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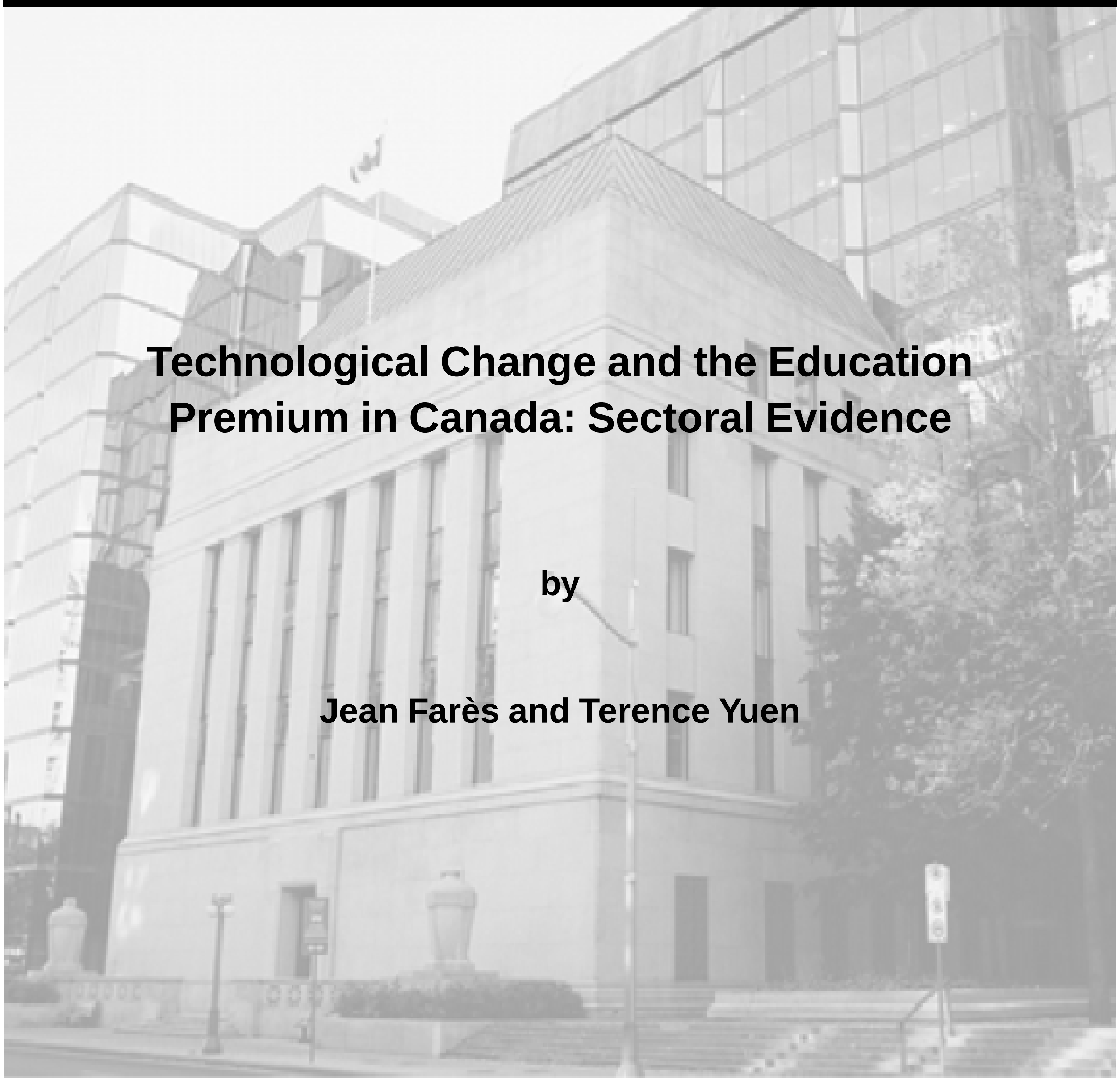

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Jean Farès and Terence Yuen

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Jean Farès[1] and Terence Yuen[2]

[1]The World Bank
1818 H Street, NW
Washington, D.C., U.S.A. 20433
jean.fares@worldbank.org

[2]Research Department
Bank of Canada
234 Wellington Street
Ottawa, Ontario, Canada K1A 0G9
tyuen@bankofcanada.ca

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Abstract

It has been well documented that the education premium measured by the wage difference between university and high school graduates has remained constant over the past two decades in Canada. Despite this stable pattern at the aggregate level, skill-biased technology could have important implications for the inter-industry wage structure. In a multi-sector economy where technological innovations are skewed towards certain industries, imperfect labour mobility implies a positive relationship between the education premium and the technological change in industry. Using data from the Survey of Consumer Finance and the Labour Force Survey, the authors obtain empirical results that would appear to confirm this link: university graduates in research and development-intensive industries are better paid. Yet, this positive correlation is largely due to the fact that high-tech industries attract more professionals who are more educated than the average university graduate.

JEL classification: J31, O30
Bank classification: Labour markets

Résumé

De nombreuses études ont montré que la prime à l'éducation, soit la différence de salaire entre les diplômés du niveau universitaire et ceux du niveau secondaire, est demeurée constante au Canada au cours des deux dernières décennies. Malgré la stabilité de cette prime à l'échelle globale, les changements technologiques qui favorisent le recours à une main-d'œuvre qualifiée pourraient avoir d'importantes répercussions sur la structure intersectorielle des salaires. Dans une économie multisectorielle où les innovations techniques ont tendance à être concentrées dans certaines branches d'activité, une mobilité imparfaite de la main-d'œuvre implique une relation positive entre la prime à l'éducation et l'évolution technologique d'un secteur. Les résultats empiriques que les auteurs obtiennent à partir des données de l'Enquête sur les finances des consommateurs et de l'Enquête sur la population active semblent confirmer que les diplômés universitaires travaillant dans les branches à forte intensité de recherche et développement sont mieux rémunérés. Cependant, cette corrélation positive tient en grande partie au fait que les industries de pointe attirent davantage de professionnels ayant une formation plus poussée que la moyenne des diplômés universitaires.

Classification JEL : J31, O30
Classification de la Banque : Marchés du travail

[We are experiencing] one of those rare, perhaps once in-a-century events — a structural technological advance. This acceleration seems to have had two important side effects. First, it has a major influence on the distribution of income in this country. . . .

As ideas become especially valuable relative to physical activity in the creation of value-added, education and intellectual skill become an increasingly major determinant of income.

Alan Greenspan
Federal Reserve Board Chairman
June 1996

1. Introduction

Technological change has important implications for a wide variety of labour market issues. One area of study focuses on the impact of technological change on wage inequality, particularly the wage differential between university and high school graduates. It has been well documented (e.g., Juhn, Murphy, and Pierce 1993) that the substantial increase in wage inequality for U.S. males since the 1970s is largely due to the divergence in earnings between skilled and unskilled workers. A possible explanation is that technological innovations have been skill-biased over the past several decades. This, in turn, leads to a sharp increase in the return to education as the relative demand for high-skilled labour accelerates. Results in Acemoglu (2002) and Autor, Katz, and Krueger (1998) are consistent with this view.

Yet, the existing literature provides limited evidence of a link between technological change and the wage structure in Canada. In contrast to the widening trend in the United States, aggregate studies (e.g., Murphy, Riddell, and Romer 1998; Burbidge, Magee, and Robb 2002) show that the education premium in Canada has been relatively flat since the early 1980s. Beaudry and Green (2000) also find that the skill premium does little to explain overall wage inequality in Canada between 1971 and 1993. Although technology appears to have had very little impact on changes in the education premium at the aggregate level in Canada, it could have important implications for inter-industry wage differentials. Considering the anecdotal evidence that technological innovations are skewed towards certain sectors, the skill-biased labour-demand hypothesis implies that high-tech sectors would pay higher wages to their workers. For instance, Bartel and Sicherman (1999) and Allen (2001) find a positive relationship between technological change and inter-industry education premium differentials in the United States. The wage gap between high school and college graduates increases in industries that have higher research and development (R&D) intensity and capital-labour ratios.

Our main goal is to describe some of the first empirical evidence of the link between technology and the education premium and how it differs across industries in Canada. Using microdata from the Survey of Consumer Finances (SCF) and the Labour Force Survey (LFS), we begin by documenting the aggregate pattern of the education premium between 1981 and 2000. We exploit the richness of the microdata to control for changes in the composition of the workforce that might be reflected in some measures of the university–high school wage gap. To identify the effects of technology on skill premiums, the analysis relies mainly on inter-industry variations. We are able to construct a panel of 10 sectors for the period 1981–97 using the SCF. More disaggregated data from the LFS allow us to look separately at 29 industries from 1997 to 2000. There are two advantages to extending the aggregate analysis to the industry level. First, in addition to year-to-year variations, it is possible to identify the effects of technological change on education premiums using inter-industry variations. Second, the extension allows us to control for unobserved heterogeneity across industries in a fixed-effects framework. In addition, this study proposes a wide range of technology indicators, including multi-factor productivity, the ratio of R&D expenditure to output, the percentage of employment engaged in R&D, and the ratio of scientists and engineers to total employment.

Our aggregate results are consistent with those of previous studies of Canada. The education premium has remained fairly constant between 1981 and 2000. While different age groups (young vs. old) might have experienced different patterns, the differences are small, particularly when compared with the outcomes witnessed in the United States. More importantly, we find that the education premium is significantly different across industries. These observed differentials, however, are associated with the composition of workers' occupations, but not with the technological change in industry. At first glance, R&D-intensive industries tend to pay their workers a higher education premium. This positive correlation is mainly explained by the fact that a larger share of their workforce are professionals, such as scientists and engineers.[1] It is not surprising that a higher ratio of professionals leads to a wider wage gap, because they are better paid than the average university graduate. These aggregate and sectoral findings are not to say that recent technology innovations have no impact on the relative demand of skilled workers and the relative wage structure. The skill-biased demand hypothesis can be reconciled by the equalizing movements from the supply side. That is, a rise in the demand for skills as a result of technological innovations has been offset by a corresponding increase in supply. There is aggregate evidence that both the relative demand and supply of skilled workers have followed a steady growth pattern as proxied by a linear time trend over the past two decades. In other words, this result does not support the general perception that the rate of increase in skill-biased demand accelerated in the second half of the 1990s.

This paper is organized as follows. Section 2 provides a theoretical framework in which the skill premium is determined by the relative demand and supply of skilled labour. Section 3 describes some data issues. Section 4 highlights the aggregate pattern of wage differentials between university and high school graduates in Canada over the period 1981–2000. In section 5, we exploit variations across industries to examine the impact of technological change on skill premiums. Section 6 offers some conclusions.

2. Simple Theoretical Framework

To illustrate the link between technological change and the education premium, we use a simple model to motivate the analysis in this paper. Following the literature, we assume that the aggregate production function is in the form of constant elasticity of substitution with two types of labour:

$$Y_t = \left[(q_{ht} H_t)^r + (q_{lt} L_t)^r \right]^{1/r} . \qquad (1)$$

[1] For a detailed definition of professionals, see footnote 28.

The aggregate output in time *t*, *Yt*, is a function of skilled (*Ht*) and unskilled (*Lt*) labour and the corresponding technology efficiency parameters $?_{ht}$ and $?_{lt}$, and *?* = 1–1/t, where t is the elasticity of substitution between the two skill groups.[2]

We can solve for the equilibrium relative wages by equating wages to the marginal product of each skill group. In this simple framework, the observed university–high school wage gap at time *t* (w_{ht} / w_{lt}) is determined by two factors: the aggregate relative supply of university-educated workers (Ht / L_t) and the skill-biased technology shock ($?_{ht}$ / $?_{lt}$). The relative wages in log is then given by[3]:

$$\log\left(w_{ht} / w_{lt}\right) = r \log\left(q_{ht} / q_{lt}\right) - \left(1 - r\right) \log\left(H_t / L_t\right). \quad (2)$$

Intuitively, an increase in the relative supply of educated workers reduces the skill premium, while improvements in technology have a positive effect.[4] Therefore, if technology is advancing at a faster rate than the aggregate supply of skills, we would expect the relative earnings of educated workers to rise over time.

Considering a multi-sector economy in which technological innovations are skewed towards certain sectors, the average wage gap in equation (2) provides little guidance to predict the industry profiles. To illustrate this point, we assume a simple economy with two sectors: a new (N) and a traditional (T) economy. Extending the aggregate model, the university–high school wage gap in sector j at time t can be written as:

$$\log(w_{ht} / w_{lt})_j = r \log(q_{ht} / q_{lt})_j - (1 - r) \log(H_t / L_t)_j ;^5 \quad j = \text{N, T}. \quad (3a)$$

Hence, the skill premium differential between the new and traditional sectors is determined by the difference in their skill-biased technology and relative supply of educated workers,

[2] We maintain the hypothesis of perfect substitution across different age groups with the same skill level. This has implications for the university–high school wage gap for different age groups. We briefly discuss this in our empirical analysis. See also Card and Lemieux (2001).
[3] For a more detailed exposition of the model, see Acemoglu (2002).
[4] This assumes that skilled and unskilled workers are gross substitutes; i.e., *t* > 1 (0 < *?* < 1). Most empirical studies (e.g., Freeman 1986) find *t* between 1 and 2.
[5] The elasticity of substitution (*?*) is the same for both sectors. This assumption simplifies the notation in equation (3b). Allowing *?* to vary across sectors does not change the main results that follow.

$$\log \frac{(w_{ht}/w_{lt})_N}{(w_{ht}/w_{lt})_T} = r \log \frac{(q_{ht}/q_{lt})_N}{(q_{ht}/q_{lt})_T} - (1-r)\log \frac{(H_t/L_t)_N}{(H_t/L_t)_T}. \tag{3b}$$

By definition, skilled workers are relatively more productive in the new economy sector; i.e., $(?_{ht}/ ?_{lt})_N > (?_{ht}/ ?_{lt})_T$. This implies that the first term of equation (3b) is larger than zero. Intuitively, $\log \frac{(q_{ht}/q_{lt})_N}{(q_{ht}/q_{lt})_T} > 0$ means that the relative demand for high-skilled workers in sector *N* is greater than it is in sector *T*.

The industry supply of skilled workers depends on the flexibility of the labour market. In general, the stronger demand of skills in the new economy sector attracts labour from the traditional sector. In the extreme case with perfect mobility, high-skilled workers are homogeneous and free to move between sectors. This reallocation process equalizes the wage differential across sectors such that

$$\log \frac{(w_{ht}/w_{lt})_N}{(w_{ht}/w_{lt})_T} = 0 \Rightarrow \log \frac{(H_t/L_t)_N}{(H_t/L_t)_T} = \frac{r}{(1-r)} \log \frac{(q_{ht}/q_{lt})_N}{(q_{ht}/q_{lt})_T}.$$

In contrast, if it takes time for high-skilled workers to move between sectors, owing to industry-specific human capital, the education premium differential persists between the new economy and the traditional sector until the labour supply is fully adjusted. The assumption of imperfect mobility does not necessarily imply a higher education premium in the high-tech sectors. Skilled workers in sector N are better paid than those in sector T only if $\log \frac{(H_t/L_t)_N}{(H_t/L_t)_T} < \frac{r}{(1-r)} \log \frac{(q_{ht}/q_{lt})_N}{(q_{ht}/q_{lt})_T} \Rightarrow \log \frac{(w_{ht}/w_{lt})_N}{(w_{ht}/w_{lt})_T} > 0$.[6]

[6] This result can be reversed if $\log \frac{(H_t/L_t)_N}{(H_t/L_t)_T} > \frac{r}{(1-r)} \log \frac{(q_{ht}/q_{lt})_N}{(q_{ht}/q_{lt})_T} \Rightarrow \log \frac{(w_{ht}/w_{lt})_N}{(w_{ht}/w_{lt})_T} < 0$. In other words, there is an "excess" supply of educated workers in the high-tech sector, who depress the skill premium

3. Data

To study the wage trends in Canada, the best available source is the SCF, published annually since the early 1980s.[7] It uses the monthly LFS sampling frame and collects income information in the spring of each year. While a survey wage rate is not available in the SCF, we canconstruct average weekly earning series using information on annual earnings and weeks worked in the reference year. The disadvantage in using SCF is that it was discontinued in 1997. As an alternative to the SCF, the revised LFS is a good source of wage data starting from 1997.[8] Unlike the SCF, the sequence of wage questions in the LFS begins by asking about the hourly rate of pay for those who are hourly-rated. For others, the respondents are asked to report the easiest pay period; their wages are then converted to an hourly rate by dividing the reported wage by the usual hours of work in the same time period. We combine the years available from the SCF with the post-1997 years from the LFS to construct 19 annual cross sections of data that cover the years 1981 to 2000. The sample is restricted to workers between the ages of 24 and 65 with reported weekly earnings above $100.

The micro-level data do not provide any information on the technological progress of the industry in which the individual works. We therefore have to match the data with some industry measures of technological change from other sources. In the remainder of this section, we address two important issues in the wage data: the differences between and similarities among the SCF and LFS, and the changes in the information collection on education and consequently the coding of education over time. We also describe the sources and measures that we use for technological change.

3.1 Education groups

Table 1 describes, by year, the shares of the education groups in both data sets. One major concern using the SCF data arises from the changes in the definitions of

[7] Census family files are also available for 1973, 1975, 1977, and 1979. To create a series consistent with the post-1981 individual files, however, the sample should be restricted to heads of households. Because the purpose of this paper is to consider changes to the wage gap in recent years, we do not include the earlier years from the family files, and consequently do not make the restrictions to heads of households.
[8] The LFS underwent a major revision in 1997 that involved, among others, adding questions about wages on a monthly basis.

education categories in 1989. At that time, Statistics Canada switched from a notion of completion of years of schooling to a notion of attainment of schooling and began to code education outside of schools (e.g., trades certificates) in new ways. Prior to 1989, individuals who earned a certificate from a program that did not require a high school diploma were categorized as having a high school education, whereas, after 1989, those individuals were categorized as having a post-secondary certificate. The two main education groups of interest in this study are: (i) those with some or a complete high school education, and (ii) those with one university degree or more. The first group includes individuals who have some post-secondary education but no post-secondary certificate or degree. Although the 1989 change in the definition does not affect those with a university degree, it does alter the composition of those assigned to the high school group. This change is expected to cause a drop in the average earnings of the less-educated group after 1989, since the recoding removes more-educated (skilled) people from the high school group. The direction of the bias is particularly important, since the hypothesis we will be testing is whether an increase in the university–high school wage gap occurred in recent years. This issue plays a significant role in interpreting the aggregate pattern of the wage gap in Canada in section 4.

3.2 The SCF vs. the LFS

In 1997, the two surveys were conducted separately. The availability of data from them allows us to evaluate the extent to which the LFS constitutes a good alternative (or extension) of the SCF. Using regression analysis and a simple human capital model of earnings, we argue that the two surveys can be treated as substitutes for some purposes, including the return-to-education issues studied in this paper. We start by estimating the following human capital model using separate data sets (SCF and LFS):

$$\log(w_i) = bX_i + dEDUC_i + u_i \,. \qquad (4)$$

Weekly earnings, W_i, are derived from the annual earnings and weeks of work in the SCF and from the wage rate and the hours of work in the LFS. X is a set of exogenous variables including age, gender, marital status, province of residence, and industry association.[9] *EDUC* is a set of five education dummies that corresponds to the following education groups: 0 to 8 years of schooling, some secondary education, high school education (as defined in section 3.1), post-secondary certificate or diploma, and university education. The estimation samples are limited to individuals who earned at least $100 per week, were not self-employed, and were between 20 and 64 years old in 1997. The parameters of interest in equation (4) are the *d*'s. We estimate these parameters separately in the two samples using simple weighted least-square methods. Columns 2 and 3 of Table 2 show the results of this exercise. The excluded category in the estimation is the university graduates, so the parameter estimates are the earning differences between each education category and the university graduates, controlling for other exogenous factors included in *X*.[10] As expected, the education wage differentials are significant in each sample. Workers with less than eight years of schooling earn around 52 per cent less than university graduates. This gap decreases to between 32 and 34 per cent for high school graduates. As the level of education continues to increase, wages rise steadily and the gap with university wages decreases. Table 2 also shows that the point estimates of the education dummies are remarkably similar across the two samples, but somewhat smaller in the LFS sample.

To test how different these estimated parameters are, we combine the two samples and create a dummy variable (D_{LFS}) equal to one if an observation is drawn from the LFS sample, and equal to zero if an observation is drawn from the SCF sample. We then allow interactions between D_{LFS} and the education dummies, $EDUC_i$. In column 4 of Table 2, we report the *t*-statistics of each interaction term separately. In all cases except one, the interaction term is not statistically significant in the two samples. The last column, however, shows that a joint test rejects the null hypothesis of no systematic differences in education differentials between the SCF and LFS. If we restrict our attention to the university–high school wage gap, the *t*-test in this case supports the null. These results suggest that the university–high school wage gap is consistently measured in the two

[9] The SCF does not provide direct information on the number of hours worked by week in the reference year. We have computed a measure of actual hours worked per week by detailed category of worker, using the monthly microdata files from the LFS from 1981 to 1997. We use this proxy measure as an additional explanatory variable to construct our regression-adjusted wage measure.

[10] For brevity, the estimates of *b* are not reported. Full results can be obtained from the authors upon request.

samples, and they therefore support our strategy of merging the two samples to construct a longer time series for the university–high school earning differentials.

3.3 Technological change

There is no consensus in the existing literature on the appropriate proxy for technological change. Our focus is on the level of skill bias. In general, indicators of technological innovations can be categorized into output-based or input-based measures. A common output-based measure is multi-factor productivity (MFP), which refers to the increase in output relative to the increase in a bundle of inputs. Hence, a technological improvement is interpreted as the ability to produce more output with the same amount of inputs. This residual measure is often controversial because of the complexity in measuring the growth rates of the inputs, particularly the capital stocks. Recent literature (e.g., Macgee and Yu 2000) finds that MFP not only captures movements in technology, but also variations in capacity utilization over the business cycle. Alternatively, an input-based technological change can be measured by the extent to which a firm adopts new technology in the workplace, such as the amount of their R&D and investment in computers.

This study uses one output-based and three input-based measures of technological change: (i) MFP growth, (ii) the ratio of R&D expenditure to output, (iii) the percentage of employment engaged in R&D, and (iv) the ratio of scientists and engineers to total employment calculated from the sample. Appendix A gives a detailed definition of each measure.

To check whether there is any overlap between these technology measures, Table 3 presents the correlation matrix. Panel A examines the contemporaneous relationship for the period 1981–97 in 10 sectors.[11] There is a lot of overlap between input-based measures. In particular, R&D expenditure is almost perfectly correlated with R&D employment. Nevertheless, MFP growth seems to be independent and it is not correlated with any of the input-based measures. A possible explanation is the cyclicality of MFP growth, as noted above. Another possibility is that the full benefits of R&D activities may not be realized in the current year. To explore the possible time lags between R&D and

[11] For a detailed description of each sector, see the SCF classifications in Appendix B.

productivity growth, we test whether the 3-year and 5-year moving averages of different technology measures are correlated. Results are reported in panels B and C. As shown in the first column, including these lag structures marginally improves the correlation between MFP growth and the input-based measures. Yet, all coefficients are statistically insignificant, except the one between the 5-year moving average of MFP growth and the ratio of scientists and engineers. Therefore, sectors with strong MFP growth do not necessarily have high R&D expenditure or employment. These results suggest that each indicator is likely to capture some aspects of the technological change and no particular one is considered the ideal measure.

4. Overview of the Aggregate Pattern

We are now ready to summarize some of the aggregate patterns in the wage differences between university and high school graduates. One measure of this wage differential is simply the difference between the average wages of high school graduates and the average wages of university graduates in a given year. Such a measure, however, does not account for the distribution of workers' characteristics over different education groupings. Given the richness of the microdata, we suggest a regression-adjusted measure for the education gap. Formally, we estimate equation (4) in repeated annual cross sections for the years 1981 to 2000. The excluded education group is the university graduates, so we interpret the estimated coefficient of the high school dummy variable, d_t, as our regression-adjusted measure of the university–high school wage differential in year *t*.

Figure 1 shows the unadjusted wage gap between high school and university graduates, as well the regression-adjusted gap $\{\hat{d}_t\}_{t=1981}^{2000}$. Over the whole sample, the unadjusted wage-gap average is 34 per cent. It rose by six percentage points during the sample period. Controlling for the observable characteristics of the workers, this estimated differential turns out to be less than the measured one, averaging 32 per cent over the sample period. The growth in this series is not as pronounced, either. Fitting a linear trend to the series shows a slightly positive slope. As discussed in the data section, some of this growth might be caused by the change in the education definition in 1989. In fact, if we regress the wage series on a time trend and a 1989 dummy, we cannot reject the hypothesis that the 1989 dummy explains the increase in the wage series. Also note that the relative wage gap seems stable throughout the second half of the 1990s, a period thought to have experienced substantial technological growth in some sectors of the Canadian economy.

We use the theoretic framework described in section 2 to guide us in interpreting this stable pattern. As suggested in equation (3a), the movement in relative wages should reflect the relative supply and demand conditions. Considering the difficulty of obtaining a correct measure of skill-biased technology, we begin our analysis by measuring the relative labour supply in the domestic market.[12] Following the literature, we map each skill type to an equivalent education category. We consider two education groups: "university equivalent" workers and "high school" equivalent workers. Workers with a high school degree supply one high school equivalent, and workers with a university degree supply one university equivalent. Those with less than a high school education supply a fraction of a high school equivalent, and workers with some post-secondary education are divided between the high school and university equivalent.[13]

Figure 2 shows that the relative supply of university graduates remained at the same level until 1988 before it started to trend upward throughout the 1990s. One could approximate the supply of skills in Canada by a constant trend over the past two decades. Furthermore, the steady growth rate of over 5 per cent per year is much higher than the estimates in the U.S. studies based on similar methods. Card and DiNardo (2002) find that the relative supply of U.S. college-educated workers followed a linear trend of only 2 per cent between 1982 and 2000. As Murphy, Riddell, and Romer (1998) point out, although both the United States and Canada are affected by a similar skill-biased technological change, the absence of a rise in the wage premium to Canadian university

[12] We do not control for external factors affecting the supply of skills. For example, international trade undoubtedly has an important effect on the relative supply. It has been well documented that the North American market has become much more integrated after the free trade agreement. Considering the case that Canada imports relatively skill-intensive products from the United States, this is equivalent to importing high-skilled workers into the Canadian labour market. This simple example illustrates the fact that a stronger trade linkage with the United States can imply an increase in the supply of skills.

[13] A worker with less than a high school degree is assumed to supply 95 per cent of a high school-equivalent labour supply, while labour supplied by a worker with a post-secondary certificate or diploma is assumed to be equally divided between high school-equivalent labour and university-equivalent labour.

graduates can be explained by a faster growth in the supply of workers who have a post-secondary education.

Given the labour supply and the observed wage gap described above, it is possible to draw some conclusions about the evolution of skill-biased demand shocks. The virtually constant wage premium implies that the demand and the supply follow the same pattern. To check whether a linear trend is a reasonable proxy for the skill-biased technological change between 1981 and 2000 in Canada, Figure 3 presents four commonly used aggregate measures of technological change[14]: (i) percentage of total business investment in computers and software, (ii) ratio of R&D expenditure to GDP, (iii) percentage of scientists and engineers, and (iv) MFP growth. An upward linear trend appears to fit well in three of the measures, especially for computer investment and R&D expenditure.[15] In sum, as opposed to a period commonly thought to have experienced an acceleration of technological advancements, these findings suggest that the skill-biased demand continued to grow at a steady rate in the late 1990s in Canada. The only exception is MFP growth, which exhibits strong volatility. On average, the MFP growth was less than 0.05 per cent during the 1981–90 period and it increased to 0.8 per cent between 1991 and 2000.

One dimension along which the university–high school premium might differ is age. In fact, Card and Lemieux (2001) show that a model where skills of young and old workers are not perfect substitutes in production is supported by data from the United States, Canada, and the United Kingdom. The evidence for Canada, using census data for 1980, 1985, 1990, and 1995, shows that the wage gap for 26- to 30-year-old men increased around 50 per cent at a time when the gap for 46- to 60-year-old men decreased almost 30 per cent. We find similar results in our annual data. Figure 4 shows that the education premiums for young and old workers have opposing trends. While the decrease in the education gap for the old could be explained by the acceleration in the relative supply of university-educated labour (Figure 5), the upward trend in the education gap for

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[14] All measures are in logs.

[15] For these two technology measures, a fitted linear trend can explain more than 90 per cent of the variations between 1981 and 2000.

young workers might be taken as some evidence that skill-biased technological shock favours them.

5. Industrial Analysis

Our aggregate results show that the skill premium in Canada has been relatively flat since the early 1980s. As noted in section 2, this aggregate pattern can have very different implications for the industry profiles, depending on the flexibility of the labour market. In an economy with different degrees of skill bias across sectors, perfect labour mobility would eliminate the inter-industry wage differentials for workers of comparable skill levels. Therefore, movements in the skill premium within each industry are similar to the aggregate pattern. As long as the total supply of skilled workers catches up with the overall rate of technological change, we would expect the skill premium to be steady in all sectors. In contrast, imperfect labour mobility has the opposite prediction. The university–high school wage gap would exhibit divergent patterns across industries. It increases in sectors with rapid technological change. To keep the skill premium constant at the aggregate level, this has to be offset by a reduction in low-tech sectors. This implies an "excess" supply of skilled workers in low-tech sectors. In this section, we extend our aggregate analysis to examine variations across industries. The main focus is on whether the skill premium follows different patterns across sectors and how it relates to the pace of technological advancement.

To examine variations of the education premium across sectors, we allow the parameter δ in equation (4) to differ across industries. Another way to consider this modification is that we allow the inter-industry wage differentials to vary across education groups.[16] Formally, we use the same regression-adjusted measure for the education gap by estimating the following regression in repeated annual cross sections for the years 1981–2000:

$$\log(w_{ijt}) = b_t X_{ijt} + d_{jt} EDUC_{ijt} + u_{ijt}; \quad t = 1981 \ldots 2000\ ;\ j = 1 \ldots J. \qquad (5)$$

[16] In equation (4), the average inter-industry wage differentials for all workers are reflected in the industry dummies in *X*.

The variables in the above model are as described in equation (4), defined for *J* separate industries. The number of industries is 10 for the SCF sample between 1981 and 1997, and 29 for the LFS sample between 1997 and 2000. The coefficient, d_{jt}, represents the log of the wage gap between university and high school graduates, for industry *j* in year *t*, adjusted for the observable characteristics of the workers.

To examine the existence of a positive relationship between the education premium and technology, we consider the following linear specification:

$$\hat{d}_{jt} = a_j + m \log\left(Tech_{jt}\right) + j_t Year_t + e_{jt} . \tag{6}$$

The education premium, d_{jt}, is the estimated coefficient from equation (5); a_j is the industry fixed effects. As noted in section 3, various technology indicators ($Tech_{jt}$) are proxies for the skill-biased technology of industry *j*. Dummy variable $Year_t$ is the year effects that capture aggregate movements over time; for example, changes in the aggregate supply of university-educated workers.

5.1 SCF (1981–97)

The adjusted education premium, d_{jt}, for each of the 10 sectors[17] in the SCF sample is plotted in Figure 6 for the period 1981–97. From casual observation, the wage gap between university and high school graduates is positive in most sectors, except in construction. The *t* statistics (not reported) show that over 93 per cent of the estimated wage gap is statistically different from zero at the 5 per cent confidence level. For ease of comparison between sectors, column 2 of Table 4 reports the average university–high school wage gap, calculated as the mean estimates from 16 regressions for the years 1981–97. Excluding a minimum of 10 per cent in construction and a maximum of 44 per cent in "other services," the average wage gaps in the other eight sectors are in the range of 22 per cent to 30 per cent. Another interesting pattern, shown in Figure 6, is that the sectoral profiles are relatively flat. In spite of the year-over-year fluctuations, the education premium has had very little upward movement over the sample period in most sectors. At a 5 per cent confidence level, fitted time trends (not shown in Figure 6) in

[17] For a detailed definition of each sector, see Appendix B.

only two sectors are significantly different from zero. Columns 3 and 4 of Table 4 compare the average return of university education for the periods before and after 1990. The only two sectors with more than a 5 per cent increase are retail and FIRE (finance, insurance, and real estate).

Table 5 reports the sectoral means of different technology indicators for the 1981–97 period, and for two subperiods, 1981–89 and 1990–97. The first observation is a considerable dispersion in the level of technology across sectors. For example, the average MFP growth between 1981 and 1997 (column 4) is negative in three sectors (construction, FIRE, and other services), while the agriculture sector experiences a growth rate of 2 per cent. The ratio of R&D expenditure to output (column 7) ranges from close to 0 per cent in construction and retail to 6 per cent in durable manufacturing. Similarly, substantial variations across sectors are evident for the other two technology measures. As noted earlier in the correlation matrix, it is not easy to find a consistent identification of high-tech sectors based on various indicators. In particular, output- and input-based measures can have very different predictions for the rate of technological change. Agriculture, with the highest level of MFP growth, ranks very low in R&D intensity. In contrast, other services have the lowest MFP growth, but relatively high values in output-based measures. There are exceptions in two sectors with relatively stable rankings. Consistent with the general perception of the high-tech sector, durable manufacturing always ranks among the top in all four indicators. Construction seems to be the loser in technological innovations.

We next examine the central issue of whether the return from a university degree is better in high-tech sectors. Using different proxies for the technological change, the estimated coefficients of the main variable of interest, μ in equation (6), are reported in Table 6. We begin with the ordinary least squares (OLS) estimation, which assumes that a_i is the same across sectors. As shown in column 1, most estimates are positive and significant. To check whether heteroscedasticity affects the inference on OLS, column 2 presents the corrected standard errors suggested by Davidson and MacKinnon (1993).[18] We also report the generalized least squares (GLS) estimates assuming groupwise

[18] Davidson and MacKinnon (1993) argue that *t*-ratios for normal White corrected standard errors are too large for small samples.

heteroscedasticity in column 3.[19] These two modified estimation procedures provide results similar to the OLS. Overall, there is some evidence that high-tech sectors pay a higher skill premium to their workers.[20]

As noted in equation (3b), perhaps the major concern of the OLS results would be the missing relative supply of skilled workers. If the supply is indeed exogenous and unrelated to the technological change, the estimates of μ are unbiased. One way to check for potential omitted variable bias is to exploit the panel nature of the data and estimate first-differenced and fixed-effects (FE) model.[21] Considering the case when skilled workers are somewhat mobile across sectors, they will move from the low-tech to high-tech sectors in response to incipient pressures for the increase in the education premium. Therefore, skilled workers are more concentrated in high-tech industries that have rapid technological advancements. This positive correlation between technology and the supply of skills would bias the OLS results towards zero. We expect the estimates of μ to be greater in FE estimations.

Surprisingly, the first-differenced and FE estimates in columns 4 and 5, respectively, of Table 6 provide the opposite picture. Compared with the positive OLS estimates in columns 1 to 3, most estimates are smaller and become virtually zero. Also, the standard errors[22] are much larger than the estimates. One might argue that this is caused by a measurement error. The FE results are contaminated when the technology proxies are badly measured.[23] To check for a measurement error, we compute the

[19] The error terms are uncorrelated, but they have different variances for each sector; that is, the covariance matrix, $\Omega = \begin{bmatrix} s_1^2 I & 0 & 0 \\ 0 & \ddots & 0 \\ 0 & 0 & s_{10}^2 I \end{bmatrix}$.

[20] For the long-term dynamics, we have replicated the analysis with lags on technological change up to t-2 in the specifications. The basic results (not reported) are similar to those reported in Table 6. The F-statistics reject the null hypothesis that the sum of technology coefficients is zero for all technology proxies, except the MFP growth.

[21] The underlying assumption is that the level of the supply of skills is sector-specific, but fixed over time. A less restrictive interpretation is that changes in the labour supply from year to year within an industry are small relative to the inter-industry differentials.

[22] Corrected standard errors using the procedure in Davidson and MacKinnon (1993) are shown in columns 4 and 5 of Table 6.

[23] To illustrate this point in a simple example, we assume that the technology proxy measures the industry skill bias with white-noise errors; i.e., $\log(Tech_{jt}) = \log(?_{ht}/?_{lt})_j + ?_{jt}$, where $(?_{ht}/?_{lt})_j$ is growing at a constant rate, $?_j$. If $?_j$ is small relative to the variance of $?_{jt}$, first-differencing the data or FE estimations would magnify the measurement error (Griliches and Hausman 1986).

Hausman specification test by instrumenting the technology proxies with their last-period values. The Wald statistics for all four proxies are either very small or negative. We cannot reject the null hypothesis of no measurement error.

How do we interpret the difference between the OLS and FE results in a demand-and-supply framework? The technology impact on the skill premium is zero after controlling for the supply of skills in the FE model. Hence, the positive OLS estimates are completely driven by sectoral differences in the relative supply. This implies an inverse correlation between technology and the supply of skills. In other words, the portion of skilled workers in low-tech sectors is higher than that in high-tech sectors. This counterintuitive explanation is easily rejected when we look at the sample correlation between technology and the share of university graduates in different sectors. The correlation coefficients between the ratio of university to high school equivalent and various technology measures are statistically insignificant. A more plausible explanation of the divergent results is that the fixed effects capture some "unobserved" sector characteristics unrelated to the supply of educated workers. Thus, the observed positive correlation between the education premium and technology from the OLS models reflects some permanent inter-industry differentials other than technology. We will further discuss the possibilities of these unobserved factors in section 5.3.

Another common argument is that firms may have behaved differently between the 1980s and 1990s. It is possible that technological innovations not only have an impact on the level of skill bias, but also on the substitutability between skilled and unskilled workers. As noted in the theoretical framework described in section 2, changes in the elasticity of substitution (t) affect the response of skill premiums to technology. To evaluate this hypothesis, we repeat the same analysis in Table 7 by interacting the technology measure with the dummy variable, *Yr90*, which equals 1 for the post-1990 period. Surprisingly, there is no observable difference between the two subperiods, as shown by the statistically insignificant effect of the interaction terms.

5.2 LFS (1997–2000)

The SCF results are subject to several criticisms. First, the industry analysis relies mainly on cross-section variations that might be averaged out in the high level of aggregation with only 10 sectors. With the recent revolution in information and communications technologies (ICT), one would expect industries with heavy use or production of ICT, such as the electrical and electronic products sector, to have the fastest rate of technological change. Yet, the durable manufacturing sector also includes other traditional industries, such as wood, furniture, and primary metal. Second, the SCF data end in 1997 and do not cover the late 1990s, a period thought to have experienced a rapid acceleration in technological progress. Third, the university–high school wage gap in the SCF sample refers to the difference in their weekly earnings. Although we include a control of average weekly hours based on age, gender, province, and year, it does not take into account the differences across industries.

To address these issues, we replicate the exercise by using the LFS data for a more recent period, 1997–2000.[24] The main advantage of the LFS is that it provides a more detailed breakdown of industries, especially in the manufacturing sector. This enables us to further separate durable and non-durable manufacturing into 17 industries, including some of the so-called "new economy" industries, such as computer and electronic products, and electrical equipment, appliances, and components. With other industries in the primary sector, construction, and services, we have a total of 29 industry groups.[25] Furthermore, as stated in section 3, the wage gap can be measured in hourly rates that are directly reported in the LFS. The sample is then restricted to workers with reported hourly wages of between $2 and $200, since observations outside that range likely result from measurement error.

We re-estimate equation (5) using the LFS sample. Table 8 shows the estimated university–high school wage gap of each industry over the period 1997–2000. The mean in column 5 ranges from a minimum of 3 per cent in fishing, hunting, and trapping to a maximum of 47 per cent in computer and electronic products manufacturing. More importantly, we observe a substantial dispersion within the manufacturing sector. For durable goods, the skill premium for workers in non-metallic mineral products is only 23 per cent, compared with 34 per cent in primary metals; 36 per cent in electrical

[24] In principle, we can combine the LFS with the SCF. However, the change in the industry grouping from SIC to the North America Industry Classification System (NAICS) prevents us from merging the two data sets at the industry level.
[25] For details of each industry, see Appendix A.

equipment, appliances, and components; and 47 per cent in computer and electronic products. A divergent pattern is also found in non-durable manufacturing. The wage gap for textiles, paper, printing, and petroleum and coal is about 25 per cent, but it increases to 38 per cent for food, beverages, and tobacco, and chemical and pharmaceutical products.

Table 9 reports the means of three technology indicators for different industries[26] for 1997–2000. The most prominent result is that R&D intensity is concentrated in one industry: the manufacture of computer and electronic products. Its ratio of R&D expenditure to output is 31 per cent, which is five times above the ratio in two other leading industries: chemical and pharmaceutical products (5.7 per cent) and transportation equipment (5.3 per cent). On average, 24 per cent of the workforce in computer and electronic products are engaged in R&D, while most of the industries remain at a level below 1 per cent. Compared with Tables 4 and 5, the results in Tables 8 and 9 highlight the diversity within sectors. The lower level of industry aggregation provides more cross-sectional variations with which to identify the effects of technology on the education premium.

Table 10 reports the re-estimation results for equation (6). The OLS estimates in column 1 indicate a positive and statistically significant correlation between the education premium and the technology. Yet, the positive OLS disappears after controlling for industry fixed effects. FE estimates in column 2 do not significantly differ from zero.[27] These results are remarkably similar to the SCF results reported in Table 7. The divergence between the OLS and FE estimates again suggests that the higher education premium in high-tech industries is driven by unobserved industry characteristics unrelated to the technology used in the industry.

5.3 Unobserved industry characteristics

It is interesting to investigate which unobserved factors are the cause of the inter-industry skill-premium differentials. At least five possibilities can provide a consistent explanation for the positive correlation between the education premium and the rate of

[26] MFP data at the industry level using NAICS classifications are not available.
[27] Standard errors in Table 10 are corrected for heteroscedasticity using the procedure described in Davidson and MacKinnon (1993).

technological change. First, higher wages in high-tech industries simply reflect rent-sharing. A number of empirical studies (e.g., Hildreth and Oswald 1997) suggest that workers' compensation is partly related to a firm's financial performance. If the adoption of new technologies has a positive impact on the profitability of firms (e.g., Stoneman and Kwon 1996), the higher education premium in R&D-intensive industries can be the result of profit-sharing for skilled workers.

Second, the competitiveness of the industry partly explains the inter-industry differentials in the return to education. A common argument is that productivity gains in a highly competitive industry are mainly reflected in the price reduction of the product. Firms, therefore, have limited room to raise wages for their increasingly productive workers. If the high-tech markets are oligopolistic, high profit margins allow firms to widen the wage gap between skilled and unskilled workers.

Third, labour market institutions, such as union coverage, have an important effect on the distribution of wages. Hirsch (1982) shows that, in the United States, there is significantly less wage dispersion in the union than in the non-union sectors. Lemieux (1993) finds similar results for Canada. If a lower percentage of workers in high-tech industries are covered by collective bargaining, this implies a wider wage dispersion.

Fourth, it has been well documented in the literature that firm size plays a crucial role in explaining inter-industry wage differentials. One possible explanation is that large firms are more willing to adopt advanced technology (e.g., Earl 2002). In this case, firm size partly captures the technology effects on skill premiums. Another explanation is that skilled workers in large firms are more productive due to better opportunities for continuous training (e.g., Black, Noel, and Wang 1999).

Fifth, Bartel and Sicherman (1999) point out that sorting based on workers' unobserved heterogeneity accounts for most of the observed higher education premium in high-tech industries. We are unable to address this issue, however, because of data limitations. The LFS is not an individual-level panel data set and we cannot formally control for workers' unobserved abilities. Instead, professional status to a certain extent reflects an individual's ability that is not captured in the return to education. As long as wages measure the productivity of workers, it is not surprising that the average income of a professional, such as an accountant or a lawyer, is higher than that of an average university graduate.

To examine the role played by these five factors in explaining the inter-industry differentials in the return to education, we introduce additional explanatory variables (E_s) into equation (6). That is,

$$\hat{d}_{jt} = a + m \log\left(Tech_{jt}\right) + \sum_{s} l_s E_{sjt} + j_t Year_t + e_{jt} . \qquad (7)$$

The variables in E_{sjt} refer to: (i) the profit margin, measured as the ratio of the operating profit to the operating revenue, (ii) the growth rate of the operating profit, (iii) the percentage of workers covered by collective agreements, (iv) the percentage of workers in firms with more than 100 employees, and (v) the percentage of professionals[28] of industry j at time t. These five variables are intended to capture the effects of the product's market-competitiveness, financial performance, union density, firm size, and workers' ability on the education premium.

Using the LFS sample, we begin with the OLS results as shown in column 3 of Table 10. The most important message is that the inclusion of explanatory variables, E_s, reduces the technology effects on the education premium. Compared with the OLS results in column 1, even though the estimates on R&D expenditure and employment are still positive, they are smaller in magnitude and insignificantly different from zero. Also, all estimates of $?_s$ are statistically insignificant, except the percentage of professionals. this is some indication that the industry fixed effects in column 2 capture the "permanent" differentials in the composition of workers' occupations. This result also suggests that R&D activities are concentrated in industries that have a relatively high proportion of professionals in their workforce. The FE estimates are reported in the last column, for comparison with the OLS. The insignificant results are probably due to the lack of year-to-year variation[29] in most variables over the short panel of four years.

[28] Professionals include managers; professional occupations in business and finance, natural and applied sciences, health, art, and culture; registered nurses; judges; lawyers; psychologists; social workers; ministers of religion; policy and program officers; teachers and professors.
[29] As noted earlier, this can be viewed as a measurement error.

6. Conclusion

Compared with the United States, the education premium in Canada has remained relatively flat over the past two decades. Our aggregate analysis shows that the rising demand for skilled workers as a result of skill-biased technological change is offset by a substantial increase in the supply of workers who have a post-secondary education. Furthermore, we find that the relative supply of these workers grew at a steady pace for the entire 1990s. Combined with the stable wage pattern, this result does not support the general perception that there has been an acceleration in the growth of skill-biased demand in the 1990s. When the skill premiums for different age groups are examined separately, the skill-biased demand hypothesis seems to be in favour of the younger generation. However, the wage-gap evolution for young and old workers in Canada remains flatter than in the United States.

Despite the constant aggregate trend, technology could play a crucial role in explaining the inter-industry wage differentials. In a multi-sector economy where technology innovations are concentrated in certain industries with imperfect labour mobility, we would expect a positive relation between the education premium and the technology change in industry. Using microdata from the SCF and LFS, we find that R&D-intensive industries tend to pay higher skill premiums. Further investigation, however, indicates that this positive correlation mainly reflects differences in the composition of workers' occupations, but not the technological change in industry. It turns out that a higher proportion of workers in R&D-intensive industries are professionals. Therefore, the wider university–high school wage gap in high-tech industries is explained by the fact that professionals are probably better paid than the average university graduate.

This finding is not to say that technological changes have no impact on the relative demand of skilled workers and the relative wage structure. The skill-biased demand hypothesis can be reconciled by the equalizing movements from the supply side. That is, a rise in the demand for skills as a result of technological innovations is offset by a corresponding increase in the supply. Our paper has also shed light on other dimensions in explaining the inter-industry wage differentials. Surprisingly, we find no evidence of profit-sharing, market competition, firm size, and union effects in the wage-determination process.

An important issue for future research is to understand the link between technology and the supply of skills. We have focused on the demand side and have simply assumed that improvements in technology are exogenous. On the other hand, under the assumption of an endogenous skill-bias model, the future path of technology advancements is determined by the current supply of skills. Given the rapid expansion in education in Canada over the past two decades, we would expect that Canada would accelerate in new technologies, but not necessarily become a leading country in R&D.[30] Being a small open economy, Canada does not rely on domestic R&D as the only source of innovations. As Gera, Gu, and Lee (1999) point out, R&D spillovers from abroad, such as imported investment, are also important for the acquisition of new ideas.

[30] In 1999, R&D expenditure was only 1 per cent of Canada`s GDP. This was only half of that in Japan, the United States, and Germany, and it ranked in the middle among OECD countries.

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Table 1: Education Frequency

Year	0-8 years	Some secondary	High school	Some post-secondary	University
SCF					
1981	13.75	14.15	44.36	14.71	13.04
1982	13.33	13.49	44.67	14.53	13.98
1984	12.04	12.92	44.79	15.41	14.85
1985	10.40	12.32	45.52	16.55	15.21
1986	9.30	12.19	45.76	16.84	15.91
1987	9.62	11.35	44.90	17.49	16.64
1988	8.74	11.42	45.42	18.14	16.28
1989	7.42	10.25	38.68	29.27	14.37
1990	6.62	10.07	38.94	29.47	14.90
1991	6.23	8.76	39.58	29.50	15.92
1992	5.08	7.91	38.62	30.44	17.94
1993	5.09	8.34	37.28	31.92	17.37
1994	5.06	7.70	35.91	32.93	18.40
1995	5.02	7.40	36.21	33.37	18.00
1996	4.55	6.82	34.22	35.15	19.26
1997	4.19	6.81	34.35	35.71	18.94
LFS					
1997	3.91	11.24	30.36	35.19	19.30
1998	3.90	10.92	30.04	35.80	19.34
1999	3.36	10.77	29.86	36.43	19.59
2000	3.23	10.19	31.18	34.95	20.45

Notes: Survey of Consumer Finances and the Labour Force Survey. The SCF was not conducted for 1983. All frequencies are weighted by the sample weights.

Table 2: OLS Estimates of the Education Wage Differentials in 1997

Education	SCF	LFS	*t*-test	F-test *p*-value
0-8 years	-0.5253 (0.0148)	-0.5124 (0.0110)	-0.698	
Some secondary	-0.4443 (0.0121)	-0.4333 (0.0074)	-0.805	
High school	-0.3433 (0.0078)	-0.3270 (0.0058)	-1.682	
Some post-secondary	-0.2552 (0.0075)	-0.2208 (0.0054)	-3.731	
				3.94 0.0034

Notes: Standard errors in parentheses. All regressions contain other exogenous variables: age, gender, marital status, province dummies, and industry dummies. University graduates are the excluded category.

Table 3: Correlation of Sectoral Technological Change, 1981–97

	MFP growth	R&D expenditure	R&D persons
		A. Contemporaneous	
R&D expenditure	0.0195		
R&D persons	0.0551	0.9735*	
% of scientists	-0.0106	0.3462*	0.3636*
		B. MA(3)	
R&D expenditure	0.0458		
R&D persons	0.0955	0.9769*	
% of scientists	0.1247	0.3445*	0.3666*
		C. MA(5)	
R&D expenditure	0.0346		
R&D persons	0.1119	0.9807*	
% of scientists	0.1943*	0.3359*	0.3620*

Notes: * significant at 1 per cent. MA means moving average.

Table 4: Means of OLS Estimates of University–High School Wage Gap by Sector, 1981–97

Industry	1981–97	1981–89	1990–97
1. Agriculture	-0.29776	-0.27368	-0.32184
2. Other primary	-0.25601	-0.23956	-0.27247
3. Manufacturing, non-durables	-0.30546	-0.28703	-0.32389
4. Manufacturing, durables	-0.27258	-0.27573	-0.26942
5. Construction	-0.10094	-0.07800	-0.12387
6. Transportation, communication and other utilities	-0.27357	-0.27157	-0.27557
7. Wholesale	-0.25837	-0.27719	-0.23956
8. Retail	-0.22471	-0.19913	-0.25029
9. FIRE[a]	-0.30066	-0.25634	-0.34499
10. Other services	-0.44149	-0.42884	-0.45414

Notes: Regressions are the same as in Table 2, except for the interaction between the education and sector dummies. University graduates are the excluded category. Numbers reported are the means of the estimates from separate regressions for each of the time periods from 1981 to 1997.

a: FIRE: Finance, insurance, and real estate

Table 5: Means of Measures of Technological Change by Industry, 1981–97

Industry	MFP growth (%)			R&D expenditure (%)			R&D person (%)			Scientist/engineer (%)		
	81–89	90–97	81–97	81–89	90–97	81–97	81–89	90–97	81–97	81–89	90–97	81–97
1. Agriculture	2.12	1.88	2.01	0.17	0.34	0.25	0.19	0.36	0.28	1.23	1.63	1.43
2. Other primary	-0.23	1.23	0.46	0.67	0.66	0.66	0.45	0.50	0.48	8.87	7.99	8.43
3. Manufacturing, non-durables	0.40	0.43	0.42	1.93	2.17	2.04	0.92	1.02	0.97	2.99	3.42	3.21
4. Manufacturing, durables	1.20	0.86	1.04	5.52	6.40	5.96	2.54	3.15	2.84	4.31	5.24	4.78
5. Construction	-0.17	-0.27	-0.22	0.02	0.05	0.03	0.02	0.06	0.04	1.03	0.78	0.91
6. Transportation, communication, and other utilities	1.12	0.71	0.93	0.73	0.69	0.71	0.42	0.37	0.40	3.49	3.95	3.72
7. Wholesale	3.01	0.04	1.61	0.36	1.11	0.74	0.25	0.87	0.56	1.46	1.31	1.39
8. Retail	0.80	0.14	0.49	0.03	0.09	0.06	0.02	0.04	0.03	0.21	0.38	0.30
9. FIRE	-1.85	1.13	-0.45	0.14	0.26	0.20	0.19	0.46	0.32	2.35	3.17	2.76
10. Other services	-1.14	-0.97	-1.06	0.82	1.43	1.12	0.18	0.33	0.25	2.57	3.44	3.00

Table 6: Effects of Technological Change on University–High School Wage Gap, 1981–97

	OLS	OLS - Robust	GLS	1st Diff - Robust	FE - Robust
1. MFP growth	0.0908 (0.3350)	0.0908 (0.3389)	0.1682 (0.2323)	0.0433 (0.3095)	0.3018 (0.2834)
2. R&D expenditure	0.0262 (0.0050)	0.0262 (0.0049)	0.0170 (0.0037)	0.0079 (0.0250)	-0.0043 (0.0123)
3. R&D persons	0.0236 (0.0059)	0.0236 (0.0054)	0.0165 (0.0038)	-0.0007 (0.0256)	0.0013 (0.0115)
4. Percent of scientists	0.0073 (0.0058)	0.0073 (0.0103)	0.0095 (0.0046)	-0.0009 (0.0055)	-0.010 (0.0038)

Notes: Standard errors in parentheses. All regressions include year dummies.

Table 7: Effects of Technological Change on University–High School Wage Gap, Pre- vs. Post-1990

	OLS	OLS - Robust	GLS	1st Diff - Robust	FE - Robust
1. MFP growth	-0.1894	-0.1894	0.0940	-0.2695	0.0261
	(0.4053)	(0.3995)	(0.2831)	(0.3359)	(0.3581)
MFP growth x Yr90	0.8778	0.8778	0.3066	1.0580	0.8423
	(0.7174)	(0.7124)	(0.5205)	(0.7427)	(0.5114)
2. R&D expenditure	0.0257	0.0257	0.0178	-0.0049	-0.0081
	(0.0063)	(0.0062)	(0.0046)	(0.0261)	(0.0130)
R&D exp x Yr90	0.0012	0.0012	-0.0022	0.0763	-0.0138
	(0.0103)	(0.0102)	(0.0077)	(0.0723)	(0.0086)
3. R&D persons	0.0237	0.0237	0.0171	-0.0063	-0.0001
	(0.0075)	(0.0069)	(0.0047)	(0.0271)	(0.0118)
R&D per x Yr90	-0.0004	-0.0004	-0.0017	0.0370	-0.0110
	(0.0123)	(0.0111)	(0.0080)	(0.0750)	(0.0093)
4. % of scientists	-0.0001	-0.0001	0.0062	-0.0010	-0.0104
	(0.0064)	(0.0085)	(0.0060)	(0.0059)	(0.0038)
% of sci x Yr90	0.0329	0.0329	0.0087	0.0008	-0.0027
	(0.0136)	(0.0134)	(0.0103)	(0.0175)	(0.0094)

Notes: Standard errors in parentheses. All regressions include year dummies.

Table 8: Estimates of University–High School Wage Gap by Industry, 1997–2000

	1997	1998	1999	2000	97-00
1. Agriculture	-0.148	-0.209	-0.291	-0.296	-0.236
2. Forestry and logging	-0.237	-0.309	-0.168	-0.200	-0.228
3. Fishing, hunting, and trapping	-0.179	-0.319	-0.301	0.674	-0.032
4. Mining and oil and gas extraction	-0.389	-0.358	-0.444	-0.379	-0.393
5. Utilities	-0.350	-0.347	-0.284	-0347	-0.332
6. Construction	-0.221	-0.213	-0.145	-0.180	-0.190
7. Food, beverages, and tobacco	-0.409	-0.380	-0.366	-0.358	-0.378
8. Textile	-0.265	-0.371	-0.211	-0.187	-0.258
9. Wood	-0.244	-0.274	-0.277	-0.233	-0.257
10. Paper	-0.279	-0.236	-0.251	-0.259	-0.256
11. Printing	-0.213	-0.331	-0.195	-0.241	-0.245
12. Petroleum and coal	-0.213	-0.208	-0.242	-0.300	-0.241
13. Chemical and pharmaceutical	-0.439	-0.383	-0.334	-0.381	-0.384
14. Plastics and rubber	-0.401	-0.144	-0.263	-0.310	-0.279
15. Non-metallic mineral	-0.270	-0.229	-0.212	-0.199	-0.228
16. Primary metal	-0.422	-0.327	-0.393	-0.224	-0.342
17. Fabricated metal	-0.253	-0.229	-0.281	-0.301	-0.266
18. Machinery	-0.277	-0.196	-0.273	-0.364	-0.277
19. Computer and electronic	-0.492	-0.521	-0.399	-0.461	-0.468
20. Electrical appliances	-0.313	-0.408	-0.478	-0.257	-0.364
21. Transportation equipment	-0.308	-0.271	-0.345	-0.312	-0.309
22. Furniture	-0.171	-0.280	-0.191	-0.333	-0.244
23. Other manufacturing	-0.432	-0.315	-0.201	-0.325	-0.318
24. Wholesale	-0.253	-0.325	-0.272	-0.219	-0.267
25. Retail	-0.235	-0.206	-0.237	-0.253	-0.233
26.Transportation and warehouse	-0.199	-0.190	-0.258	-0.254	-0.225
27. FIRE	-0.295	-0.311	-0.290	-0.323	-0.305
28. Health and social assistance	-0.422	-0.394	-0.403	-0.398	-0.404
29. Other services	-0.448	-0.460	-0.472	-0.469	-0.462

Notes: Regressions are the same as Table 2, except the interaction between the education and industry dummies. University graduates are the excluded category. Column 97–00 reports the mean of the estimates for 1997–2000.

Table 9: Means of Measures of Technological Change by Industry, 1997–2000

	R&D exp.	R&D person	Sci. & eng.
1. Agriculture	0.25	0.56	0.86
2. Forestry and logging	0.27	0.31	5.56
3. Fishing, hunting, and trapping	0.61	0.98	0.90
4. Mining and oil and gas extraction	0.42	0.48	9.61
5. Utilities	0.72	0.90	11.10
6. Construction	0.07	0.12	1.24
7. Food, beverages, and tobacco	0.38	0.44	1.83
8. Textile	1.28	0.91	1.57
9. Wood	0.37	0.40	1.14
10. Paper	1.15	0.88	3.40
11. Printing	0.17	0.20	1.27
12. Petroleum and coal	4.00	0.14	9.40
13. Chemical and pharmaceutical	5.67	4.98	8.77
14. Plastics and rubber	1.11	1.02	2.27
15. Non-metallic mineral	0.33	0.53	2.44
16. Primary metal	1.62	1.42	4.61
17. Fabricated metal	0.64	0.92	3.02
18. Machinery	2.98	3.80	6.95
19. Computer and electronic	31.11	24.27	17.26
20. Electrical appliances	4.19	3.78	5.17
21. Transportation equipment	5.30	2.90	5.85
22. Furniture	0.15	0.21	1.13
23. Other manufacturing	1.79	0.73	1.21
24. Wholesale	1.11	1.21	1.66
25. Retail	0.09	0.06	0.76
26. Transportation and warehouse	0.06	0.05	1.46
27. FIRE	0.08	0.21	4.34
28. Health and social assistance	0.65	0.22	0.63
29. Other services	0.70	0.66	6.18

Table 10. Effects of Technological Change on University–High School Wage Gap, 1997–2000

	OLS	FE	OLS	FE
A. R&D expenditure	0.0264	-0.0469	0.0115	-0.0572
	(0.0048)	(0.0544)	(0.0097)	(0.0694)
Profit margin			-0.0472	0.2429
			(0.2661)	(0.3027)
Profit growth			0.0008	0.0009
			(0.0010)	(0.0028)
Union density			0.0365	1.1729
			(0.0563)	(1.4466)
% Large firms			0.1251	0.0687
			(0.2082)	(0.1686)
% Professionals			0.4812	1.3269
			(0.0896)	(0.9801)
B. R&D persons	0.0269	0.1200	0.0137	0.1506
	(0.0052)	(0.1585)	(0.0090)	(0.1650)
Profit margin			-0.0764	0.3345
			(0.2401)	(0.3481)
Profit growth			0.0008	0.0040
			(0.0010)	(0.0041)
Union density			0.0476	1.2694
			(0.0598)	(1.3474)
% Large firms			0.1268	0.0630
			(0.1997)	(0.1574)
% Professionals			0.4941	1.1882
			(0.0837)	(0.9971)
C. % of scientists	0.0238	-0.0058	0.0081	-0.0015
	(0.0125)	(0.0190)	(0.0041)	(0.0161)
Profit margin			-0.1618	0.1892
			(0.2226)	(0.2933)
Profit growth			0.0005	0.0019
			(0.0011)	(0.0026)
Union density			0.0140	1.2166
			(0.0525)	(1.3844)
% Large firms			0.1549	0.0576
			(0.1693)	(0.1552)
% Professionals			0.4918	1.2145
			(0.0837)	(1.0426)

Notes: Standard errors in parentheses are corrected by Davidson and MacKinnon (1993). All regressions include year dummies.

Figure 1: University- High School Wage Gap, 1981- 2000

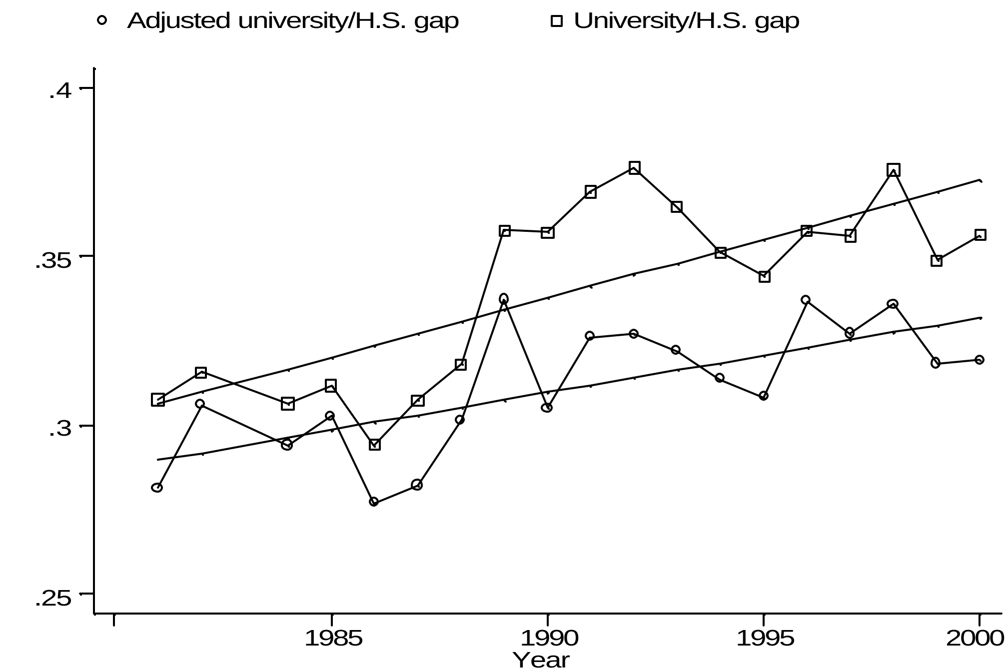


Figure 2: Aggregate Relative Supply of University-Educated Labour, 1981- 2000

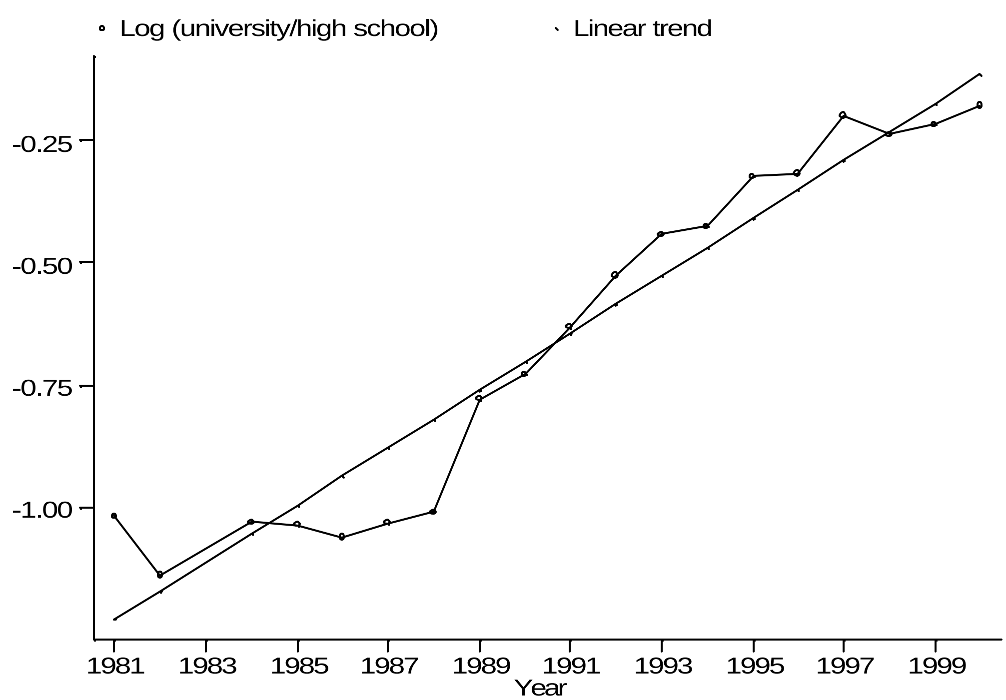


Figure 3: Aggregate Measures of Skill-Biased Technology, 1981–2000

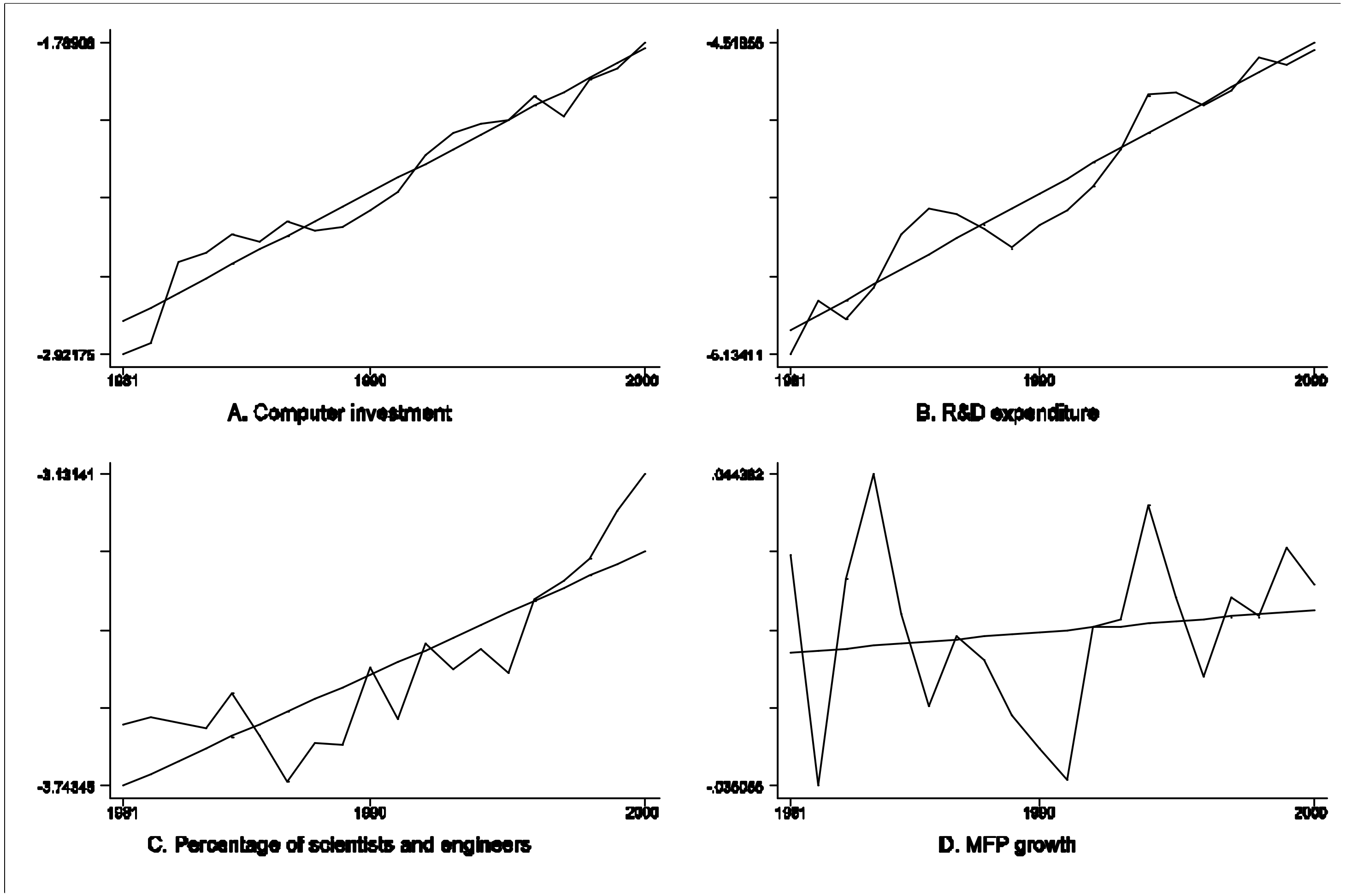


Figure 4: Estimated University- High School Wage Gap by Age Group, 1981- 2000

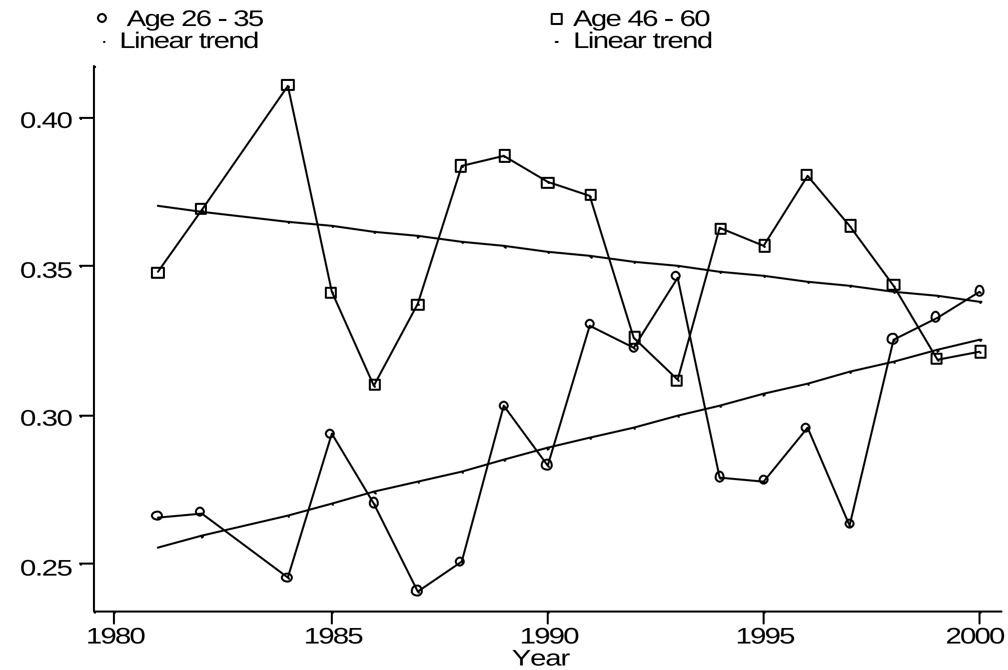
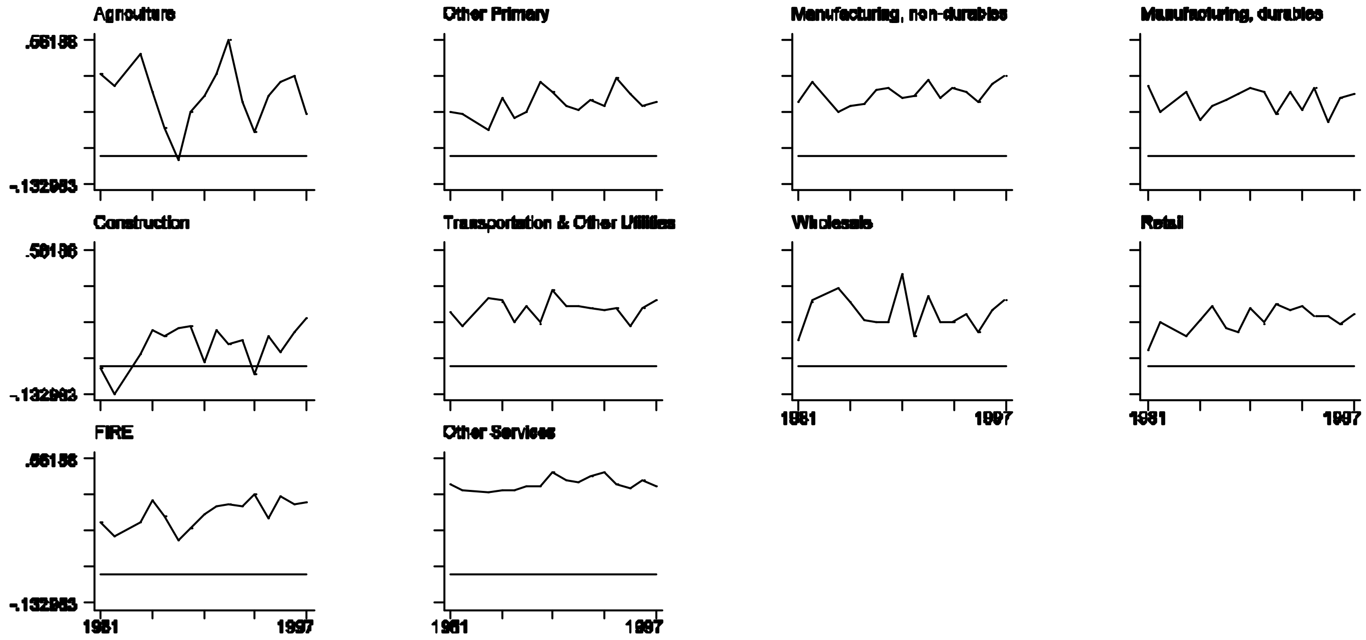


Figure 5: Age-Specific Relative Supply of University-Educated Labour, 1981- 2000

Figure 6: Estimated University- High School Wage Gap by Sector, 1981- 1997



Appendix A: Indicators of Technological Change

A.1 MFP growth

This measure is available from Statistics Canada for 47 industries in the business sector between 1981 and 1997. In general, it is a residual measure of the change in gross output relative to the change in intermediate inputs, which include labour, energy, materials, and services. For more details on the calculation procedure, see *Productivity Growth in Canada*, Statistics Canada (Catalogue no. 15-204).

A.2 The ratio of R&D expenditure to output

The ratio of R&D expenditure to output is defined as the real R&D expenditure as a percentage of real output. Total R&D expenditure in current dollars is based on an annual survey conducted by Statistics Canada since 1955. Prior to 1997, all companies that performed R&D were included in the survey. Since that time, the survey sample has been limited to large firms that spend more than $1 million annually on R&D. Data for small firms are collected from the Canada Customs and Revenue Agency. The total expenditure on R&D includes: (1) labour costs, (2) fringe benefits, (3) purchases of materials and supplies, (4) contracts for services, and (5) capital expenditure, classified into land, building, and equipment. For more details, see various issues of *Industrial Research and Development*, Statistics Canada (Catalogue no. 88-202). The GDP deflator is used to obtain the real R&D expenditure. Real output for different industries is measured as the GDP at factor cost or basic prices.

A.3 Percentage of employment engaged in R&D

Data come from the same survey that collects information on R&D expenditure. The total number of persons engaged in R&D is calculated as the full-time equivalent (FTE). Adjustment is made for persons who work only part-time on R&D to estimate their FTE. For more details, see various issues of *Industrial Research and Development*, Statistics Canada (Catalogue no. 88-202).

A.4 The ratio of scientists and engineers to total employment

Based on the occupational classification, this measure is calculated directly from the sample. For the SCF sample, "scientists and engineers" includes architects, engineers, and workers in occupations related to physical sciences, life sciences, mathematics, statistics, and systems analysis (i.e., 1980 Standard Occupational Classification (SOC) = 211, 213, 214, 215, 218). For the LFS sample, this group refers to professional occupations in natural and applied sciences (i.e., 1991 SOC = C0).

Appendix B: Industry Groupings

Original industry groupings in the SCF and LFS have to be recategorized to match the industry measure of technological change. Furthermore, workers in the public sector are excluded for two reasons. First, public workers in Canada are highly unionized (Robinson 1995). The literature (e.g., Freeman 1982 and Lemieux 1993) suggests that the wage distribution among union workers is more compressed. Second, there was public sector restructuring in the 1990s to cut deficits and reduce the debt burden at all levels of government. In addition to the significant decline in public sector employment (Fenton, Ip, and Wright 2001), the legislated wage freezes would affect the evolution of the wage premium.

B.1 SCF

Industries are grouped into 10 sectors, according to the 1980 Standard Industrial Classification: (1) agriculture; (2) other primary; (3) manufacturing, non-durables; (4) manufacturing, durables; (5) construction; (6) transportation, communication, and other utilities; (7) wholesale; (8) retail; (9) FIRE; and (10) other services. Table B1 gives a detailed breakdown of each sector and the employment share. As expected, the general pattern is an employment shift from the manufacturing sector to the service sector between 1981 and 1997.

B.2 LFS

Industry groupings in the LFS are more refined. Instead of the 10 sectors in the SCF, there are 29 industry groups under the North America Industry Classified System: (1) agriculture; (2) forestry and logging; (3) fishing, hunting, and trapping; (4) mining and oil and gas extraction; (5) utilities; (6) construction; (7) food, beverages, and tobacco, (8) textiles; (9) wood; (10) paper; (11) printing; (12) petroleum and coal; (13) chemical and pharmaceutical products; (14) plastics and rubber products; (15) non-metallic mineral products; (16) primary metal; (17) fabricated metal products; (18) machinery; (19) computer and electronic products; (20) electrical equipment, appliances, and components;

(21) transportation equipment; (22) furniture and related products; (23) other manufacturing; (24) wholesale; (25) retail; (26) transportation and warehouse; (27) FIRE; (28) health and social assistance; and (29) other services. Table B2 shows the employment share for each group.

Table B1. Sectors in SCF

Sector	Employment share (%)	
	1981	1997
1. Agriculture	1.1	1.3
2. Other primary i) Fishing, trapping, logging, and forestry ii) Mining, quarrying, and oil wells	3.1	2.6
3. Manufacturing, non-durables Food, beverages, and tobacco Rubber and plastic products Leather and allied products Primary textile, textile products, and clothing Paper, printing, publishing, and allied products Refined petroleum and coal products Chemical and chemical products Other manufacturing	11.7	10.0
4. Manufacturing, durables i) Wood, furniture, and fixture ii) Primary metal, fabricated metal products iii) Machinery and transportation equipment iv) Electrical and electronic products non-metallic mineral products	12.1	10.0
5. Construction	6.6	5.4
6. Transportation, communication, and other utilities	10.3	9.0
7. Wholesale	5.3	5.2
8. Retail	11.3	11.2
9. Finance, insurance, and real estate (FIRE)	6.5	6.2
10. Other services i) Educational, health and social service ii) Amusement and recreational iii) Service religious organizations iv) Accommodation, food, and beverage service v) Personal and household service vi) Membership organization vii) Business services viii) Miscellaneous services	32.0	39.0

Table B2. Industry Groupings in LFS

Industry	Employment share (%)	
	1997	2000
1. Agriculture	0.8	0.8
2. Forestry and logging	0.6	0.6
3. Fishing, hunting, and trapping	0.1	0.1
4. Mining and oil and gas extraction	1.7	1.5
5. Utilities	1.3	1.2
6. Construction	4.7	4.7
7. Food, beverages, and tobacco	2.4	2.3
8. Textile	0.5	0.4
9. Wood	1.2	1.4
10. Paper	1.2	1.1
11. Printing	0.8	7.9
12. Petroleum and coal	0.2	1.8
13. Chemical and pharmaceutical products	1.0	1.1
14. Plastics and rubber products	1.0	1.2
15. Non-metallic mineral products	0.5	0.5
16. Primary metal	1.1	1.0
17. Fabricated metal products	1.3	1.4
18. Machinery	1.0	1.1
19. Computer and electronic product	1.0	1.3
20. Electrical equipment, appliances, and components	0.6	0.5
21. Transportation equipment	2.8	3.0
22. Furniture and related products	0.7	0.9
23. Other manufacturing i) Clothing and leather products ii) Miscellaneous manufacturing	1.9	1.7
24. Wholesale	3.7	4.2
25. Retail	10.8	10.5
26. Transportation and warehouse	5.9	6.1
27. Finance, insurance and real estate (FIRE)	7.4	6.8
28. Health and social assistance	12.5	12.6
29. Other services i) Information, culture, and recreation ii) Professional, scientific, and technical services iii) Management and administrative iv) Educational services v) Accommodation and food service vi) Miscellaneous services	30.9	30.8

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