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Oleksiy Kryvtsov and Alexander Ueberfeldt

Canadian Economic Analysis Department
Bank of Canada
Ottawa, Ontario, Canada K1A 0G9
okryvtsov@bankofcanada.ca
aueberfeldt@bankofcanada.ca

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Abstract

This paper analyzes the differences in wage ratios of university graduates to less than university graduates, the education premium, in Canada and the United States from 1980 to 2000. Both countries experienced a similar increase in the fraction of university graduates and a similar increase in skill biased technological change based on capital-embodied technological progress, but only the United States had a large increase in the education premium. Using a calibrated Krussel et al. (2000) model, the paper finds that the cross country difference is in equal proportion due to the effective stock of capital equipment, the growth in skilled labor supply relative to unskilled labor and the relative abundance of skilled population in 1980. Growth in the working age population is unimportant for the difference.

JEL classification: E24, E25, J24, J31
Bank classification: Labour markets; Productivity

Résumé

Les auteurs analysent la prime à l'éducation, c'est-à-dire la disparité salariale entre les diplômés du niveau universitaire et de niveau préuniversitaire, au Canada et aux États-Unis de 1980 à 2000. Si la proportion des diplômés d'université a crû de manière analogue dans ces deux pays, de même que le rythme du progrès technique intégré au capital et favorisant la demande de main-d'œuvre qualifiée, ce n'est qu'aux États-Unis que la prime à l'éducation a fortement augmenté. À l'aide d'une version étalonnée du modèle de Krusell et autres (2000), les auteurs constatent que l'écart entre le Canada et son voisin américain est imputable, à parts égales, au stock réel de biens d'équipement, à la croissance de la main-d'œuvre qualifiée par rapport à la main-d'œuvre non qualifiée et à la relative abondance des travailleurs qualifiés en 1980. La croissance de la population en âge de travailler n'est pas un facteur significatif.

Classification JEL : E24, E25, J24, J31
Classification de la Banque : Marchés du travail; Productivité

1. Introduction

The United States experienced a large increase in wage inequality since 1980. A big part of this change was due to the increase in earnings per hour of university graduates relative to less than university graduates, the education premium. While the United States saw an increase in the education premium, Canada experienced a relative constancy of its education premium.[1] Over the same period, both countries saw a comparable increase in the relative supply of university graduates and, as we find, a similar increase in capital-embodied technological progress. The paper addresses the following questions: Firstly, can a model of the education premium based on capital-skill complementarity and skill-biased technological progress account at the same time for the large increase in the education premium in the United States and the small increase in Canada? Secondly, what are the main driving forces behind the observed differences?

This paper, first, provides a formal analysis of the Canadian and the U.S. education premium and establishes that capital-embodied skill-biased technological progress together with capital-skill complementarity can indeed account for the observed patterns of the education premium in the two countries. Second, we use an accounting procedure that allows to quantify the relative importance of the various sources of the cross-country education premium difference. We find two potential sources of wage inequality related to university education, that in sum account for two thirds of the education-premium difference. These important sources of the cross country difference are: the fraction of university graduates in working age population in 1980 and the rate at which the fraction of university educated in the working age population growth. In particular, the 1980 values of the supply of university graduates relative to the less than university graduates are very important for the stagnation of the education premium in Canada compared to the United States.

In our analysis, we employ a partial equilibrium model developed in Krusell et al. (2000). The core of this approach is a technology in which capital equipment is complementary to the labor input of skilled workers, i.e. university graduates, and this combined aggregate is a relative substitute to unskilled labor. The driving engine of the wage premium is an increase in the productivity of capital equipment that increases the demand for skilled labor and at the same time drives up the wage premium.[2] Using labor data taken from various surveys

[1] This difference in the cross country pattern has been noted before, for example by Bar-Or, Burbidge, Magee, and Robb (1995) for the period 1971 to 1991, and Burbidge, Magee, and Robb (2002) for the period 1981 to 2000.

[2] Our work is related to a large host of papers, that consider the education premium in the United states. The positive secular co-movement of relative wages and total hours in the United States has been a subject

and the National Accounts of both Canada and the United States, we show that a calibrated version of the model is consistent with many features of the education premium data in both countries. In particular the model captures the initial slow growth in the education premium for the United States from 1961 to 1980 and the strong increase thereafter. For Canada the model captures the initial decline in the education premium in the early 80s, the stagnation till the 1990s and the increase at the end of the 1990s. Considering the quotient of the education premia for the two countries (education premium Canada over education premium U.S.), we show that the model matches its hockey-stick shape nearly perfectly and the level very well.

Building on this success, we propose a decomposition of the education premium into different components. This decomposition, in the spirit of a variance decomposition, allows us to quantify the importance of the factors affecting the education premium. One main conclusion is that differences in quality-adjusted capital equipment per skilled hour worked only account for about 1/3 of the cross-country difference in the wage premium differential. The major part of the difference is attributed to labor factors. Here we show that differences in population growth rates between the two countries play a small role for the wage premia difference.[3] In contrast, the fraction of skilled individuals in the working age population and its growth play a very important role, indeed nearly twice as important as skill-biased technological progress.

Our analysis suggests, that the difference in the initial (1980) skill distribution in the working age population is very important for the development of the education premium thereafter. The key here is that Canada in 1980 has 10.8% skilled workers, compared to 17.3% in the U.S. The intuition behind this finding is that the higher fraction of schooled workers in the working age population implies slower growth of total schooled hours relative to total unschooled hours, putting pressure on the education premium to grow faster. We also find that while the level of the fraction of schooled population is important for the overall trend in the education premium difference, its growth rate helps explaining the year-to-year changes.

Our findings highlight that the effect of skill-biased technological progress on wage inequality is determined to a large extent by education choice and labor supply. In particular,

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of research effort for many years. One prominent theory is skill-biased technological change, going back to Katz and Murphy (1999). Murphy, Riddell, and Romer (1998) extended this analysis to Canada and found a shift in the demand for skilled labor comparable to that found for the United States.

[3] He (2007) finds that demographic change played an important role in the development of the U.S. education premium.

we show that depending on initial levels and relative growth of (skilled and unskilled) labor supplies, education premia can range from constant across time to quickly increasing. The effect of the initial conditions also suggests that a future increase in the education premium in Canada is more likely than no increase at all.

The rest of the paper proceeds as follows. Section 2 describes the main data facts. Section 3 presents the model. That model is calibrated in Section 4 and then employed in Section 5 to evaluate the cross country differences with respect to education inequality, labor supply, and investment. Section 6 concludes.

2. Main facts for Canada and United States

This section presents data on the wage of schooled compared to the wage of unschooled individuals, as well as working time, and the relative size of the two groups for Canada and the United States. Furthermore, we show the data for capital equipment and structures. Due to data availability, we consider data for the United States from 1961 to 2002 and for Canada from 1980 to 2000. We utilize a longer range of data for the United States to calibrate the Krusell et al. (2000) model that we use to account for the education premium differential. Moreover, we emphasize the similarities between Canada after 1980 and the United States between the 1960s and the 1980s. In many respects, skill supply and education based inequality today are similar in Canada to the respective statistics for the United States in the 1980s.

2.1 Main facts for education premium and hours

The data on working hours and earnings for the United States are based on the March supplement of the Current Population Statistics (CPS) as provided by the IPUMS project.[4] The analogous data for Canada are taken from the census and the Survey of Consumer Finance.[5] Following a convention in the literature, we restrict our sample to males aged 16

[4] IPUMS-CPS home at www.ipums.org/cps for the 1962 to 2003 surveys (Miriam King, Steven Ruggles, Trent Alexander, Donna Leicach, and Matthew Sobek. Integrated Public Use Microdata Series, Current Population Survey: Version 2.0. [Machine-readable database]. Minneapolis, MN: Minnesota Population Center [producer and distributor], 2004).

[5] We would have prefered to get all the Canadian data from one consistent source, unfortunately this was not possible. There was a break in the educational data provided by Statistics Canada for all annual surveys in 1989. This break is due to a change in the educational attainment question that allows more cathegories to choose from. In particular the question was changed from an 'educational attendance' to an 'educational attainment' question. This led to a decrease in the official measure of university graduates. We made an adjustment for that break to obtain consistent data series for the years 1980 to 2000 using the educational

to 64. Before age 16, 85% of men go to school and after 64 (the common retirement age) the fraction of males working decreases by about 80%.[6]

The population in our sample is divided into two education groups: university graduates (or "schooled") and less than university graduates ("unschooled"). This is a convenient division and has been used before, for example by Krusell, Ohanian, Rios-Rull, and Violante (2000). In the case of the United States a schooled individual is a person that has completed at least 4 years of college. In contrast an unschooled individual is a person in the population with 0 years of schooling up to 3 years of college completed. For Canada a schooled individual is a person with a bachelors degree or more, while an unschooled individual is a person without any higher university degree.[7] A finer division of the group of unschooled persons does not alter our main facts. For example, the group of persons with 1 to 3 years of college is much closer in terms of their earnings per hour to the group of highschool graduates, than to the group of college graduates.[8]

Given these groups, we are interested in documenting the evolution of average hours worked per person, the proportion of schooled individuals in the working age population, and earnings per hour for each education group in the last four decades.

Consider the following decomposition of average hours worked:

$$\frac{H}{N} = \frac{N_s}{N}\frac{H_s}{N_s} + \left(1 - \frac{N_s}{N}\right)\frac{H_u}{N_u} \ , \tag{1}$$

where H_i, N_i, and N stand, respectively for the total hours worked by group i, the number of persons in group i, and the working age population.[9] By definition, $H_s + H_u = H$ and $N_s + N_u = N$. We define $h_i \equiv H_i/N_i$ as the average hours worked for group i. We refer

attainment definition. Appendices A and B provide detailed descriptions of the data and their treatment for both countries.

[6] The main reason for restricting our attention to males instead of the whole population is that earnings per hour of women, especially of less educated women, are catching up with those of males. By including women in the analysis, we would add issues that we believe to be unrelated to the fundamentals that drive the education premium change. For a treatment of the gender-wage-gap we refer to Jones, Manuelli, and McGrattan (2003).

[7] Idealy, we would have used the same definition for the two goups in both countries. Unfortunately, this is not feasible due to data availability restrictions. Eckstein and Nagypal (2004) show that the two measures in the case of the CPS for the United States are highly correlated for whenever they are both available.

[8] As pointed out by Eckstein and Nagypal (2004), there appears to be a considerable difference between pure undergraduate degree holders and graduate degree holders in terms of their earnings per hour. Unfortunately for the CPS, a subdivision of the group of college graduates is infeasible for the whole period and would introduce arbitrariness if we did it. Therefore we abstain from performing it.

[9] An alternative decomposition would distinguish between employed and not employed individuals in the

to $E \equiv N_s/N$ as the fraction of schooled individuals in the working age population. The earnings per hour for each education group are measured by the hours weighted median earnings per hour of employed persons in the respective group. To be comparable with the widely used measure of average earnings, we use an hours-weighted median. Using the median and not the mean helps us to navigate around the change in the CPS' top coding procedure.[10] For convenience, we refer to the median earnings per hour as wage. Finally, we define the education premium as the wage of a university graduate to that of a less than university graduate.

The evidence is divided into three groups. We first report the facts related to the observed wage inequality between schooled and unschoooled in Canada and U.S. Then we present two facts on the relative supply of labor of schooled and unschooled workers. In the last subsection, we report the key fact regarding capital stocks.

Fact W1: While the United States experienced a strong increase in the education premium from 1980 to 2000 (+26%), Canada saw no increase at all (0.0%) (see Table 1, last column).

Fact W2: During the 1980s the United States experienced a much stronger increase in the education premium than Canada. The 1990s was a period of slow overall growth and some setback in the education premium for the United States. Overall Canada's education premium varied considerably around a mean of 1.5 over the whole period from 1980 to 2000 (see Figure 1).

Next, we compare the two countries' wage premia. Let $w^i_{j,t}$ denote wage per hour of workers of type j in country i in year t. Types are "schooled" and "unschooled" workers,

working age population:

$$\begin{aligned}\frac{H}{N} &= \frac{H}{\widetilde{N}} \times \frac{\widetilde{N}}{N} \\ &= \left[\frac{\widetilde{N}_s}{\widetilde{N}}\frac{H_s}{\widetilde{N}_s} + \left(1 - \frac{\widetilde{N}_s}{\widetilde{N}}\right)\frac{H_u}{\widetilde{N}_u}\right] \times \frac{\widetilde{N}}{N}\ ,\end{aligned}$$

where $\widetilde{N}_i$, $\widetilde{N}$ denote the number of workers in group i, and the employed population respectively. We find that, since we focus on *male* population, the paths of the fractions of employed to working age population (within groups and total) are not important for explaining the wage premium differential.

[10]The CPS puts an upper cap on the highest amount of earnings per year that is reported. Changes in this cap can affect the mean, but not the median. An example for a change in the cap is a doubling of the cap in 1988. For a discussion of top coding on inequality measures see Bernstein and Mishel (1997).

$j = \{s, u\}$, and countries are U.S. and Canada, $i = \{US, CA\}$. The ratio of education premia, i.e. the education-premium differential (EPD) is defined as

$$EPD_t = \left(\frac{w_{s,t}^{CA}}{w_{u,t}^{CA}} \right) / \left(\frac{w_{s,t}^{US}}{w_{u,t}^{US}} \right) \tag{2}$$

Figure 2 shows the EPD_t for the period from 1980 to 2000. Relative to the U.S. the education premium was falling from 1980 to around 1994, with the differential falling from 1.13 to 0.84. After 1994 the premia were growing at approximately the same rate, with the differential increasing slightly from 0.84 to 0.90. We summarize this in as follows:

Fact W3: The education-premium differential between Canada and the United states is hockey-stick shaped, with the initial point being above one and the end point being below one.

Next, we consider the relative labor supply of the two education groups. This will give us a feeling of the relative importance of the labor supply side for the wage determination. The relevant data are summarized in Figures 3, 4 and Table 1.

Fact L1: Both countries experienced a large increase in the relative supply of schooled total hours (7.3% in Canada compared to 6.4% in the U.S.). The main difference is in the *level* of labor supplies stemming from a lower fraction of schooled in the working age population in Canada, 10.8%, compared to higher fraction of 17.3% in the United States.

The increase in the relative labor supply can in turn be decomposed into contributions from the relative fraction of schooled persons and the ratio of average hours worked in each group:

Fact L2: (i) The relative increase in schooled total hours is mostly due to an increase in the fraction of schooled persons in population. In Canada the increase was 6.5 percentage points and in the United States 6.2 percentage points.

(ii) In contrast, average working hours barely increased over the whole period. Figure 4 shows that average hours varied sizably around a constant mean. It is noteworthy that the schooled persons work more on average in the United States than in Canada, while the unschooled work roughly the same in the two countries.

To summarize, in 1980-2000 both the United States and Canada experienced a large increase in schooled total hours that is mostly due to an increase in the fraction of educated persons in the working age population. Despite this, the paths of education premia differ in the two countries: in the United States the premium increased considerably, while it stagnated in Canada.

2.2 Capital and technological progress

Another important aspect of our analysis is related to capital stocks. We divide the capital stock into two components: structures and equipment. For the purpose of this paper we are mainly interested in quality changes in equipment and, in particular, in capital-embodied technological progress. Since Krusell et al. (2000) capital-embodied technological progress is considered as one of the main drivers of the demand for schooled workers through its complementarity with skilled labor. Thus differences in capital-embodied technological progress could account for the difference in the education premia. While there are many empirical studies that have looked at capital-embodied technological progress in the United States, nearly no work has been done for Canada.[11] For consistency, we undertake the same approach for constructing the capital equipment stocks for both Canada and the United States.[12]

Following Greenwood et al. (1997), Krusell et al. (2000), and Cummins and Violante (2002), we make an adjustment to capital equipment that is based on the approach introduced by Gordon (1990). This adjustment captures quality improvement that was underestimated by the statistical agencies. The stock of capital equipment is reported in National Income and Product Account (NIPA) tables and for most of our period of interest the Bureau of Economic Analysis does not adjusted for quality changes. Gordon (1990) conducts a hedonic regression analysis to document the quality component of the growth of equipment. He finds that the quality of capital equipment increased by a factor of 4 from 1961 to 1982. Krusell et al. (2000) use Gordon's quality time series and extrapolate it to cover their period of interest.

[11] Statistics Canada has used hedonic pricing techniques for the case of computers and related equipment. This started at the end of the 1980s.

[12] In the appendix, we evaluate the validity of this proceedure, by comparing our construct for the United States with measures derived by Cummins and Violante (2002), Krusell et al. (1998), and Greenwood et al. (1997). We find that the differences are fairly small particularly for the period from 1980 to 2000.

Equations (3) and (4) present the measurement and quality adjustment of capital stocks:

$$K^{st} = \frac{\text{Structures NIPA}}{\text{Structures deflator NIPA}} \tag{3}$$

$$\widetilde{K}^{eq} = \underbrace{\frac{\text{Equipment NIPA}}{\text{Qual. adj. Equipment deflator NIPA}}}_{K^{eq}} \cdot \underbrace{\frac{\text{Qual. adj. Equipment NIPA}}{\text{Equipment deflator NIPA}}}_{q} \tag{4}$$

Equation (4) captures the quality adjustment of the stock of equipment, where K^{st} and $\widetilde{K}^{eq}$ are, respectively, measured real stocks of capital structures and equipment. The tilda as in K^{eq} denotes the quality-adjusted stock and q is the quality adjustment factor.

The construction of the exact measures proceeds as follows: We use the capital stocks as reported in the asset part of the NIPA together with the investment and consumption deflator. As a first step, we calculate the structures capital stock:

$$K_{structures} = \frac{\text{nominal structures}}{\text{consumption deflator}}.$$

Next, we construct the quality adjustment factor. Here, we go back to the work done by Gordon (1990) and Cummins and Violante (2002). For a given year t, the quality factor is moving according to:

$$q_t = \frac{d_{equipment,t}}{d_{consumption,t}} \times (1.024)^{1960-t}\,; \forall t = 1960, ..., 2002.$$

This approach suggests that for the period from 1960 to 2002 the capital stock experienced an average quality improvement of 2.4% above what is already part of ratio between the investment deflator and the consumption deflator. This average quality adjustment growth is close to what Gordon and others find for the United States. Since, we have no comparable study for Canada, we assume that it experienced the same long run average quality improvement in equipment as the United States.[13]

To convert the NIPA equipment into quality-adjusted equipment, we perform the following

[13] To the extend that a large fraction of Canadian equipment is imported with the majority from the United States (in this contect Dion et al. 2005 estimate an import propensity of 70%), this seems to be a reasonable benchmark. In Section 5 we show that our main results are not sensitive to alternative definitions of the quality factor.

calculations. First, we take the standard measure of capital equipment[14], i.e. what consumers effectively spend on investment, and evaluate it in terms of the spending on consumption.

$$\widetilde{K}_{eq,t} = \frac{\text{nominal equipment in } t}{d_{consumption,t}}.$$

Then we use the quality factor to find the quality-adjusted capital equipment as given by:

$$K_{eq,t} = \frac{\widetilde{K}_{eq,t}}{q_t}.$$

We now analyze the stocks of capital equipment both quality and quantity for Canada and the United States. The following summarizes the findings for capital stocks per working age male. Figure 5 presents the capital stocks per working age male in real consumption units. All the data are normalized to 100 in 1980. The data for capital stocks show that over the period from 1980 to 1998, Canada's capital stocks (both equipment and structures) are lagging behind the respective counterpart in the U.S.[15] Next, we turn to the quality adjustment factor. In Table 2 and Figure 6 the data for the quality adjustment factor are presented. Figure 6 also shows the quality-adjusted equipment capital stock. All presented series are normalized to be 100 in 1980. We find that in both countries a large decrease in the relative price of investment in capital equipment occurred. The magnitude of the decline for the two countries is comparable. Now we are ready to combine these facts and look at the quality-adjusted equipment stocks. Here we can see that the quality-adjusted equipment stock for Canada increased by nearly the same factor as that of the United States. This is to a large part due to an increase of the quality component of the equipment stock.

We close this section by combining the findings on quality-adjusted capital equipment with education data. In particular we are interested in the quality-adjusted stock of capital equipment per schooled hour. To this end we combe data on quality-adjusted capital equipment with data on total hours supplied by schooled males. Figure 7 is a plot of the quality-adjusted equipment per male-schooled hour operated in Canada and the United States. We refer to this ratio as the equipment-skill intensity. The measure for both countries is normalized to

[14] We use both residential and non-residential equipment stocks. Where the residential part is negligible. One implicit assumption we are making is that the residential equipment exhibits the same quality change as the non-residential equipment.

[15] One difference between capital stock treatment in Canada and the U.S. is that Statistics Canada is using a higher depreciation rate when constructing the capital series. We assume that this is justified by having a higher economic depreciation. It is noteworthy that Canada has a higher fraction of structures compared to the United States.

100 in 1980.

Fact K: The equipment-skill intensity in Canada and the United States increased considerably over 1980-2000 and 1961-2000 periods respectively. Canada increased faster during the 1980s but fell behind the United States at the beginning of the 1990s. The gap for 2000 was 16%.

To summarize the insights regarding capital equipment: Both countries experienced a considerable increase in the equipment embodied technological progress. Taking the supply of skill into account reveals that Canada has a deficit in the equipment-skill intensity relative to the United States that has started in the early 1990s and has persisted since then.

3. Krusell et al. (2000) model

In this Section we present the partial equilibrium model of skill-biased technological change due to Krusell et al. (2000). The key element of this model is a technology that exhibits a complementarity between capital equipment and skilled labor. In such an environment an increased supply in capital equipment drives up the demand for skilled labor. This technology is consistent with the data in that it admits for both the secular rise in relative wages and the rise in schooled hours (see footnote 16). The precise definition of the technology is provided by a production function $F(\cdot)$ that has four input factors: aggregate stocks of capital equipment K_{eq} and structures K_{st}, total hours of schooled workers H_s and total hours of unschooled workers H_u :

$$\begin{aligned} F\left(K_{eq}, K_{st}, H_s, H_u\right) &= A\left(K_{st}\right)^{\alpha} \times \\ &\left[\theta_u\left(A_s H_u\right)^{\eta} + \left(1-\theta_u\right)\left(\theta_k\left(K_{eq}\right)^{\kappa} + \left(1-\theta_k\right)\left(A_s H_s\right)^{\kappa}\right)^{\eta/\kappa}\right]^{(1-\alpha)/\eta} \end{aligned} \tag{5}$$

The parameters of the technology are constrained to guarantee two input relationships. First, capital equipment and labor services of schooled are complementary, that is if $\kappa < 0$. Second, total hours of unschooled, on the other hand, are substitutes with capital-skill aggregate, so that $\eta > 0$. The technological progress is embodied in capital equipment and thus implicitly (given the complementarity assumption between capital and skill) an increase in effective capital equipment is the source of an increasing demand for hours of college graduates in the model. The remaining parameters include: share parameters α, θ_u, $\theta_k \in [0, 1]$, total factor productivity $A \in \mathbb{R}_{++}$, and the labor-efficiency parameter $A_s \in \mathbb{R}_{++}$.

Under competitive factor markets, wages of schooled, w_s, and unschooled, w_u, hours are equal to their respective marginal products:

$$\frac{w_s H_s}{Y} = \frac{(1-\alpha)\,\Theta\left(\frac{\theta_K}{1-\theta_K}\left(\frac{K_{eq}}{A_s H_s}\right)^{\kappa}+1\right)^{\frac{\eta-\kappa}{\kappa}}}{\left(\frac{H_s}{H_u}\right)^{\eta}+\Theta\left(\frac{\theta_K}{1-\theta_K}\left(\frac{K_{eq}}{A_s H_s}\right)^{\kappa}+1\right)^{\eta/\kappa}} \tag{6}$$

$$\frac{w_u H_u}{Y} = \frac{(1-\alpha)\left(\frac{H_s}{H_u}\right)^{\eta}}{\left(\frac{H_s}{H_u}\right)^{\eta}+\Theta\left(\frac{\theta_K}{1-\theta_K}\left(\frac{K_{eq}}{A_s H_s}\right)^{\kappa}+1\right)^{\eta/\kappa}} \tag{7}$$

where $\Theta \equiv \frac{(1-\theta_u)(1-\theta_K)^{\frac{\eta}{\kappa}}}{\theta_u}$ and Y denotes aggregate output,

$$Y = F\left(K_{eq}, K_{st}, H_s, H_u\right) \tag{8}$$

Equations (6) and (7) imply the following expression for the education-premium:

$$\frac{w_s}{w_u} = \Theta\left(\frac{H_s}{H_u}\right)^{\eta-1}\left(\frac{\theta_K}{1-\theta_K}\left(\frac{K_{eq}}{A_s H_s}\right)^{\kappa}+1\right)^{\frac{\eta-\kappa}{\kappa}} \tag{9}$$

According to (9), the education premium is ceteris paribus negatively related to relative total hours (note that $\eta - 1 < 0$). Hence, for the model to be consistent with the positive secular movement of relative wages and hours in the U.S. (Facts W1, L1 and L2 in Section 2), capital equipment K_{eq} must grow fast enough relative to skilled hours (in efficiency units), $A_s H_s$. In our data, the ratio of the quality-adjusted capital equipment stock to total schooled hours indeed increases: by a factor of eight for the U.S. from 1961 to 2002, and by 2.4 for Canada from 1980 to 2000, see Fact K. Therefore, the Krusell et al. technology, as opposed to other standard aggregate technologies, is consistent with the secular increases in relative wages and hours.[16] In the next Section, we show that Krusell et al. model (9) is able to predict main

[16]The education premium derived from a Cobb-Douglas technology is

$$\frac{w_s}{w_u} = \text{const} \cdot \left(\frac{H_s}{H_u}\right)^{-1}$$

so that the education premium and relative total hours are negatively related.

If the CES technology is symmetric in schooled and unschooled hours, relative wages and hours are (as in the Cobb-Douglas case) negatively related, unless labor efficiency A_s grows fast enough:

$$\frac{w_s}{w_u} = \text{const} \cdot A_S^{\eta}\left(\frac{H_s}{H_u}\right)^{\eta-1}$$

differences in education premia between Canada and the U.S. given their historical paths of quality-adjusted capital equipment and total hours of schooled and unschooled labor.

4. Calibration

To be able to shed light on the evolution of the EPD between U.S. and Canada, we first need to replicate the paths of education premia and the corresponding EPD shown in Figures 1 and 2. This Section describes the calibration procedure that is a simplified version of the one in Krusell et al. (2000). While Krusell et al. estimate a stochastic version of the model, we assume that the model (9) is a deterministic function of historical time series with quality-adjusted capital equipment and labor hours as in the data. In particular, we assume that A_S is a real number (fixing the efficiency of unschooled labor to 1). We show below that a deterministic version of the model does well in predicting the behavior of the education premium in both the U.S. and Canada.[17]

In our calibration, we follow Krusell et al.'s idea and choose the elasticity and share parameters to match the main facts for the U.S. from 1961 to 2002. The advantage of calibrating the model to the U.S. data is twofold. First, it is a longer time series than data for Canada. Second, the education premium in the U.S. exhibits an uneven growth: flat in pre-1980 and growing in post-1980. We think that a successful replication by the model of the complicated path for the U.S. education premium, is a key test of its capability of performing a cross-country comparison.

As noted in the previous Section, Krusell et al.'s aggregate technology in combination with competitive factor markets implies that the education premium is a (nonlinear) function of two ratios: total hours of schooled workers per total hours of unschooled workers, $\frac{H_s}{H_u}$, and equipment per total schooled hours (in efficiency units), $\frac{K_{eq}}{A_s H_s}$. The education premium function contains six parameters: factor demand elasticities $\frac{1}{1-\eta}$, $\frac{1}{1-\kappa}$, share parameters α, θ_u, θ_k, and the labor-efficiency parameter A_s.

The labor-efficiency parameter, A_s, is chosen so that capital equipment per effective schooled labor hour is unity in 1980 This particular normalization is irrelevant for the results that follow. The share of capital structures, α, is pinned down by the ratio of capital

KORV point out that the growth in labor efficiency required to account for labor facts is implausibly large: 11% per year, or a factor of 25 over 30 years.

[17]Simplifying the model is also helpful given the small number of time series observations.

structures to equipment (in consumption units) in 1961.[18] Share parameters, θ_u and θ_K, are determined to match 2002 levels of the total labor share and the wage-bill ratio. Given the calibration of the share parameters, the elasticity-related parameters η and κ are chosen to minimize the sum of squared deviations between the historical and the predicted education premium between 1961 and 2002. Table 2 contains the calibrated parameter values.

Figure 8 demonstrates that the model can replicate both the growth of the U.S. education premium for the post-1980 period, as well as its stagnation for the pre-1980 period. Overall, the model explains 59% of the total variance of the U.S. education premium. The root mean squared error of the predicted education premium in the U.S. is around 7% of its mean for the 1961-2002 period, and it is 6% and 7% respectively in the periods pre- and post-1980. These errors are less than one fifth the size of the secular change of the education premium for the whole period, which is small given the simplicity of the model and the small number of observations. Hence we confirm Krusell et al.'s success in predicting the uneven growth of the U.S. education premium.

Next, keeping the elasticity parameters the same, we recalibrate the share parameters α, θ_u, θ_K to fit the same target moments for Canada in 1980.[19] The predicted path of the education premium in Canada is then given by the paths of capital equipment per effective schooled labor hour, the ratio of total hours as well as those parameters that differ. Figure 8 shows that the model developed in Krusel et al. (2000) can predict slower growth of the education premium in Canada. The root mean squared error of the predicted education premium for Canada is 6% of its mean.

Figure 9 gives the corresponding EPD predicted by the Krusell et al. model. The figure captures two main features of the observed behavior of the education-premium differential between the U.S. and Canada: its decline from above 1 to below 1 between 1980 and 1994 and the standstill thereafter. The mean of the model's EPD, 1.02, is somewhat higher than that in the data, 0.95, because the model predicts lower education premium in the U.S. for the 1980-1995 period, and higher premium in Canada for 1995-2000 period. Given that the levels of education premia can be easily matched by share parameters θ_u or θ_K, we focus our analysis on explaining the variance of the EPD relative to its mean. In that respect, we find

[18] In the model,

$$\alpha = \frac{1 - \text{labor share}}{\left(qK^{eq}/K^{s}\right)\left(r^{s} - \delta_{s} + \delta_{eq}\right)/r^{s} + 1} .$$

Following Krusell et al. (2000), we assume that $r^s = 0.10$, $\delta_s = 0.05$, and $\delta_{eq} = 0.125$

[19] We determine A_s so that capital stock per effective schooled labor hour, $\frac{K_{eq}}{A_s H_s}$, is 1 for Canada. This assumption has no effect on the results.

that Krusell et al. model explains around 78% of the variation in the education-premium differential between U.S. and Canada from 1980 to 2000.

To sum up, the model can successfully capture the education premium facts (W1 and W2) as well as the education-premium differential fact W3. This allows us to use it to quantify the relative contributions of the factors affecting the education premium. We undertake this task in the next section.

5. Accounting for the U.S.-Canada education-premium differential

The model proposed in Krusell et al. (2000) as summarized in equation (9) identifies the factors shaping the path of the education premium. The first question we address is, how important are the relative supplies of each of the following factors in explaining the cross country difference in the education premium: capital equipment per effective schooled labor hour, $\frac{K^i_{eq,t}}{A^i_e H^i_{s,t}}$, income share of capital equipment, θ_K, and relative total hours (schooled to unschooled), $\frac{H^i_{s,t}}{H^i_{u,t}}$? The latter can be represented as the product of the ratio of average hours worked, $\frac{h^i_{s,t}}{h^i_{u,t}}$, and the ratio of the proportion of schooled working age population to that of unschooled, $\frac{E^i_t}{1-E^i_t}$:

$$\frac{H^i_{s,t}}{H^i_{u,t}} = \frac{h^i_{s,t}}{h^i_{u,t}} \cdot \frac{E^i_t}{1 - E^i_t} \tag{10}$$

According to equations (9) and (10) a slowdown in the education premium growth rate may come (all other things equal) from:

1. a lower income share of equipment,

2. a lower growth rate of equipment per efficient schooled hour,

3. a faster growth in the average hours worked by schooled workers relative to those of unschooled workers, or

4. a faster growth in the relative fraction of schooled population.

We quantify the importance of these effects for the observed pattern of the education-premium differential.

The calibrated equipment income share for Canada is somewhat higher than that in the U.S., which would contribute to *higher*, not lower, growth rate of the EPD, making it an unlikely candidate for explaining its variance. Figures 3, 4, and 7 provide time series for each of the three remaining factors for Canada and the U.S. from 1980 to 2000. Capital equipment per effective schooled labor hour in Canada grew slower than in the U.S. Its average annual growth rate was 3.8% versus 5.4% in the U.S. The relative fraction of schooled population in Canada grew faster than in the U.S., 2.7% compared to 1.9% per year on average. Hence both of these two factors are likely to contribute to the explained variation of the EPD. The ratio of average hours (schooled to unschooled) is very similar for Canada and U.S. for most of the period, making it an unlikely factor in explaining the EPD.

Our goal is to quantify the fraction of the variance of the EPD due to the factors above. To describe our methodology, we expand definition (2) of the education-premium differential as follows:

$$EPD\left(\frac{K_{eq,t}^{CA}}{A_s^{CA}H_{s,t}^{CA}}, \theta_K^{CA}, \frac{h_{s,t}^{CA}}{h_{u,t}^{CA}}, \frac{E_t^{CA}}{1-E_t^{CA}} \mid \frac{K_{eq,t}^{US}}{A_s^{US}H_{s,t}^{US}}, \theta_K^{US}, \frac{h_{s,t}^{US}}{h_{u,t}^{US}}, \frac{E_t^{US}}{1-E_t^{US}}\right)$$
$$= \frac{f\left(\frac{K_{eq,t}^{CA}}{A_s^{CA}H_{s,t}^{CA}}, \theta_K^{CA}, \frac{h_{s,t}^{CA}}{h_{u,t}^{CA}}, \frac{E_t^{CA}}{1-E_t^{CA}}\right)}{f\left(\frac{K_{eq,t}^{US}}{A_s^{US}H_{s,t}^{US}}, \theta_K^{US}, \frac{h_{s,t}^{US}}{h_{u,t}^{US}}, \frac{E_t^{US}}{1-E_t^{US}}\right)} \tag{11}$$

Here $f(\cdot)$ is the education premium as a function of the four respective factors, given by the model equations (9) and (10).

The analysis is complicated by the fact that $EPD(\cdot)$ in (11) is a nonlinear function of its arguments and that the number of observations is small. To evaluate the importance of each of the four factors $\left(\frac{K_{eq,t}^{i}}{A_s^{i}H_{s,t}^{i}}, \theta_K^{i}, \frac{h_{s,t}^{i}}{h_{u,t}^{i}}, \frac{E_t^{i}}{1-E_t^{i}}\right)$ for the $EPD(\cdot)$, we substitute consecutively each of the Canadian factors with the corresponding U.S. factor. For example, we start by substituting $\frac{K_{eq,t}^{CA}}{A_s^{CA}H_{s,t}^{CA}}$ in the nominator of (11) with $\frac{K_{eq,t}^{US}}{A_s^{US}H_{s,t}^{US}}$, then θ_K^{CA} with θ_K^{US}, etc. After all Canadian factors are substituted for U.S. factors, the $EPD(\cdot)$ is identically one. To obtain the fraction of variance of the education-premium differential, we regress the log difference in the change of the $EPD(\cdot)$ corresponding to the switch in a given factor, on the log total education-premium differential. For example, the fraction of variance explained by equipment per effective schooled labor hour is given by the following regression:

$$
\begin{aligned}
& \ln\ EPD\left(\frac{K_{eq,t}^{CA}}{A_s^{CA}H_{s,t}^{CA}}, \theta_K^{CA}, \frac{h_{s,t}^{CA}}{h_{u,t}^{CA}}, \frac{E_t^{CA}}{1-E_t^{CA}} \mid \frac{K_{eq,t}^{US}}{A_s^{US}H_{s,t}^{US}}, \theta_K^{US}, \frac{h_{s,t}^{US}}{h_{u,t}^{US}}, \frac{E_t^{US}}{1-E_t^{US}}\right) \\
& -\ln\ EPD\left(\frac{K_{eq,t}^{US}}{A_s^{US}H_{s,t}^{US}}, \theta_K^{CA}, \frac{h_{s,t}^{CA}}{h_{u,t}^{CA}}, \frac{E_t^{CA}}{1-E_t^{CA}} \mid \frac{K_{eq,t}^{US}}{A_s^{US}H_{s,t}^{US}}, \theta_K^{US}, \frac{h_{s,t}^{US}}{h_{u,t}^{US}}, \frac{E_t^{US}}{1-E_t^{US}}\right) \\
= \quad & \texttt{const} + \alpha \ln\ EPD_t + \texttt{residual}
\end{aligned}
$$

where α provides the estimated fraction of EPD variance explained by the difference in historical paths of the capital equipment per effective schooled labor hour in Canada and U.S.

The proposed method has the advantage of not depending on the order of "switching" between countries (Canada with U.S. or vice versa) or between factors. The order of switching the factors does not affect the variance decomposition because f is multiplicative in all factors except $\frac{K_{eq,t}^i}{A_s^i H_{s,t}^i}$ and θ_K^i. In the latter case, the effect of switching order on the decomposition is negligible because of the small difference between θ_K^{CA} and θ_K^{US}. Finally, the variance decomposition uses the least number of degrees of freedom, which is useful given the small number of time series observations.

Column I of Table 3 provides the variance decomposition for all four factors. Equipment per effective schooled labor hour - stemming from its growth (Fact K) and share in income - accounts for about 1/3 of the variance. Note that, if not for higher income share, lower growth rate of capital equipment per schooled hour in Canada would have explained more than a half of the education premium difference. Hence, this result maintains the spirit of the Krusell et al. analysis in that wage differences are to a large extent driven by technological change embodied in capital equipment, which in turn increases the demand for hours supplied by schooled individuals.

Next, we find that the relative fraction of schooled-to-unschooled population (Fact L2 (i)) explains almost 2/3 of the EPD variance, whereas average hours worked (Fact L2 (ii)) do not contribute to the difference. We summarize that our findings on one hand quantify the effect of skill-biased technological change on cross-country education premium difference, and on the other hand suggest that education choice is also important for the education premium.

In column II of Table 3, we provide regression results when independent variable - EPD - is taken directly from the data. Although the variance decomposition in this case holds only approximately, our main results are intact. This is because the model does well in capturing the hockey-stick shape of the secular change in the education-premium difference between the two countries.

The last column of Table 3 corresponds to decomposition of the EPD predicted by the model under the lower growth rate of the quality-adjusted capital equipment in Canada. For the benchmark model, we assumed that the quality of capital equipment in Canada grows at the same rate of 2.4% per year as in the U.S. We repeat the decomposition assuming that the quality growth is 1% per year lower (column III) than in the benchmark decomposition.[20] Even for this much slower quality growth, our main results hold: the relative fraction of schooled in population accounts for a half of the variance of the education-premium differential.

Given the importance of the relative supply of schooled hours, we further decompose $\frac{E_t^i}{1-E_t^i}$ into several components. Let ε_t be the fraction of working age population that becomes schooled in period t, we call it the "schooling rate" in period t :

$$\varepsilon_t^i = \frac{N_{s,t}^i - N_{s,t-1}^i}{N_t^i}$$

where $N_{s,t}^i$ and N_t^i denote schooled and total working age population respectively. Notice that the schooling rate takes into account the net change in the number of schooled workers due to (i) college completion, and (ii) death or retirement of old schooled workers. The fraction can now be written as

$$\begin{aligned} E_t^i &= \frac{N_{s,t}^i}{N_t^i} = \frac{N_{s,1980}^i + \sum_{t'=1981}^{t} \left(N_{s,t'}^i - N_{s,t'-1}^i\right)}{N_t^i} \\ &= \frac{N_{s,1980}^i + \sum_{t'=1981}^{t} \varepsilon_{t'}^i N_{t'}^i}{N_t^i} \end{aligned}$$

dividing through by N_{1980}^i we obtain

$$E_t^i = \frac{E_{1980}^i + \sum_{t'=1981}^{t} \varepsilon_{t'}^i \nu_{1980,t'}^i}{\nu_{1980,t}^i} \tag{12}$$

where $\nu_{t,t'}^i = N_{t'}^i / N_t^i$ is the growth rate of the working age population between the years t and t'. Equation (12) allows us to further decompose the relative fraction of schooled-to-unschooled population $\frac{E_t^i}{1-E_t^i}$ into three components: the fraction of schooled population in

[20] Note that the calibrated parameter values for Canada do not change.

the total working age population in 1980, E^i_{1980}, the schooling rate, $\varepsilon^i_{t'}$, and the working age population growth, $\nu^i_{1980,t'}$.

According to (11) in combination with (12), the growth rate of the education premium is lower if

1. the share of schooled individuals among the 1980 working age population is lower (unambiguously since it is below a half for both countries),

2. the schooling rate is low or grows faster, or

3. the working age population growth is lower.

The share of schooled individuals in the 1980 population in Canada is 61% of that in the U.S., 0.108 compared to 0.196. Figure 10 provides the paths for the schooling rates. Both time series are quite volatile with the schooling rate in Canada on average lower than that in the U.S., 0.46% as opposed to 0.54%. They range between -0.5% and 1.3% for most years, except from 1987 to 1991 for the U.S. when the schooling rate went down from its highest level of 2.4% to its lowest level of -1.5%. Finally, Figure 11 shows that the growth rate of the working age population in Canada, 1.2% per year, is slightly higher than in the U.S., 1.1% per year.[21]

We repeat the EPD variance decomposition, but now incorporating the effect of each of these three additional components. Since the relationship (12) is highly nonlinear, the sequence in which we exchange the components with their U.S. counterpart affects the estimated explained fraction of the variance. Table 4 provides the fraction of the EPD variance explained for each of the 6 combinations of the three components, as well as averages over all combinations.

Two components related to schooling: the fraction of schooled individuals in working age population in 1980 and the schooling rate, each accounts for about one third of the EPD variance. The share of variance explained by the fraction of schooled persons in the population in 1980 is between 25.9 and 41.0% across 6 combinations, averaging 33.4%. Such a big effect owes to the fact that the growth rate of the relative fraction of schooled workers,

[21]For Canada, the growth rate of working age population based on SCF survey is slightly higher than the rate based on the Census data. To be consistent with the growth in the working age population as directly provided by Statistics Canada, we adjust the census years and preserve the series obtained from the SCF. Our results are robust to using alternative time series for the growth rate of working age population in Canada - see details in the Appendix.

$\frac{E_t^i}{1-E_t^i}$, decreases with the *level* of the fraction. In Canada the level of the fraction of schooled workers among the employed population in 1980 is almost half of that in the U.S. In terms of the education premium equation (9), the higher fraction of schooled workers in the employed population implies slower growth of total schooled hours relative to total unschooled hours, putting pressure on the education premium to grow faster. This result brings up the caveat that the secular stagnation of the education premium in Canada is most likely due to the low proportion of schooled individuals in the working age population.

The schooling rate also explains a significant fraction of the EPD variance, between 24.7 and 40.7%, averaging 32.7%. The importance of the schooling rate for the EPD variation stems from explaining its fluctuations around a trend, in particular its sharp decline from 1987 to 1991.[22]

Finally, the effect of the working age population growth is small, ranging from -3.7 to -4.9%, with an average of -4.4%.

Hence the factors related to schooling - the fraction of schooled individuals in working age population in 1980 and the schooling rate - are as important for explaining the U.S.-Canada education-premium difference as the capital equipment per effective schooled hour, which is the standard source of wage inequality in theories based on skill-biased technological change. According to our methodology, each of these three sources accounts for about one third of the variance over 1980-2000 period. These findings emphasize education choice as a key source of wage inequality on par with skill-biased technological progress. Secondly, our results suggest that working age population growth is an unlikely source of the change in wage inequality.

6. Conclusion

We analyze the wage differences between university graduates and less than university graduates for Canada and the United States. We present facts showing that both countries experienced a similar increase in the fraction of university graduates and a similar increase in capital-embodied technological progress, but only the United States had a large increase in the education premium. Furthermore, the wage premium differential between the two countries is hockey-stick shaped with the United States initially lagging in the wage pre-

[22]When we regress on the EPD from the data, the explained fraction shifts from the schooling rate to the level of the fraction of schooled. This happens because the fraction of schooled better explains the hockey-stick shape of the EPD, than the schooling rate which is better at capturing fluctuations around the trend in the model.

mium, then overtaking Canada and only recently starting to loose ground to Canada. This paper uses the methodology developed in Krusell et al. (2000) to show that capital-embodied technological progress together with capital-skill complementarity accounts for these main features of the education premium in both countries. It is established that factors related to schooling - the level and growth of the university educated population - are as important for the cross-country wage premia difference as the effective stock of machinery and equipment goods, each of the three sources accounts for about a third of the difference in the education premium.

Our analysis suggests that low level of capital equipment per hour worked by skilled workers in Canada is underlying its currently lower education premium relative to the United States. Furthermore, we attribute the stagnation of the education premium in Canada to the low fraction of skilled individuals in the working age population. A key prediction here is that as this fraction keeps increasing, the wage inequality between university graduates and less than university graduates should rise. Hence the effect of social policies on schooling - specifically, on long-run levels and growth rates of the fraction of university educated in the working age population - should be a key subject of research on wage inequality.

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Table 1: Working time decomposition for 1961 and 2002.

	United States						
	H/N	N_s/N	H_i/N_i		w_i		w_s/w_u
		in %	S	U	S	U	
1980	29.6	19.6	39.9	27.5	17.7	12.8	1.38
2000	31.4	24.4	39.7	28.7	22.2	12.7	1.75
% change	5.8		-0.5	4.4	24.4	-0.0	26.0
%**pt** change		6.2					
	Canada						
	H/N	N_s/N	H_i/N_i		w_i		w_s/w_u
		in %	S	U	S	U	
1980	30.1	10.8	36.1	29.4	21.5	13.7	1.57
2000	29.1	17.3	34.0	28.1	22.1	14.1	1.57
% change	-1.0		-5.7	-4.3	2.8	2.9	0.0
%**pt** change		6.5					

Note: The notational convention as in the text is that H_i, N_i, N stand, respectively for the total hours worked by group i, the number of persons in group i, and the working age population. The groups are S-schooled and U-unschooled. We define as the average hours of group i : H_i/N_i. We refer to N_s/N as the fraction of schooled in the working age population. We use the hours weighted median over pre-tax earnings per hour worked and note it for group i by w_i.
For the U.S. part of this table we used Current Population Survey data and for the Canada part we used both census data. For details on the data sources and the adjustments, please see the appendix.

Table 2: Calibrated parameter values

Parameter	Canada	U.S.
Elasticity between schooled and unschooled labor hours, η	0.555	
Elasticity between schooled hours and capital equipment, κ	-0.591	
Share of capital structures in output, α	0.274	0.230
Share of unschooled labor hours in output, θ_u	0.461	0.417
Share of capital equipment in output, θ_K	0.426	0.379
Schooled labor efficiency, A_s	474.8	393.6

Table 3: Variance decomposition of the education-premium differential

Factor in variance decomposition	Independent variable		
	EPD_t model	EPD_t data	EPD_t model, slower quality growth in Canada
	(I)	(II)	(III)
Capital equipment per effective schooled labor hour, $\frac{K_{eq}}{A_s H_s}$	54.7	48.3	64.2
Income share of capital equipment, θ_K	-17.9	-18.2	-15.3
Ratio of average hours worked, $\frac{h_s}{h_u}$	1.5	6.7	1.1
Relative fraction of schooled, $\frac{E_s}{1-E_s}$	61.7	50.2	50.0
Total	100.0	87.0	100.0

Note: Entries correspond to the fraction of the EPD variance explained. We regress the log difference in the change of the education premium differential (EPD) from (11) corresponding to the switch in a given factor, on the log total education-premium differential. Corresponding regression coefficients provide the estimated fraction of the EPD variance explained by the difference in historical paths of that factor in Canada and U.S.. Independent variables are: Column I - EPD predicted by the model, Column II - data EPD, Column III - model EPD when the growth rate of capital equipment in Canada is 1% lower than in the benchmark.

Table 4: Variance decomposition of the relative fraction of workers

Factor	Sequence in decomposition of $\frac{E_t}{1-E_t}$						Average
	E ε ν	E ν ε	ν E ε	ε E ν	ε ν E	ν ε E	
Fraction in 1980, E_{1980}	41.0	41.0	40.7	25.9	25.9	25.9	33.4
Schooling rate, ε_t	25.6	24.7	24.7	40.7	40.7	39.5	32.7
Population growth rate, $\nu_{1980,t}$	-4.9	-4.0	-3.7	-4.9	-4.9	-3.7	-4.4
Total, relative fraction of schooled, $\frac{E_t}{1-E_t}$	61.7	61.7	61.7	61.7	61.7	61.7	61.7

Note: relative fraction of schooled-to-unschooled persons in working age population depends on the number of schooled persons, schooling rate and population growth rate, according to equation (12). For the variance decomposition, the sequence in which we "switch" these components affects the estimated explained fraction of variance. Columns provide explained fractions of variance for 6 combinations of the sequence of switching three factors contributing to the relative fraction of workers. For example, first column corresponds to switching the number of schooled persons, E, first, then the schooling rate, ε, and finally the population growth rate, ν.

Figure 1: Education premium in Canada (–) and U.S. (- -).

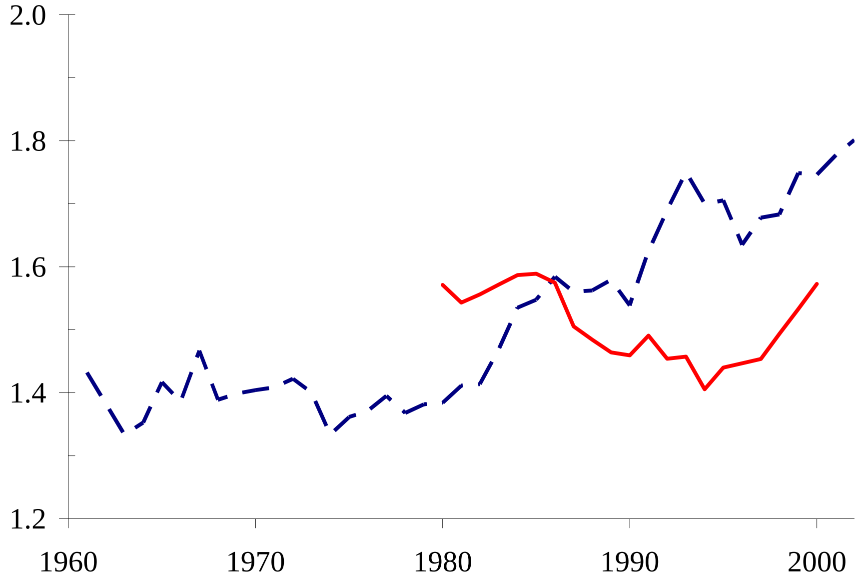


Figure 2: Education premium differential between Canada and U.S., 1980-2000.

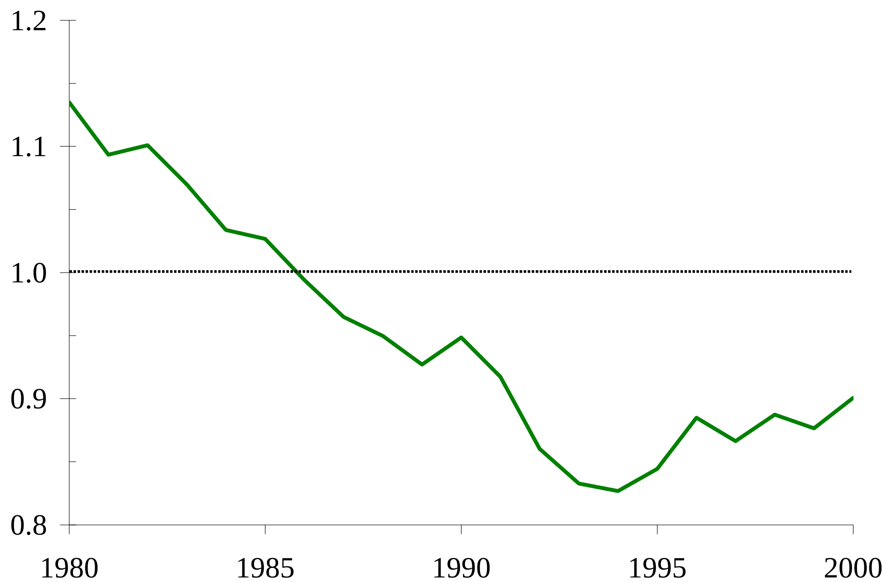


Figure 3: Labor supply of schooled relative to total in Canada (–) and U.S. (- -).

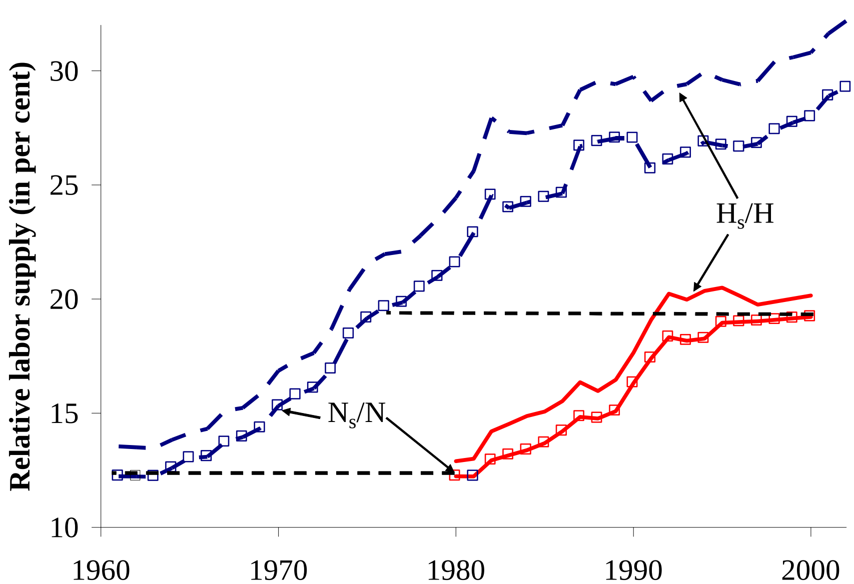


Figure 4: Average hours worked by schooled and unschooled individuals in Canada (–) and U.S. (- -).

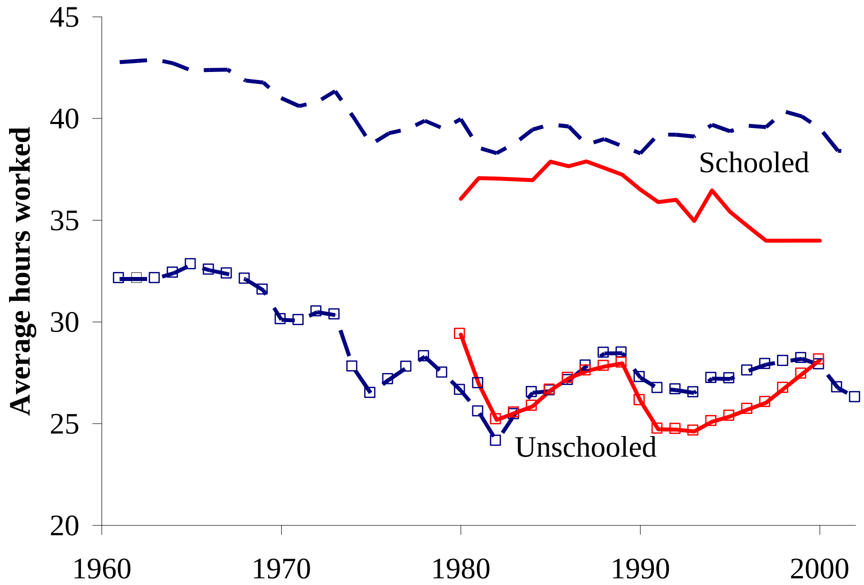


Figure 5: Capital structures and equipment in Canada (–) and U.S. (- -).

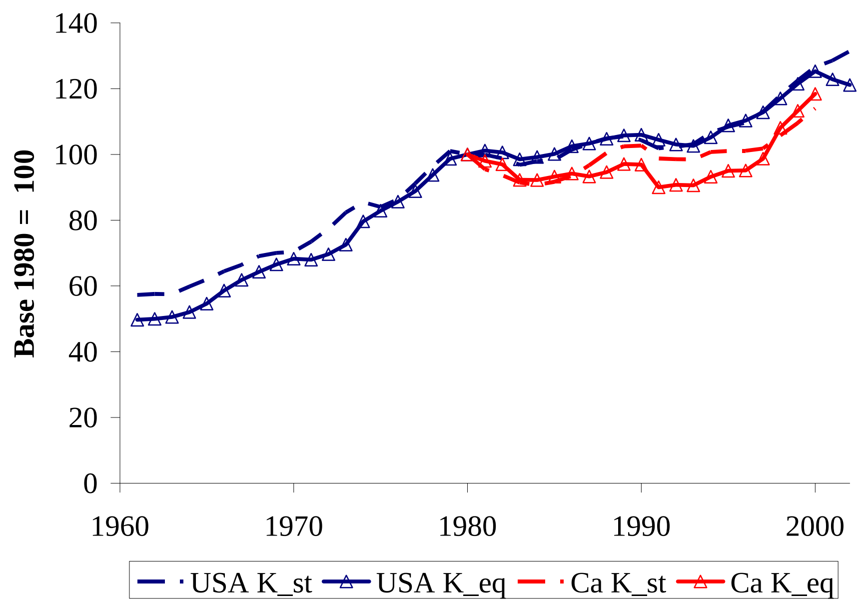


Figure 6: Quality adjsuted capital equipment and the relative price of equipment in Canada (–) and U.S. (- -).

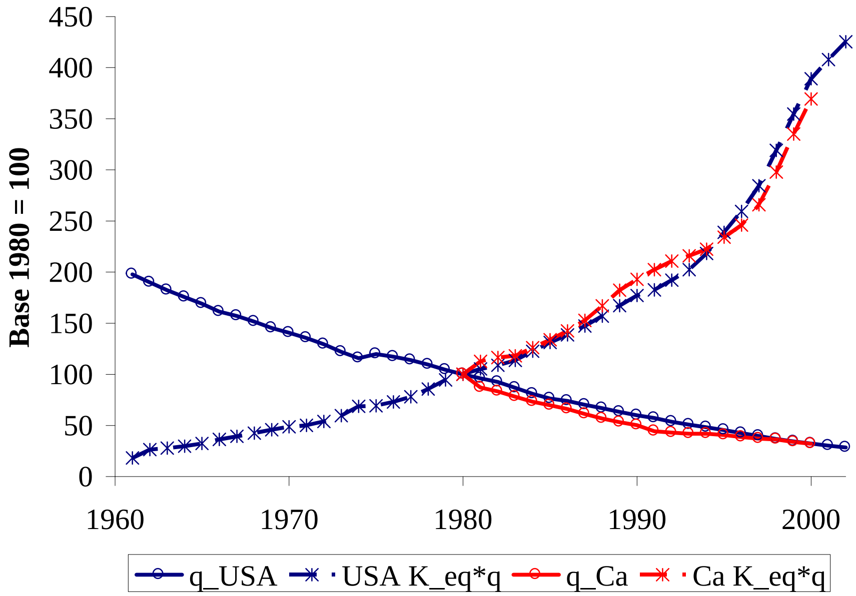


Figure 7: Quality adjusted capital stock per schooled hour worked in Canada (–) and U.S. (- -).

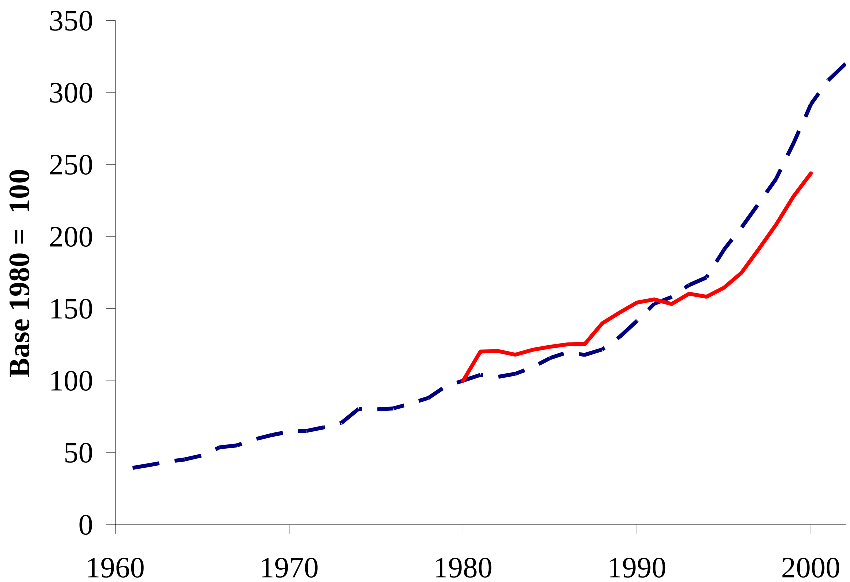


Figure 8: Education premia in U.S. and Canada: data vs KORV model, 1980-2000.

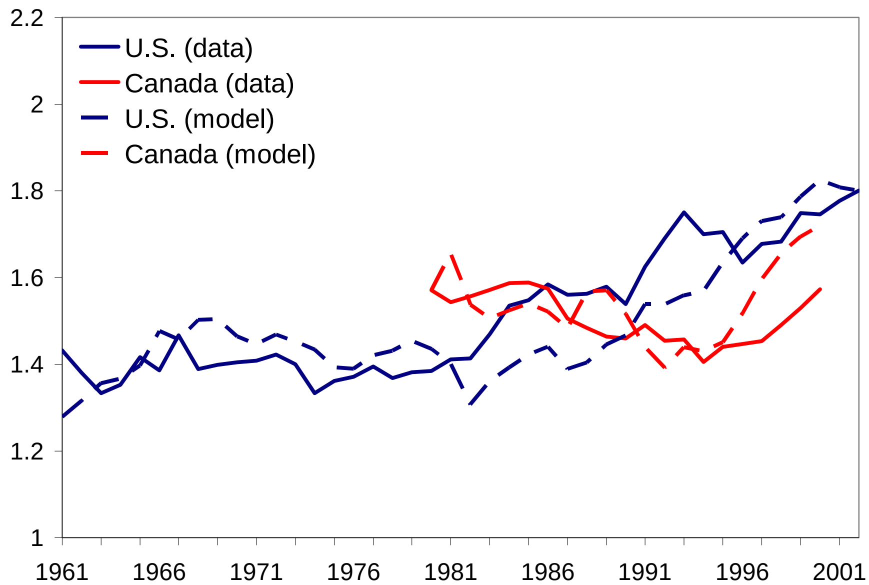


Figure 9: Education premium differential between U.S and Canada: data vs KORV model, 1980-2000.

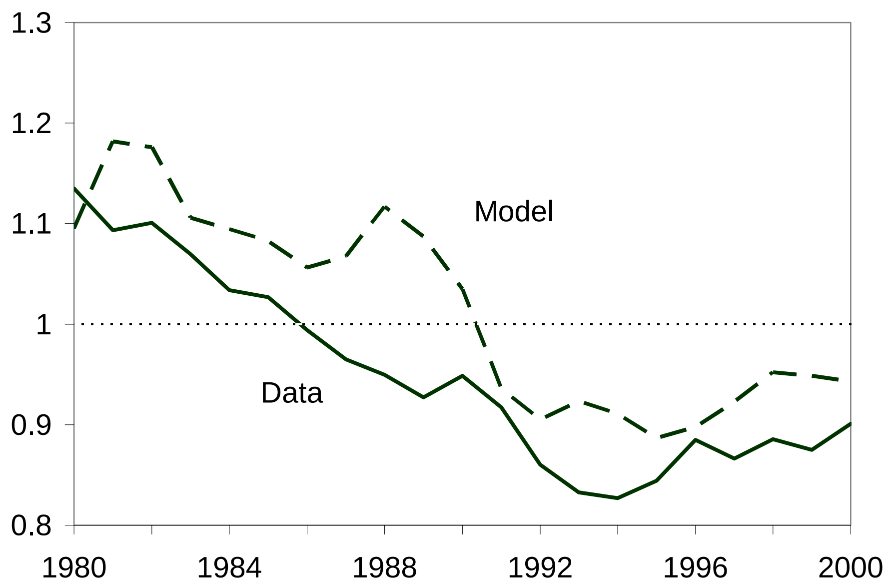


Figure 10: "Schooling rate": change in the number of schooled population (as fraction of total working age population) in Canada and U.S., 1980-2000.

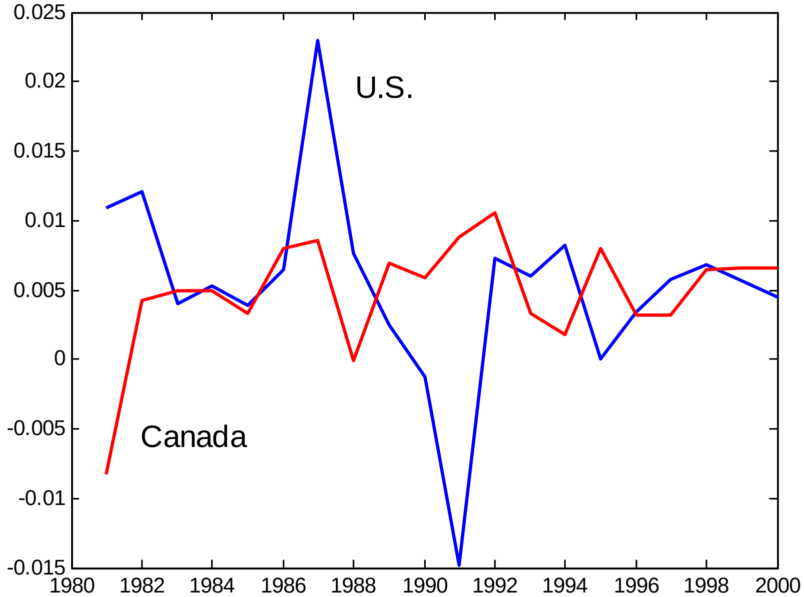
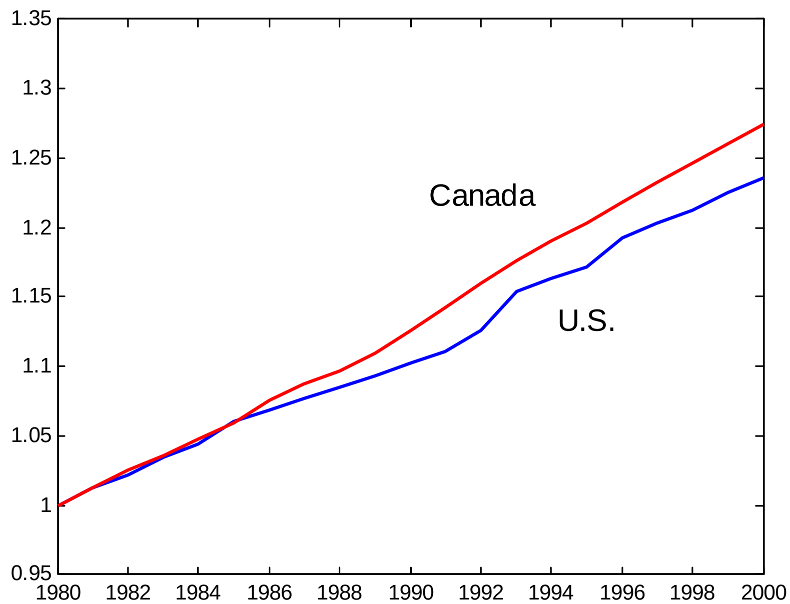


Figure 11: Working age population in Canada and U.S., 1980-2000.



Data appendix

Main data sources

The data sources for the two countries differ: All the labor data, including wage data for the United States, are taken from the March Supplement of the Current Population Survey (CPS). We were not able to find one all encompassing data source for all the labor data for Canada. For the years 1981 and 2001 the census was used; for the years 1982–83, 1985-98 we used the Survey of Consumer Finance (SCF).[1]

USA: We downloaded the following variables from the IPUMS-CPS home at www.ipums.org/cps for the 1962 to 2003 surveys (Miriam King, Steven Ruggles, Trent Alexander, Donna Leicach, and Matthew Sobek. Integrated Public Use Microdata Series, Current Population Survey: Version 2.0. [Machine-readable database]. Minneapolis, MN: Minnesota Population Center [producer and distributor], 2004).

Canada: The SCF labor force data were provided to us in their micro formate by Statistics Canada. Similarly, Statistics Canada provided us with the Census data for the years 1981 and 2001.[2]

Table 1 lists all the variables from the different surveys used to calculate the macro variables needed for our analysis.[3]

[1] Furthermore we made use of the 1991 census to compare the results with those from the same years Survey of Consumer Finance. We found that regarding the variables we are interested in the differences were minor.

[2] For both Canadian and U.S. data some variables like age refers to the year the question is asked, while others like weeks worked last year refers to the preceeding year. This creates a timing issue for variables like earnings per hour worked that takes earnings from last year, weeks worked last year, and hours worked per week in this year to find the correct statistic. We follow the convention that all labor variables refer backward to the previous year. So, according to our convention the earnings per hour from the 1981 census is a measure relevant for the year 1980.

[3] For Canada the table 1 only lists the census names of the variables. This is done, since the census has a relatively consistent way of naming the variables, which is not the case for the Survey of Consumer Finance.

Table 1: CPS variables used.

Variable		Content	Restrictions used
US-CPS	Ca-Census		
		LABOR and INCOME data	
perwt	weightp	frequency weight	
year	(each year individually)	year of survey	
age	agep	age	16-64
sex	sexp	gender	male
educrec		educational attainment record	grades >=1
	dgreep	highest degree earned	
empstat	lfactp	employment status	employed / employed at work
classwkr	cowp	class of worker	control for self employment
wkswork1	wkswkp	weeks worked last year	1976 to 2003
hrswork	hrswkp	hours worked last week	
incwage	wagesp	total wage income last year	

Canada: Education variable

For Canada we encountered some problems with the education variable in the Survey of Consumer Finance for the pre 1990 period. Before 1990, Statistics Canada focused in its Labour Force Survey and related Survey of Consumer Finance on 'educational participation' rather then 'eduational attainment'.[4] Instead of counting the university graduates they were just counting the university attendees. This led to an overcounting of university graduates for the pre 1990 period. Fortunately for us, for the later years we have the education variable according to both definitions and are able to compare the resulting aggregate variables under the two definitions. Using the years for which we have both definitions, namely the census

[4] This problem was stated in the Statistics Canada publication The Labour Force of 1990 in an article by Hélène Lavoie.

years and the post 1998 period, we construct the data we needed in the following way. We illustrate our approach of excluding the persons with some university but no bachelors degree using the example of employment. Our aim is a consistent definition of the group of university graduates that are employed.

Let $E\left(UA\right)$ be the number of employed university attendees (using the old education variable definition) and $E\left(UG\right)$ the number of employed university graduates (using the new education variable definition). We then determine the ratio $r\left(UG\right)=\frac{E(UG)}{E(UA)}$ that gives us the fraction of university graduates as a fraction of all university attendees among the employed. For the period where the ratio is defined we find that it is fairly stable around the mean of 0.8856, with a standard deviation of 0.0117 and no trend. We then construct the time series of university graduates, that are employed, as follows:

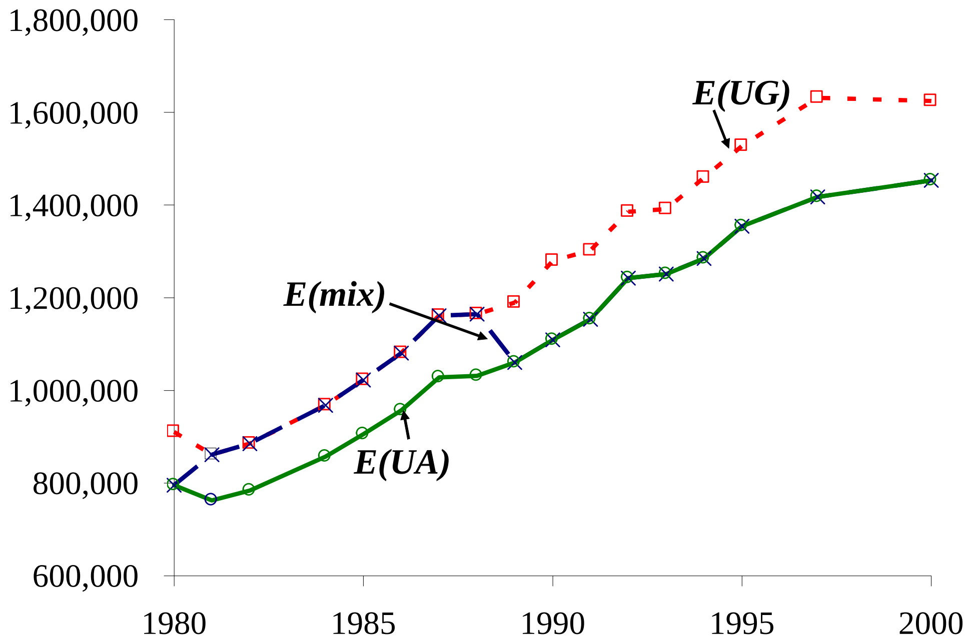
$$\begin{aligned}
E\left(UG,t\right) &= E\left(UA,t\right)\times r\left(UG,t\right), \\
\text{with } r\left(UG,t\right) &= \left\{ \begin{array}{c} r\left(UG,t\right) \text{ for } t\in\{1982,...,1989\} \\ 0.8856 \text{ otherwise} \end{array} \right\}.
\end{aligned}$$

Thus for all points in time where we know the true value of university graduates, we use it, for the other periods we use the average fraction of university graduates among the university attendees as our measure. This gives us the number of schooled persons and the number of unschooled persons is adjusted to included the university attendees that are not university graduates as determined by: $E\left(UA,t\right)-E\left(UG,t\right)$.

Figure 1 shows the three series that one gets depending on the definition used and the adjustment made. A naive use of the education variable that just takes the university variable at face value would result in the series $E\left(mix\right)$, the dashed-cross line. This series will give an early jump and then later a surprise drop. A consistent definition of university attendees results in $E\left(UA\right)$, the solid-circle line. This shows a fairly smooth line. A use of the just outlined adjustment results in the series $E\left(UG\right)$, the dotted-square line. This line shares features with the line of university attendees, $E(UA)$, and shows no sudden sharp drop when the definition changes.

We use similar adjustment for all the other variables we use (e.g. wages, population, hours worked). The respective ratios of the UA compared to the UG variable all were stable with little variation thus making the adjustment a reasonable thing to do. We belief that

Figure 1: Adjustment to SCF data for employed university graduates.



the resulting data are a good approximation of the actual trends for university graduates.[5] It is noteworthy, that none of our main facts depends on the presence or absence of the adjustment. The main reason we make the adjustment is to have a consistent definition of a university graduates for Canada and the United States.

Canada: Population

When aggregating the micro data to obtain the working age population, we made use of the population weights as provided by Statistics Canada in the Public Use Microdata. Despite that there is an inconsistency between the census data and the Survey of Consumer Finance data. It turns out that both the average growth per year and the levels are different for the two sources. To get a better understanding of the overall development and to allow for a sensitivity analysis, we obtain a working age population series from Statistics Canada (Cansim number 051-0001). We find that the growth rate as displayed by the working age population from the Survey of Consumer Finance is consistent with that of the Cansim-series. Thus we decide to adjust the level in the working age population for the two census years

[5] For comparison purposes, there are other papers, notably Bar-Or et al. (1995), and Burbidge et al. (2002) that noted the data inconsistency problem but decided to not make any adjustment to the data, resulting in a slightly different movement of the education premium, especially in the year of the education variable change in the SCF.

1980 and 2000 to make them consistent with the Survey of Consumer Finance. To do this we assume that the average growth as displayed by the SCF data is preserved for the 1980 and the 2000 point.

Beyond that we perform a sensitivity analysis in which we use the working age population series from Statistics Canada instead of our series. We find that this substitution has no effect on any of the main results. In particular the result that population growth does not contribute to the education premium differential between the two countries is preserved.

Other data sources for the US

To determine the relevant capital stock, output and income data for the United States we used the following tables (see Table 2 for details) from the National Income and Product accounts as supplied by the Bureau of economic analysis (from http://www.bea.gov/ downloaded between January and March 2006). We downloaded the tables for the year 1960 to 2002 at the annual rate.

Aside from this we have to adjust our micro wage income data for wage supplements. To get the right adjustment factor we make use of both the income side of the national accounts and a detailed listing of the wage supplements as provided by the BEA. The income side is also used to determine the capital income share in GDP.

Table 2: NIPA tables used.

Table	Content	
	National GDP accounts	
1.1.5.	Gross Domestic Product	Nominal
1.10	Gross Domestic Income	Nominal
1.1.4.	Price Indices for GDP	Base 2000
2.7.	Investment in Private Fixed Assets, Equipment and Software, and Structures by Type	Historical-Cost
2.8.	Investment in Private Fixed Assets, Equipment and Software, and Structures by Type	Chain-Type Quantity Indices
	Fixed assets accounts	
2.1.	Private Fixed Assets, Equipment and Software, and Structures by Type	Current-Cost Net Stock
2.2.	Price indices for Net Stock of Private Fixed Assets, Equipment and Software, and Structures by Type	Chain-Type Quantity Indices
	Wage supplements	
7.8	Supplements to wages and salaries by type	Nominal

Note: Wage supplements consist of all fringe benefits that an employed person may receive from the employer, either publicly or privately provided.

For capital equipment from 1963 to 1992 we make use of the time series provided by Krusell et al. (2000). We use a suggestion by Robert Gordon (see Greenwood, Hercowitz annd Krusell, 1997) to extend the series from 1992 to 2002.

Other data sources for Canada

The following is a list of all the data series used from Canada's National Income and Product Accounts as well as regarding the capital stock and deflators. We downloaded the data from CANSIM and a detailed list of the used CANSIM series is available upon request. All data were requested for the period 1980 to 2002.

Note that the 1997 deflators were calculated by the ratio of expenditures in current prices and at 1997 constant prices multiplied by 100. The deflators were then converted into constant Ca$ 2000 by dividing the individual deflators by the 2000 deflators. To make the Canadian data comparable with the U.S. data we create the variable structures, that consists of building construction with residential and non-residential components and engineering construction. It is noteworthy that engineering construction include structures like highways, dams, etc. which in the U.S. accounts would be included in structures.

For cross country comparison purposes we use a Purchasing Power Parity deflator. This is taken from the Centre for the Study of Living Standards, <http://www.csls.ca/data/ipt1.asp>.

Data transformation

In this section we describe how we transform the variables we get from our various sources to make them conform with the basic requirements of our model.

Labor variables

For all the variables generated, we restricted our sample to males age 16 to 64 population. Furthermore, we defined schooled (S) to be all persons in the sample, that have at least 4 years of college completed in the case of the United States or hold at least a bachelors degree in the case of Canada. We define unschooled (U) all individuals that have either 1 to 12 years of highschool or 1 to 3 years of college in the case of the US, respectively all persons without a bachelors degree in the case of Canada. All the time series generated are for the respective groups.

For the working time and wage variables, we restrict our attention to the persons actually at work during the last week. To determine the number of employed persons we include the persons at work and the persons who are employed by not at work.

From IPUMS for the U.S. and from the data for Canada, we determined the objects in the aggregate and for each group for the respective :

Table 3: CPS data generated.

Name	Content	Variables used‡	Operation on sample
wap	Working age population	perwt	sum
emp	Employment	empstat, perwt	sum
$hours(ave)$	Average annual hours	empstat, perwt, wkswork, hrswork	average(wkswork* hrswork)
$hours(med)$	Median annual hours	empstat, perwt, wkswork, hrswork	median(wkswork* hrswork)
$hours$	Total hours worked	empstat, perwt, wkswork, hrswork	
$wph(ave)$	Average wage per hour	empstat, perwt, incwage wkswork, hrswork	average(incwage/ wkswork*hrswork)
$wph(med)$	Median wage per hour	empstat, perwt, incwage wkswork, hrswork	median(incwage/ wkswork*hrswork)

‡ We report the used variables by their CPS name, for Canada we used the analogous once.

The mapping was chosen to optimize the consistency with aggregate data provided by the BEA.

Based on these primary results we determined the following objects for each education group:

$$\begin{aligned}
emp \text{ fraction of schooled} &= \frac{emp\,[S]}{emp\,[S+\ U]} \\
\text{total hours fraction of schooled} &= \frac{emp\,[S] \times hours\,[i]}{emp\,[S+\ U] \times hours\,[S+\ U]} \\
\text{workweek}\,[i] &= \frac{hours\,[i]}{emp[i] \times 5200} \\
\text{average hours}[i] &= \frac{hours[i]}{wap[i]}
\end{aligned}$$

where the square brackets represent the restriction to a subgroup (schooled or unschooled). The adjustment factor 5200 in average hours worked is used to normalize the annual hours worked to the interval zero one.

To make the wage data comparable, we used the consumption deflator from the National Income and Product Accounts.