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Productivity and economic output of the education sector

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Abstract The paper constructs a direct output measure of the education sector for Canada and uses the measure to examine its productivity performance. It makes an explicit quality adjustment of the output of the education sector by proposing and implementing a hedonic approach. The approach represents a practical approach for the quality adjustment in education output and can be applied using the existing data from statistical agencies. The measurement of education output in the paper is predicated on the notion that the output of the education sector represents investment in human capital and it has two variants. The income-based approach measures investment in education as increments in the future stream of earnings arising from education. The cost-based approach measures investment as total expenditures related to education.

Keywords Human capital · Education · Productivity

JEL Classification H52 · J24

1 Introduction

Education is an important economic activity in Canada. Education, at 15 % of consolidated government expenditures, was the third-largest item, following health (19 %) and social services (30 %), in 2009. However, little is known about the productivity performance of the education sector, as the output of the education sector has been measured largely by inputs in Canada.

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In the National Accounts of Canada and those of most other countries, the volume of output of the education sector has been measured in the past by the volume of inputs in the education sector, where total inputs include labour costs for teachers and administrative staff, capital input, and intermediate inputs. Since the volume of output is measured by the volume of inputs in the education sector, the ratio of output to inputs does not accurately measure productivity performance for that sector. To properly measure the productivity performance of the education sector, the direct output measure must be developed. The objective of this paper is to develop such measure for Canada that can be used to examine productivity performance in the education sector.

The output of the education sector is defined as the effect of education on the level of knowledge, skills, and competencies of students or investment in human capital (Jorgenson and Fraumeni 1992; Schreyer 2012; OECD 2010). According to this definition of *education output*, the task of measuring education services is essentially one of measuring investment in human capital. The empirical literature has developed two approaches to measuring the value of investments in human capital. The first is the income-based approach developed in a series of papers by Jorgenson and Fraumeni (1989, 1992, 1996). The approach measures the nominal value of education output as the increase in the student's present discounted value of lifetime income arising from education. The second approach is the cost-based approach, which measures the nominal value of education as total expenditures on education (Kendrick 1976).

A major challenge with respect to the measurement of education services is to capture changes in the quality of the education that students receive. There have been numerous attempts to take into account quality changes in

the measure of education output (see Schreyer 2009; Abraham 2010 for a review). The approaches for quality adjustment are mostly arbitrary in previous studies. More recently, Diewert (2011) and Schreyer (2012) propose that the hedonic technique can be used to make quality adjustment for the output of the nonmarket service sectors such as education sector. Essentially, the quality adjustment for education service output is similar to the quality adjustment that has been made for the output of computer technology and other information and communications technologies (ICT) products, which have benefited from improvements in their quality over time. However, to our knowledge, the hedonic approach has not been applied in previous empirical studies on the measurement of output and productivity in the education sector.

A contribution of this paper is to present and apply the hedonic technique in order to adjust the output of the education sector for changes in quality. The approach represents a practical approach for quality adjustment for the output of the education sector, as the data for implementing the approach are readily available in statistical agencies.

To measure the productivity performance defined as the ratio of the volume index of education output to the volume of index of education input, the nominal value of education output need to be decomposed into the volume and price components. To do that, both income-based and cost-based approaches start with the number of student enrolments or the number of graduates, disaggregated by education level, type of education program, age, and gender. The two approaches differ in the weights assigned to, or the unit prices used to weigh, the different types of enrolments or graduates in order to derive a volume index of education output.

For the income-based approach, the volume index of education output is calculated as a weighted sum of student enrolments. Weights are based on the value of education which is measured in terms of its effect on students' lifetime labour incomes. For the cost-based approach, the volume index of education output is calculated as a weighted sum of student enrolments using weights based on total expenditures per student. Total expenditures include teacher salaries, intermediate inputs, and a capital consumption allowance.

Diewert (2011) analyzes three approaches to measure the price and volume index of non-market government output. The first approach values the government output at purchaser's value or market prices. The second approach values the output at unit costs of production or quasi prices. The third approach measures the volume of output as the volume of output. The first two approaches correspond to the income- and cost-based approaches for measuring education output in this paper. The third approach is the approach used in many statistical agencies and does not provide for an analysis of productivity performance in the education sector.

The paper will focus on the education function of the education sector, which includes primary and secondary education, colleges, and universities. The research output of universities is estimated by the number of publications. It is then aggregated with university enrolments using the relative cost shares of teaching versus research to form the cost-based estimate of university output. Education also yields benefits beyond increased future streams of earnings for students, such as making students 'better' citizens and 'better' parents. However, those benefits are excluded from our measure of education output, which focuses on the economic output.

The rest of the paper is organized as follows. Section 2 presents the cost-based and income-based estimates of education services for Canada. Section 3 presents quality-adjusted education output. Section 4 concludes the paper.

2 Measuring the output of the education sector

This section presents two approaches for measuring the economic output of the education sector. One, the income-based approach, is based on the future stream of earnings that education can be expected to provide; the other, the cost-based approach, is based on the costs of education. The two approaches are described below, in Sects. 2.1 and 2.2, and are used to produce estimates of the output of the Canadian education sector, in Sect. 2.4.

2.1 Income-based approach to the measurement of education services

The income-based approach measures the value of education services as the effect of education on an individual's lifetime income. As the value of education depends on the student's age, sex, and education level, the approach disaggregates students by their age, sex, and education level.

Gu and Wong (2010) estimated the present discounted value of market lifetime labour income (or the value of human capital) for all individuals aged 15–74 in Canada.[1] In the study, the estimate is derived by using cross-sectional data. It is assumed that expected incomes in future periods are equal to the incomes of individuals of the same gender and education, according to the age that the individuals will have in the future time period, adjusted for increases in real income. The lifetime incomes can be calculated by a backward recursion, starting with age 74, which is assumed to be the oldest age before retirement. The expected income for a person of a given age is that

[1] Liu (2011) estimated the stock of human capital as the present discounted value of market lifetime income for selected OECD countries.

person's current labour income plus his or her expected lifetime income in the next period multiplied by survival probabilities. For example, the present value of lifetime income of 74-year-olds is their current labour income. The lifetime income of 73-year-olds is equal to their current labour income plus the present value of lifetime income of 74-year-olds, adjusted for increases in real income.

Let denote $h^t_{s,e,a}$ denote the discounted lifetime income (or human capital stock) of individuals of sex s, educational attainment e, and age a in year t, and $N^t_{s,e,a}$ denote the number of students of sex s, and age a who are enrolled in education level e. It is assumed that individuals enroll in school in order to attain a higher education level—that is, the individuals who are enrolled in education level e have already achieved education level e-1.

The nominal value of education services (V) is estimated as increments in lifetime incomes arising from increases in education summed over all students:

$$V^t = \sum_{s,e,a}\left[h^t_{s,e+1,a+m}((1+g)^m/(1+r)^m)sr_{a,a+m} - h^t_{s,e,a}\right]N^t_{s,e,a} = \sum_{s,e,a} I^t_{s,e,a}N^t_{s,e,a}. \quad (1)$$

It is assumed that individuals with education level e-1 who are enrolled in school need to spend an average of m additional years in school in order to achieve higher education level e. g is the expected growth rate in real income, and $r$is the discount rate used to calculate the present value of future lifetime labour income. $sr_{a,a+m}$ is the probability that an individual aged a will survive for m more years. $I^t_{s,e,a}$ is the investment in human capital for a student, and $N^t_{s,e,a}$ is the number of students.

The nominal value of education output in Eq. (1) can be divided into volume and price components (Diewert 1976). The volume index of education output (denoted by Q) is an index number derived through a Tornqvist aggregation on the basis of school enrolments. It is calculated as a weighted sum of student enrolments across different types of students by using as weights the increment in lifetime labour incomes due to education:

$$\ln Q^t - \ln Q^{t-1} = \sum_{s,e,a}\bar{v}_{s,e,a}(\ln N^t_{s,e,a} - \ln N^{t-1}_{s,e,a}), \quad (2)$$

where

$$\bar{v}_{s,e,a} = 1/2\left(\frac{I^t_{s,e,a}N^t_{s,e,a}}{P^tQ^t} + \frac{I^{t-1}_{s,e,a}N^{t-1}_{s,e,a}}{P^{t-1}Q^{t-1}}\right),$$

$\bar{v}$ is the share of individuals with s, e, a in the total value of investment in education, averaged over year $t-1$ and year t.

The price index of education services (P) is estimated by dividing the nominal value of education services by the volume index of education services:

$$P_t = V_t/Q_t. \quad (3)$$

The estimates of education output and prices in Eqs. (1), (2), and (3) are based on the number of pupils enrolled at different levels of education. Alternatively, the estimates of education output can be based on the number of graduates who obtain a particular educational qualification in a given year and leave the school system.[2] The output of the education sector based on the number of graduates is estimated as the sum of lifetime incomes embodied in those graduates. It can be shown that the estimates of education output based on the number of enrolments are identical to those based on the number of graduates.

In practice, data on enrolments are readily available. In addition, estimates based on school enrolments allow us to estimate education output for institutions of different levels of education, such as primary education, secondary education, and postsecondary education. The estimate based on graduates attaining a particular qualification reflects the sum of the contribution of all education institutions leading to the qualification. For these reasons, data on student enrolments are used to estimate education output.

2.2 Cost-based approach to the measurement of education services

In contrast to the income-based approach, the cost-based approach measures the output of education services by using the cost of inputs to education. The approach typically disaggregates students by education level (elementary, secondary, or postsecondary), since students enrolled in the various education levels require different amounts of those inputs. In addition, as discussed by Fraumeni et al. (2008), it may be important to differentiate along the lines of other student characteristics, such as regular education versus special education or native English speakers versus non-native English speakers.

The nominal value of education services V arrived at by using the cost-based approach is the following:

$$V^t = \sum_i C^t_i N^t_i, \quad (4)$$

where: N^t_i is the number of students enrolled in a specific education level (primary, secondary, or postsecondary) or in a specific education program (regular education vs. special education); and C^t_i is the costs of inputs per student.

Once again, the nominal value of education services can be divided into price and volume components. The volume index of education services is a weighted sum of student enrolments across different education levels using the share

[2] Fraumeni et al. (2008) provided a brief survey of methodologies used in a number of countries that are based on either student enrolments or the number of graduates.

of the education levels in total input costs as weights. The price index of education services is the ratio of the nominal value of education services to the volume index.

There are advantages and disadvantages associated with the cost-based approach as compared with the income-based approach. The cost-based approach is more consistent with the existing national accounts framework (Schreyer 2009). It maintains the existing boundary of the national accounts while the income-based approach extends the boundary of national accounts to cover household activities.

Diewert (2011) argues that the income-based approach represents the best option for measuring the output of the education sector as the valuation of government nonmarket output from the purchaser perspective is more consistent with the valuation of market sector output. The approach is also preferred by Eurostat (2001) and Atkinson (2005).

But there is disadvantage associated with the income-based approach. The approach assumes that the earning differentials among individuals reflect the effect of investment in formal education (Rosen 1989). To the extent that the earning differentials also capture the effect of on-the-job training, gender discrimination, and individuals' ability, the income-based approach overestimates the level of education output.

2.3 Data

The data required for estimating education output start with information on enrolment. In addition, the income-based approach requires data on the impact of education on lifetime labour income or data on investment in education, and the cost-based approach requires data on education expenditures at different levels of education.

2.4 Data on student enrolments

The data on enrolment are taken from various surveys on student enrolments. From those surveys, time series data are constructed on the number of pupils enrolled in school, cross-classified by gender, education level (one of five levels), and age (age 6–74). The five education levels are defined as follows: 0–8 years of schooling; some or completed high school; some or completed postsecondary school below bachelor's degree; bachelor's degree; and master's degree or above. The data cover the period from 1972 to 2005. There appears to be a break in enrolment data for education level 3 (some or completed postsecondary education below bachelor's degree) in 1976. The data for the period from 1976 to 2005 are used in this paper.

The enrolment data for elementary and secondary education are obtained from the Elementary-Secondary Education Statistics Project (ESESP) for the years after 1997. For 1997 and prior years, the enrollment data are obtained from the Elementary/Secondary School Enrolment (ESSE) survey.

The ESESP is an annual survey that collects aggregate data from each provincial/territorial Ministry or Department of Education. Specifically, the information on enrolments pertains to the following two streams: regular education; and minority- and second-language education. Information on regular-education programs is collected by type of program (regular, upgrading, or professional), education sector (youth or adult), grade, and sex. Information on minority- and second-language programs is collected by type of program (immersion, as language of instruction, as a subject taught) and grade.

For the years before 1997, the data on enrolment are obtained from the ESSE survey. This survey collects data on enrolments by type of school (public, private, schools for the visually or hearing impaired, federal schools, and Department of National Defence schools). The data are broken down by age and gender and by grade and gender. Data on public schools are provided to Statistics Canada by the provinces and territories. For private schools, survey methods vary. Some provinces supply both private and public schools, while, for other provinces, Statistics Canada surveys institutions directly.

The enrolment statistics for primary and secondary education from the ESESP provide information on the grades in which students are enrolled (grade 1 to grade 13), but the ESESP does not have information on the ages of the pupils. The age of pupils is inferred from the fact that pupils generally start grade 1 at age 6 in Canada. The pupils enrolled in grade 1 are assumed to be 6 years old; those enrolled in grade 2 are set to be 7 years old; and so forth.

The enrolment data for postsecondary education are obtained from the Postsecondary Student Information System (PSIS) for 1992 and subsequent years. For the years before 1992, the data are obtained from three separate surveys: the University Student Information System (USIS); the Community College Student Information System (CCSIS); and the Trade/Vocational Enrolment Survey (TVOC).

The Postsecondary Student Information System (PSIS) is a national survey that provides detailed information on enrolments and graduates of Canadian postsecondary education institutions. The PSIS collects information pertaining to the programs and courses offered at an institution, as well as information regarding the students themselves and the program(s) and courses in which they were registered or from which they have graduated.

In the year 2001, the PSIS began to replace the University Student Information System (USIS), the

Community College Student Information System (CCSIS), and the Trade/Vocational Enrolment Survey (TVOC) with a single survey offering common variables for all levels of postsecondary education. Historical enrolment and graduate data from previous surveys have been converted by using PSIS variable definitions and code sets in order to maintain the historical continuity of the statistical series.

2.5 Data on investment in human capital

Data on investment in human capital arising from the education of each student, cross-classified by gender, education, and age are obtained from Gu and Wong (2010). The human capital estimate from Gu and Wong (2010) includes all individuals in the Canadian working-age population aged 15–74. For the purpose of this paper, the human capital estimates from Gu and Wong (2010) are extended to include individuals aged 6–14.

The estimates of lifetime income and investment in human capital from education depend on the expected future real income growth and the discount rate used to discount the future income. The estimates used for this paper are based on the expected real income growth of 1.7 % per year and the discount rate of 1.7 %. Gu and Wong (2010) shows that the estimates of the volume index of investment in human capital are not sensitive to the choice of those two parameters. Therefore he output and productivity estimates of the education sector from the income-based approach are not affected by the choice of the parameters.

To estimate human capital stock for individuals aged 6–14, the paper makes the following assumptions. Individuals aged 6 are assumed to be enrolled in grade 1 and are expected to complete grade 8 when they are 14 years old. Those individuals are assigned the lifetime income of individuals aged 15 with education level 1 in 8 years. Individuals aged 7 are assumed to be enrolled in grade 2 and are expected to complete grade 8 when they are 14 years old. Those individuals will be assigned the lifetime income of individuals aged 15 with education level 1 in 7 years. The lifetime labour income of those individuals aged 8–14 is estimated in a similar fashion.

The discounted lifetime labour income for individuals aged 6 to 14 can be estimated as the following:

$$h^t_{s,e,a} = h^t_{s,e,15}\left((1+g)^{15-a}/(1+r)^{15-a}\right)sr_{s,a,15}, \quad \text{for} \quad 6 \le a \le 14 \quad \text{and} \quad e = 1, \tag{5}$$

where: $sr_{a,15}$ is the probability that an individual of sex s and age a will survive to age 15; g is real income growth; and r is the discount rate used to discount future income.

Investment in education is measured as the increase in the discounted lifetime labour income resulting from spending an additional year in school. For students enrolled in education level 2 or above, the estimate of investment in education is based on the difference in human capital stock between individuals enrolled in that education level and individuals enrolled in a lower education level:

$$I^t_{s,e,a} = h^t_{s,e+1,a+m}((1+g)^m/(1+r)^m)sr_{a,a+m} - h^t_{s,e,a}, \quad \text{for} \quad e \ge 2, \tag{6}$$

where m in the equation denotes the number of years that an individual spends in order to complete the next education level. It is assumed that individuals with 0–8 years of schooling spend 3 years to complete the next education level (some or completed high school), that individuals with some or completed high school spend 2 years to obtain some or completed postsecondary education below bachelor's degree, that individuals with some or completed postsecondary education below bachelor's degree spend 2 years to obtain a bachelor's degree, and that individuals with a bachelor's degree spend at least 2 years to obtain a master's degree or above.[3]

For students enrolled in education level 1 (0–8 years of schooling), investment in education is measured as the increase in their lifetime labour income compared with the lifetime labour income of those individuals who do not have education. But the human capital stock for those individuals with no education cannot be estimated directly using data from the Census of Population, as individuals are not coded as having no education in the household surveys or in the Census.

To estimate investment in education for those pupils enrolled in education level 1 (0–8 years of schooling), we use the fact that individuals start grade 1 at age 6 and that primary-level education is mandatory in Canada. For individuals enrolled in grade 8 who are age 14, investment in human capital is calculated as the difference between the lifetime income of those individuals and the lifetime income of the individuals of the same age who are enrolled in a lower grade (grade 7). Since the individuals who are enrolled in grade 7 are all presumed to be 13 years old, the lifetime income of individuals who are enrolled in grade 7 who are 14 years of age is not observed. It is assumed that the individuals who are enrolled in grade 7 who are 14 years of age will achieve the lifetime income of individuals enrolled in grade 7 who are 13 years of age, with a 1-year lag. Investment in human capital for 14-year-olds is estimated as the following:

[3] The number of years m that is required to obtain an education level depends on students' ages. The year of education of younger students within the education level is calculated by inference. It is assumed that older students are equally distributed among the various years of education in the education level (for details, see Gu and Wong 2010).

$$I^t_{s,1,14} = h^t_{s,1,14} - h^t_{s,1,13}((1+g)/(1+r))sr_{s,13,14}. \quad (7)$$

In general, investment in education for students enrolled in education level 1 who are of age a ($6 \leq a \leq 14$) can be estimated as the following:

$$I^t_{s,1,a} = h^t_{s,1,a} - h^t_{s,1,a-1}((1+g)/(1+r))sr_{s,a-1,a}. \quad (8)$$

2.6 Data on expenditures by education level

Student enrolments are disaggregated by education level in order to construct the cost-based estimates of education services. The cost of education includes labour costs (salaries of teachers), capital costs, and intermediate inputs.[4]

Data are obtained from the Canadian Input–Output Tables for three levels of education: primary and secondary education, college education, and university education.

Data on the costs of education are not available at individual education levels before 1997. It is assumed that the relative differences in unit costs across three education levels did not change for the period before 1997 and are set to be equal to those in year 1997.

2.7 The output of the education sector

This section first presents the income-based estimate and the cost-based estimate of the output of the education sector. It then compares the two estimates.

2.8 The income-based estimate of education output

Figure 1 plots trends in school enrolments by education level over the period from 1976 to 2005. Enrolment in primary and secondary education fell from 1976 to the mid-1980s as the baby boomers left the primary and secondary education sectors. Enrolment in grades 1–8 then gradually increased after the mid-1980s and fell again after the mid-1990s as the school-aged population declined. Enrolment in secondary school (grades 9–13) increased after the mid-1980s and levelled off after the mid-1990s.

Figure 2 plots school enrolments by gender over the period from 1976 to 2005. Enrolments increased faster for women than for men, as a result of large increases in the former's participation in colleges and universities over the period. After the mid-1980s, enrolment by women exceeded enrolment by men. Women now account for more than half of all pupils enrolled in schools in Canada.

Table 1 presents annual growth rates of student enrolments. The most notable increase was observed for enrolments in colleges and universities: 2.6 % per year from 1976 to 2005. While some of this increase was due to the demographics of the baby boomers, most of the increase was attributable to increases in participation in college and university education among Canadians aged 18–26 (Emery 2004).

Table 2 presents the income-based estimates of investment in education in current dollars for the period from 1976 to 2005. The nominal value of education services in Canada, as measured by the impact of education on the lifetime labour income of students, is large. The share of investment in education in unrevised nominal gross domestic product (GDP) is large. But, it declined over time.[5] Over the period 1976 to 2006, the share of investment in education in nominal GDP declined from 94 to 34 %. The decline in the share of investment in education in nominal GDP reflects general trend towards increases in the ratio of fixed capital to labour or capital deepening in the developed countries.

The nominal value of education services is divided into price and quantity components in Tables 3 and 4. The quantity index of education output (weighted sum of enrolments) is estimated to have increased at an average rate of 0.8 % per year for the period from 1976 to 2005. The price index of education output increased at 2.4 % per year over the period. Figure 3 plots the weighted and un-weighted sum of enrolments in the education sector. The weighted sum of enrolments increased faster than the un-weighted sum of enrolments. The difference between the weighted and un-weighted measures reflects the rising enrolments in secondary and postsecondary education with larger investment in human capital from education over the period. The difference was large for the period 1976 to 1985 as a result of relatively large increase in school enrolment in college education.[6]

The price index of education output rose by an average of 2.4 % per year for the period from 1976 to 2005. It increased at a much slower rate after the mid-1990s. It grew at an average annual rate of 0.9 % over the period from 1996 to 2005. The slower growth in the price index of education for that period reflects slower earnings growth in that period.

The growth rates of the price and volume indices of education output are lower than the growth rates of the

[4] Capital cost in the education sector is restricted to capital consumption in the National Accounts and does not include a return to capital.

[5] In a more integrated account, investment in education is added to nominal GDP and nominal GDP will increase significantly as a result. For example, nominal GDP adjusted for investment in education would increase by 34 % in 2005.

[6] To the extent that the portion of the difference between investment in human capital from education between male and female students is due to discrimination, the weights used to weight enrolments for females are too low. The volume index of investment in education that is based on investment in education adjusted for discrimination should be higher.

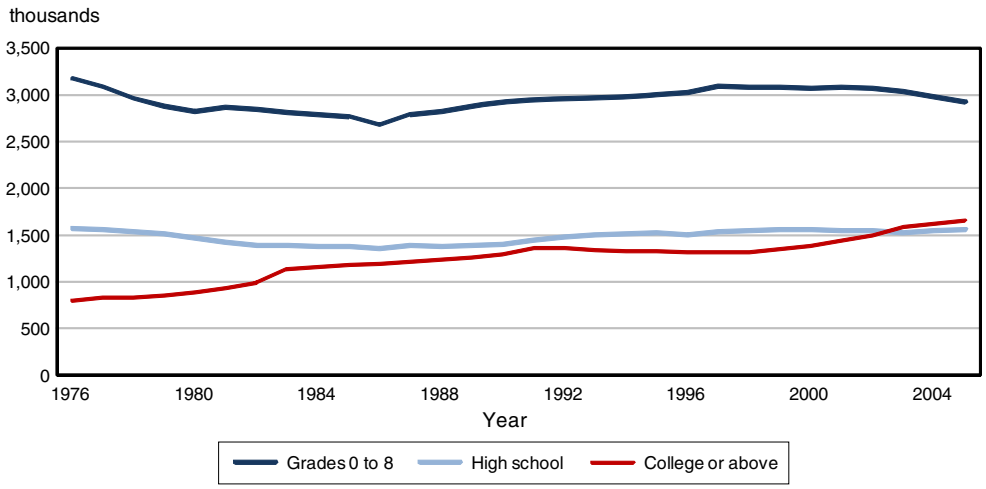

Fig. 1 School enrolment in Canada, by education level. Source: Statistics Canada, authors' calculations

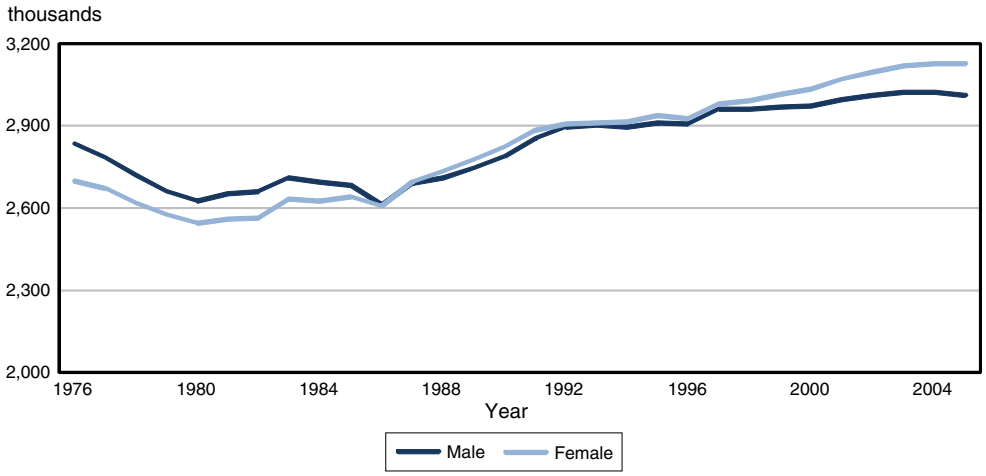

Fig. 2 School enrolment in Canada, by gender. Source: Statistics Canada, authors' calculations

Table 1 Annual growth in school enrolment in Canada, 1976–2005

Characteristic	1976–2005 Percent	1976–1986	1986–1996	1996–2005
Total	0.4	−0.6	1.1	0.6
Male	0.2	−0.8	1.1	0.4
Female	0.5	−0.3	1.2	0.7
Grades 0–8	−0.3	−1.7	1.2	−0.3
High school	0.0	−1.4	1.0	0.5
College or above	2.6	4.1	1.0	2.6

Source: Statistics Canada, authors' calculations

price and volume index of gross domestic product (GDP). Real GDP increased by 2.9 % per year over the period from 1976 to 2005. The price index of GDP increased by 3.9 % per year during the period.

The rate of growth in the price of education output accounts for about two-thirds of the rate of growth of nominal education output. In contrast, the rate of growth of the GDP price index accounts for a lower portion (60 %) of the rate of growth in nominal GDP.

The level of investment in education for men has consistently exceeded that for women, as shown in Table 2. The difference between the two narrowed around the mid-1980s as a result of increased enrolments by women over that period. After the mid-1980s, the difference in investment in education between women and men was virtually unchanged.

The growth rate of investment in education in constant prices was much higher for women than for men before the mid-1980s; the growth rates for women and for men were similar after the mid-1980s (as shown in Table 3). This difference in investment in education between men and

Table 2 Nominal investment in education in Canada, by gender and education level, 1976–2005

Year	Total	Male	Female	Grades 0–8	High school	College or above
	Billions of current dollars					
1976	187.4	102.1	85.2	46.7	94.5	46.2
1977	196.7	107.7	89.0	47.6	101.1	47.9
1978	196.9	108.1	88.8	47.9	99.3	49.7
1979	197.4	110.5	86.9	49.0	98.5	49.9
1980	205.8	111.6	94.3	51.7	103.4	50.6
1981	242.5	130.4	112.1	60.8	118.7	63.1
1982	264.2	139.2	125.0	64.4	124.1	75.6
1983	251.4	131.2	120.2	64.8	106.4	80.2
1984	266.8	145.8	121.0	68.9	110.5	87.4
1985	262.1	145.5	116.6	72.4	103.1	86.6
1986	281.4	151.0	130.4	74.0	113.1	94.3
1987	302.6	160.5	142.1	81.5	124.4	96.8
1988	301.6	158.1	143.5	87.3	118.9	95.4
1989	335.9	183.1	152.7	94.7	135.7	105.4
1990	440.9	242.4	198.5	109.1	173.5	158.3
1991	461.9	245.0	216.9	116.1	166.9	178.8
1992	443.0	235.4	207.6	117.0	165.4	160.6
1993	408.8	228.2	180.6	115.0	150.9	142.9
1994	399.2	217.6	181.7	113.3	145.9	140.0
1995	416.4	217.5	198.9	115.9	153.8	146.7
1996	407.6	224.4	183.2	118.0	145.4	144.3
1997	410.5	230.4	180.1	124.7	143.8	142.0
1998	415.7	232.7	183.0	128.1	142.4	145.1
1999	423.8	234.3	189.6	131.2	147.7	145.0
2000	445.4	238.0	207.4	132.7	160.9	151.8
2001	454.6	241.0	213.6	138.3	153.7	162.6
2002	476.9	265.9	211.0	138.7	171.7	166.5
2003	483.6	259.9	223.7	136.7	178.0	168.9
2004	472.7	246.9	225.8	140.9	152.4	179.4
2005	469.9	251.6	218.4	144.8	145.4	179.8

Source: Statistics Canada, authors' calculations

Table 3 Annual growth in the volume index of investment in education in Canada, 1976–2005

Characteristics	1976–2005	1976–1986	1986–1996	1996–2005
	Percent			
Total	0.8	0.6	1.2	0.7
Male	0.6	0.0	1.3	0.5
Female	1.1	1.3	1.2	0.9
Grades 0–8	−0.3	−1.8	1.3	−0.3
High school	0.3	−0.4	1.3	−0.1
College or above	2.7	4.5	1.2	2.4

Source: Statistics Canada, authors' calculations

Table 4 Annual growth in the price index of investment in education in Canada, 1976–2005

Characteristics	1976–2005	1976–1986	1986–1996	1996–2005
	Percent			
Total	2.4	3.5	2.5	0.9
Male	2.6	4.0	2.7	0.8
Female	2.1	3.0	2.2	1.1
Grades 0–8	4.3	6.6	3.5	2.6
High school	1.2	2.3	1.2	0.1
College or above	2.1	2.8	3.1	0.1

Source: Statistics Canada, authors' calculations

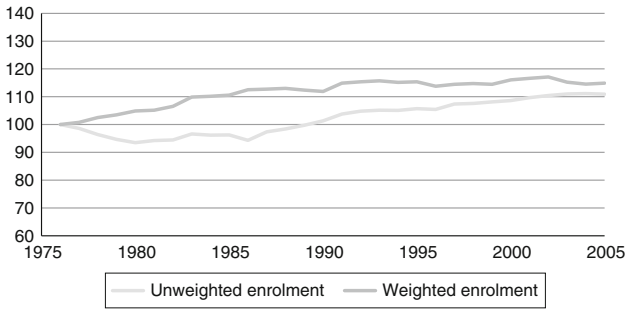

Fig. 3 Weighted and unweighted enrolments in the education sector

women reflects the difference in their enrolment numbers as discussed above. For the period from 1976 to 1986, investment in education for women increased by 1.3 % per year, while investment in education for men remained unchanged over the period. After the mid-1980s, investment in education for men grew at a rate similar to that for women.

The real output of the postsecondary education sector (colleges and universities), as measured by investment in education, increased the most (as shown in Table 3), growing by 2.7 % per year during the period from 1976 to 2005. The output of the primary and secondary education sector changed little over that period.

Tables 5 and 6 present the underlying data on investment per student in current and constant dollars that are used to produce the income-based estimates of education output.

Investment in education per student in constant prices rose steadily over time for both men and women. This reflects rising enrolment in secondary and postsecondary education. The value of investment in education per student in constant dollars was greater for men than for women. The difference between women and men decreased slowly in the period before 1990. After 1990, the difference was broadly stable. In 2005, investment in

Table 5 Nominal investment in education per student in Canada, by gender and education level, 1976–2005

Year	Total	Male	Female	Grades 0–8	High school	College or above
	Thousands of current dollars					
1976	33.9	36.0	31.6	14.7	60.2	58.2
1977	36.1	38.7	33.3	15.5	65.1	57.9
1978	36.9	39.8	34.0	16.2	64.5	59.6
1979	37.7	41.5	33.8	17.1	65.3	58.5
1980	39.8	42.5	37.0	18.4	70.7	57.0
1981	46.5	49.2	43.8	21.2	83.7	68.0
1982	50.6	52.4	48.7	22.7	89.0	76.5
1983	47.0	48.4	45.7	23.0	76.3	70.4
1984	50.1	54.1	46.1	24.7	80.5	75.3
1985	49.2	54.2	44.2	26.2	75.1	73.2
1986	53.9	57.8	50.0	27.7	83.2	79.3
1987	56.2	59.6	52.7	29.2	89.8	79.8
1988	55.4	58.4	52.5	30.9	86.2	77.0
1989	60.9	66.8	55.0	32.9	98.0	83.8
1990	78.6	87.0	70.4	37.4	124.0	122.6
1991	80.5	85.8	75.2	39.5	115.9	131.8
1992	76.4	81.3	71.4	39.5	111.5	118.4
1993	70.3	78.6	62.0	38.7	100.3	106.4
1994	68.7	75.1	62.3	38.1	96.8	105.3
1995	71.2	74.7	67.7	38.7	100.9	110.7
1996	69.9	77.2	62.6	39.1	97.0	109.8
1997	69.1	77.8	60.5	40.3	93.9	108.1
1998	69.8	78.6	61.2	41.6	92.0	109.8
1999	70.8	78.9	62.9	42.6	94.6	107.8
2000	74.1	80.1	68.3	43.2	103.6	109.5
2001	74.9	80.4	69.5	44.9	99.3	113.0
2002	78.1	88.2	68.2	45.2	111.1	111.3
2003	78.7	85.9	71.7	45.1	117.1	106.3
2004	76.9	81.7	72.2	47.2	98.7	110.6
2005	76.6	83.5	69.9	49.5	93.0	109.0

Source: Statistics Canada, authors' calculations

Table 6 Real investment in education per student in Canada, by gender and education level (Chained 2002 dollars), 1976–2005

Year	Total	Male	Female	Grades 0–8	High school	College or above
	Thousands of 2002 dollars					
1976	66.7	78.1	55.5	45.3	93.9	105.2
1977	67.2	78.9	55.7	45.2	94.6	102.2
1978	68.3	79.7	57.2	45.2	94.6	104.9
1979	69.0	80.2	58.1	45.1	95.3	104.5
1980	69.9	81.2	58.8	45.1	97.6	104.1
1981	70.1	81.1	59.2	45.2	99.5	104.8
1982	71.0	82.3	60.0	45.2	100.8	105.7
1983	73.2	83.0	63.3	45.1	101.6	108.1
1984	73.4	83.2	63.5	45.1	100.6	109.8
1985	73.7	83.3	64.1	45.1	100.6	110.0
1986	75.0	84.6	65.4	45.0	103.8	109.2
1987	75.1	84.6	65.6	45.0	105.9	109.0
1988	75.3	84.8	65.9	45.0	107.2	108.8
1989	74.9	84.4	65.5	45.0	106.5	108.6
1990	74.6	84.1	65.1	45.0	104.8	109.0
1991	76.6	86.6	66.6	45.0	108.1	111.1
1992	76.9	87.3	66.6	45.1	110.3	109.8
1993	77.1	87.7	66.7	45.1	110.8	110.2
1994	76.8	87.3	66.4	45.1	109.4	110.6
1995	76.9	87.2	66.7	45.1	109.3	111.6
1996	75.8	86.2	65.6	45.1	107.1	110.8
1997	76.3	86.7	66.1	45.1	109.0	112.1
1998	76.5	86.7	66.4	45.1	109.2	112.0
1999	76.3	86.5	66.3	45.1	110.1	109.3
2000	77.4	87.5	67.5	45.1	110.7	111.7
2001	77.7	87.8	67.9	45.2	111.2	111.7
2002	78.1	88.2	68.2	45.2	111.1	111.3
2003	76.8	87.4	66.6	45.3	105.2	110.3
2004	76.4	86.9	66.2	45.3	101.7	110.1
2005	76.6	87.0	66.5	45.3	101.6	109.2

Source: Statistics Canada, authors' calculations

education per student for women was about three-quarters that for men.

The real value of investment in education per student in colleges and universities also increased over time. In 2005, the real value of investment in education for a student enrolled in college or university was more than two times that for a student enrolled in primary education.

2.9 The cost-based estimate of education output

Table 7 and Fig. 4 present the cost-based estimate of the value of education services in Canada. For comparison, they also present the income-based estimate of the value of education services.

Table 7 Annual growth in cost-based and income-based estimates of education services in Canada

Estimates	1976–2005	1976–1986	1986–1996	1996–2005
	Percent			
Cost-based				
Nominal value	5.8	8.7	5.0	3.5
Quantity index	0.6	0.0	1.1	0.9
Price index	5.2	8.8	4.0	2.6
Income based				
Nominal value	3.2	4.2	3.8	1.6
Quantity index	0.8	0.6	1.2	0.7
Price index	2.4	3.6	2.5	0.9

Source: Statistics Canada, authors' calculations

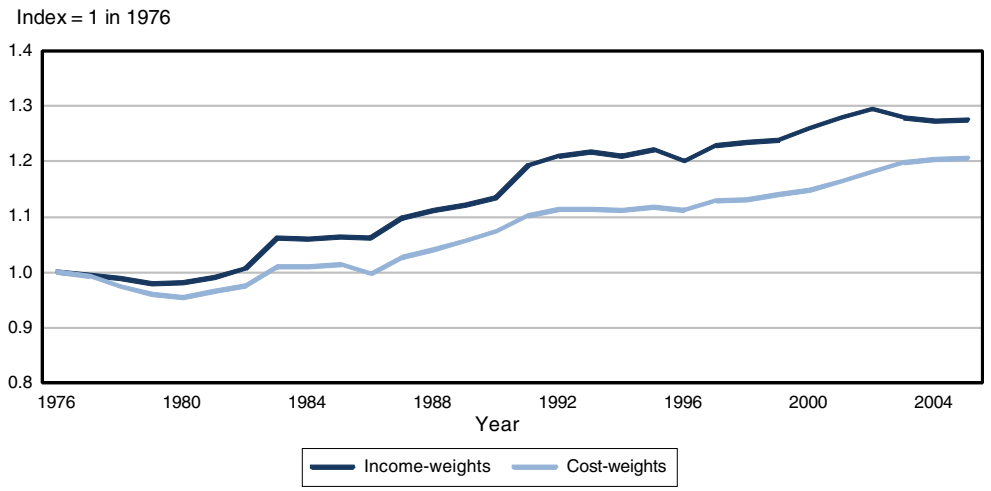

Fig. 4 The income-based and cost-based estimates of the volume index of the education-sector output in Canada. Source: Statistics Canada, authors' calculations

The nominal value of education service output from the cost-based approach increased faster than that from the income-based approach. Over the period 1976 to 2005, it increased at 5.8 % per year for the cost approach compared with 3.2 % per year for the income-based approach.

The difference in the growth rates in the nominal output from the two approaches was almost entirely due to the difference in the growth rates in the price index of education sector output. There was much less difference in the growth rates of the volume index of education sector output between the two approaches, especially after the mid-1980s. The price index of education sector output from the cost-based approach increased at much faster rate than that from the income-based approach (5.2 % per year vs. 2.4 % per year for the period 1976–2005).

While a part of the difference in the price index of education output from the two approaches was due to the difference in aggregation, the relatively large increase in the price of education output from the cost-based approach suggests that the cost of education increased faster than the benefits of education in terms of increase in the lifetime incomes. This is consistent with previous findings in the decline in the return to education in Canada, especially before the mid-1980s (Emery 2004).

The cost-based and income-based approaches yield similar estimates of the growth rates of the real education output, particularly after the mid-1980s. The cost-based estimate increased by 0.6 % per year over the period from 1976 to 2005, while the income-based estimate rose by 0.8 % per year over the period. The income-based approach yields a slightly higher growth rate of education output. The difference in the rate of growth between the two estimates can be attributed to the differences in the level of aggregation for enrolments and weights used to aggregate enrolments between the two approaches.

As the estimates of education output from the cost approach is based on three broad levels of education, the estimates should be considered a lower bound estimates of the growth in the volume index of education output. A more detailed cost-based measure of university education output would distinguish between different types of programs (such business programs, science and engineering programs, and arts programs), since education expenditures are different across those programs. For primary and secondary education, more detail would require a distinction between special programs and regular programs, since expenditures for special education are much higher.

The growth rate in the price index of education output was larger than the growth rate of volume index of the education sector output from both approaches. The findings for Canada are consistent with those for other countries. For example, Fraumeni et al. (2008) found that the price index of the output of primary and secondary education increased much faster than the volume index for the United States for the period 1980–2001.

While the two approaches yield similar estimates of the growth in real education output, they produce very different estimates of the level of education output (Fig. 5). The income-based estimate of the nominal value of education services was about 6.8 times as large as the cost-based estimate in 2005.

The nominal value of education services arrived at by using the income-based approach is also found to be much larger than the nominal value estimated by means of the cost-based approach for the U.S. education sector (Jorgenson and Fraumeni 1992). Abraham (2010) provided a number of possible explanations for this difference. The discount rate used to calculate the present value of future lifetime income may be too low. The costs of time spent by students in studying are not included in the cost estimates.

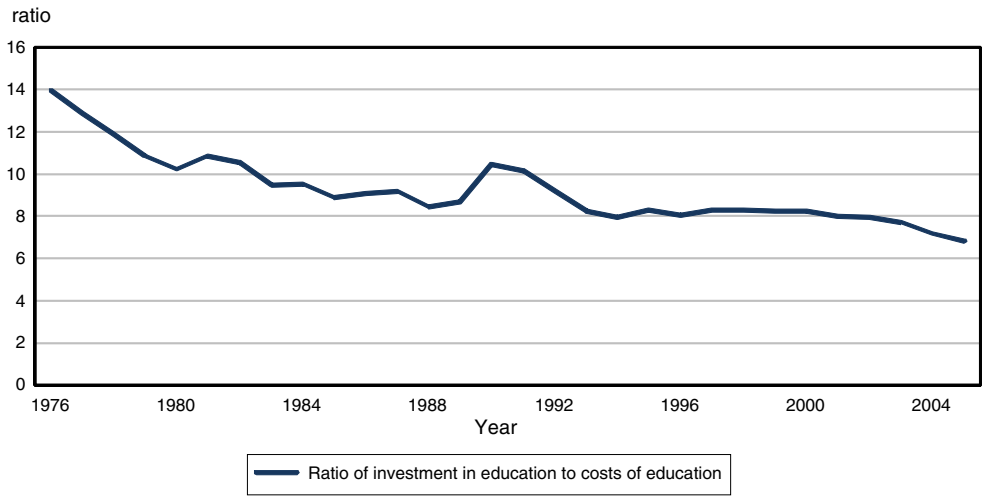

Fig. 5 Ratio of income-based to cost-based estimates of the nominal value of education services in Canada. Source: Statistics Canada, authors' calculations

The earning differences between more educated and less educated individuals may reflect a host of other factors, such as student ability, family background, and differences in on-the-job training.

The relative levels of the two estimates of education output in Fig. 5 can be interpreted as the ratio of the economic benefits of education to the costs of education. That ratio declined from 1976 to the mid-1980s. It remained virtually unchanged from the mid-1980s to 2000, and declined again after 2000. This suggests that the return to education declined from 1976 to the mid-1980s; it declined again post 2000, following a period of little change from the mid-1980s to 2000. This is consistent with the findings on the trends in the rate of return to education in Canada (Emery 2004). Emery examined the rate of return to undergraduate university education for the period from 1960 to 2000 and observed reductions in returns to university education in the late 1970s and early 1980s; by 2000, the returns to education had resumed the levels of the 1960s and early 1970s.

The cost-based estimate in Table 7 can be extended to include the research component of the university sector output. The research output is estimated by the number of publications that can be obtained from the Canadian Bibliometric Database (Gingras et al. 2008). The estimated number of publications from that database increased by 3.3 % per year over the period 1996–2005, while university enrolment increased by 2.6 % per year for the same period. The cost-based estimate of the university output that aggregates research and teaching components using the relative cost shares of teaching and research is estimated to have increased by 2.8 % per year for the 1996–2005 period, which was slightly higher than the 2.6 % annual growth of university output estimate that only includes school enrolment.[7] The cost-based estimate of the output of the total education sector increased by 1.0 % per year over the period 1996–2005 when university research is included, compared with 0.9 % annual growth when university is not included.

Our evidence suggests that the research component has little effect on the overall growth of education output, though there are some uncertainties in the consistency in the estimated number of publications over time. The rest of the paper will therefore focus on the estimate that excludes university research.

2.10 Comparison with the System of National Accounts

In contrast to the two experimental estimates presented above, the System of National Accounts also produces an estimate of the education sector output that is based mostly on inputs.[8] The nominal value of education output is the sum of labour compensation, intermediate inputs, and capital consumption allowance. The volume of education output is equal to the volume of total inputs used for primary and secondary education and for college education. For university education, the volume of education output was measured in the past by the volume of total inputs; it is measured by student enrolments for more recent years.

[7] Allen (1998) breaks down total costs of universities in British Columbia between different functions. He finds that 67 % of the total costs in academic year 1989/90 is linked to teaching, the remainder 33 % is attributed to research and services. The cost shares are used for aggregating reach and teaching components of the university output.

[8] This is the third option as discussed in Diewert (2011).

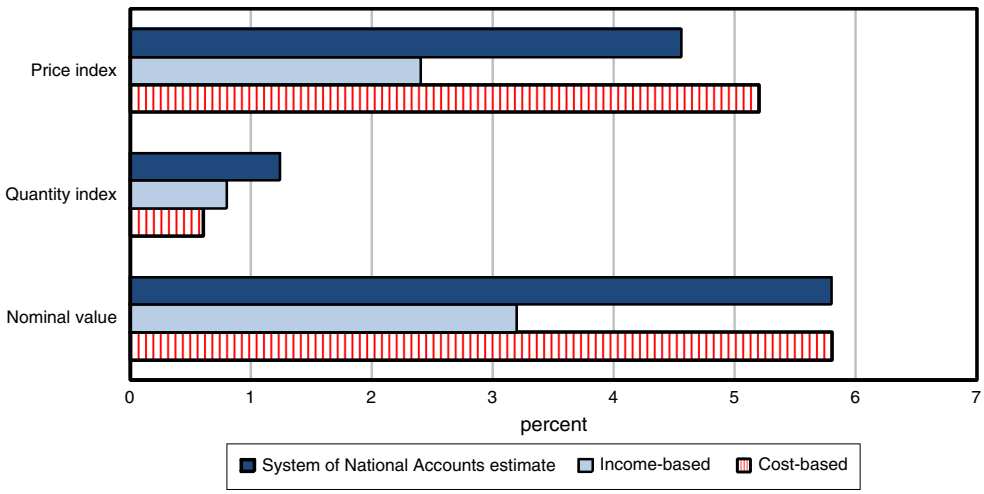

Fig. 6 Annual growth rates of education output in Canada, 1976–2005. Source: Statistics Canada, authors' calculations

The existing national accounts input-based estimate of education output is compared with the income-based estimate and the cost-based estimate of education output in Fig. 6. The results show that the two new estimates of the volume of education output increased at a slower rate than the current national accounts estimate of education output. The national accounts estimate of education output increased by 1.2 % per year over the period from 1976 to 2005, while the income-based estimate and the cost-based estimate rose by 0.8 % and 0.6 %, respectively. The nominal value of education output estimated from the cost-based approach and the nominal value of education output estimated from the existing national accounts are both equal to the sum of labour costs, capital consumption allowance, and intermediate inputs in the education sector. The growth in the nominal value of education output from the cost-based approach and from the existing national accounts is much faster than the growth from the income-based approach (5.8 % per year vs. 3.2 % per year).

2.11 The productivity performance of the education sector

Figure 7 plots trends in labour productivity of the Canadian education sector based on the three alternative measures of education output (two output-based measures of education services and one input-based measure of education services). All three measures of labour productivity show that labour productivity declined in the Canadian education sector before 1990 and increased after 1990. Labour productivity based on income-based estimates of education output declined at an average annual rate of 1.6 % in the education sector for the period from 1976 to 1990. During the period from 1990 to 2005, labour productivity increased by 0.4 % per year.

The decline in labour productivity before 1990 reflects the high growth in the number of teachers in that period. Total hours worked in the education sector increased by 2.5 % per year before 1990 while the number of students barely increased during that period. After 1990, the growth in total hours worked in the education sector was slow, while the number of students increased at a faster pace. For that period, labour productivity growth increased by half of 1 % point per year.

Labour productivity from the income-based approach increased at a slightly higher rate compared with that from the cost-based approach and input-based approach. That is due to the slightly higher rate of growth in the volume index of education output estimated from the income-based approach. The labour productivity growth from the input-based approach was the lowest.

3 Accounting for quality changes in education services

A significant challenge for measuring the output of the education sector arises when it comes to adjusting for changes in the quality of education services over time. To the extent that the income and cost estimates of the volume of education output do not capture quality improvements, the changes in real education output will be underestimated and price changes will be overestimated.

The weighted sum of student enrolments across different categories (classified by education level, gender, and age) is a correct measure of the volume of education output when education output in terms of investment in human capital from education within each category are comparable and do not change over time. When the quality of education or education output with each category change over time, the weighted sum of student enrolments is no longer a correct measure of education output. Students taught in smaller classes by more experienced teachers require an upward adjustment of the volume of education services and a downward adjustment of their price. Similar

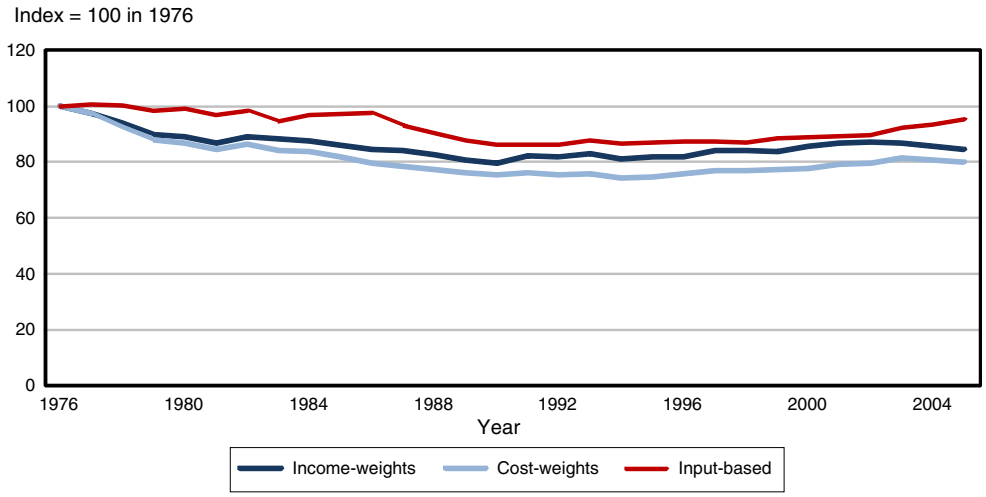

Fig. 7 Labour productivity of the education sector in Canada. Source: Statistics Canada, authors' calculations

adjustments must be made for students with higher scores who graduate rather than drop out.

The purpose of quality adjustment is to isolate pure price changes from price changes due to changes in characteristics of students where the price is the increments in lifetime income due to education per student, for the income-based approach and is unit expenditures for the cost-based approach. To the extent that education expenditures and the increments in lifetime income due to education reflect improvements in education quality, they should be counted as increases in the volume of education output rather than as increases in the price of education output.

The implementation of the hedonic method consists of two main steps. First, data are collected on various factors that may reflect the quality of the education that students receive. These factors can include the quality and quantity of inputs to student education (such as class size, the number of experienced teachers, the use of information and communication technologies) and the outcomes of education (test scores).[9]

The next step is to estimate a hedonic function that relates the indicators of education quality to the price component of education output, which is investment in education per student for the income-based approach and education expenditures per student for the cost-based approach. The coefficients on the indicators of education quality are also known as the implicit prices of the indicators of education quality (Triplett 2006). This second step is often ignored in previous empirical studies. Rather, the coefficients that relate the indicators of education quality to education output are assumed in those studies.

In general, the hedonic regression for the output of education services takes the following form of the standard Mincer-type human capital equation (Mincer 1974),

$$\begin{aligned} \ln Y_{it} &= \alpha_o + (\alpha_2 + \beta_2 X_{it})A2_{it} + (\alpha_3 + \beta_3 X_{it})A3_{it} \\ &\quad + (\alpha_4 + \beta_4 X_{it})A4_{it} + (\alpha_5 + \beta_5 X_{it})A5_{it}, \\ &\quad + \gamma Z_{it} + \varepsilon_{it}. \end{aligned} \tag{9}$$

where Y_{it} is the present discounted value of lifetime income (or human capital stock) for the income based approach or the total cumulative expenditures that an individual spent for the cost-based approach for a individual i at time t. X_{it} is the vector of characteristics that reflect the quality of education that includes class size, test scores, use of advanced technologies, and experience of teachers.

The dummy variables $A2$–$A5$ are the dummy variables that represent the levels of education achieved. We assume that the individuals who achieved a higher education level also received the lower level. For an individual whose highest level of education is level 5, dummy variables $A2$–$A5$ are all set equal to 1. For an individual whose highest level of education is level 4, dummy variables $A2$–$A4$ are all set equal to 1, and dummy variable $A5$ is set equal to 0. The vector Z is the set of control variables including gender, age, age squared, and proxies for student abilities.

The coefficients $(\alpha + \beta X_{it})$ on variables $A2$–$A5$ represent the increase in the lifetime income of achieving that education level over the previous level of education for the income-based approach. For the cost-based approach, the

[9] Diewert (2011) presented a complete list of factors that might be expected to affect the quality of education output. The use of information and communication technologies (ICTs) are also expected to affect the quality of education as ICTs are found to contribute to the productivity and the output growth in service sectors for Canada, the United States and other developed countries (Stiroh 2002; Rao et al. 2010).

coefficients represent the increments in total cumulative expenditures for achieving an education level over the previous level, which is equal to the expenditures spent on that education level. In the regression, we allow those marginal gains to change with control variables X. The coefficients β on the characteristics X represents the implicit prices associated with those characteristics.[10]

Once the indicators of education quality are collected and implicit prices associated with those indicators are estimated from hedonic regressions, changes in the price index of education output that can be attributed to the changes in education quality can be estimated. The imputed changes in the price index of education output resulting from changes in education quality are then included in the change in the quality-adjusted volume index of education output.

The rest of the paper will focus on hedonic quality adjustment for the volume and price indices of education output from the income-based approach. Nevertheless, the same approach can be used for quality adjustment with respect to the measures of education output from the cost-based approach.

3.1 Education quality, test scores

For this paper, test scores are used as an indicator of education quality. Specifically, time-series data on test scores in literacy and related cognitive skills for the individuals that obtained a specific qualification in different years are used as an indicator of education quality. The time series data on test scores are constructed from the Canadian data from the 2003 International Adult Literacy and Skills Survey (2003 IALSS), a seven-country initiative conducted in 2003 that measured prose and document literacy as well as numeracy and problem-solving skills (Statistics Canada and OECD 2005).[11]

The 2003 IALSS includes standard questions on demographics, labour force status, and earnings, but it also attempts to measure literacy and related cognitive skills in four broad areas: prose literacy, document literacy, numeracy, and problem solving. Test scores in those four broad areas of literacy and cognitive skills will be used to capture the quality of education. Hanushek and Zhang (2006) also used the literacy scores from the 2003 IALSS to measure the quality of education.

The 2003 IALSS asks respondents about their age at the time of the survey (2003) and the age at which they completed their highest level of education. The information is then used to infer the year when respondents completed the highest level of education. The average test scores for individuals who completed an education level in a given year is used as indicators of education quality at the education level in that year.

Individuals may lose and gain skills as a result of the aging process or on-the-job training. On the one hand, if individuals tend to lose skills over time as a result of aging, exam scores for early cohorts of graduates will underestimate the quality of education for those cohorts. On the other hand, if individuals tend to gain skills over time as a result of on-the-job training, exam scores for early cohorts will overestimate the quality of education for those cohorts. The effect of aging and on-the-job training on the text scores for various cohorts of graduates is controlled for in regression analysis in order to provide an unbiased estimate of changes in education quality.

Literacy scores of cohorts of graduates may also reflect the effect of student ability and family background in addition to the effect of education. To control for the effect of student ability, the following three dummy variables from the 2003 IALSS are included in the regression for literacy scores (Green and Riddell 2007). A dummy variable equals 1 if the respondent agreed or strongly agreed with the statement that he or she got good grades in math while in school; a dummy variable equals 1 if the respondent agreed or strongly agreed with the statement that teachers often went too fast and he or she often got lost; and a dummy variable equals 1 if the respondent answered that he or she received remedial help or attended special classes to assist him or her with reading at school. To control for the effect of family background on test scores, we add variables on parental education and immigrant status.

Since our objective is to examine the education sector in Canada, we exclude from our sample anyone born outside of Canada or educated outside of Canada. We also drop the over-sampled First Nations observations from the 2003 IALSS. The survey covers individuals over age 16, but we exclude individuals who list their main activity as *student*, in order to highlight the effect of completed schooling and what happens to literacy and skills once individuals have completed their schooling. We exclude those individuals who completed the highest level of education before 1976 since we are interested in the changes in the education quality for the period after 1976 in this paper.

The method that is used to obtain time series data on test scores for various cohorts of graduates from IALSS 2003 is similar to the one used by Coulombe et al. (2004) in their

[10] Alternatively, the dependent variable Y can be defined as the expenditure spent on a specific education level while the corresponding dummy variable for an education level are set to equal to one for that individual obtains that individual or zero otherwise.

[11] The OECD Program for International Student Assessment (PISA) survey provides alternative data source for estimating changes in education quality over time.

study on the long-term relationship between human capital and economic growth.

In summary, to estimate the test scores for the cohorts of graduates at each education level, we estimate the following regression on literacy scores using the Canadian data in the 2003 IALSS:

$$\begin{aligned}\ln(score)_{it} = {} & \alpha_o + \alpha_2 E2_{it} + \alpha_3 E3_{it} + \alpha_4 E4_{it} + \alpha_5 E5_{it} \\ & + \beta_1(t * E1_{it}) + \beta_2(t * E2_{it}) + \beta_3(t * E3_{it}) \\ & + \beta_4(t * E4_{it}) + \beta_5(t * E5_{it}) + \gamma Z_{it} + \varepsilon_{it}. \end{aligned} \tag{10}$$

The dependent variable is the literacy scores of the individual i who achieved the highest level of education in year t, where the literacy score is an average score in four broad areas of literacy and related cognitive skills: prose literacy, document literacy, numeracy, and problem solving The variables $E1$–$E5$ are the dummy variables indicating the highest level of education that the individual achieved. For example, $E1$ is set equal to 1 if the highest level of education for that individual is level 1 (0–8 years of schooling). t is the year in which the individual completed the highest level of education, and is set equal to 1 for the year 1976, 2 for the year 1977, and so forth. The vector Z is the set of control variables, including gender, age, age squared, proxies for student abilities, and variables for family background.

The estimated coefficients β_1–β_5 measure the percent change in the literacy scores of graduates at each education level over time and will be used to capture the change in the quality of education services at each education level.

The equation is estimated using the weighted least square that uses population size as weights. The regression results are presented in Table 8: for instance, the coefficient on the variable *time* × *0–8 years of schooling* shows the change in the literacy scores for the individuals who obtained 0–8 years of schooling. The results show that test scores increased over time for graduates at education levels 1 (primary education) and 2 (secondary education). However, we observe no statistically significant changes in test scores for graduates at the postsecondary education (education levels 3–5). Literacy scores increased by 1 % per year at the primary education level and increased by 0.2 % per year at the secondary-education level.

The results for the effects of the student-ability and family-background variables on literacy scores are consistent with those in Green and Riddell (2007). Student ability and parental education levels both have positive effects on literacy scores. The immigration status of parents does not appear to have a significant effect on literacy scores. Controlling for the effect of student ability and of family background does not lead to a significant difference in the estimated changes in education quality.

3.2 Hedonic regression

Canadian data from the 2003 IALSS are used to estimate the hedonic function (9) for education output that relates test scores to increments in lifetime incomes. Ideally, we would like to construct the present discounted value of lifetime incomes for all individuals in the sample and to estimate a hedonic function that relates test scores to the lifetime income. In this paper, we will use the current labour income from education (or returns to education) as a proxy for gains in lifetime labour incomes.

The vector Z is the set of control variables including gender, age, age squared, and proxies for student abilities. The variables for family background are excluded in the estimation, since the variables are found to have no effect on individuals' earnings. The vector X is the literacy scores in logarithm for an individual. The coefficient β on the log of literacy scores represents the implicit prices associated with literacy scores. We assume that a 1 % increase in test scores will have the same percentage-point contribution to the marginal gains of achieving an education level, since we find that there are no statistically significant differences in that coefficient between the five levels of education used for this paper. In general, coefficient β will vary across education levels.

The sample used for estimating the hedonic regression is similar to the one used for estimating literacy scores, except that we have eliminated those individuals who are self-employed for the hedonic regression. Those individuals whose annual earnings are less than $2,000 or over $1,000,000 are eliminated from our sample. The latter restriction eliminates retired individuals, the unemployed, and others who are not in the labour force. It also cuts out a small number of individuals with earnings that are substantial outliers relative to the rest of the sample. Self-employed workers are also dropped from the sample in order that we may examine the remuneration of skills in the labour market, since self-employment earnings reflect both remuneration and returns to capital.

The parameter estimates from the hedonic regression are presented in Table 9. The estimated β is 0.57 and is statistically significant. This suggests that a 1 % increase in test scores is associated with a 0.57 % increase in gains from achieving a higher level of education.

3.3 Quality-adjusted price and volume indices of education output

The results from estimating the literary score and earnings regressions can be used to estimate the quality-adjusted price and volume indices of education output. The estimated literacy score equation provides an estimate of average literacy scores for individuals who achieved

Table 8 Regression results for the log of literacy scores in Canada

Variable	Model 1		Model 2		Model 3	
	Coefficient	t-statistic	Coefficient	t-statistic	Coefficient	t-statistic
Constant	5.3040	106.75	5.1631	63.97	5.0467	43.36
Some or completed high school	0.3118	6.24	0.4170	5.11	0.4259	3.91
Postsecondary education below bachelor's	0.3774	7.55	0.5110	6.27	0.5273	4.85
Bachelor's degree	0.4426	8.86	0.5657	6.95	0.5665	5.21
Master's degree or above	0.4872	9.69	0.6077	7.35	0.6168	5.66
Time × 0–8 years of schooling	…	…	0.0086	2.24	0.0099	1.93
Time × some or completed high school	…	…	0.0021	3.42	0.0017	1.75
Time × postsecondary education below bachelor's	…	…	0.0005	0.70	−0.0008	−1.07
Time × bachelor's degree	…	…	0.0011	1.76	−0.0006	−0.78
Time × master's degree or above	…	…	0.0012	1.35	−0.0008	−1.09
Female	…	…	…	…	−0.0102	−1.74
Age	…	…	…	…	0.0080	4.44
Age squared	…	…	…	…	−0.0001	−5.82
Good math grades	…	…	…	…	0.0473	8.20
Teachers too fast	…	…	…	…	−0.0258	−2.01
Reading difficulties	…	…	…	…	−0.0637	−5.21
Mother postsecondary education	…	…	…	…	0.0360	5.69
Father postsecondary education	…	…	…	…	0.0338	5.74
Mother Canadian	…	…	…	…	−0.0143	−1.37
Father Canadian	…	…	…	…	0.0051	0.53

Source: Statistics Canada, authors' calculations

Table 9 Hedonic regression results for the price of education output in Canada

Parameters	Regression results	
	Estimates	t-statistic
α_0	8.5386	68.90
α_2	−2.3987	−6.95
α_3	−2.8526	−8.49
α_4	−2.9765	−8.74
α_5	−3.1603	−8.81
β	0.5657	9.74
γ_0 (female)	−0.3227	−10.99
γ_1 (experience)	0.0930	19.69
γ_2 (experience squared)	−0.0019	−14.53
Γ_3 (good math grades)	0.0948	2.82
Γ_4 (teachers too fast)	−0.0812	−1.29
Γ_5 (reading difficulties)	−0.0829	−1.46

Source: Statistics Canada, authors' calculations

education level e in year t ($score_e^t$). The earnings regression provides an estimate of the effect of literacy scores on returns to education (β). The quality-adjusted price index for student enrolments disaggregated by sex, education level, and age is estimated as follows:

$$adjI_{s,e,a}^t = I_{s,e,a}^t / (hedonic\ quality\ adjustment), \quad (11)$$

where

$$(hedonic\ quality\ adjustment) = (score_e^t)^{\beta}.$$

Those quality-adjusted price indices are then aggregated to obtain the quality-adjusted price index of education services by means of Tornqvist aggregation. The quality-adjusted quantity index of education services is calculated by dividing the nominal value of education output by the quality-adjusted price index.

Table 10 presents the quality-adjusted output of the education sector. The quality adjustment raised the growth of education output by 0.2 % points per year and lowered the growth of the corresponding price index by 0.2 % points per year. The 0.2 %-point quality-adjustment factor for Canada is similar to the 0.25 % quality-adjustment factor per year that is utilized in the U.K. official estimates of the volume index of education services (see Fraumeni et al. 2008).

Table 10 Annual growth in the quality-adjusted education output in Canada determined by means of the income-based approach

Estimates	1976–2005	1976–1986	1986–1996	1996–2005
Without quality adjustment				
Volume index	0.8	0.6	1.2	0.7
Price index	2.4	3.5	2.5	0.9
With quality adjustment				
Volume index	1.0	0.8	1.4	0.9
Price index	2.2	3.3	2.3	0.7

Source: Statistics Canada, authors' calculations

4 Conclusions

This paper develops a direct output measure of the education sector in Canada and uses that measure to examine the productivity performance of the education sector. In the past, the volume of output has been measured by the volume of inputs, such as labour costs for teachers and administrative staff, as well as capital input. This has not allowed for a measure of productivity performance for this sector.

It produces two alternative estimates of economic output in education—one income-based, and the other cost-based. In the cost-based approach, education output is calculated as a weighted sum of student enrolments, using weights based on total spending per student as the unit price of education. Spending includes teacher salaries, intermediate inputs, and a capital consumption allowance. In the income-based approach, education output is calculated as a weighted sum of student enrolments using weights based on the value of education. This is calculated as the difference between the lifetime income of an individual enrolled in that education level and that of an individual with a lower education level.

The paper finds that the two approaches yield similar estimates of the *growth* in education output. Over the period from 1976 to 2005, the income-based measure of the real output of the education sector in Canada is estimated to have increased by 0.8 % per year, while the cost-based estimate rose by an estimated 0.6 % per year.

The paper finds that labour productivity in Canada's education sector declined between 1976 and 1990. Subsequently, between 1990 and 2005, it rose at an annual average rate of 0.4 % from both approaches. The decline in labour productivity in education prior to 1990 reflected the strong growth in the number of teachers and slow growth in the number of students during that period. Total hours worked in the education sector increased by 2.5 % per year on average before 1990, while the economic output of the education sector based on the number of students barely increased during that period. After 1990, the growth in total hours worked in the education sector was slow at 0.4 % per year. On the other hand, the economic output of the education sector increased at 0.8 % per year from both approaches.

The paper also makes a methodological contribution to the measurement of education output. While previous studies have attempted to capture quality changes in education output, they have often lacked precise methodologies to do so. This paper proposes and estimates the hedonic equation for the output of the education sector. Literacy scores are used as a measure of education quality. The equation is then estimated using the micro data from the OECD International Adult Literacy and Skills Survey. The paper finds that a 1 % increase in test scores is associated with a 0.57 % increase in gains from achieving a higher level of education. The hedonic adjustment for quality changes in education services raised the growth of education output by 0.2 % points per year over the period from 1976 to 2005.

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