) and Kuruscu (2006). The model has heterogeneous human capital (“skills”), associated with different schooling groups, that command different prices. In choosing a specific schooling level, individuals choose a specific skill and an associated production function for post-school investment. Individuals differ in their initial endowed ability. Higher ability individuals choose a higher level of schooling, produce more human capital at each schooling level, and are more productive in post-school investment. As in Heckman, Lochner and Taber (1998), the individual’s choice problem can be thought of in two stages: condition on a schooling level and optimize the post-schooling investment profile given the on-the-job production function (and type of human capital) associated with that schooling level; then select among schooling levels.

A key aspect of the analysis in BR, and the extension to a structural model in Agopsowicz, Bowlus and Robinson (2016), is the incorporation and measurement of important cohort effects induced by technological change in the human capital production functions, and selection effects based on completed education levels by cohort. There are two sources of cohort effects in BR: (1) effects arising from heterogeneity in ability and (2) effects arising from technological change, broadly interpreted, in the production of the different types of human capital. A third source of cohort effects introduced in Bowlus and Robinson (2016) is the increased incentive for females to invest in

human capital following the large secular increase in their participation rates.

In BR, cohort effects are introduced into the framework via changes in education patterns and the human capital production functions for different cohorts. As in Heckman, Lochner and Taber (1998), an individual's ability affects the amount of human capital they produce in the schooling phase and hence their stock at the start of the post-school phase. In choosing a schooling level in the first stage of the life-cycle optimization problem, individuals with higher ability choose higher levels of education. This induces cohort effects due to selection on ability within a cohort into college. Assuming a common initial ability endowment distribution across cohorts, changes in the fraction of a birth cohort whose highest level of education is a college degree imply changes in the mean endowed ability of the college graduates from that cohort.<sup>23</sup> This effect is incorporated by allowing the human capital stock (for each human capital type) at the start of the post-school phase to vary by birth cohort.<sup>24</sup> Cohort effects due to secular technological changes in the production of human capital may be incorporated in a similar way.

Within this framework, differences in the human capital stocks of the two countries may result from a variety of sources. First, there are substantial cross country differences in education systems, in expenditure on education and education subsidies at various levels, as well as a different mix of private and public provision. This implies potential differences in the underlying production function, and the rate of technological improvement in human capital production. Second, there are substantial differences in student loan systems and the effective tax rate on human capital investment.<sup>25</sup> These imply potential differences across countries in the life-cycle paths of supplied efficiency units, and hence, human capital stocks, for each of the education groups. Third, there are differences in the levels and the time path of the secular increase in educational attainment across the two countries, as well as differences in the correlation between measures of ability and completed education level.<sup>26</sup> Finally, there are differences in the time path of labour force participation patterns. These differences and the potential difference in technological changes in human capital production imply potentially different cohort effects in the two countries, which have implications for wages, the path of the university premium, and inequality in the two countries.

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<sup>23</sup>It should be noted that this is not an innocuous assumption. The initial endowment distribution is determined both by attributes at birth and the influence of early childhood factors in the household which may change over time.

<sup>24</sup>Effects through selection on the "ability to learn" in the post schooling phase could also be allowed.

<sup>25</sup>See Belley, Frenette and Lochner (2014) and Burbidge, Collins, Davies and Magee (forthcoming).

<sup>26</sup>See Belley, Frenette and Lochner (2014) for evidence on the cross country differences on the relationship between ability measures and attendance at post-secondary institutions.



## 6.1 Cohort Effects on Life-cycle Human Capital Profiles

In BR, the quantity increase for university graduates over the period of the rapidly increasing skill premium reflects cohort effects due to technological improvement in the production of human capital, and to selection of better university graduates from the initial endowment distribution as the cohort fraction of university graduates declined rapidly from its peak in the 1946 birth cohort. The magnitude of the selection effects depends on the correlation of “ability” and completed education, and the time path of completed education by birth cohort. BR report a large increase (50 percent) in the fraction of university graduates from the birth cohorts of the mid 1930s to the 1946 birth cohort, followed by a substantial drop to a trough with the 1958 birth cohort, before a recovery. Analysis of the Canadian census data shows that the qualitative pattern for university graduates is very similar across countries, though the levels are quite different. Figure 7 compares the pattern for both countries.<sup>27</sup>

A more detailed picture of the sources of efficiency units differences in Canada and the US can be obtained from estimating the life-cycle human capital profiles for the same birth cohorts in the two countries. Identifying the life-cycle profile of the (supplied) quantity of human capital from wage data requires identification of the price. Even with panel data on wages, following a cohort over time does not identify the profile unless the price is constant over the lifetime. In almost all of the literature on life-cycle earnings a constant price is a maintained assumption.<sup>28</sup> However Figures 1 and 3 indicate that the rental price is not constant in either country. In fact, the evidence suggests that the price movements have been large in the last three or four decades in the US, and of a similar magnitude for Canada for the shorter period that the series can be computed.

BR compared the estimated human capital profiles for each education group for a variety of birth cohorts whose wages are observed in the 1963-2008 period using the benchmark price series with the implied profiles using the standard constant price assumption in the literature. The results showed that, under the constant price assumption for high school graduates, for example, the life cycle

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<sup>27</sup>University graduates are a much smaller share of the total in Canada than in the US. At the other extreme, dropouts are a much larger fraction in Canada. While dropouts in the US are not much above 10 percent by the 1946 birth cohort, at that point in Canada they are still not much below 30 percent and do not fall below 20 percent until the 1967 birth cohort. The high school graduates and some college groups are more difficult to compare across the two countries because of the different definitions used.

<sup>28</sup>The main exception is Heckman, Lochner and Taber (1998). More recently Huggett, Ventura and Yaron (2006) relaxed the constant price assumption and assumed a constant rate of growth for the rental rate equal to the average growth rate in mean real earnings. Guvenen and Kuruscu (2007) take a similar approach in calibrating their model of inequality.

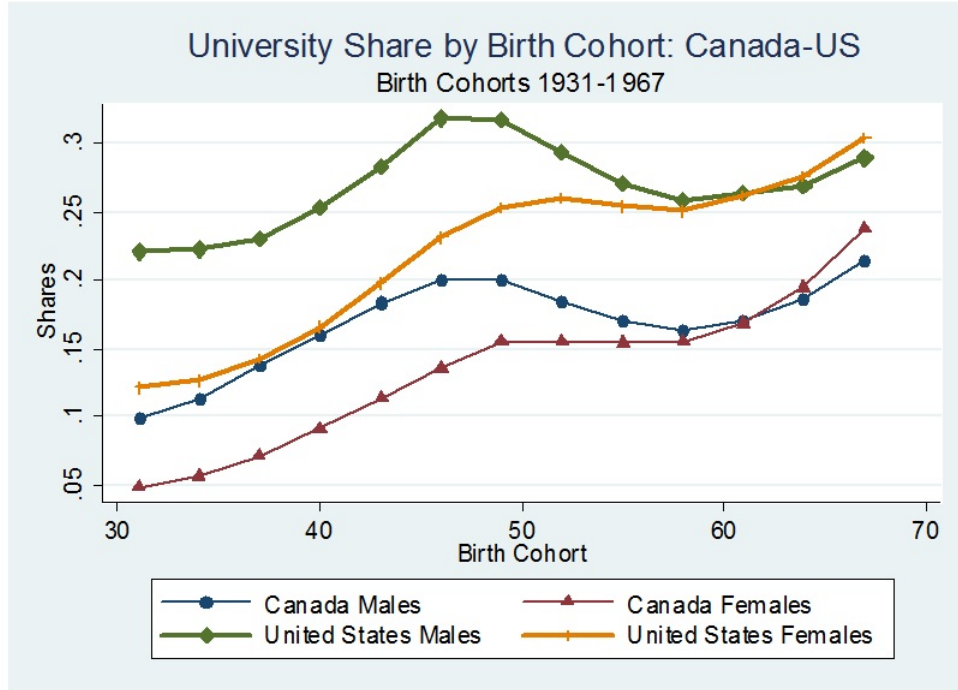


Figure 7: University Education by Cohort: Canada vs. US

human capital profiles are difficult to make sense of within a standard Ben-Porath model.<sup>29</sup> They have different shapes and often cross. By contrast, using the benchmark price series, the pattern represents a sequence of cohort profiles all with the classic Ben-Porath shape. Instead of varying shapes and profile crossing, the profile shapes are much closer to each other and to a standard concave profile. The benchmark price series produces these readily interpretable sequences of concave profiles across cohorts for all education groups.

## 6.2 Estimating Cohort Effects on the Life-cycle Human Capital Profiles of University Graduates

The university premium increased from 1980 to 2000 in both countries primarily for young university graduates.<sup>30</sup> As reported in Table 5, the decomposition of the young university premium, shows that

<sup>29</sup>All of the life-cycle analysis is done for males only. A full analysis for females needs to deal with the selection arising from a different life-cycle participation pattern.

<sup>30</sup>In fact, for Canada the premium for older university graduates actually fell over the period.

the major source of the premium increase is the the increase in relative quantities rather than in relative prices. The actual efficiency units for the median young male Canadian university graduate in Table 5 shows a 13.8% increase; the pattern is similar for the US. In the BR framework the increased efficiency units for young male university graduates reflect cohort effects due to time varying selection into university and technological improvement in human capital production. These effects may be seen by plotting the human capital profiles for different cohorts and approximate magnitudes of the cohort effects may be simply estimated, as in BR, using a standard parametric form for the human capital profiles. A similar life-cycle analysis is conducted for Canada using the Census data.

Different vintages of university graduates may have different types of human capital or different amounts of the same type. The maintained hypothesis in BR is that university graduates have the same type of human capital across cohorts and therefore that shifts across cohorts in human capital profiles reflect different amounts of the same type of human capital associated with different vintages of university graduate. The human capital profiles for Canadian male university graduates, using the benchmark price series is plotted in Figure 8. The analysis is, unfortunately, more limited for Canada because of the later start date for the price series (1980 vs. 1963). It is not possible to use birth cohorts much before the late 1930s. However, for the available birth cohorts, there is again a sequence of relatively very smooth profiles with the classic Ben-Porath shape using the benchmark price series.

The direction and magnitudes of the shifts is examined in more detail, as in BR, by imposing a common quadratic specification for the profiles in experience for as many three year birth cohorts as possible given the span of the data and estimating the cohort intercepts. The results for both countries are shown in Table 4.

The omitted cohort is 1946 (1945-1947) which, in terms of cohort effects due to selection, is the turning point in both Canada and the US. The results for the US from BR using cohorts from 1937 to 1961 over the age range (30-45) shows a pattern of cohort intercepts, relative to 1946, that is exactly what would be expected, given the cohort education patterns in Figure 7. By assumption for cohorts after 1946, the effects due to technological improvement in human capital production are positive and increasing. In addition, for the 1949 to the 1958 cohort, the effects due to selection for males are positive, while from 1946 to 1949 and from 1958 to 1961 they are zero. The cohort dummy variables reflect this pattern with relatively large increases between 1949 to 1958. The intercept

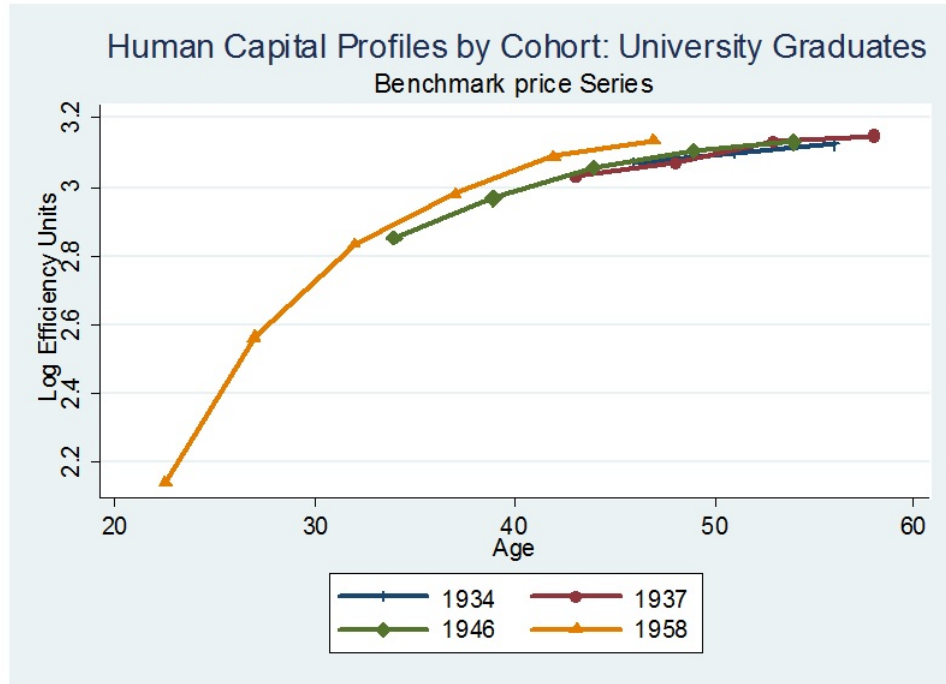


Figure 8: Life-cycle Efficiency Units Profiles: Canadian Male University Graduates

difference over 15 years from the “worst” post war cohort of 1946 to the “best” cohort of 1961 is 10.8. Of the 1946 birth cohort, 30.47% were university graduates; by the 1961 cohort this had fallen to 24.62%, implying a potentially large selection effect as up to 20% of the worst students are no longer going to university.

For the US male cohorts before 1946, the selection effects imply improved cohorts, but this may be partially offset by the negative effect of moving to earlier human capital production functions. The estimates show this: moving backwards from 1946 the intercepts increase, but by more modest amounts than the increase moving forward. The 1943 and 1958 cohorts have roughly similar fractions going to university and therefore differ mainly because of technological improvement. The magnitude suggests secular technological improvement at an annual rate of about a third to half a percentage point. This implies that the improvement in the 1958 male cohort over the 1946 cohort is composed

Dependent Variable: Log Efficiency Units		
Birth Cohort	Cohort Dummy Coefficient	
	United States	Canada
1937	0.0447(*)	.
1940	0.0420(**)	.
1943	0.291(*)	0.0030
1949	-0.0031	-0.0026
1952	0.0178	0.0207(**)
1955	0.0483(**)	0.0337(**)
1958	0.0865(**)	0.0506(**)
1961	0.1076(**)	0.0658(**)
Age	0.0914(**)	0.0815(**)
Age Squared	-0.0009(**)	-0.0008(**)
$R^2$	0.8866	0.9938
N	144	30
Note: Significance levels at 5% and 1% levels indicated by * and **		

Table 4: Estimated Life-cycle Human Capital Profiles for Males by Cohort: Canada and the US

of roughly equal contributions from selection effects and technological improvement.<sup>31</sup>

The shorter price series for Canada results in a more limited analysis over the birth cohorts from 1943 to 1961. Nevertheless, the results for these cohorts are again consistent with the BR framework. They show exactly the same pattern of improved cohorts after 1946 when the selection effects implied by Figure 7 reinforce the secular technological improvement in human capital production as was observed for the US. The improvement is, however, more muted for Canada.<sup>32</sup>

The potential magnitudes of the selection effects for the US were assessed in BR by examining the distribution of human capital quantities within the 1946 birth cohort which had the largest fraction of the cohort completing university. The average real hourly wage in the FTFY sample for males

<sup>31</sup>As an alternative, the cumulative difference in the profiles (compared to the 1946 profile) over 30-45 was estimated without the quadratic approximation and produced the same pattern.

<sup>32</sup>The results for Canada for cohorts before 1946 are limited to the single 1943 cohort. For the US this has a small positive and significant effect, interpreted in the BR framework as a relative strong selection effect outweighing the negative effect from an older human capital production technology for this cohort. For Canada the point estimate is positive, but the magnitude is very small and insignificantly different from zero. If the secular technological improvement rate from advancing knowledge is the same in the two countries, this implies a weaker selection effect for Canada between the 1946 and 1943 birth cohorts. In fact, inspection of Figure 8 shows a potentially weaker selection effect. For the US, the fraction of university graduates in the birth cohort increases by 12.61% between the 1943 and 1946 birth cohorts (.2831 to .3188). For Canada the increase was only 7.00% (.1858 to .1988).

between 40 and 49 years of age, in this cohort is \$16.06. The (negative) difference in the fraction of college graduates in the 1937 and 1946 birth cohorts is about 37%, and between the 1958 and 1946 birth cohorts is about 21%. Assuming a stable correlation of one between ability and education, the potential selection effect can be estimated by comparing the unconditional mean \$16.06, with the conditional mean after removing 37% (1937-1946) or 21% (1958-1946). The predicted difference due to selection for the 1958 cohort over the 1946 cohort is 14.60%, and for the 1937 cohort is 25.81%. Given the assumption on the correlation these are upper bounds. In Table 4 the human capital of the 1958 US birth cohort is 8.65% above the 1946 birth cohort, which includes both selection and technological improvement effects. Attributing one half of this to selection is quite consistent with a positive correlation between ability and education of much less than one.

The potential magnitude of the selection effects for Canada are assessed in a similar way. The results show very similar magnitudes for any given percentage changes from the 1946 birth cohort's fraction completing university. The percentage changes from the 1949 cohort to the 1961 cohort for the US and Canada are declines of 16.87% and 14.42%, respectively. The decline in the US is larger. This produces a larger increase in the potential per capita quantity increase in the US. Using the actual percentage changes in real hourly wages at the 16.87% and 14.42% cutoffs, the potential quantity increase is 22% larger for the US (12.19 vs 10.01). This is consistent with the more muted increase in the intercepts for the post war cohorts in Canada compared to the US. The actual quality increase also depends on the correlation between ability and completed education. Evidence from Belley, Frenette and Lochner (2014) shows a stronger correlation for the US, controlling for parental income, between ability and post-secondary attendance. However, they are much closer for attendance at a 4 year institution.<sup>33</sup>

Overall, the life-cycle evidence for males in Canada is consistent with the same factors driving cohort effects of similar magnitudes in both countries due to similar technological improvement in human capital production and similar selection effects as the fraction of birth cohorts with a university degree peaked around 1946 and then declined substantially in both countries. In particular, at the university level the evidence is consistent with similar rates of technological improvement.

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<sup>33</sup>The picture is complicated by the interaction with parental income differing across the two countries.

## 7 Human Capital and Growth in Canada and the US

Within the heterogeneous human capital framework of the previous sections, overall growth in human capital depends on per capita growth for each of the four human capital types through cohort effects estimated in the previous section, on education choices that determine the fraction of the four human capital types, and on growth in the working population. However, the heterogeneous human capital framework is not particularly convenient for aggregate growth studies which tend to use a single measure for the labor input. A homogeneous human capital model has great benefits as the conceptual basis for defining an aggregate labor input and corresponding aggregate wage. The single price feature of the model provides an elegant solution to the definition of the aggregate wage: the price of an efficiency unit,  $\lambda$ , of homogeneous human capital. The single type feature provides a similarly elegant solution to defining the aggregate labor input: the quantity of efficiency units,  $E$ . The high correlation exhibited by the price series for both countries documented in Figures 1 (US) and 3 (Canada) implies that for aggregate level analysis the homogeneous price assumption could be used as a reasonable approximation for aggregate analysis. With homogeneous human capital a total efficiency units series can be calculated simply by dividing total wage payments by the (single) price series,  $\lambda_t$ .<sup>34</sup>

In this section aggregate efficiency units series for each country using single price series derived by pooling the highly correlated series in Figure 1 (US) and Figure 3 (Canada) are compared with more conventional simple aggregate hours or composition adjusted aggregate hours measures for each country. The estimates of per capita human capital quantities for the US in BR, and similar results for Canada in Table 4 above show substantial cohort effects for the university group, through selection and technological improvement in human capital production, on median efficiency units within age (experience) and education groups. As reported in BR, this results in substantial under-estimation of the growth in the true labor input for the US over 1975-2000, and hence substantial over-estimation of the growth in MFP over the same period, relative to those obtained using standard composition adjusted input measures. It is shown below that this is also the case for Canada.

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<sup>34</sup>The issue is quite different if human capital is heterogeneous. If human capital is heterogeneous and the types are observationally identifiable by, say, education level, there is little to be gained by arbitrarily aggregating the different types. The production function could simply be modelled with all of the different human capital types. A recent example of this is Johnson and Keane (2008) who estimate a model with 160 different types of human capital.

## 7.1 Composition Adjusted Hours

Most standard aggregate labor input measures are some form of composition adjusted hours. The BLS provides the main official composition adjusted series for the US as part of its Multi-factor Productivity (MFP) Program. This measure is used in the construction of the BLS MFP index. The BLS measure is described in detail in the BLS Handbook of Methods (1997), and in BLS Bulletin 2426 (1993), which reported the first estimates. It is based on a Tornqvist chained index of weighted hours of workers classified by skill and demographic characteristics.<sup>35</sup>

Other measures of aggregate input, focusing on composition adjustment, have been constructed in the business cycle literature and the macroeconomics literature more generally. Examples include Hansen (1993) and Kydland and Prescott (1993) for a single aggregate, and Katz and Murphy (1992) and Krusell et.al. (2000) for aggregates by skill group. These series are all efficiency units based, either for the economy as a whole or within skill group. They all use a composition adjustment approach, and they produce very similar estimates to the BLS estimates, to which they are closely related.

Statistics Canada takes a similar position to the BLS in recognizing the need to adjust the aggregate hours measures for composition changes, especially regarding skill levels. The current methods make use of a very similar chaining technique to that used by the BLS. The Canadian procedure uses the Fisher ideal index rather than the Tornqvist index. However, these methods produce almost identical estimates. As of 2001, Canada used a two stage approach, first constructing aggregate hours measures at the industry level, and then aggregating the hours growth rates at the industry level using weights based on composition shares. However, an approach similar to that of Jorgenson and the BLS that incorporates composition adjustment at an earlier stage has also been used.<sup>37</sup> Estimates from this approach are presented in Gu *et al.* (2002).

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<sup>35</sup>Prior to the development of the BLS measure, a number of authors had developed and published composition adjusted aggregate hours series. See, for example, Chinloy (1980), Denison (1985), and Jorgenson, Gollop and Fraumeni (1987). The most well known current version of these is the Jorgenson series for the U.S. private economy, 1977-2000.<sup>36</sup> When the Jorgenson series is scaled to the BLS series in 1977, the two labor input series look almost the same. See BR for more details.

<sup>37</sup>See Statistics Canada (2001), Appendix 1.



## 7.2 Aggregate Labor Input: Comparison of the Alternative Measures

Table 5 reports the growth rates from 1980 to 2000 for the three alternative aggregate labor input measure for the two countries for paid workers, age 20-64.<sup>38</sup> The BLS-style (Tornqvist) composition adjusted series was calculated as described in BR, using 120 groups classified by education, age and sex for paid workers aged 20-64.<sup>39</sup> Total unadjusted hours grew faster in the United States (47%)

	Canada			United States		
	All	Males	Females	All	Males	Females
Efficiency Units	0.6603	0.4464	1.1889	0.8548	0.6658	1.3029
Hours	0.3987	0.2458	0.6688	0.4699	0.3573	0.6377
BLS	0.5640	.	.	0.6402	.	.
BLS(A)	.	0.3626	1.0620	.	0.4732	1.0365
BLS(B)	.	0.3968	0.9618	.	0.5371	0.8677

Table 5: Growth Rates of Alternative Labor Input Series

than in Canada (40%), due to the faster growth of hours for US males. The growth in female hours was slightly higher in Canada (67% vs. 64%) but male hours grew much slower in Canada (25% vs. 36%). The growth in hours was substantially less than the growth in composition adjusted hours in both countries. In addition, for both countries the growth in composition adjusted hours was itself substantially less than the growth in efficiency units. Composition adjusted hours grew faster than the unadjusted series because of the increased education level in the population. Efficiency units grew faster than composition adjusted hours because the composition adjustment ignores the cohort effects.

The magnitudes of the differences between the measures are large for both countries. For Canada, the growth rate in efficiency units was 66.03%, compared to 56.40% growth in composition adjusted hours and 39.87% growth in aggregate hours. For the US efficiency units grew by 85.48%, compared to 46.99% for aggregate hours and 64.02% for composition adjusted hours. For both countries the composition adjustment rate was about the same. For Canada, the composition adjustment produces a labor input growth that is about 40% higher than the unadjusted hours growth. However, the growth in efficiency units was 65.6% higher. The standard composition adjustment to hours is

<sup>38</sup>Comparison of the three measures have simple interpretation within the homogeneous human capital framework derived in BR.

<sup>39</sup>The March supplement weights were used for all the total estimates, for the US. For Canada the RDC census file weights were used.

therefore only about 60% of the full adjustment to aggregate hours that is necessary to estimate labor input growth between 1980 and 2000 for Canada. Similarly, for the US, the standard composition adjustment to hours is only about 45% of the full adjustment.

Table 5 also reports the growth rates of alternative labor input measures by sex. The price series are all estimated using wage data from males. The significant variation in life-cycle and secular female labor force participation, as well as discrimination, introduces major difficulties in estimating the price series from female wage data.<sup>40</sup> The BLS method for total hours uses compensation shares to weight the growth of each type of hours, including male versus female. The logic of this weighting suggests that to get separate totals for males and females, the total labor input estimate should be split between males and females according to the compensation shares in the year, assuming no discrimination. The results for this method are denoted BLS (A). An alternative is to apply the BLS method separately to estimate compensation share weighted male hours growth and compensation share weighted female hours growth. The results in this case are denoted BLS (B).

The use of compensation shares in the BLS method implicitly assumes that the wage rate for females reflects the true marginal product, i.e. there is no discrimination. The estimates of total efficiency units in Table 5 are also based on this assumption. If discrimination creates a significant difference between the wage and the marginal product of female labor, without adjustment the total efficiency units series would be underestimated, and the degree of underestimation would vary over time as the degree of discrimination varied. In a standard employer discrimination model, where efficiency units of males and females are identical, but females receive a lower rental rate due to discrimination, the true efficiency series should be calculated separately for males and females. For males it is calculated as before by dividing total wage payments by the estimated price; for females, the total wage payments first have to be scaled up according to the amount of the discrimination. If, for example, discrimination against females was declining over the period, the growth in efficiency units for females would be over-estimated.<sup>41</sup>

Human capital theory predicts that the increased labor market attachment of females in both countries has increased female human capital investment. The substantial literature on female wage differentials has documented this increase, which has taken many forms, including more market oriented human capital investments for females at university. This increase has resulted in an

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<sup>40</sup>See Bowlus and Robinson (2016) for more discussion of this issue.

<sup>41</sup>See Bowlus and Robinson (2016).

increase in the total labor input of females by all measures, including total hours. Bowlus and Robinson (2016) provide estimates of increased efficiency units supplied by females within education and experience cells for the U.S. using both the wage-based methods employed in BR, but also using job-skills data.

In Canada, total hours for female paid workers increased by 66.88% from 1980 to 2000, which is more than double the growth in male hours of 24.58%. The growth in efficiency units for females, however, is particularly pronounced. From 1980 to 2000 the growth in efficiency units for females is 118.89%, which is almost double the growth in hours. In contrast, much smaller rates of growth are estimated using the BLS style measures: 106.20% for BLS (A) and 96.18% for BLS (B). The same pattern is observed in the US. Efficiency units grow by 130.29% but the BLS measures show much smaller growth, with 103.65% for BLS(A) and 86.77% for BLS(B).

Estimated growth rates were also constructed using fixed weight methods. BR constructed efficiency unit aggregates by skill and in total using a method analogous to Krusell *et al.* (2000) and Kydland and Prescott (1993). These fixed weight methods are similar to the BLS and Jorgenson methods in that they aggregate the hours of different types of workers using average wages as weights, classifying the different types of workers according to age, sex and education. The composition adjustment applied to aggregate hours implied by the fixed weight approach is almost identical to the estimates obtained for BLS style methods. Thus, the fixed weight method has the same degree of underestimation of the increase in the labor input as the BLS method. Fixed weight methods, by construction, do not permit total efficiency units of labor to increase if the demographic composition does not change, except through hours.

### 7.3 Other Evidence on Cohort Effects

The estimates of the true labour input presented in Table 5 reflect three important cohort effects that cannot be picked up by standard composition adjustment methods: (1) strong increases in per capita efficiency units supplied by higher skilled workers in the birth cohorts from 1946 to 1963 due to selection effects on ability in education and technological improvement in human capital production, and more modest increases thereafter as selection effects reverse; (2) strong increases in per capita efficiency units supplied by females in most of the post-war birth cohorts induced by higher expected working lifetime for these cohort, and (3) a decrease in per capita efficiency units supplied by lower skilled male workers. In this paper, the net cohort effects for each worker type are identified using

estimates of human capital prices obtained by the flat spot method. This provides a general method for obtaining human capital quantities, adjusting for cohort effects, from wage data. However, there is also other evidence from other approaches supporting the importance of cohort effects and the patterns reported here.

Cohort effects, with a particular emphasis on measuring increases in per capita efficiency units supplied by females in post-war US birth cohorts, are examined in Bowlus and Robinson (2016), contrasting the “wage-based” approach used in BR and in this paper, with a “job-skills” based approach.<sup>42</sup> They show that the same qualitative pattern of cohort effects can be found from both the indirect wage-based approach and the more direct job-skills based approach. In particular, using the job-skills approach Bowlus and Robinson (2016) find: (1) increases in per capita efficiency units supplied by higher skilled workers in the birth cohorts from 1949 to 1963, with particularly strong increases for females, and (2) decreases in per capita efficiency units supplied by lower skilled workers, but much less for females.

Carneiro and Lee (2011) present evidence on cohort effects that imply increased per capita efficiency units supplied by higher skilled workers in the birth cohorts from 1949 to 1963 due to selection effects on ability in education, but use a different approach to the flat spot method employed in this paper. Instead Carneiro and Lee (2011) compare the wages in the same US state market at the same time of university graduates that came from different states where the cohort patterns by education were different. Their main finding is that there are important cohort effects on the measured skill premium due to an inverse correlation between average ability of university graduates and the fraction of the birth cohort enrolling in university. They use data from the National Longitudinal Survey of Young Males, the National Longitudinal Survey of Youth (1979), National Longitudinal Survey of Youth (1997), SAT and International Adult Literacy Survey to show that empirical results from many different sources of direct skill measures are all consistent with their main finding. They also show that for the birth cohorts after 1949, when college enrollment declined, there was a “quality” improvement.<sup>43</sup>

Hendricks and Schoellman (2014) also use evidence from standardized test scores to show a

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<sup>42</sup>The job-skills based approach uses job-skills data from the Dictionary of Occupational Titles to construct skill portfolios by occupation and assigns these skill portfolios to workers based on their 3-digit occupation code. See Bowlus and Robinson (2016) for more details.

<sup>43</sup>They note that from 1990 to 2000 the quality of university workers in the age group 36-40 increased substantially. In 1990 this age group represents the birth cohorts starting in 1950 when college enrollment started the significant decline from its peak shown in Figure 7.

growing gap between the abilities of the higher skill (college educated) and lower skill workers. They argue that most of the rise in the college premium is explained by changes in the relative ability of university students and note that: “This result is derived from a different methodology but arrives at a similar conclusion as Bowlus and Robinson (2012), who find that 72% of the rise in the college wage premium between the years 1980-1995 can be attributed to changes in the quantity of labor services provided by college relative to high school graduates.”<sup>44</sup>

BR argue that, in addition to education selection effects that make some cohorts of university graduates better than others, more recent university graduates embody more advanced knowledge. The medical, engineering or physics labour input of a university graduate of a given ability entering the market in 2000 is greater than the corresponding input of a graduate of the same ability entering the market in 1960. The large increase in efficiency units for the young university graduates over the 1980-2000 period combines both this secular improvement in human capital production at the university level and a positive selection effect. In contrast, the efficiency units of lower skill workers declined, suggesting a potential deterioration in human capital production at the elementary and/or secondary school level.

Evidence on the effectiveness of the general education system for more recent cohorts for several countries is examined in Green and Riddell (2013) and Barrett and Riddell (2016), using evidence from the International Adult Literacy Survey, the International Adult Literacy and Life Skills Survey, and the Survey of Adult Skills (PIAAC). Their evidence is consistent with the decrease in per capita efficiency units supplied by lower skilled workers. They show evidence of strong cohort effects for many OECD countries, including the US and Canada. Importantly, they show that these cohort effects are negative for recent cohorts in a majority of OECD countries. These studies also try to assess the relative importance of parental background and formal schooling to the generation of literacy and find a very important role for the formal schooling system. The conclusion from Green and Riddell (2013) is that “we are doing a poorer and poorer job of educating successive generations.”<sup>45</sup>

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<sup>44</sup>Hendricks and Schoellman (2014), p. 14.

<sup>45</sup>Green and Riddell (2013), p.17.

## 7.4 Consequences for Multi-factor Productivity

One important consequence of taking into account the cohort effects on the aggregate labour input is the potential for serious overestimation of MFP and underestimation of human capital in growth. In fact, a major motivation for the construction of quality adjusted labor input series like those of Jorgenson, the BLS and Statistics Canada is that the use of unadjusted hours results in a substantial bias in the estimation of MFP. MFP is defined in a similar way in the United States and Canada. Since changes in MFP are defined as the residual change in output that cannot be accounted for by the changes in the inputs, the estimates of these changes are sensitive to the estimates of the changes in the inputs. For the US for the period 1975 to 2001, the growth in hours underestimates the growth in efficiency units of paid private workers by 62.04 percentage points. Since the share of labor in total costs is roughly two thirds,<sup>46</sup> this implies that MFP would be overestimated by about 40 percentage points if unadjusted hours were used. Using composition adjusted hours makes a substantial correction to this, but still underestimates the growth in efficiency units by 36.46 percentage points. Hence, this BLS type adjustment still implies an overestimate of the growth of MFP of 24 percentage points. The actual BLS estimate of MFP growth in the private business sector between 1975 and 2001 is 23.76 percent.<sup>47</sup> The results therefore suggest that all of this could be due to an undercount of the increase in the labor input. In fact, as noted earlier, our efficiency units estimate for females is probably too high which exaggerates the underestimate of efficiency units and the overestimate of MFP. For example, the overestimate of MFP would be reduced to below 20 percentage points if discrimination against females over the period declined in the range of 10-12 percentage points.

Even with a reasonable adjustment for the estimated increase in female efficiency units, these results for MFP indicate that much of the source of improvement over time in standard of living is due to technological improvements in the production of human capital or increased human capital investment. Individuals exposed to more recent education and on-the-job training systems receive more value added to their human capital. This is not captured by composition adjustment. Similarly, composition adjustment cannot capture the increased human capital for females that would be expected from a large increase in lifetime participation and hours for females.

For Canada, for the 1980 to 2000 period, efficiency units for paid workers grew by 26 percentage

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<sup>46</sup>The BLS estimates for labor share in total cost are 0.678 in 1975 and 0.686 in 2001.

<sup>47</sup>See Table PB4a in mfp2ddod.txt at the BLS Multi-factor Productivity website.

points more than unadjusted hours and 10 percentage points more than composition adjusted hours. (The differences for the US for the same population and period are 38 and 21.) The labor share of total costs in Canada is similar to that in the US at about two thirds. This implies an over-estimate of MFP growth by 7 percentage points over the 1980 to 2000 period. This is one half of conventional estimates of MFP growth for the period, suggesting again that a substantial part of estimated growth is actually due to an undercount of the increase in the labor input.

The results for both countries show large effects on the estimates of MFP when quality variation across time in the labor input is controlled for. MFP no longer appears to be the main driver of within country changes in standard of living. Rather, the main driver appears to be increases in per capita human capital, adjusted for quality. There is a large and increasing literature on incorporating quality adjustments to human capital measures for international comparisons and international growth studies. In a recent paper that re-opens the question on the sources of cross country variation in wealth, Manuelli and Seshadri (2014) argue that quality differences in human capital, that are not captured by observed measures that are typically used in composition adjustments, substantially reduces the role of MFP differences in explaining cross country differences in wealth. Their estimates show very little cross country difference in MFP when the quality of human capital is taken into account. TFP in the poorest countries is not much smaller than that of the United States at around 73% of the United States figure. By contrast, studies that do not take into account human capital quality find rates for the poorest countries at only 20% of the United States value. This mirrors the findings in this section that there is much less difference across time within countries in MFP when the quality of human capital is taken into account.

## 8 Conclusions

Canada and the US showed different paths in wages, skill premiums, and inequality over the last three or four decades. The evidence presented in this paper suggests that a major reason for these different paths was a different evolution of human capital prices in the two countries over the period, especially the relative decline in the price for university level human capital in Canada compared to the US. Analysis of this difference in price paths within the framework of the canonical model suggests that one reason for the depressed the skill price in Canada relative to the US is the difference in the “immigration shocks” in the two countries analyzed in Aydemir and Borjas (2007). Differences

in firm productivity and SBTC may also have played a role.

In both countries there are declines in worker productivity for young, lower skilled workers. In the US all lower skill workers show declining productivity, but in Canada the older lower skilled workers show no decline. In contrast, university graduates in both countries show increasing productivity. A notable feature of the cross country comparison in median wages is a clear difference by age for the less skilled (below university) workers. In the US, less skilled older workers experienced the same declines as younger workers, but not in Canada, where older workers avoided the large declines experienced by younger workers. Using the price series estimates, this results in an increase in efficiency units for older workers in Canada below university level that does not occur for the US. The different pattern of wages for the older non-university groups in Canada may be influenced by institutional differences across countries, in particular the much larger presence of unions and the public sector partially protecting older workers from downward wage adjustment.

In terms of wages, university graduates do much better in the US than in Canada. This is not due to differences in the path of high skill worker productivity in the two countries, but rather to the difference in the cross country difference in the path of the high skill price series. A decomposition of the path of the university premium shows that in both countries the increase in the premium was mainly due to a relative per worker quantity increase in the human capital of university graduates compared to high school graduates that was similar in both countries. For Canada, almost all the premium increase is due to this relative quantity change. For the US, the larger premium increase reflects a similar relative quantity change, but is larger because of the added contribution of a relative price increase. However, as for Canada, the contribution of the relative quantity change is much larger than the contribution of the relative price change. For Canada almost all the increase is due to relative quantity changes, while in the US it is about two thirds.

In both countries the per worker relative quantity changes in human capital reflect cohort effects due to selection and technological progress in human capital production, especially for the university educated workers. Estimates of these effects in a life-cycle framework show a common pattern across countries in the relation between the human capital profiles of university graduates from successive birth cohorts. Both countries show the pattern that would be expected from a combination of secular technological improvement in human capital production and selection effects implied by the changing fraction of university graduates by birth cohort. While the qualitative patterns in the path of the fraction of university graduates by birth cohort are the same across countries, there are



some differences in the magnitudes. These differences are consistent with different magnitudes for the selection effects in Canada implied by the differences across countries in the magnitude of the changes in the fraction of university graduates by birth cohort.

The estimated price series for the two countries allow the estimation of the growth in the true labor input in each country, taking into account changes in efficiency units within age, sex and education groups that cannot be captured in standard composition adjusted hours measures. The omission of these effects in standard measures leads to a substantial under-estimation in the growth of the true labor input in both countries in the 1980-2000 period. The difference is mainly due to technological improvement in human capital production, broadly interpreted, and the increased human capital investment of females from more recent cohorts implied by their higher levels of labor force participation. For both countries, adjusting the labor input for quality changes by using the estimated quantity series dramatically reduces the contribution of MFP growth in standard of living growth. This parallels the recent result in Manuelli and Seshadri (2014) that quality adjustment to international comparisons of human capital comes close to eliminating MFP differences as the source of cross country differences in wealth.

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