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HUMAN CAPITAL ACCOUNTS: CHOICE OF RATES AND CONSTRUCTION OF VOLUME INDICES

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ABSTRACT

Both human capital and nonhuman capital play an important role in economic growth. Estimates of nonhuman (physical) capital exist for many more countries than for human capital. Recently there has been a significant increase in the number of countries for which estimates of human capital exist, primarily because of the OECD human capital project, which has constructed nominal Jorgenson-Fraumeni human capital stocks for eleven countries.

As the OECD project continues, it is important to reflect on the rates used in this project and in other efforts. Although two real rates need to be chosen: a discount rate and a rate of growth of labor income, what really matters is the size of the adjustment factor which incorporates both rates.

In order to best understand the role of human capital in economic growth, volume (quantity) indices need to be constructed. This paper outlines how total and partial indices can be constructed, which along which companion contributions, will allow for more informative and detailed cross-country and individual country analyses.

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Choice of Rates and Construction of Volume Indices"

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Introduction

Now that basic nominal Jorgenson-Fraumeni (J-F) human capital accounts exist for many countries, it is time to think about the choice of discount and income growth rates, and the construction of contribution and volume indices.[1] As will be shown in this paper with estimates for China as an example, rate choices can have a significant impact on the size of the human capital estimates. Both estimates for China and Canada will illustrate the methodology employed and usefulness of constructing volume-based contribution and decomposition indices. The opportunity for making significant inroads to move beyond nominal accounts for J-F accounts for most countries lies with the OECD human capital project.[2]

Among the seminal papers on human capital are those by Becker (1964), Mincer (1974), and Schultz (1961). Becker likened investment in human capital, notably education and training, to business investment in equipment. Mincer's research on explaining schooling group earning differentials gave rise to a host of commonly estimated Mincer equations. Schultz noted that although economists have been hesitant to describe human beings as capital, the concept of human capital is worthwhile as it leads to making investments in people through education, training, and investments in health. These investments can open up opportunities for individuals and fosters economic growth of countries. Each of these papers made a significant contribution to the notion of human capital without attempting to measure the stock of human capital.

[1] In the international System of National Accounts, the word 'volume' is used to denote 'quantity' as it is defined in the National Income and Product Accounts.
[2] OECD (2010) and Mira and Liu (2010).

There are two major approaches to the measurement of human capital: a cost approach and an income approach.[3] The most widely used cost approach is Kendrick's. Kendrick (1976) estimates both tangible and intangible human capital. Tangible human capital includes child rearing costs. Intangible human capital includes education, training, medical, health and safety expenditures, and mobility costs. Human capital stocks are created using a perpetual inventory method where investment expenditures are cumulated and existing stocks are depreciated. Currently the most widely used income approach is Jorgenson and Fraumeni's (1989, 1992a, 1992b). Others who have used an income approach include Haveman, Bershadker, and Schwabish (2003) and for males only Graham and Webb (1979), Eisner (1980), and Weisbrod (1961).[4] This paper will focus on Jorgenson-Fraumeni (J-F).

Jorgenson and Fraumeni last collaborated on measuring human capital almost twenty years, so the question is why has there been an upsurge in interest in updating their estimates or applying their methodology to new countries? The proximate cause in most cases was the formation of the Stiglitz Commission: The Commission on Economic Performance and Social Progress. This commission was created in 2008 at the request of President Sarkozy of France, who then was then the President of the European Union. The overarching theme of the commission was to go beyond GDP in proposing new measures, particularly those having to do with well-being and sustainability. The Turin Workshop on Measuring Human Capital took place in 2008 as a result of the commission's interest in human capital. That workshop led to the establishment of the OECD human capital project, which adopted J-F methodology.[5]

There are twenty-one countries that either are participating in the OECD human capital consortium or who are not, but for which J-F human capital accounts exist. These include: Argentina, Australia, Canada, China, Denmark, France, Israel, Italy, Japan, Korea, Mexico, Netherlands, Norway, New Zealand, Poland, Romania, Russia, Spain, Sweden, United Kingdom, and the United States.[6] In addition, two international organizations are participating in the OECD human capital consortium: European Commission (Eurostat) and the International Labour Organization. Results from the nominal J-F human capital accounts project were presented at this seminar by Marco Mira d'Ecole for eight of the consortium countries: Australia, Canada, France,

[3] Other approaches include the World Bank residual approach (World Bank, 2006), the attribute approach of Laroche and Merette (2000), and indicator approaches, such as that of the Lisbon Council (2006), or use of educational attainment statistics.

[4] An excellent summary and comparison of these applications of an income approach is in Haveman et. al. (2003).

[5] Separately, the Joint UNECE/Eurostat/OECD Task Force on Measuring Sustainability was established. One goal of the task force is to include a measure of human and social capital as they relate to sustainability (Statistical Commission, 2009).

[6] Citations for single country, applications of Jorgenson-Fraumeni (J-F) methodology include: Argentina (Coremberg, 2010), Australia (Wei, 2004, 2007), Canada (Gu and Wong, 2008, 2009), China (Li, Fraumeni, Liu, and Wang, 2009a, 2009b; Li, Fraumeni, Liang, Liu, and Wang, 2010, and Li, 2010), New Zealand (Le, Gibson, and Oxley, 2003, 2005a, 2005b, 2006), Norway (Liu and Greaker, 2009), Sweden (Ahlroth and Bjorkland, 1997), the United States (Christian, 2009a, 2009b, 2009c, 2010, 2011). O'Mahony and Stevens (2004) applied J-F methodology to evaluate government provided education in the United Kingdom.

New Zealand, Norway, Poland, Spain, and the United States.[7] It is expected that additional country results will be available in 2011 as well as volume estimates for selected countries.

Jorgenson-Fraumeni Lifetime Income Approach

The Jorgenson-Fraumeni lifetime income approach applies the neoclassical theory of investment (Jorgenson, 1967) to human capital. According to this theory, the price of capital goods depends upon the discounted value of all future capital services derived from the investments. On a per unit, or per capita basis, this means that the value of the human capital of an individual can be determined from that person's discounted lifetime income. There is a difference between nonhuman capital and human capital in terms of what is typically known. The price per unit for nonhuman capital, e.g., plant and equipment, can typically be observed in the market, but the price for human capital cannot be observed. For nonhuman capital, given market prices, there is no need to estimate the expected future income. For human capital, as the price of human capital is unknown, the J-F methodology for determining the value of human capital in a certain year is to estimate the present value of expected future lifetime income, allowing for changes in wages, additional education, differential patterns of labor force participation, and mortality. The neoclassical theory of investment explains both phenomena, but from a different perspective, that of present vs. future information.

J-F applied their methodology to both market and nonmarket activities in determining lifetime income. They identified five life stages. The choice of these stages was dictated by typical life stages and data availability.[8] In the equations that follow, the following notation is used:

For variables:

cmp: Hourly wage rate applied to market and nonmarket time

life: The sum of expected lifetime market and nonmarket income

mi: Expected lifetime market income, discounted to the present

nmi: Expected nonmarket lifetime income, discounted to the present

R: The adjustment factor applied to lifetime income

= (1 + real rate of growth on labor income)/(1 + real discount rate)

sr: Survival rate

senr: School enrolment rate

[7] See OECD (2010).

[8] The equations for these stages and equations are described in detail in the appendix to Jorgenson and Fraumeni (1992a).

wrkhrs: Hours worked per day on average

ymi: Yearly market income

ynmi: Yearly nonmarket income

For subscripts:

a: Age

e: Highest level of education completed

enr: Education enrollment level

older: Equal to a + 1

s: Gender

school: Equal to e +1.

The specific equations for the nominal values are as follows:[9]

Stage 1: No school or work, ages 0-4
For these ages, everything depends upon what happens in the future as currently no income is earned and it is assumed that no one goes to school. Human capital is probabilistically determined from future events as long as individuals survive until they are one year older.
ymi(s,a,e)=ynmi(s,a,e)=0
mi(s,a,e)= sr(s,older)*mi(s,older,e)*R
nmi(s,a,e)= sr(s,older)*nmi(s,older,e)*R

Stage 2: School only, ages 5-15
For these ages, individuals may attend school, but no income is being earned. For survivors, future income is higher the more years of school completed. There are some school and work assumptions and special circumstances. It is assumed that any individual that is in school in April finishes the school year and that no one repeats or skips a grade. It is possible that some individuals attend school at a younger age or work before they turn 16, but the data the U.S. data is inadequate to account for these circumstances. However, having data for these types of cases would make little difference in the size of the estimates. If individuals are enrolled, they are assigned the future lifetime income of an individual who has completed the enrolled level. If individuals are not enrolled, they are assigned the future lifetime income of someone with the individual's current educational attainment.
ymi(s,a,e)=ynmi(s,a,e)=0
mi(s,a,e)=[senr(s,a,enr)*sr(s,older)*mi(s,older,school)

[9] The construction of volume indices will be discussed in a subsequent section.

+(1- senr(s,a,enr))*sr(s,older)*mi(s,older,e)]*R
nmi(s,a,e)=[senr(s,a,enr)*sr(s,older)*nmi(s,older,school)
+(1- senr(s,a,enr))*sr(s,older)*nmi(s,older,e)]*R

Stage 3: Work and school, ages 16-34

For these ages, individuals can attend school and their time is valuable even if they do not do market work. Time spent in basic maintenance: sleep, eating, and personal maintenance, are assigned a value of zero and assumed to take 10 hours per day. Accordingly, total time that can be valued is 5,096 hours per year (14 hours per day times 7 days per week times 52 weeks per year). These hours are specifically allocated to market work hours and school hours, with the residual allocated to nonmarket work hours. It is assumed that school, including homework, takes up 1,300 hours per year. Both market and nonmarket hours are valued at the average wage paid for the corresponding gender, age, and highest education level completed category using opportunity cost methodology.

ymi(s,a,e)=wrkhrs(s,a,e)*cmp(s,a,e)

ynmi(s,a,e)=[14*7*52-wrkhrs(s,a,e)-1,300*senr(s,a,enr)]*cmp(s,a,e)
mi(s,a,e)=ymi(s,a,e)+[senr(s,a,enr)*sr(s,older)*mi(s,older,school)
+(1-senr(s,a,enr))*sr(s,older)*mi(s,older,e)]*R
nmi(s,a,e)=ynmi(s,a,e)+[senr(s,a,enr)*sr(s,older)*nmi(s,older,school)
+(1-senr(s,a,enr))*sr(s,older)*nmi(s,older,e)]*R

Stage 4: Work only, age 35-74

For these ages, it is assumed that no one is enrolled in school as insufficient data existed on students above the age of 34. Human capital therefore depends only on a person's expected future market and nonmarket lifetime income.

ymi(s,a,e)=wrkhrs(s,a,e)*cmp(s,a,e)
ynmi(s,a,e)=[14*7*52-wrkhrs(s,a,e)]*cmp(s,a,e)
mi(s,a,e)=ymi(s,a,e)+sr(s,older)*mi(s,older,e)*R
nmi(s,a,e)=ynmi(s,a,e)+sr(s,older)*nmi(s,older,e)*R

Stage 5: Retirement, age 75+

Although some individuals work beyond the age of 74, insufficient data existed on work hours and wage rates to incorporate the value of human capital for these older individuals.

ymi(s,a,e)=ynmi(s,a,e)=mi(s,a,e)=nmi(s,a,e) = 0

These equations are estimated in a backwards recursive fashion, beginning with stage 5. Expectations about future lifetime income (for all stages) and education (for stages 2 and 3) come from those alive in a particular year, i.e. 2000. For someone 75 in 2000, human capital and market and nonmarket income are zero. For someone 74 in 2000, if they survive to age 75, that person's future income is zero, however, this person has a positive human capital equal to the sum of that person's market and nonmarket income for 2000. For someone 73 in 2000, if they survive to age 74, their future income is equal to that of someone who is 74 in 2000, appropriately discounted and adjusted for future real wage increases by 'R,' plus the 73 year old's market and nonmarket income in 2000. Although wages can increase over time, future relative wage rates are assumed to remain constant when computing human capital in any given year.

A final step is to construct the nominal value of total human capital by adding market and market lifetime income:

life(s,a,e) = mi(s,a,e) + nmi(s,a,e).

Modifications to the Jorgenson-Fraumeni Lifetime Income Approach

The J-F methodology just described has been modified to reduce the estimation data and time requirements, to deal with data availability constraints, and to reflect country-specific condtions. In addition, almost all studies have estimated only market lifetime income because of the additional assumptions and time data needed to include nonmarket lifetime income as part of human capital.

Fraumeni (2007, 2008a, 2008b) realized that it was unlikely that researchers, particularly those in government agencies, would be able to spend the years it took J-F to construct human capital estimates using the lifetime income approach. A simplified approach was proposed which incorporated aggregated, categorical data. With this approach, wage and hours worked data by categories, such as ages 16-17, 18-24, 25-34, etcetera, and highest education level attained for those no longer in school, such as grades 1-8, high school 1-3, high school 4, etcetera, might be combined with information on enrollment by individual ages and individual grade level. A trial set of estimates not allowing for future education was constructed (Fraumeni, 2008a), but the approach was never completely implemented or tested for the United States.

Mincer equations have been used to derive income estimates for Argentina (Coremberg, 2010) and China (Li, et. al., 2009a, 2009b, 2010a). Mincer equations are a well-tested and highly regarded methodology for estimating income based upon available information on individuals. In both cases, at least some of the source data was categorical data.

Educational attainment in China has increased substantially over the period covered by Li and his co-authors. Accordingly, it was not reasonable to assume that the probability an individual completed a certain grade level could be inferred by completion rates in the estimated year as completion rates were rising. Education data included information on initial enrollment in broad education levels: primary school, junior middle school, senior middle school, and college and above (or college and university separately.) For any individual of a particular age, the probability that someone completed an education level was derived from the initial enrollment data the appropriate number of years later: 6 years for primary and 3 years for junior and senior middle school. This methodology allowed the human capital estimates to more accurately reflect changes in educational attainment in China.

The OECD human capital project also used econometric estimation and at least some categorical data. Parabolic curves were employed to estimate income from 5-year age groups. Enrollment (employment) rates by single year of age are assumed to be equal to the enrollment (employment) rates for 5-year age groups. It makes sense for the J-F methodology to be modified in these ways as needed.

Real Rates

Now that J-F human capital estimates exist for a number of countries, it is time to seriously consider the choice of the real rates that form ‘R.’ J-F initially used a long-run rate of return for the private sector of the economy (4.58%) for the real discount rate and a growth rate of Harrod neutral productivity growth (1.32%) for the growth rate of real labor income from Jorgenson and Yun (1991).[10] The OECD human capital project used these same rates for all countries (OECD, 2010).

Several alternative rates have been used by Li et. al., however with the exception of the discount rate used in the recent World Bank publication (World Bank, 2011), all are consistent with the J-F rates. For China, since economic growth has been so strong and differs significantly by location, it made sense to use a higher growth rate of real labor income and to employ different rates for those living in the rural versus urban areas. Consistently in all publications by Li et. al., a real labor income growth rate of 4.11% was used for rural areas and a real labor income growth rate of 6.00% was used for urban areas. These growth rates are the average rates of growth in labor productivity for these locations over the past 30 years. A discount rate of 3.14% was initially used as it is the long-term average Chinese government bonds real interest rate for the sample period. However, subsequently the computations of a real discount rate from the 10-year bond secondary market resulted in possible discount rates that bracketed the J-F 4.58% discount rate. Accordingly, a decision was made to adopt the J-F 4.58% rate (Li, 2010 and Li et. al., 2010a).

For the recent World Bank publication (2011), the Ramsey formula was used to derive the discount rate to be consistent with the methodology underlying the separate wealth estimates for

[10] In their later publication (1992a), J-F adopted 4% and 2% as the corresponding rates as they did not have updated figures.

over 120 countries. The Ramsey formula used to determine the discount rate, r, for China of 8.26% is as follows:

$$r = \rho + \eta * \Delta c/c,$$

where r is the social rate of return on investment, ρ is the pure rate of time preference (assumed equal to 1.5 by the World Bank), η is the elasticity of utility with respect to consumption (assumed equal to 1.0 by the World Bank), and $\Delta c/c$ is the rate of change in per capita consumption, 1970-2008 from the World Bank wealth data set.[11]

The concept underlying the Ramsey formula discount rate is different than that underlying the J-F discount rate. The J-F rate is a long-term private rate of return, from the point-of-view of an individual. The World Bank Ramsey formula rate is an autarkical social rate, "…one a government would choose in allocating resources across generations (p. 25)." In addition, the Ramsey World Bank rate "…implicitly assumes that consumption is on a sustainable path, that is, the level of saving is enough to offset the depletion of natural resources (p. 144)." No such assumption is made in the derivation of the J-F discount rate.

What ultimately matters in terms of the impact of the two rates is the value of 'R,' rather than the value of the individual pieces. The following table in the data first row in the 80/20 and 55/45 columns shows 'R' for J-F and OECD, as OECD uses the J-F 4.58% and 1.32% rates. In the next three rows in the same columns show the value of R (equal to (1 + real rate of growth on labor income)/(1 + real discount rate)) under two different scenarios for China. Since the real labor income growth rates for China differ for rural versus urban locations, in order to display the value of 'R' with different component rates, the 80/20 column presents 'R' with the approximate the rural/urban population ratio in 1985 and the 55/45 column presents 'R' with the approximate the rural/urban population ratio in 2007. The final row at the bottom shows the ratio of the 'R' for the October 2010 Li paper to the World Bank 2011 publication.

[11] See World Bank, 2006, p. 144 for the Ramsey formula.

‘R’ Comparisons				
	80/20	**55/45**	**Discount Rate**	**Labor Income Rate**
J-F & OECD	**.969**	**.969**	**4.58**	**1.32**
World Bank	**.965**	**.970**	**8.26**	**4.11/6.00**
Oct. 2010	**.999**	**1.004**	**4.58**	**4.11/6.00**
Oct. 2009	**1.013**	**1.018**	**3.14**	**4.11/6.00**
Ratio of October 2010 scenario ‘R’ to World Bank scenario ‘R’				
	1.031	**1.040**		

The first two data rows show that there is very little difference on net of using the J-F and OECD rate assumptions versus those used in the World Bank publication in spite of the significant differences in the component rates. The net effect is greater if the J-F and OECD or World Bank assumptions are compared to either of the “October’ rows. A sense of the potential size of the net difference is indicated in the last data row, which compares the latest set of estimates for China to that in the World Bank publication by calculating the ratio of the relevant ‘R’s.

The following table shows what difference different ‘R’s make to the magnitude of the value of human capital in 2007. The discount rates and labor income rates are identical to those in the previous table with one exception. In a paper completed after the World Bank estimates were completed, the World Bank Ramsey rate was modified slightly, falling from 8.26% to 8.14% with the addition of new consumption data. This table shows that in 2007 the value of human capital using the October 2010 rates is about twice that for the value of human capital using J-F and OECD rates. In addition, this table demonstrates that the October 2009 estimates are even larger.[12] This analysis shows that much more attention needs to be paid to the choice of rates.

Nominal Total Human Capital for China, 2007 Trillions of RMB			
Scenario	**Li et. al. (2010b)**	**Discount Rate**	**Labor Income Rate**
J-F & OECD	**163.74**	**4.58**	**1.32**
World Bank updated	**176.16**	**8.14**	**4.11/6.00**
Oct. 2010	**322.48**	**4.58**	**4.11/6.00**
Oct. 2009	**437.55**	**3.14**	**4.11/6.00**

[12] The October 2010 estimates are preferred to the October 2009 estimates as they incorporate some refinements in methodology, notable the discount rate change.

Also, arguably for emerging and other countries such as China, perhaps these rates should be allowed to vary over time. Finally, there is the question of whether rates should be held constant across countries in one scenario to allow for cross-country comparisons and allowed to vary between countries in another scenario.

Volume Indices

J-F human capital volume indices exist for only a subset of the countries which have constructed J-F estimates. At this point, the OECD human capital project has constructed only nominal estimates (for Australia, Canada, Denmark, France, Israel, Italy, Korea Netherlands, Norway, New Zealand, Poland, Romania, Spain, United Kingdom, and the United States.)[13] Recent volume estimates exist for several of these countries, including Canada and the United States.[14] In most cases when volume indices have been constructed, the methodology has followed the J-F methodology.[15]

J-F constructed Divisia (Tornqvist) volume indices.[16] Other types of chain index formulas include Paasche, Laspeyres, and Fisher index formulas. Divisia indices can be constructed for total human capital, which can be decomposed into a human capital per capita and a population component. Partial human capital indices can be constructed by subcomponents and for human capital per capita. The various human capital volume indices can be decomposed into the contributions of the individual components. Divisia volume indices are a rich source of information for researchers.

All of these types of Divisia volume indices will be illustrated with estimates for China and Canada.

The first step is to construct the total human capital Divisia (Tornqvist) volume index. A Divisia index is a weighted growth rate, where the weights are the average shares in nominal human capital and the growth rate is of population. If gender (s), age (a), and educational attainment (e) are the subcomponents of the index:

$$dlnHK = \Sigma\Sigma\Sigma \{.5 * [v_t(s,a,e) + v_{t-1}(s,a,e)] * dlnPOP(s,a,e)\},$$

where the summation is over gender, age, and educational attainment, POP represents population, ‘t’ is time, and the ‘v’s are the shares of the subcomponent in total nominal human capital.

[13] Expectations are that volume estimates will be constructed by OECD sometime during 2011.
[14] See Gu and Wong for Canada (2008, 2009) and Christian for the United States (2009a, 2009b, 2009c, 2010, 2011).
[15] In the case of the China estimates, the featured estimate deflates nominal human capital using a Consumer Price Index, although volume estimates using J-F methodology which will be featured in part of this section also exist.
[16] A Tornqvist index is a discrete approximation to a continuous Divisia index. Sometimes the word ‘Translog’ is used to describe a Divisia (Tornqvist) index.

Human capital per capita (HKPK) can also then be constructed as the index resulting from the calculation just described above divided by population. The contribution of human capital per capita and population to growth in total human capital is the share of the growth rate of the volume of human capital per capita and the growth rate of the volume of population in the growth rate of the volume of total human capital.

The next two tables present the Divisia results for total human capital, human capital per capita and for population for China (Li et. al., 2010b) and Canada (Gu and Wong, 2008). In both tables, the contributions of human capital per capita and population to growth in the volume of total human capital are shown in parentheses.

Note that the number of subcomponents differed substantially among the J-F estimates and those by Gu and Wong for Canada and by Li et. al. for China. J-F separately identified 2700 subcomponents: gender (2 components), age (by single year: 75 components), and educational attainment (by individual level: 18). Li et. al. identified a maximum of 1416 components: gender (2), age (by single year 0-59 for males and 0-54 for females, for a total of 60 or 55 components), educational attainment, including illiterate (5 if college and above is the highest category, 6 if university or above is the highest category), and location (rural or urban, for a total of 2). Gu and Wong identified 30 components: gender (2), age (young, prime age, or older, for a total of 3), and educational attainment (5). In any estimated indices, subcomponents can be aggregated to facilitate analysis.

Implicit in the identification of subcomponents is a homogeneity assumption. For example, if the China estimates did not identify location as a subcomponent, for a particular gender, age and educational attainment category, an individual living in a rural area is assumed to be identical to an individual in an urban area in terms of that person's human capital. Identification of subcomponents is typically driven by data availability, but their existence, or lack of, have clear implications for any analysis of the results.

In splitting the volume of total human capital between human capital per capita and population, it is human capital per capita which reflects the impact of changes in human capital composition, or, alternatively stated, the impact of heterogeneity. Population in this presentation is created via additive aggregation, accordingly the assumption is being made that all individuals are identical in any such aggregation of population.[17]

The table for China shows that the rates of growth for total human capital has stayed relatively constant over the whole period and the two subperiods, however that the contributions have varied considerably.[18] For the subperiods as a whole, in the first subperiod populations is clearly

[17] Jorgenson uses the term 'quality' as opposed to 'composition' to refer to the component which reflects changes in the composition of human capital over time.
[18] By construction, the sum of the human capital per capita and the population growth rates must equal the total human capital growth rate.

the primary source of growth in human capital, while in the second subperiod human capital per capita is beginning to catch up to population as a source of growth in human capital.

Growth Rates for the Volume of Total and Per Capita Human Capital and Population, China			
% Rate of Growth of Volume Measures	**Total Human Capital**	**Human Capital per Capita**	**Population**
1985-2007	**2.35**	**.78 (33%)**	**1.57 (67%)**
1985-1995	**2.42**	**.49 (20%)**	**1.93 (80%)**
1995-2007	**2.28**	**1.02(45%)**	**1.27(55%)**

The estimates for Canada tell quite a different story. For the subperiods as a whole, the contribution of population to growth in total human capital is growing over time, whereas in China it was decreasing. In the first subperiod, the estimates show the impact of the substantial increases in college enrollments, a trend that occurred both in Canada and the United States. These years are not covered in the estimates for China, but if they were a similar trend in educational attainment is not expected. In the last two subperiods the rate of growth of human capital for Canada is less than half that of China. The contribution of human capital per capita was increasing in China, whereas in Canada it was declining, even becoming negative in the last period.

Growth Rates for the Volume of Total and Per Capita Human Capital and Population, Canada			
% Rate of Growth of Volume Measures	**Total Human Capital**	**Human Capital per Capita**	**Population**
1970-2007	**1.7**	**.2 (12%)**	**1.5 (88%)**
1970-1980	**3.0**	**.9 (30%)**	**2.1 (70%)**
1980-2000	**1.2**	**.0 (0%)**	**1.2 (100%)**
2000-2007	**1.1**	**-.2 (-18%)**	**1.3 (118%)**

As previously noted, partial Divisia volume human capital indices by subcomponents can be constructed. For example, a partial index might be constructed for males versus females, or those with differing educational attainment, and even for males with differing educational attainment versus females with differing educational attainment. Any combination of subcomponents can be used to create a partial Divisia volume human capital index. In the previous formula, only the subscripts of interest are identified to create a partial index. For example, to create a partial human capital index for gender, separately, the weights are the share of male and female nominal human capital in total nominal human capital, which are multiplied times the growth rates of the male and female population. This methodology produces a total of two weighted growth rates. For this case, males and females can be different with respect to human capital, but it is assumed there are no human capital differences between males (females) of different ages and educational attainment levels.

The following table gives an example of Divisia decompositions (partial indices) from Gu and Wong (2008) which can be used to show the contribution of age groups to the growth in total human capital.[19] The relative contribution of age categories to growth in human capital has varied significantly over time, with the young accounting for the largest contribution in 1970-1980 and 2000-2007, and the prime age individuals accounting for almost all of the growth in human capital in 1980-2000.

Contribution of Age to the Growth Rate in Total Human Capital Canada				
% Rate of Growth of Volume Measures	**1970-2007**	**1970-1980**	**1980-2000**	**2000-2007**
Total	**1.7**	**3.0**	**1.2**	**1.1**
Young	**.7 (41%)**	**2.3 (77%)**	**.0 (0%)**	**.6 (55%)**
Prime Age	**.9 (53%)**	**.7 (23%)**	**1.2 (100%)**	**.3 (27%)**
Older	**.1 (6%)**	**.1 (3%)**	**.1 (8%)**	**.2 (18%)**

Another source of information about changes in the volume of human capital comes from looking at partial indices for human capital per capita.[20] These partial indices differ from those discussed earlier, i.e. those for young, prime age, and older for Canada, in two respects. First, they are at the top level of the characteristic, i.e. age rather than young, prime age, and older. Second, they isolate the contribution of the characteristic(s) by subtracting the higher order indices which include the characteristics of interest. The following discussion and tabular presentation will clarify the nature of these differences.

These characteristic indices are computed by single characteristics and multiple characteristics up to the maximum number of characteristic types. For example, in Li, et. al. (2010a) as shown in the following table, there are four 1st order indices: age (a), education level (e), gender (g), and location (l); six 2nd order indices: ae, ag, al, eg, el, and gl; three 3rd order indices: aeg, agl, and egl; and one 4th order index: aegl. As noted previously a lower order index subtracts the higher order indices of the relevant types. In this way, the joint effects of two or more characteristics are identified separately from the effects of other combinations involving a smaller number of these characteristics. In addition, the change in the rate of growth of population is also subtracted to convert total human capital into human capital per capita. For example, the partial index for human capital per capita for age and gender is computed as follows:

$dlnHKPK_{a,s} = dlnHK_{a,s} – dlnPOP – dlnHKPK_s - dlnHKPK_a$.

[19] The numbers, as reported in Gu and Wong (2008), may not sum to the totals because of rounding.
[20] This basis for this discussion is Jorgenson, Ho, and Stiroh (2005), section 6.2.4, pp. 211-214.

The 1st order indices only subtract the change in the rate of growth of population. Because of way in which these indices are constructed, the sum of all of the partial indices must equal the rate of growth of total human capital per capita. Accordingly in the table for China below, the sum of the all partial indices: 1st through 4th, must equal .8. The table shows that location and education have substantially contributed to growth in human capital per capita in China, while age has substantially detracted from growth in human capital. The changes in composition reflected in these indices certainly are the increase in educational attainment, the migration of the Chinese population from rural to urban areas, and the aging of the population in combination with a lower birth rate. The interaction effects as shown in the 2nd through 4th indices are relatively small.

Characteristic Contribution to the Average Annual Rate of Growth of Human Capital per Capita China, 1986-2007	
Total	**.8**
1st order age	**-.70**
1st order education	**.86**
1st order gender	**-.0006**
1st order location	**1.05**
All 2nd order indices (6)	**-.38**
All 3rd order indices (3)	**-.03**
4th order indices (1 – a, e, g, l)	**.0005**

Conclusion

This paper has focused on two aspects of construction of J-F human capital accounts: the choice of rates and the construction of volume indices. This paper has not attempted to discuss other issues that arise in construction of J-F accounts. It is recognized that J-F methodology will continue to be adapted and refined as more researchers become involved in the construction of these accounts.[21] Certainly as more developing and emerging countries attempt to construct such measures changes will be necessitated in recognition of additional data limitations and country-specific conditions. It is hoped that sometime in the near future J-F nonmarket human capital accounts will be developed for a number of countries, both to present a more complete picture and to recognize significant country differences in the locus of economic activity.

[21] An excellent discussion of possible modifications to J-F methodology is in Abraham (2010). Sensitivity of estimates for the United States to alternative assumptions about income growth rates, discount rates, the treatment of taxes, smoothing and imputation of wages, employment and school enrollment rates and the definition of nonmarket production is examined in a draft paper by Christian (2011).

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