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ABSTRACT

Given the challenges in quantifying the role of human capital on economic development, measuring human capital itself becomes an important issue. It is desirable to have a comprehensive human capital measure that goes beyond the traditional measures based on education attainment, yet is relatively simple to obtain. In this study, we apply the Jorgenson-Fraumeni human capital measurement framework and modify it to estimate provincial level human capital in China. We produce a provincial level panel dataset from 1985 to 2014 that is ready to use, with various J-F based and traditional human capital measures. We then combine the provinces into four different regions that are at different stages of economic development and discuss the regional pattern and trend of human capital, as well as their correlation with other economic indicators such as GDP and physical capital. Moreover, we conduct a Divisia decomposition analysis to investigate the contribution of different factors, such as education, urbanization, population aging and gender composition, to the quantity and quality growth of human capital in each region.

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I. Introduction

Human capital has been generally recognized as an important factor for economic development in both theoretical and empirical studies. Its quantitative importance in explaining economic growth and regional income differences, however, remains controversial. Some studies have identified an important effect of human capital (for example, Lucas, 1988; Barro and Sala-i-Martin, 1992; Mankiw, Romer and Weil, 1992; Manuelli and Seshadri, 2014), but other works have found that total factor productivity (TFP), instead of human capital, can explain more on cross country inequality (e.g., Hall and Jones, 1999; Bils and Klenow, 2000; Hendricks, 2002).

One particular difficulty in studying human capital is related to its measurement. Most commonly used human capital measures are education-based, such as average years of schooling, various enrollment rates, illiteracy rates, etc. (for example, Barro and Lee, 2013). However, education can only partially measure the human capital stock of an individual as it omits many other aspects, such as on-the-job learning, health, cognitive and noncognitive ability, etc. Moreover, it generally lacks a good representation of quality of schooling. The non-education aspects of human capital and the quality aspect of education are mostly unobservable, but they are important parts of human capital (see, for example, Manuelli and Seshadri, 2014; Hanushek and Woessmann 2011 and Schoellman 2012).

However, searching for a comprehensive measurement of human capital has been quite a challenge. Studies concerning the quality and the unobserved parts of human capital normally need complicated techniques and specific data. For example, Manuelli and Seshadri (2014) constructs a lifetime income maximization problem with a human capital production function at different stages, and then calibrates the model to estimate human capital for various countries.

Hendricks (2002) estimates unobserved human capital across countries using U.S. immigrant data. Those studies provide deep insights on the nature of human capital; however, they are generally not ready to use for estimating human capital for other studies. In general, data on human capital is far less available compared to other economic variables, such as physical capital.

For a large range of studies and policy analyses, human capital measures are used as one variable, such as in estimating production functions, investigating economic growth across countries or regions, and in studying economic convergence. Therefore, it is highly desirable to have a comprehensive measure on human capital that is ready to use, in addition to various measures on education attainments. Barro and Lee (2013) provides a comprehensive dataset on estimated education attainment in the world, and has been consistently ranked as a top download for many years.[1] The high demand for their dataset demonstrates the importance of a relatively simple, yet ready to use, human capital measure. A comprehensive human capital measure beyond education attainment would aid human capital research in a significant way.

As a starting point in this study, we provide a new estimate of human capital for China at the provincial level for multiple years. Our estimate includes various aspects of human capital accumulation, including education, on-the-job training, and other unobserved aspects such as health, abilities, etc. The estimation results in a new panel dataset with various human capital measures that are ready to be used in research work. Moreover, our human capital data can be disaggregated based on urban/rural areas, education, age, and gender population groups. In addition, we also provide estimates for related traditional human capital measures in the data for comparison.

[1] The 2013 article describing the methodology underlying the data set is the most cited Journal of Development Economics article published since 2011 according to Scopus. http://www.journals.elsevier.com/journal-of-development-economics/most-cited-articles

We estimate human capital in China for a number of reasons. First, even for a relatively simple human capital estimation technique, a large amount of data is still needed. Conducting such an exercise for most countries in the world as Barro and Lee did is very difficult due to data limitations, and more importantly, because of the vast differences in social and economic institutions. Therefore, human capital estimation for one country would provide useful information for further research that covers more countries. Second, China is the largest developing country with impressive economic growth for the past 30 plus years. The role of human capital in China's economic development has drawn an increasing interest among scholars and policy makers. A new human capital measure in China would be very helpful for such studies.

Moreover, the rising regional inequality in China is becoming a significant issue (for example, see Wan 2007; Fleisher et al. 2010). For example, the ratio of the highest to lowest provincial per capita GDP was around 12 during 1995 to 2005. Although it has declined since then, it was still about 6 in 2014. The provincial level human capital measures can be used to study the regional distribution of human capital and its evolving patterns, which will help bring understanding to the association between regional human capital and its economic development. More specifically, we divide China into four regions (excluding Tibet) by distinguishing features of economic development, following the practice of National Bureau of Statistics of China: east region, northeast region, interior region and west region.[2]

[2] Following the *China Statistical Yearbook 2015* (http://www.stats.gov.cn/tjsj/ndsj/2015/indexch.htmhttp://www.stats.gov.cn/tjsj/ndsj/2015/indexeh.htm), we divide the four regions as follows. The east region includes Beijing, Tianjin, Hebei, Shanghai, Jiangsu, Zhejiang, Fujian, Shandong, Guangdong, and Hainan; the northeast region includes Heilongjiang, Jilin, and Liaoning; the interior region includes Shanxi, Anhui, Jiangxi, Henan, Hubei, and Hunan; the west region includes Inner Mongolia, Guangxi, Chongqing, Sichuan, Guizhou, Yunnan, Shaanxi, Gansu, Qinghai, Ningxia, and Xinjiang. We exclude Tibet because of data limitation.

The east region is the most developed along the coastline, and the west region is the least developed, while the interior region is in between in terms of both the location and stage of development. The northeast region was China's industrial base before the 1980s and was the most developed region then. However, it has lost its lead in the past two decades, presumably due to the large share of state-owned sectors and manufacturing oriented industries. The east region has the top three provinces with the highest per capita GDP (Shanghai, Beijing and Tianjin), while the bottom three provinces with lowest per capita GDP are all located in the west region (Guizhou, Yunnan and Guangxi). As can be seen in Figure 1, GDP per capita shows a clear regional pattern, where the east is the highest and the west is the lowest. In 2014, GDP per capita in the west region was 48% of the east; the interior region was 53% of the east. Moreover, the gap between the east and interior/west regions is increasing. For example, the proportion was 60% to 51% respectively in 1985. The northeast region used to enjoy a higher GDP per capita. For example, it was 103% of the east in 1985, but became 83% in 2014.

In general, regional per capita GDP represents the stage of economic development in that region. Some existing research shows that human capital is one of the major factors contributing to regional inequality in China (Chi, 2008; Kuo and Yang, 2008; Fleisher et. al., 2010; Zhang and Zhuang, 2011). Therefore, our regional human capital estimates can show their spatial differences and provide visible information on how regional human capital distribution is correlated with regional economic development. Finally, we conducted an in-depth Divisia decomposition exercise to investigate how different factors affect the growth of human capital quantity and quality in each region. If human capital affects future economic development in a region, such a growing trend of human capital will have important implications for regional economic disparity. Therefore, the Divisia decomposition results will shed additional light on the convergence or divergence of the Chinese economy.

The rest of the paper is organized as follows: Section II discusses human capital estimation methodology and the modifications for applying to China. Section III discusses the data used in human capital estimation. In section IV, we present the new human capital panel data. We discuss regional distributions and the trend of human capital across four regions in China in section V. In section VI, we introduce the Divisia decomposition methodology and discuss factors affecting regional human capital growth. Section VII concludes.

II. Human capital estimation methodology

There are different ways to estimate aggregate human capital stock. Kendrick (1976) pioneered the cost-based approach, in which the value of human capital is based on total investment (costs). However, the data requirements for this approach are enormous and make it very difficult to implement in China. Additionally, the Kendrick approach gives no clear rationale for some important costs, such as for the split of health expenses between investment and preventative costs. Another method is the attribute-based approach which is usually considered to be a variant of the income-based approach (Le, Gibson and Oxley 2003). It constructs an index value of human capital instead of a monetary value. World Bank (2006, 2011) uses a residual-based approach to estimate human capital for 120 countries, where the stock of human capital is measured as the difference between the total discounted value of each country's future consumption flows (as a proxy for total wealth) and the sum of the tangible components, i.e. produced capital and the market-component of natural capital (Ruta and Hamilton, 2007). This approach, however, cannot separate human capital from other intangible social capital such as social institutions, and has other limitations (see Liu and Fraumeni, forthcoming).

The Jorgenson and Fraumeni (J-F) method (Jorgenson and Fraumeni, 1989, 1992a, 1992b) is an income-based approach that estimates an individual's lifetime earnings as his/her value of human capital. The advantage of this approach is that it has a sound theoretical foundation, i.e., the value of an asset is determined by the market. Because the measurement is based on labor market outcomes, i.e., earnings, it captures not only education, but also on-the-job learning, health and other unobserved human capital. Moreover, the J-F approach is relatively feasible to implement because the data required are generally accessible. As a result, the J-F method is the most widely used approach in estimating human capital stock and has been adopted by a number of countries and the OECD to construct their human capital accounts.[3]

In order to apply the J-F framework in China, especially to overcome the data limitations, we modified the J-F method. First, due to the lack of earnings data, we incorporated the Mincer model into the China J-F framework; and moreover, we augmented the standard Mincer model with provincial level aggregate variables to estimate individuals' earnings at each province. Second, we created a cross-province living-cost index to adjust the estimated earnings based on "purchasing power parity" so that the human capital estimates are comparable across provinces.[4] Finally, we estimated human capital for rural and urban areas separately so that we can capture the effect of urbanization during the past 30 years, and we also incorporated many other institutional details in every stage of the calculation.

[3] Among the most recent human capital estimates, i.e., Australia (Wei, 2007), New Zealand (Le, Gibson, and Oxley, 2003), Sweden (Ahlroth, Bjorklund, and Forslund, 1997), United Kingdom (Jones and Chirpanhura, 2010), and the United States (Christian, 2010, 2014) (Christian, for the United States, includes a full set of nonmarket activities). The J-F approach was adopted by the OECD human capital consortium. In addition, the World Bank is planning to estimate human capital for 150 countries based on the J-F method.
[4] Note that our adjustment index is based on cost of living.

In particular, the J-F approach estimates each individual's expected lifetime income and then aggregates all individuals together to get total human capital stock.[5] The total human capital stock K_t for a country is calculated by the following equation,

$$K_t = \sum_s \sum_a \sum_e \sum_r mi_{s,a,e,r,t} \cdot l_{s,a,e,r,t} \ , \qquad (1)$$

where the subscript *t*, *s*, *a*, *e* and *r* denotes, respectively, year, gender, age, educational attainment, and location, and $mi_{s,a,e,r,t}$ stands for the average lifetime labor income for the specific category defined by gender(*s*), age(*a*), education(*e*) and location (*r*) at the *t* period; and $l_{s,a,e,r,t}$ is the population in the respective categories.

In the J-F approach, the life cycle is divided into five stages. At the fifth stage-retirement, future market earnings are assumed to be zero. The preceding four stages include: work-only, work-school, school-only, and pre-school. The estimation is conducted in a backward recursive fashion beginning with the retirement age. More specifically, the lifetime income of an individual at age *a* is the present value of the expected lifetime income of an individual at age *a+1* plus his/her income in the current year, after accounting for the probabilities of being in the labor market (such as full-time in school or unemployed). Future income is estimated with a projected exogenous labor income growth rate and then discounted to the present value before summation.

Based on the Chinese system, we define *s*=(male, female), *a*=(age from newborn to retirement), *e*=(below elementary, elementary, middle school, high school, 3-year college, 4-year

[5] A limitation for the J-F framework, as well as for any other income-based human capital measures, is that, if earnings reflect one's marginal productivity, it will include the effect of physical capital and TFP. However, based on Manuelli and Seshadri (2014), in their theoretical model of human capital that incorporates both quantity and quality measures, they showed that "identical individuals" with exactly the same level of schooling had different levels of human capital (quality) and the quality of human capital depended on the TFP of the country (region). One reason is that the level of early childhood human capital increases with TFP.

university or above), and r=(urban, rural).[6] Because of the drastic structural difference between urban and rural areas in China, we calculate the human capital separately for urban and rural populations. This approach will generate more accurate estimates of total human capital, and also allow us to investigate urban-rural disparities in human capital and the effect of urbanization on human capital.

In first stage, i.e., pre-school, the human capital of an individual at age *a* is the lifetime income of someone with the same gender and schooling at age *a+1*, adjusted by the survival rate and exogenous income growth and discounted to the current year. The second stage is for school-only. In China, due to the nine-year compulsory education system, this stage only applies to elementary and middle school.[7] The possibility of not enrolling in middle school (e.g., before the implementation of compulsory education law or when the law was/is not fully enforced) is taken into account in the calculation.

For the third stage (work-school), an individual might work, go to school, or do both in the U.S., particularly when they are enrolled in higher education. However, in China students rarely work, so in our approach, it is assumed that no students work. Individuals have only two choices, i.e., to work or go to school. In China, this stage applies to high school or above. In particular, we take an 18-year old individual who has completed high school as an example, his/her expected lifetime income would be as follows, if he/she chooses to work (skipping the location subscript for simplicity),

$$mi_{t,s,18,highschcompleted-working} = ymi_{t,s,18,highschcompleted-working} + sr_{t,s,18to19} \cdot mi_{t,s,19,highschcompleted-working} \cdot \frac{1+G}{1+R}, \quad (2)$$

[6] In China, the legal retirement age is 60 years old for male and 55 years old for female.
[7] The compulsory education law in China was implemented in 1986. Based on the law, when a child reaches 6 years old, he/she is required to enroll in elementary school, but the enrollment age can be postponed to 7 years old in less developed areas. Based on our data, in rural areas, a majority of children enroll in elementary school at age 7 before year 2005; while in urban areas, after 2001, a majority of children enrolled at age 6. The elementary school is six years in China, and three years for middle school and three years for high school.

where mi stands for an individual's lifetime market labor income, ymi denotes an individual's annual market income, adjusted by the probability of being employed as above, sr is the survival rate, defined as the current year probability of becoming one year older, G is the real income growth rate, and R is the discount rate.

In the J-F approach, because the expected lifetime for the individual at age *a+1* would be achieved in year *t+1*, it is then adjusted by the real income growth $(1+G)$ and discounted by $(1+R)$. The real income growth rate is exogenously given rather than derived from the models, reflecting overall future productivity improvements (Jorgenson and Fraumeni, 1989, 1992a, 1992b). Although the estimated value of human capital is sensitive to the choice of the real income growth rate and discount rate, the growth of human capital is not because its effect in growth is differenced out.

In the second case, if the individual at 18-year old chooses to go to school, he/she can go to three-year college or four-year university. In the Chinese system, higher education is mainly composed of three-year colleges and four-year universities. High school graduate students with higher scores in the national entrance examinations can enroll in university and those with lower scores can enroll in college.[8] The expected income, for example, of going to a four-year university is calculated as,

$$mi_{t,s,18,university} = sr_{t,s,18to19} \cdot sr_{t+1,s,19to20} \cdot sr_{t+2,s,20to21} \cdot sr_{t+3,s,21to22} \cdot mi_{t,s,22,universitycompleted-working} \cdot \left(\frac{1+G}{1+R}\right)^4, \quad (3)$$

$$mi_{t,s,22,universitycompleted-working} = ymi_{t,s,22,universityompleted-working} + sr_{t,s,22to23} \cdot mi_{t,s,23,universitycompleted-working} \cdot \frac{1+G}{1+R}, \quad (4)$$

Similarly, if someone completed middle school and started to work at age 16, his/her lifetime income will be estimated by a string of earnings, and the earnings will increase with

[8] Based on the numbers from *China Educational Yearbook* 1985-2014, the average ratio of new enrollments in four-year universities to that in three-year colleges from 1985-2014 is 1.07, and the ratio reached the peak of 1.52 in year 1998 and 1999 due to the rapid expansion of higher education. Since 2010, the ratio has been generally above 1.10.

years of job experience due to on-the-job training (which increases one's human capital). However, for those individuals enrolled in high school, they can either finish high school and work or continue to college/university, as specified above. In this case, the enhancement of their human capital compared to middle school graduates is due to higher level of education, in addition to job experience.

A further problem in applying the standard J-F framework to China is that earnings data for individuals with different education, age, and gender are not generally available. Such data are critical in applying the J-F method. In order to overcome the data difficulty, Li et al. (2013) uses the Mincer model (1974) to estimate individual earnings using survey data in calculating the human capital at the national level in China. However, at provincial level, this approach requires survey data for each province; and moreover, the data need to have sufficient sample size for urban, rural, male and female categories separately. Such survey data at provincial level is not available.

Therefore, we augment the traditional Mincer model by incorporating province-specific aggregate variables as follows, in order to capture the province-specific earnings structure (Li et al, 2014),

$$\begin{aligned} \ln inc_{ij} = \beta_0 + \beta_1 \cdot \ln avwage_j + \beta_2 \cdot sch_{ij} + \beta_3 \cdot sch_{ij} \cdot GDP\_PC_j + \\ \beta_4 \cdot sch_{ij} \cdot Primary_j + \beta_5 \cdot \exp_{ij} + \beta_6 \cdot \exp_{ij}^2 + u_{ij} \end{aligned}, \qquad (5)$$

where $\ln inc_{ij}$ is the logarithm of annual income of the employed, sch_{ij} is years of schooling, $\exp_{ij}$ is years of working experience, and u_{ij} is the error term, for individual *i* in province *j*. In the model, the aggregate variables are used to control for province-specific factors on the earnings structure, so that we can run the Mincer model using much larger national samples from survey data.

More specifically, $avwage$ is the average wage of a province, which reflects the earnings differentials across provinces due to the living costs and total factor productivity; and thus can control for the provincial differences in the earnings of new labor market entrants (for those with no schooling and no labor market experience), i.e., the province-specific intercept in the Mincer model.[9] We use two other aggregate variables to control for province-specific return to education, where the variable GDP_PC is provincial GDP per capita, and $Primary$ is the proportion of the labor force employed in the primary industry. Those two aggregate variables can generally capture the major features of different economic development stages and labor markets across provinces that will affect the returns to schooling (see for example, Li, 2003; Zhang et al., 2005; and Yang, 2005).[10] The Mincer model augmented above is estimated using samples on different rural/urban and male/female combinations.

Additionally, because provincial human capital stock is based on individuals' expected lifetime income, a monetary value, the resulting estimates may not be comparable due to various heterogeneity across provinces. For example, higher income may partially reflect the living cost of a province. Therefore, we construct a provincial living cost index, following Brandt and Holz (2006), to adjust earnings across provinces.[11]

[9] Another option is to use the provincial minimum wage. However, the minimum wage was not fully implemented in China until 2004, and thus we do not have the data for most years covered in our calculation.
[10] We assume that returns to experience do not change across provinces.
[11] Cross location comparison of human capital based on the J-F approach is still a challenge. It is a main obstacle in the work of the OECD human capital Consortium in establishing a comparable cross-country human capital measure using J-F. Our approach of using living cost index to make the adjustment is only a partial solution.

III. Data

In order to calculate the provincial level human capital stock, we need population data by urban/rural, gender, age and education (total of four dimensions) for each province in every year. Population by gender, age, and educational attainment in urban and rural areas are available only in the census years, 1982, 1990, 2000, and 2010; as well as for the years with a 1% national population survey sample: 1987, 1995, and 2005. The data come from various provincial statistical yearbooks. For the missing years, we adopt a perpetual inventory method combined with birth rates and survival rates by age and gender to estimate the population for the above four dimensions.

With the four-dimension population for 1985-2014 estimated, we then estimate in-school population based on the enrollment at different education levels. However, at the provincial level, total enrollment data classified as the above four dimensions are not available. The available information is provincial annual new enrollment by rural/urban, male/female and education level. Thus, we calculate the total enrollment based on annual new enrollments and related survival rates for each province. However, provincial annual new enrollment data do not have information on age, so we use the age distribution of students at the national level as a proxy.[12] After obtaining the four-dimensional total for in-school population, we can subtract it from the four-dimensional total population estimated above to get the four-dimension out-of-school population.[13]

[12] In the national data, the age distribution of annual new enrollment is available but not separated by gender. We inferred gender-based age distribution for new enrollment based on the gender distribution for the total enrollment. Data are from the *China Education Statistical Yearbook* and provincial statistical yearbooks.

[13] It is possible to get negative out-of-school numbers in some cases. We replace the negative numbers with zero, but it will lead to that the total imputed population is larger than the actual population. We scale back the imputed population in-school and out-of-school to insure that the sum of them is equal to the actual total population.

For enrollment rates, which are used to calculate the expected lifetime income for individuals at different school stages, we got an estimate for each education category based on the probability of advancing to the next higher education level and the minimum years to accomplish a degree.[14] Specifically, the probability of advancing to the next higher educational level is estimated as the ratio of the number of students of age *a* enrolled in year *y* to the number of students of age *a+n* enrolled in the next higher educational level *n* years later, where *n* denotes the minimum years to complete an educational level.[15] For example, for someone enrolled in the first year of elementary school, the enrollment rate is estimated by the ratio of the number of students in the first year of middle school six years later when the student is six years older, to the number of students in the first year of elementary school (a combined effect of enrollment rate for middle school and annual survival rate).

To calculate employment rates by age, gender and education level, we use the number of employed population divided by the corresponding population. Provincial level economic data, such as provincial GDP and employment, are from various provincial statistical yearbooks.

In order to estimate the above augmented Mincer model for each province (separated by urban/rural and male/female) for each year, we use five well-known household surveys in China, Urban Household Survey (UHS) 1986-1997; the Chinese Household Income Project (CHIP) 1988, 1995, 2002, and 2007; the China Health and Nutrition Survey (CHNS) 1989, 1991, 1993, 1997, 2000, 2004, 2006, 2011; the China Household Finance Survey (CHFS) 2010; and the Chinese Family Panel Studies (CFPS) 2009 and 2011.[16] For missing years, the Mincer

[14] We assume that all students complete an educational level in the same number of years, no drop-outs return to school, no grades are skipped and that education continues without a break. Note that, in this case, the enrollment rate includes survival rate.

[15] One complication is that an individual may enter school at different ages. We allow for this possibility in the calculation. In particular, in our calculation, the age range for enrolling in elementary school is 5-10, middle school is 11-16, high school 14-19, and college and university 17-22.

[16] UHS: http://www.usc.cuhk.edu.hk/DCS/DCS31-1-86-92.aspx

parameters are imputed by a linear or exponential line. Based on the estimated Mincer models, we can estimate earnings for each location (urban/rural), gender, age, and education category for each year of 1985-2014.[17] Note that in the rural area, an individual's earnings come from family farming, and we estimate an individual's earnings from family farming earnings based on his/her hours worked.

Additionally, for the J-F calculation, we need to estimate the real wage growth rate, which reflects the economy-wide productivity increases. The wage growth rate is calculated as the average annual growth rate of earnings for 1985-2014, for urban and rural areas, separately.[18] The range of the average growth rate varies largely, for example, from 6.16% (Qinghai) to 10.06% (Beijing) for urban areas; and from 4.85% (Qinghai) to 7.46% for rural areas (Zhejiang).

The living cost index is constructed based on the prices for a specific basket of goods, using Beijing as the base area and 1985 as the base year. Then, with the inflation index for each province, we can get the annual living cost index matrix for all provinces for 1985-2014. Therefore, all the human capital estimates can be comparable for all the provinces and all years. To get the present value, we adopt a 4.58% discount rate used by Jorgenson and Fraumeni (1992a) and the OECD consortium (OECD 2010).[19]

IV. Provincial human capital panel data

CHIP: http://www.icpsr.umich.edu/icpsrweb/ICPSR/series/00243
CHNS: http://www.cpc.unc.edu/projects/china/data
CHFS: http://www.chfsdata.org/
CFPS: http://www.isss.edu.cn/cfps/

[17] It is known that if we simply exponentiate the predicted value for $\ln inc$, the prediction will systematically underestimate the predicted earnings, because of the error term in logarithm. We estimated the adjustment factor, which is related to the variance of error term if the error is normally distributed, to adjust the predicted earnings.

[18] In urban, we use wage growth for formal employees; and in rural area, we use the growth of average earnings.

[19] This discount rate of 4.58% fits China well as it is between the average interest rate on the 10-year government bonds (net of inflation, 2.24%) and the average benchmark 5-year lending rate to commercial banks in the period from 1996 to 2012 (net of inflation, 5.33%), see *Almanac of China's Finance and Banking*, 1997-2013, and *China Statistical Yearbook*, 2013.

In this section, we present the estimated human capital panel data for China based on the methodology described above, and we also compare J-F based human capital estimates with other conventional human capital measures.[20] The panel data consist of annual human capital measures for 30 provinces for 1985-2014.[21] They can be used for a wide range of studies, such as estimating a provincial production function, studying economic convergence, investigating the impact of human capital on economic growth, etc.[22]

Table 1 presents the descriptive statistics for the human capital panel data with the simple sample average across provinces for selected years based on the J-F estimates. For comparison, we also provide our estimates of the provincial physical capital.[23]

The data show that the annual average of various human capital measures increases constantly. The annual growth rate of total human capital (HC) for the period of 1985-2014 is 6.87%, and the annual growth of per capita human capital (PCHC) is 6.24%. Both are slower than the 9.73% economic growth rate in this period. However, the growth of HC and PCHC has accelerated since 1995, with an annual growth rate of 8.54% and 8.13%, respectively.

Labor force human capital (LFHC) measures the human capital of the labor force, i.e.,

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[20] Unless otherwise specified, the data on GDP, physical capital and various human capital measures are in real values with 1985 as the base year. The real value of physical capital is calculated by nominal gross fixed capital formation (GFCF) and price index for investment in fixed assets, grouped by "construction and installation," "purchase of equipment and instruments" and "others." Human capital in real values is adjusted by a living cost adjustment index.

[21] The data are freely available upon request.

[22] In the strict sense, in an aggregate production function, the service of physical capital and human capital should be included as production inputs. Fraumeni (2012) discusses the possibility of human capital in a production function.

[23] Physical capital is estimated following the method outlined in the OECD Manual (OECD Manual 2009: Measuring Capital, Second edition. OECD, Paris.) and the physical capital chapter in the OECD Manual (OECD Manual 2001b: Measuring Capital–Measurement of Capital Stocks, Consumption of Fixed Capital and Capital Services. OECD, Paris; OECD Manual 2001c: Measuring Productivity – Measurement of Aggregate and Industry-Level Productivity Growth. OECD, Paris.). Aggregate wealth capital stock is obtained by summing three asset-specific wealth capital stocks ("construction and installation", "purchase of equipment and instruments" and "others"), and each asset-specific wealth stock are calculated with investment values in form of gross fixed capital formation multiplied by survival function and age-price profile. Based on experiences in other countries and taking China-specific circumstances into account, we set average service lives of physical assets be 40 years for "construction and installation", 16 years for "purchase of equipment and instruments", and 25 years for "others". The sources of data are obtained from National Bureau of Statistics website, *China Compendium of Statistics: 1949-1998*, *Data of Gross Domestic Products of China:1952-2004*, *China Statistical Yearbook* and provincial statistical yearbook.

those who are not students and are between age 16 and retirement age (60 for males and 55 for females).[24] It represents human capital used in the current production. As shown in Table 1, the annual growth rate of provincial LHFC is 6.60%, and per capita labor force human capital (PCLF) is 5.31%. For comparison, the average growth rate of physical capital is 13.47% for 1985-2014, and 14.43% for 1995-2014, much faster than LFHC. It reflects a feature of Chinese economic growth in the past 30 years, i.e., mostly driven by physical capital investment.

Among all provinces, the top three provinces with the largest total human capital stock in 2014 are Guangdong, Shandong, and Jiangsu, mainly due to their population size. However, per capita human capital measures the human capital intensity and the quality of the labor force. The top three provinces with the highest average labor force human capital are Beijing (462 Thousand RMB), Shanghai (412 Thousand RMB), and Tianjin (377 Thousand RMB); while the bottom three are Guizhou (81 Thousand RMB), Gansu (75 Thousand RMB), and Yunnan (73 Thousand RMB). The gaps are very large.

In order to compare with our estimates of comprehensive measures of human capital, we also calculate the traditional measures of human capital, and present their descriptive statistics in Table 2. Those traditional measurements are mostly education-based and have been widely used in literature. During this period, the proportion of the labor force with high school education or above in China increased from 12.90% in 1985 to 32.45% in 2014, more than doubling. The proportion of labor force with a college education or above increased even faster, from 1.52% to 14.60%. As a result, the average years of schooling for the labor force increased from 6.21 years to 9.82 years in this period.[25] In other words, in 1985, an average labor force participant in China only had an

[24] In this paper, the term "labor force" refers to all working-age individuals who are not students from age 16 to retirement age. Some of these individuals may not participate in the labor force as it is commonly defined.
[25] In this section, the purpose is to introduce the panel data on human capital. Therefore, all averages are simple sample average, not weighted, for example, by provincial population. Such average figures may not be comparable

elementary school education (6 years), but rose to more than a middle school education in 2014.[26] However, as discussed above, those human capital measures based on education do not capture the quality of schooling and other aspects of human capital accumulation. For example, in China, the quality of schooling varies largely across provinces, due to dramatic differences in school investment, teaching quality and even human capital externalities.[27] On the other hand, the average age of the labor force increased from 32.29 to 37.00 years in mainland China.

As shown in Table 1, for 2014, the average human capital per capita in China was RMB 307,000 ($46.3 thousand) and the average per capita labor force human capital is RMB 162,000 ($24.4 thousand).[28] An international comparison of J-F based human capital measures is complicated due to different institutions, systems and markets across different countries. However, to get a sense of international comparison, we adjusted J-F based human capital estimates for a few countries using purchasing power parity for private consumption. For example, in 2006 China's human capital per capita for population aged 16-64 is $98 thousand, while in Japan and South Korea it is $490 thousand and is $641 thousand in the US (Fraumeni, 2015). It shows that the gap between China and the developed countries in human capital per capita is still huge.[29]

V. Regional distribution and dynamics of human capital

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with other studies on national level as their numbers are either calculated at the national level or are weighted average.

[26] Compared to other countries (based on data in 2010), China is in line with countries like Austria (9.60 years), Italy (9.63 years) and Finland (9.84 years) in terms of years of education; but the average years of schooling in the US is 13.18. In the Barro and Lee report for China, except for the population aged 15-19 (10.23 years), no age group for the population has an average educational attainment of over 9 years (http://www.barrolee.com/data/yrsch.htm, version 2.1, February 2016). However, our estimates are based on much more detailed data sources at less aggregated provincial level.

[27] In our separate work, we estimated unobserved human capital, which included schooling quality, across regions in China. The differences are fairly large.

[28] It's calculated based on the exchange rate of 6.63.

[29] The retirement ages in other countries are different, which will affect the lifetime income.

In this section, using the panel data estimated in the above section, we investigate the regional distribution of human capital as well as its dynamics in the past 30 years. The map and trend of regional human capital should provide useful information for further studies and policy analysis related to regional disparity.

We first discuss total human capital and then per capita human capital. Total human capital represents the size across regions, while average human capital provides useful information on regional human capital intensity.

1. Total human capital across regions

Total human capital (HC) accounts for the overall human resources in a region, and covers all individuals from the newborn to the retirement age. It includes the human capital reserve, i.e., young people who have not yet entered the labor market (full-time students and those aged 15 or below), and human capital in use, the human capital of the labor force (LFHC).

Figure 2 shows the distribution and trend of regional total human capital. Although it shows a clear regional pattern, their relative positions are less important, because the stock of human capital mainly depends on the population size of the region. However, their growth trends contain important information about regional disparity. For all regions, total human capital showed very slow growth for the period of 1985-1994; but it grew much faster in the later period from 1995 to 2014. This is consistent with the economic structural change that occurred around 1994 (Fleisher et al., 2010). However, the east region took a lead with an annual growth rate of 9.20% for 1995-2014, and the west and northeast grew the slowest with an annual average growth rate of 7.01% and 7.17%, respectively, and the interior region was in the middle, at a rate of 8.14% (see Table 4). [30] Overall, the human capital gap between the east and other regions is rising.

[30] All growth rates and per capita results at the regional level are weighted by population unless otherwise specified. For regional total human capital by region, it is a direct summation of regional provincial human capital.

For different components of the total human capital, the ratio of LFHC/HC, i.e., the share of human capital in use, is generally below 50%. In general, the expected lifetime income for young people is higher than that for the older people. This effect is strengthened by the better education opportunities for younger generations in China. The northeast region has the highest ratio, and the interior region has had the lowest ratio since 2010 (around 36% for 2014). Because the human capital of children and students will be used for future production as they join the labor force, the result indicates that northeast region has the lowest share of human capital reserve. The relative size of labor force human capital and human capital reserve is determined by the age and education structure of the non-retired population.[31] In fact, the interior and west regions have the highest proportion of children (around 27% in 2014), while northeast has the lowest proportion (around 18% in 2014), followed by the east region (23% in 2014). Consistently, the northeast region has the oldest average population of approximately 32 years of age, with only an average of 28 years of age for the interior and west regions.

As physical capital is often used in conjunction with labor force human capital in production, it is useful to compare their relative magnitudes. For all regions, the relative size of labor force human capital to physical capital decreased rapidly over time (Figure 3). The decreasing trend may reflect the high level of physical capital investment in China, which has been a major driving force for China's economic growth. However, the decrease has been stabilized since 1995, which is consistent with the fast human capital growth since then. Interestingly, there seems to be a regional convergence of the relative size between LFHC and physical capital. Because of the government "West-Development" policy, a large amount of physical capital

[31] In this study, we have a few definitions on population, in particular, 1) non-retired population includes all individuals below the retirement age (including children); 2) labor force includes all individuals aged 16 to retirement age (excluding students); 3) human capital reserve includes children (aged below 16) and full-time students.

investment has been channeled into the west region. For the period of 1995-2014, the growth of physical capital in the west is in line with the east.

In general, the productivity of human capital and physical capital can be measured by their ratio to GDP, an indicator of their efficiency in production. Interestingly, for all regions, the trend for GDP/LFHC goes up, but the ratio of GDP to Physical Capital goes down (Figure 4 and 5). The different trends of the two productivity measures show that the marginal productivity of human capital is higher than its average productivity, but the opposite is true for physical capital. Moreover, both ratios show a trend of convergence across regions.

2. Regional human capital per capita

Per capita human capital (PCHC) can represent the intensity of human capital, a quality measure of the population. In Figure 6, the PCHC shows a strong growth after 1995, similar to the growth of the total human capital. The east region has the highest human capital intensity, while the west has the lowest, with the northeast and interior regions in the middle and very close to each other. In 2014, PCHC for the east region was RMB 386,000. However, the PCHC was RMB 194,000 for the west, approximately 50% of the east. Moreover, the gap between the east and other regions, especially the west, is growing. For example, in 1995, the PCHC of the west was around 62% of the east, much higher than its percentage in 2014. In fact, all the top five provinces in PCHC are located in the east region.

For the labor force, the per capita labor force human capital (PCLF), an indicator of labor force quality, follows a regional pattern similar to the PCHC. From 1995 to 2014 (see Table 4), the PCLF in the interior and east grew at 7.08% and 7.04% per year respectively, while the west only increased by 6.00% annually. The different paces of the increase in labor force human capital intensity will further enlarge this gap with other regions.

Human capital can also serve as a beyond GDP measure of economic and social development. More specifically, the expected lifetime income of a newborn can be a good indicator of the relative stage of economic development (Figure 7 and Table 3). For all regions, the human capital for the newborn rises rapidly, especially in the east region. In 1985 a newborn would earn a RMB 133,000 lifetime income in the east, while it rose to RMB 1.22 million in 2014 based on constant dollars, an eight-fold increase. The regional gaps are also substantial; in 2014 an infant's expected lifetime income in the east region was more than three times that of the west region, and approximately double that of the interior region. Based on human capital, it is clear that the east region is the most developed, followed by the northeast, and the interior, with the west far behind so far.

Another interesting age of human capital per capita is 16, when an individual is about to enter the labor force. It can measure the human capital intensity of an average labor market new entrant. For human capital at this age, the west region is approximately 46% of the east region (2014). Although the gap is still drastic, it is not as profound as for a newborn because the human capital of a newborn in the west region is only 30% of that in the east region. This result is concerning, because the east-west gap for the younger generation is getting even larger than the older ones.

VI. Divisia decomposition of human capital growth

The distribution and trend of human capital discussed above provide a relatively complete picture about China's regional human capital. A further question would be about the factors that contribute to the regional pattern of human capital. As can be seen in the J-F framework, many factors influence human capital growth, such as age composition, education, migration, health, and even market and economic structure. In this study, we conduct a Divisia decomposition analysis to investigate the impact of four major factors on human capital growth, i.e., urbanization, education, age structure and gender compositions (for a general discussion on the Divisia index, see Hulten, 1973).[32] Those factors represent the major components in the J-F framework.

1. Divisia decomposition methodology

A Divisia decomposition of J-F human capital can yield valuable information about the growth of a country's human capital (see, for example, Jorgenson, Gollop and Fraumeni, 1987). More specifically, assume the human capital stock in period *t*, K_t based on equation (1) can be written as:

$$K_t = MI_t \cdot L_t = \sum_{i=1}^{n} mi_{it} \cdot l_{it}, t = 0,1,...T , \qquad (6)$$

where MI_t is a vector of average lifetime income for an individual in a particular group at period *t*, i.e.,

$MI_t = (mi_1, mi_2, mi_3,...mi_n)$, and L_t is a vector that denotes the size of population in the corresponding groups, $L_t = (l_1, l_2, l_3,...l_n)$, and i is the total number of groups classified by the characteristics of the population. In the calculation discussed in Section II above, those characteristics include gender (*s*), age (*a*), education (*e*) and rural-urban location (*r*), as shown in equation (1), and the total number of groups is the combination of all subgroups for various categories of population characteristics.

A human capital index $K_{t/0}$ can be defined as:

[32] Another approach to investigate the effect of those factors is to estimate structural models for human capital, but it is out of scope of this study.

$$K_{t/0}=\frac{K_t}{K_0}=e^{\ln MI_t\cdot L_t-\ln MI_0\cdot L_0}=e^{\int_c \frac{d(MI_t\cdot L_t)}{MI_t\cdot L_t}}$$

$$=e^{\int_0^T \frac{\sum_i l_{it}\cdot dmi_{it}}{\sum_i^n mi_{it}\cdot l_{it}}}\cdot e^{\int_0^T \frac{\sum_i mi_{it}\cdot dl_{it}}{\sum_i^n mi_{it}\cdot l_{it}}}, \qquad (7)$$

In equation (7), we define $P_{t/0}=e^{\int_0^T \frac{\sum_i l_{it}\cdot dmi_{it}}{\sum_i^n mi_{it}\cdot l_{it}}}$ as the Divisia price index, which measures the accumulated weighted growth rate of expected lifetime income from current period to the based period, with corresponding population shares as weights; and define $Q_{t/0}=e^{\int_0^T \frac{\sum_i mi_{it}\cdot dl_{it}}{\sum_i^n mi_{it}\cdot l_{it}}}$ as the Divisia quantity index, which measures the accumulated weighted growth rate of the population from current period to the base period, with the corresponding shares of lifetime income as weights. The price index measures the growth caused by monetary income (a price effect), while the quantity index measures the growth due to change in population composition.

In order to investigate how the changes in population structure affect human capital growth, we will focus on the Divisia quantity index in this study. The quantity index provides useful information on how changes in population composition affect human capital. For example, if more individuals receive higher level of education, how will human capital increase? The analysis of the quantity index can generate direct policy implications on education, urbanization, population aging, gender composition, etc.[33]

By taking logs on both sides, the Divisia quantity index becomes

[33] Note that, the analysis focusing on the Divisia quantity index is equivalent to assuming for purposes of analysis that the price effect is zero (i.e., no change in *mi*).

$$\ln Q_{t/0} = \int_0^T \frac{\sum_i mi_{it} \cdot dl_{it}}{\sum_i^n mi_{it} \cdot l_{it}} = \int_0^T \sum_i (\frac{mi_{it} \cdot l_{it}}{\sum_i^n mi_{it} \cdot l_{it}}) \cdot \frac{dl_{it}}{l_{it}} = \int_0^T \sum_i v_{it} \cdot d\ln l_{it} \approx \sum_{t=1}^T [\sum_i \overline{v}_{it} \cdot (\ln l_{it} - \ln l_{it-1})], \quad (8)$$

where $v_{it} = \frac{mi_{it} \cdot l_{it}}{\sum_i^n mi_{it} \cdot l_{it}}$ is the share of lifetime income for each group. In discrete case, we define

$\overline{v}_{it} = \frac{1}{2}(v_{it} + v_{it-1})$ as an average between two time periods, *t-1* and *t*. Thus, the Divisia quantity index is an accumulated weighted population growth, weighted by their shares in total human capital.

Similarly, the Divisia decomposition can also be applied to human capital per capita. In particular, based on equation (7) and (8), the Divisia index of human capital per capita can be written as follows.

$$AQ_{t/0} = \frac{Q_t}{L_t} / \frac{Q_0}{L_0} = e^{\int_0^T \frac{\sum_i mi_{it} \cdot dl_{it}}{\sum_i^n mi_{it} \cdot l_{it}}} \cdot e^{-\int_0^T \frac{dL_t}{L_t}}, \quad (9)$$

By taking logarithm for equation (9), we get

$$\begin{aligned} \ln AQ_{t/0} &= \int_0^T \sum_i v_{it} \cdot d\ln l_{it} - \int_0^T (d\ln \sum_i l_{it}) \\ &= \sum_{t=0}^T [\sum_i \overline{v}_{it} \cdot (\ln l_{it} - \ln l_{it-1})] - \sum_{t=0}^T (\ln \sum_i l_{it} - \ln \sum_i l_{it-1}) \end{aligned}, \quad (10)$$

Note that, in the above equation, the difference between the weighted growth of the population and the un-weighted growth of the population reflects the compositional change of human capital. Therefore, the Divisia quantity index of human capital per capita equals to the Divisia quantity index of total human capital minus the population growth rate. A Divisia per capita quantity index is typically referred to as a quality index in the literature (Jorgenson, Gollop and Fraumeni, 1987; Jorgenson, Ho, and Stiroh, 2005).

The above equation (10) can be modified to get the annual Divisia quality index of human capital based on the annual growth rate as below,

$$\ln AQ_{t/t-1} = \sum_s\sum_a\sum_e\sum_r \overline{v}_{s,a,e,r,t} \cdot \left(\ln l_{s,a,e,r,t} - \ln l_{s,a,e,r,t-1}\right) - (\ln \sum_s\sum_a\sum_e\sum_r l_{s,a,e,r,t} - \ln \sum_s\sum_a\sum_e\sum_r l_{s,a,e,r,t-1}) , \quad (11)$$

where the summation goes through all sub-categories of individual characteristics, rural-urban location (r), education (e), age (a), and gender (s), and the weights are defined as

$$\overline{v}_{s,a,e,r,t} = \frac{1}{2}(v_{s,a,e,r,t} + v_{s,a,e,r,t-1}) , \text{ and } v_{s,a,e,r,t} = \frac{mi_{s,a,e,r,t} \cdot l_{s,a,e,r,t}}{\sum_s\sum_a\sum_e\sum_r mi_{s,a,e,r,t} \cdot l_{s,a,e,r,t}} .$$

Additionally, following Chinloy (1980); Jorgenson, Gollop and Fraumeni (1987); Jorgenson, Ho and Stiroh (2005), we can use partial Divisia quantity indices to identify the contribution of each human capital characteristic after excluding the (un-weighted) population growth.[34] More specifically, in the J-F framework, we can establish four first order partial human capital indices based on the four human capital characteristic categories: education (e), age (a), gender (s) and location (r).

For example, according to the equation (11), the first order Divisia quality decomposition based on education (e) can be written as,

$$\ln AQ^e_{t/t-1} = \sum_e \overline{v}_e \cdot (\ln \sum_s\sum_a\sum_r l_{s,a,e,r,t} - \ln \sum_s\sum_a\sum_r l_{s,a,e,r,t-1}) - (\ln \sum_s\sum_a\sum_e\sum_r l_{s,a,e,r,t} - \ln \sum_s\sum_a\sum_e\sum_r l_{s,a,e,r,t-1}) , \quad (12)$$

[34] The quality component is frequently called the composition effect by other authors.

where $\bar{v}_e = \frac{1}{2}(v_{e,t} + v_{e,t-1})$, and $v_{e,t} = \frac{\sum_s \sum_a \sum_r mi_{s,a,e,r,t} \cdot l_{s,a,e,r,t}}{\sum_s \sum_a \sum_e \sum_r mi_{s,a,e,r,t} \cdot l_{s,a,e,r,t}}$, and *e* refers to six education levels in China, i.e., below elementary, elementary, middle school, high school, 3-year college and 4-year university. The quality index defined in equation (12) represents the contribution of education to human capital quality growth. The contribution of other factors can be defined similarly.

The partial Divisia quality indices can be computed by a single characteristic or multiple characteristics. There exists four first order indices (age, education, gender, and location), six second order indices, four third order indices, and one fourth order index, based on various combinations of the characteristics. The partial Divisia quality growth rates of human capital are the partial Divisia quantity growth rates of human capital deducted by lower order partial Divisia quantity indices that share all the sub-categories of the higher order growth rate. With this deduction, the joint effects of characteristics in the higher order indices can be identified. For example, the partial Divisia growth rate for human capital per capita, due to the joint effects of age and education, is defined below,

$$d \ln AQ_t^{e,a} = d \ln Q_t^{e,a} - d \ln L_t - d \ln AQ_t^{e} - d \ln AQ_t^{a}, \qquad (13)$$

It reflects the joint contributions of age and education on the growth of human capital per capita. The third order and the fourth order partial Divisia growth rates can be defined accordingly.

2. Regional Divisia quantity and quality growth index in China

As discussed above, the Divisia quantity growth rate of total human capital (HC, for all non-retired population including students and children) can be decomposed into two parts: per capita human capital (PCHC) Divisia quality growth and population growth. Figure 8 presents the cumulative quantity index for total human capital. For all regions, except for the northeast, the total human capital quantity increases, but the speed is much slower than total human capital as in Figure 2. Moreover, the regional gaps among the east, interior and west are much smaller. More specifically, the total human capital increased at an annual rate above 7% for the 1995-2014 period for all regions, but the quantity index, measured by the population composition change weighted by the relative human capital shares, increased only at a rate below 2%. Therefore, the price effect on total human capital growth appears to be much larger than the quantity effect. Moreover, it seems that the price effect drives most of the regional inequality, as can be seen by comparing Figure 2 (total HC) and Figure 8 (the cumulative quantity index).

After removing the population growth from the human capital quantity index, we can get the quality index, a measure of growth in per capita human capital. The regional pattern on the quality index is similar to the quantity index. The quality in northeast region declines, while in all other three regions goes up, with west region rising the fastest.

As shown in Table 5 and Figures 9 and 10, there is a striking difference between the two periods. For the first period of 1985-94, the growth for the quantity of total human capital is mostly driven by population growth for all regions. However, for the second period of 1995-2014, the fastest growth for the interior and west regions came from human capital quality (i.e., per capita human capital growth). The east region is the only one maintaining a relatively high population growth of 1.17% in the second period, while other regions experienced negligible or even negative population growth. In the northeast region, the population declines in the 1995-2014 period; and moreover, its human capital quality declined in both periods. The northeast region is the traditional manufacturing base for China, but has been stagnant in growth. The interior region and west region experienced large quality growth from the first period to the second period, and human capital quality grew the fastest in the west region.

The labor force human capital quantity and quality growth follows a generally similar pattern to the total human capital. However, a very interesting difference is that human capital quality growth is higher than labor force human capital quality growth in the second period, except for in the northeast region. For example, labor force human capital quality rises at an annual rate of 0.58% for the interior region and 0.65% for the west region, but the numbers for total human capital quality growth are 1.38% and 1.52%, respectively, more than doubled.

For regional trends, during 1985-94, the west had a higher quantity growth for both total human capital and labor force human capital. Yet, for the period of 1995-2014, the advantage moves to the east region, mostly because the population and labor force grew much faster in the east region. However, the west and interior regions experienced much higher quality growth in human capital. If the inflow of migrants to the east gradually slows down and if human capital quality continues to grow at a higher rate in the west and interior regions, the regional gap between the east and west/interior will become smaller. However, the northeast region continues to fall behind with negative growth in population and human capital quality.

3. The contribution of education to human capital growth

The relatively faster increase of the quality indices in the west and interior regions is probably caused by improvement in education and population structure. The factor contribution to quality growth can be more clearly seen in the first order Divisia quality decomposition. Table 6 and Figures 11 and 12 show the regional partial first order Divisia indices for human capital per capita, i.e., the independent contributions of urbanization (i.e., the relative size of population in rural and urban), education, age, and gender composition to human capital growth.

As seen in Figure 13 and 14, in both periods, education makes the largest contribution to labor force human capital quality growth. The regional differences are not large except with the northeast region. In fact, the education contribution in the northeast region is the smallest (around 1.0-1.2%), but for all other regions, education contributes to an annual growth of LFHC quality in the range of 1.7-1.8%. Interestingly, education makes a much smaller contribution to total human capital quality growth. The west region has the highest contribution, but the rate is still below 0.5%.

The main reason for the difference is probably the dramatic increase in education levels in China during the past 30 years, especially in the higher education system.[35] For example, from 1985 to 2014, new college enrollments increased from 1.45 million to 10.49 million, and the total enrollment for 3-year college and 4-year universities increased from 3.52 million to 33.86 million.[36] The expansion of education has significantly improved the education structure of the labor force, and much more so than for the population as a whole. As a result, the average years of education of the labor force increased from 6.21 to 9.82 (Table 2). While the education attainment for children (0-15 years old) also increased, the extent is not as large, from 4.72 to 6.79. The overall improvement in education, especially the expansion of education at high school and higher education, as well as expanded lifelong learning opportunities, directly affects the education of labor force, and thus is the driving force for labor force quality. Therefore, the contribution of education to the quality of labor force human capital is significantly larger.

As for the regional pattern, for the period of 1995-2014, education contribution is similar for the west, interior, and east regions, the smallest contribution of education is clearly in the northeast region. The west and interior region traditionally have much lower educational

[35] Based on Li and Liu (2014), from 1999 to 2004, the average annual growth in new enrollments of undergraduate students was 29.0%, and for graduate students was 27.8%. In 2010, the number of undergraduate students who completed their degree was nearly 5.8 million, which almost equaled to the total number of undergraduate students graduated in the fifteen years from 1978 to 1992.

[36] Both the new college enrollments and total enrollments include adult education. Data are from *China Educational Yearbook* 2014 and statistic on Ministry of Education website: http://www.moe.gov.cn/s78/A03/moe_560/jytjsj_2014/2014_qg/201509/t20150902_205106.html.

attainments, while the northeast region has the highest education level. As a result, education increases slower in the northeast region, and has a smaller effect on human capital growth. For example, the average years of schooling of the labor force increased 69% in the west but only 36% in the northeast from 1985 to 2014.

The education effect on the labor force human capital quality is quite consistent across the two periods. Moreover, the effect on total human capital increased in the second period, even for the northeast region, where the education contribution was negative in the first period. Those results indicate that education has a sustainable impact on human capital quality growth.

Additionally, although the east region receives large inflow of migrants from other regions, i.e., it experienced high growth of both the non-retired population and labor force. The effect of education for its total human capital is still very small. It is likely that the young migrants (not in the labor force yet) from other regions generally have relatively lower education levels and thus are slowing down the growth of education attainment for the east.

4. The contribution of urbanization to human capital growth

In our calculation, human capital is separated between urban and rural areas in China. In general, human capital per capita is higher in urban areas due to its higher expected lifetime income (i.e., the higher realization of human capital value). In China, there has been large scale rural to urban migration since the start of economic reform. Additionally, as the economy continues to grow, a large part of rural areas have and will become urban. The rapid urbanization process has been one of the main features of the Chinese economy. In 2009, for the first time, the size of the urban population surpassed that of rural areas. At the national level, the percentage of the urban population increased from 22.77% in 1985 to 55.95% in 2014.

At the regional level, the northeast had the highest degree of urbanization before 2005. After that, the east region became the most urbanized, with 66% of the non-retired population in urban areas in 2014, followed by 60% for the northeast region. The interior and west regions fell much behind. In 1985, they had only around 18% of non-retired population in urban areas, and the percentage was still below 50% in 2014.

As a result, over the entire period, urbanization has made the largest contribution to quality growth of total human capital and the second largest contribution to labor force human capital, as shown in Figures 11, 12 and 13, 14. More specifically, the urbanization effect is the largest on total human capital for the west region, with an annual contribution rate of 1.51% to the total human capital quality growth, and the smallest for the northeast region (0.41%) for the entire period of 1985-2014. The northeast historically has had a much higher degree of urbanization, and thus experienced slow increase in urbanization. From 1985 to 2014, the urban percentage of non-retired population increased from 44% to 60% for northeast, and from 18% to 49% for the west region. Moreover, the contribution of urbanization is larger in the second period for every region, probably due to the accelerating urbanization process in China.

It is interesting to note that education has the largest effect on labor force human capital quality while urbanization has the largest impact on the total human capital. This is probably because urbanization brings a large number of relatively young but less educated people into the urban areas, and thus it greatly increases the total human capital due to young age (especially children), but with moderate effect on labor force human capital (due to relatively low education levels). Urbanization creates a much better expected opportunity in education and employment for rural children, and thus affects the human capital reserve significantly.

The joint effect of education and urbanization on human capital can be seen more clearly via the second order quality Divisia indices reported in Table 7 and Figures 15 to 18. The joint contributions of urbanization and education to the growth of the quality index of both total human capital and labor force human capital are negative in all regions. As discussed above, during the urbanization process, a large number of low-educated people became urban residents, and thus they exerted negative influences on human capital growth. The results show that such an effect is stronger for labor force human capital, consistent with other results discussed above.

5. The effect of population aging and gender composition on human capital growth

The contribution of age structure to the quality index of both total human capital and labor force human capital is negative for every region, with the largest effect in the northeast region. This result reflects the impact of population aging in China. In the northeast, in 2014, the population is the oldest with the average age of 38.9 years for the labor force, while in other regions it is around 36.6 years.

For all regions, the negative effect of age structure on labor force became stronger in the second period. Therefore, it appears that rapid population aging has been generating an accelerating effect in hindering the rise of labor force human capital quality.

The contribution of gender composition is very small and negligible. It appears that the changes in gender structure related to human capital have not caused major changes in human capital quality in China. For example, the bias in gender ratio caused by the One-child policy does not show an impact on human capital.

Education and age jointly contribute positively to the growth of total human capital quality (Figure 15 and 16), mainly because the young population receives much better education. However, their joint contribution to labor force human capital is negative for all regions.

Although labor force education is improving, the rapid aging of labor force seems to dominate the overall effect. Another reason is that the labor force has excluded students, but the total number of students increased significantly from 16.47 million to 75.56 million during 1985-2014. The large student body increases the total human capital, but not the labor force.

Urbanization and age jointly have a compound effect on human capital growth, through the channel of the younger rural population migrating to the urban area. Unlike other joint effects, urbanization and age have a mostly positive effect in the first period and a mostly negative effect in the second period. It is possible that in the earlier years, rural to urban migrants were very young and significantly improved the age structure in the urban areas, and thus promoted human capital growth. However, in the second period, due to overall population aging, the age structure of newly urbanized areas may not be better, which results in negative effects.

Among all regions, the northeast region was affected most negatively by the urbanization/age effect, which contributed -2.4% to the quality growth of total human capital and -1.5% to labor force human capital in the second period. From 1995 to 2014, for the northeast region, the total non-retired population declined at an annual rate of approximately 0.2%, but labor force grew at an annual rate around 0.4%. Thus, the size of the children population decreased rapidly there. It is possible that the younger population moved out of the northeast region and then older people within the region moved from rural to the urban areas, thus resulting in the negative joint effect of urbanization and age.

VII. Conclusions

While most studies use GDP, income, or consumption to measure and study the regional differences, in this study, we investigate the regional disparity in human capital in China. In particular, we construct a comprehensive measure of human capital based on Jorgenson-Fraumeni framework after modifying it to fit Chinese data. Our measurement of human capital goes beyond the traditionally education-based partial measure, by incorporating many other aspects of human capital accumulation. For comparison, we also calculated the traditional human capital measures.

We calculated total human capital and labor force human capital based on the J-F framework separately for urban and rural areas for each province in China from 1985 to 2014, adjusted to make them comparable across time and locations. Those two human capital measures can generate a rich set of various human capital indicators via combinations with other provincial variables on the economy and labor market. As a result, we produce a provincial level panel dataset of human capital measures. The human capital panel dataset, appended with provincial physical capital, living cost index, GDP and other population measures, can be used widely in various researches.

Moreover, we investigated the regional distribution of human capital in China, and discussed the regional patterns and trends of aggregate human capital stocks, per capita values, and the comparisons with other economic variables. Given the importance of human capital on economic development and inequality, a complete map of regional human capital distribution together with its trends in China would have important implications in further research and policy studies. Finally, in order to have a better understanding of the causes for human capital growth, we conducted a detailed analysis based on Divisia decompositions.

There are many interesting results from this study. First, in China, human capital growth shows a very different structural pattern, growing very slowly between 1985-1994 and then much faster after 1995, for all regions. However, human capital growth has been slower than

GDP and much slower than physical capital. Human capital in the east region increased the fastest; and the human capital gap between the east and other regions is enlarging.

In per capita measures, regional disparity in human capital is substantial, especially between the east and west regions, followed by the interior and northeast regions. By 2014, per capita human capital and per capita labor force human capital in the west region is approximately one half of that in the east region. Moreover, in 2014 the expected human capital for labor market new entrants and for newborn in the west is merely 46% and 30% of that in the east region, respectively.

The Divisia quantity index growth, measured by the weighted quantity change of the population composition (or labor force), is mostly driven by population (or labor force) growth in the 1985-1994 period, but human capital quality increase plays a major role in the 1995-2014 period. While the east region continues to enjoy the high growth in population and labor force, the west and interior region have much higher quality growth. The northeast region, on the other hand, gets worse continuously due to the decline in both population size and human capital quality.

Among factors affecting human capital, education has contributed significantly to the human capital growth, but has mostly benefited the labor force as the largest factor contribution rate among all factors studied. The most obvious regional pattern of education is that its role in the northeast is the smallest.

The large scale rural-urban migration and accompanied rapid urbanization in China significantly increased human capital. Urbanization makes the largest contribution to quality growth of total human capital and the second largest contribution to labor force human capital (after education). The effect is the largest in the west region, and again the smallest for the northeast region.

The contribution of age structure to the quality growth of both total human capital and labor force human capital is negative for every region, with the largest effect in the northeast region. This reflects the impact of population aging in China, and the effect became stronger in the second period. There are also interesting findings based on the joint effect of those factors on human capital growth.

Overall, the regional disparity of human capital is significant, especially between the east and other regions. Yet, the disparity based on Divisia quality measures is not as dramatic, especially between the east and interior/west regions. The Divisia decomposition results provide a relatively optimistic picture on regional disparity because education and urbanization are making the largest impact in the less developed west and interior region. Moreover, for the interior and west regions, the negative aging effect on human capital is smaller than in other regions. However, the northeast region appears to be falling behind. For both total human capital and labor force human capital, urbanization and education contribute to the quality growth in the northeast region the least compared to other regions, and population aging reduces its human capital quantity growth more than in other regions.

It is fairly clear from our results that population aging is hindering human capital growth. From this perspective, the new "Two-child" policy should be able to help offset such a trend.[37] Moreover, given the smaller effect of education on overall human capital than on labor force human capital, if education expands more at the lower level schools by implementing 12-year compulsory education as an example, it will speed up the growth of human capital reserve and

[37] The "Two-child" policy was implemented in China in 2016 to allow a couple to have a second baby, as a proactive response to the aging population.

total human capital. Additionally, given the slower growth of human capital compared to physical capital, it would be helpful to move some resources from physical capital investment to human capital. Such a shift is also consistent with China's move into a more innovative economy.

At the regional level, education investment and the urbanization process have enhanced human capital intensity in the interior and especially west regions at a pace faster than in other regions, and thus can help gradually reduce their gaps with the east. The question is to what extent urbanization can go further, given that more than half of the country has already been urbanized. It is likely that education will eventually play a leading role in the quality improvement of regional human capital. On the other hand, the northeast region appears to be in a trouble stage, based on various human capital measures and trends. Some creative policies are needed to speed up the growth in this region. The recent initiative of reinvention for the northeast region from the Chinese government seems to be a right move.

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Table 1 Descriptive Statistics for the J-F Based Human Capital Measures

(annual mean value based on the province panel data)

Year	Total Human Capital (HC) (Billion RMB)	Labor Force Human Capital (LFHC) (Billion RMB)	Per Capita Human Capital (PCHC) (Thousand RMB)	Per Capita Labor Force Human Capital (PCLF) (Thousand RMB)	Total Physical Capital (Billion RMB)
1985	1,681	687	56	38	44
1990	2,104	924	66	44	73
1995	2,080	883	62	40	132
2000	3,429	1,435	99	60	237
2005	5,664	2,146	166	88	453
2010	8,684	3,508	249	136	988
2014	11,004	4,185	307	162	1,707

Notes:

1. All average measurements are simple averages, i.e., the sum of all provinces divided by the number of provinces.
2. The table is based on the panel data for the 30 provinces every year from 1985 to 2014. We only show numbers for every five years.
3. All the measurements are in real values with 1985 as the base year.

Table 2 Descriptive Statistics for Traditional Human Capital Measures

(annual mean value based on the province panel data)

Year	Proportion of labor force with high school or above (%)	Proportion of labor force with college or above (%)	Average years of education of the labor force	Average age of the labor force
1985	12.90	1.52	6.21	32.29
1990	15.94	2.57	7.15	32.26
1995	17.89	3.91	7.70	33.72
2000	21.13	5.44	8.40	34.62
2005	23.35	7.97	8.70	36.53
2010	28.90	11.86	9.49	36.38
2014	32.45	14.60	9.82	37.00

Notes:

1. All average measurements are simple averages, i.e., the sum of all provinces divided by the number of provinces.
2. The table is based on the panel data for the 30 provinces every year from 1985 to 2014. We only show numbers for every five years.

Table 3 Regional Comparison of Human Capital, Physical Capital and GDP

(in thousand Chinese RMB)

	Year	East	Northeast	Interior	West
Per Capita Human Capital	1985	67.56	55.77	47.59	42.91
	1995	76.43	60.14	52.32	46.95
	2005	205.02	142.86	135.76	115.75
	2014	386.05	258.13	262.36	194.45
Per Capita Human Capital for Age 0	1985	132.92	105.48	82.49	70.97
	1995	171.49	123.27	98.82	84.63
	2005	657.12	383.79	316.31	255.22
	2014	1218.31	714.84	544.28	369.28
Per Capita Human Capital for Age 16	1985	85.17	68.01	56.16	52.50
	1995	111.27	85.78	71.79	67.02
	2005	367.62	266.54	219.73	197.26
	2014	709.87	528.82	428.85	324.46
Per Capita Labor Force Human Capital	1985	46.03	38.52	32.48	30.60
	1995	47.97	40.98	34.15	31.85
	2005	110.39	83.78	74.15	63.37
	2014	207.28	144.67	140.98	110.33
Per Capita GDP	1985	1.22	1.26	0.73	0.63
	1995	3.63	2.62	1.58	1.38
	2005	9.98	6.70	4.17	3.73
	2014	22.77	18.86	11.97	11.00
Per Capita Physical Capital	1985	1.64	1.98	1.10	1.26
	1995	5.82	4.50	2.38	2.55
	2005	20.02	11.06	7.33	8.17
	2014	60.16	49.78	32.14	35.38

Table 4 Average Annual Growth Rates (%)

	Period	East	Northeast	Interior	West
Human Capital	1985-94	3.35	2.27	3.17	3.27
	95-2014	9.20	7.17	8.14	7.01
Per Capita Human Capital	1985-94	2.12	1.51	1.90	2.05
	95-2014	7.92	7.37	8.16	7.01
Labor Force Human Capital	1985-94	3.14	3.66	4.03	4.58
	95-2014	8.86	6.70	7.24	6.23
Per Capita Labor Force Human Capital	1985-94	1.35	1.45	1.48	1.60
	95-2014	7.04	6.30	7.08	6.00
Per capita GDP	1985-94	11.68	7.57	7.67	8.00
	95-2014	10.33	10.83	11.29	11.29
Per capita Physical Capital	1985-94	13.68	8.57	7.76	6.75
	95-2014	13.42	13.28	14.26	14.05
Total GDP	1985-94	12.99	8.36	8.99	9.29
	95-2014	11.61	10.61	11.25	11.28
Physical Capital	1985-94	15.01	9.38	9.09	8.02
	95-2014	14.74	13.04	14.21	14.05

Note: In west region, the average growth rate for per capita physical capital is 14.05091%, and for physical capital is 14.04537%, very close to each other.

Table 5 Divisia Decomposition of Human Capital and Labor Force Human Capital Growth (%)

		Total Human Capital		Labor Force Human Capital	
Region	Average Growth Rates	1985-1994	1995-2014	1985-1994	1995-2014
East	Divisia quantity growth	1.567	1.995	1.747	2.205
	Divisia quality growth	0.379	0.831	0.017	0.571
	Population growth	1.188	1.164	1.730	1.634
Northeast	Divisia quantity growth	0.073	-0.625	1.737	-0.207
	Divisia quality growth	-0.668	-0.429	-0.409	-0.564
	Population growth	0.741	-0.196	2.146	0.358
Interior	Divisia quantity growth	1.380	1.344	2.678	0.708
	Divisia quality growth	0.147	1.375	0.223	0.578
	Population growth	1.233	-0.032	2.455	0.130
West	Divisia quantity growth	1.766	1.521	3.501	0.854
	Divisia quality growth	0.578	1.516	0.656	0.645
	Population growth	1.188	0.005	2.845	0.209

Note: Total human capital Divisia quantity growth can be decomposed into two parts: per capita human capital Divisia quantity growth (i.e., human capital Divisia quality growth) and total population growth. It also applies to labor force human capital.

Table 6 First Order Divisia Indices for Quality Decomposition (%)

		Per Capita Human Capital		Per Capita Labor Force Human Capital	
Region	Factor Contributions	1985-1994	1995-2014	1985-1994	1995-2014
East	Urbanization	0.772	1.338	0.527	0.867
	Education	-0.183	0.230	1.648	1.777
	Age	-0.686	-0.948	-0.768	-0.946
	Gender	-0.014	0.018	-0.026	0.038
Northeast	Urbanization	0.321	0.450	0.169	0.225
	Education	-0.234	0.131	1.021	1.220
	Age	-1.116	-1.346	-0.692	-1.365
	Gender	0.006	0.023	0.032	0.050
Interior	Urbanization	0.657	1.649	0.435	0.965
	Education	0.102	0.242	1.800	1.795
	Age	-0.754	-0.619	-0.471	-0.849
	Gender	-0.005	-0.003	-0.023	-0.004
West	Urbanization	1.065	1.713	0.697	1.045
	Education	0.366	0.477	1.648	1.814
	Age	-0.705	-0.544	-0.175	-0.878
	Gender	0.002	0.010	-0.010	0.016

Table 7   Second Order Divisia Indices for Quality Decomposition (%)

		Per Capita Human Capital		Per Capita Labor Force Human Capital	
Region	Factor Joint Contributions	1985-1994	1995-2014	1985-1994	1995-2014
East	Urbanization & Education	-0.145	-0.272	-0.297	-0.542
	Education & Age	0.720	0.548	-0.801	-0.515
	Urbanization & Age	2.154	-0.915	2.066	0.225
Northeast	Urbanization & Education	-0.164	-0.287	-0.126	-0.259
	Education & Age	0.527	0.634	-0.515	-0.100
	Urbanization & Age	-0.339	-2.364	1.280	-1.496
Interior	Urbanization & Education	-0.304	-0.383	-0.291	-0.649
	Education & Age	0.527	0.650	-0.967	-0.425
	Urbanization & Age	1.541	-0.424	2.286	0.183
West	Urbanization & Education	-0.464	-0.583	-0.449	-0.797
	Education & Age	0.322	0.521	-0.893	-0.312
	Urbanization & Age	1.894	-0.820	3.476	-0.347

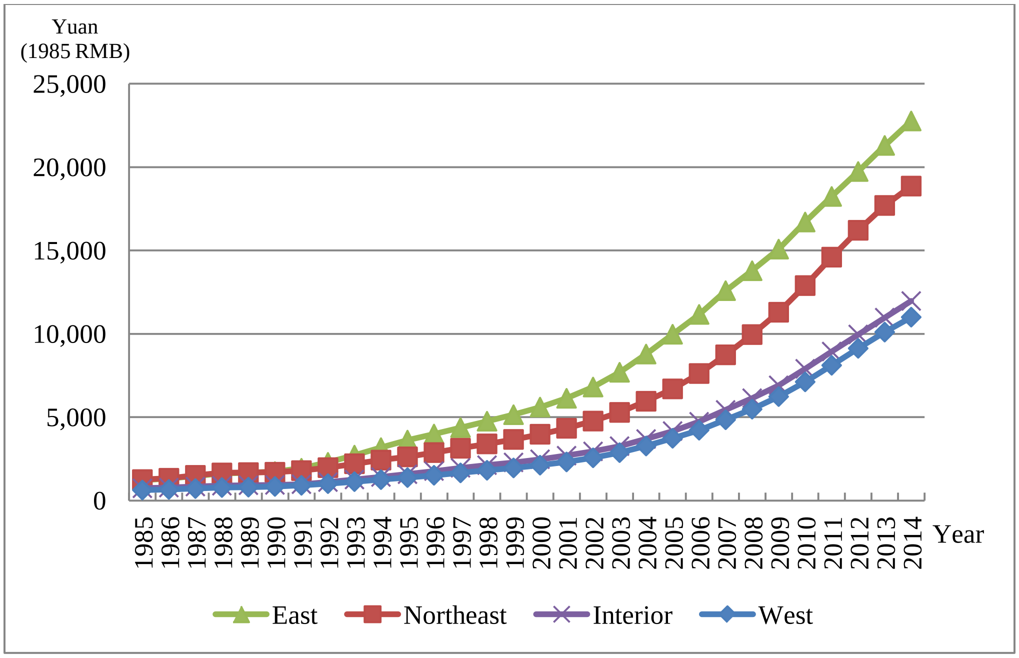

Figure 1 Per Capita GDP by Region

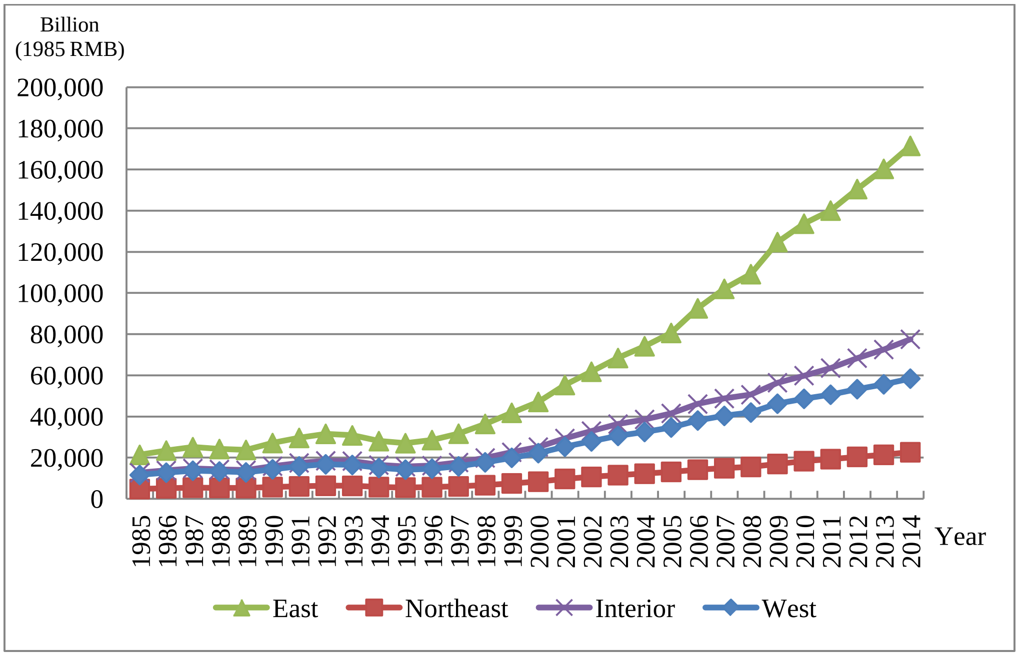

Figure 2 Total Human Capital by Region

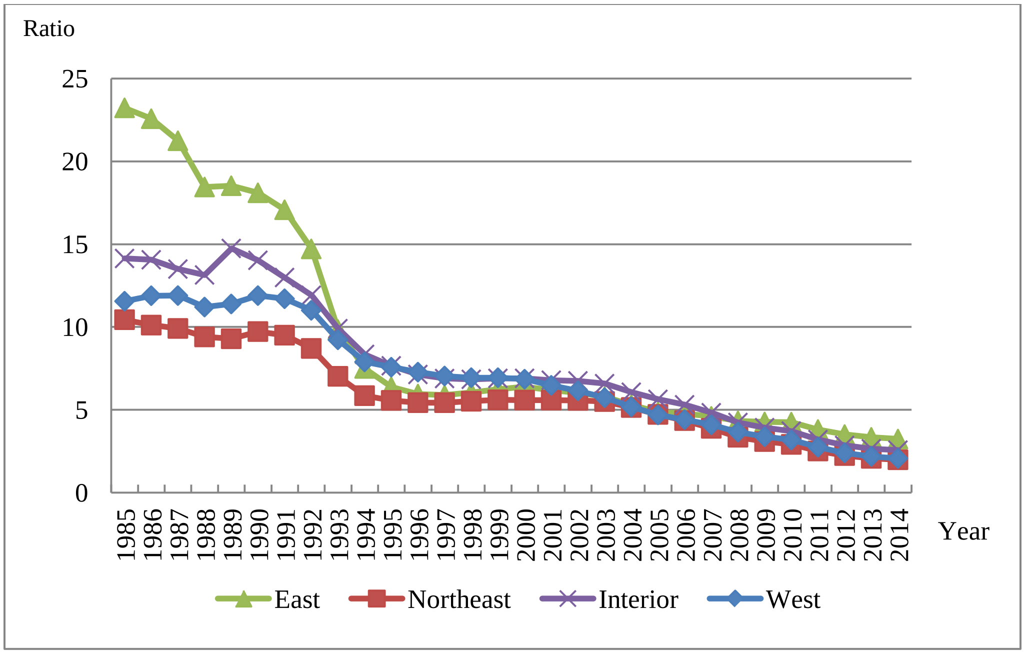

Figure 3 Ratio of LFHC to Physical Capital

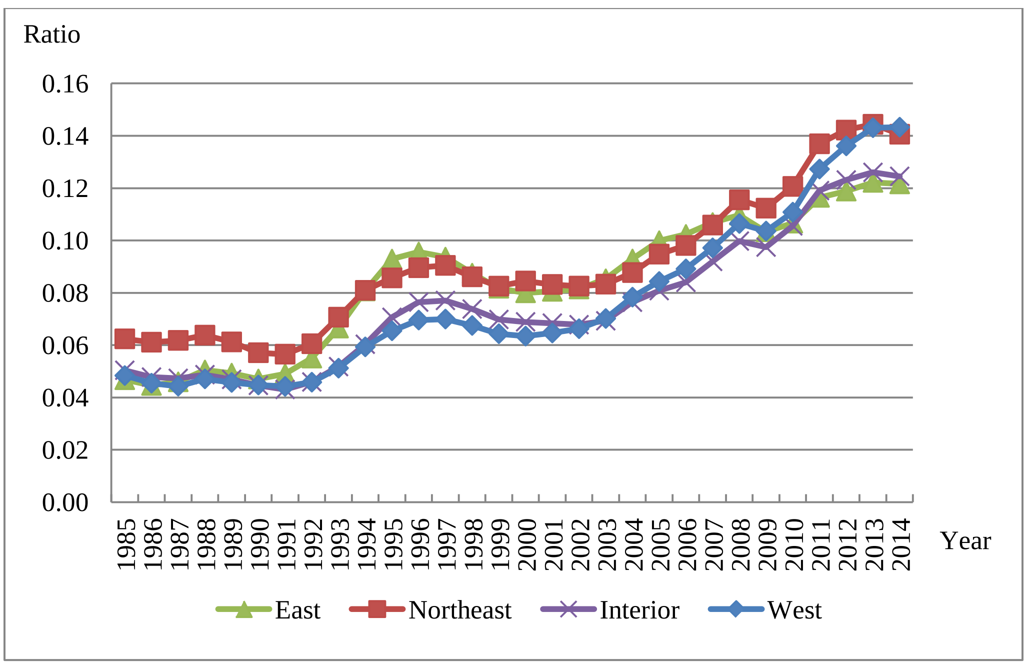

Figure 4 Ratios of GDP to LFHC

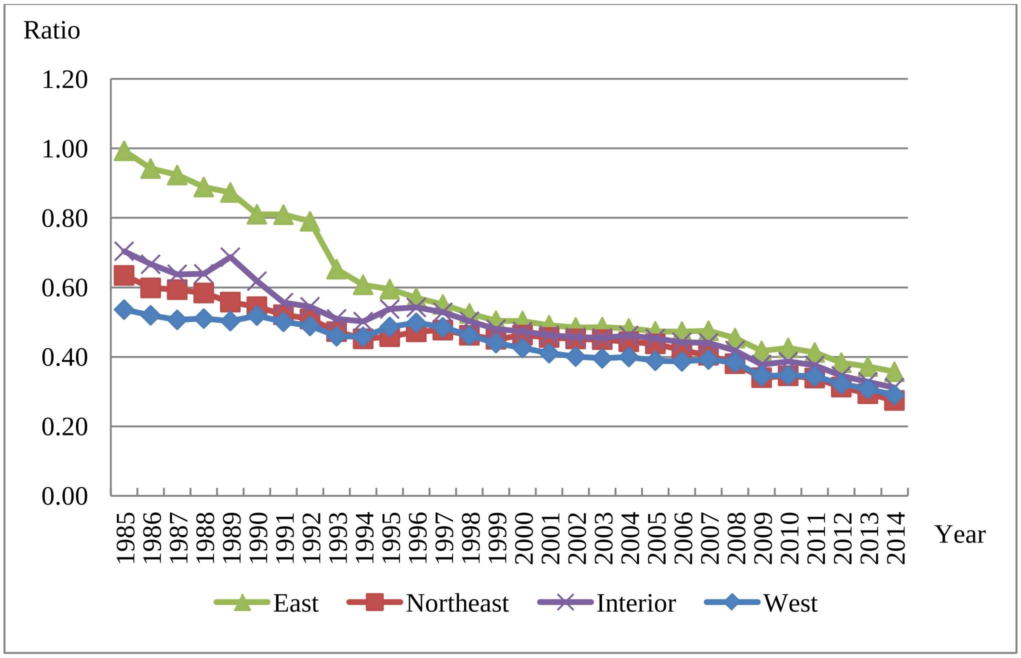

Figure 5 Ratios of GDP to Physical Capital

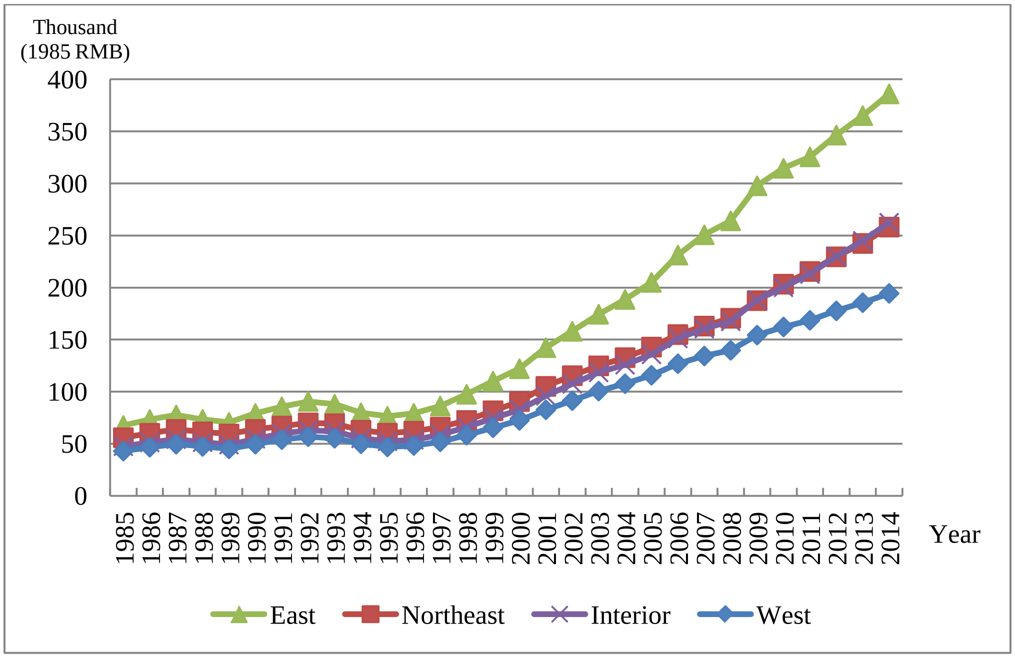

Figure 6 Per Capita Human Capital by Region

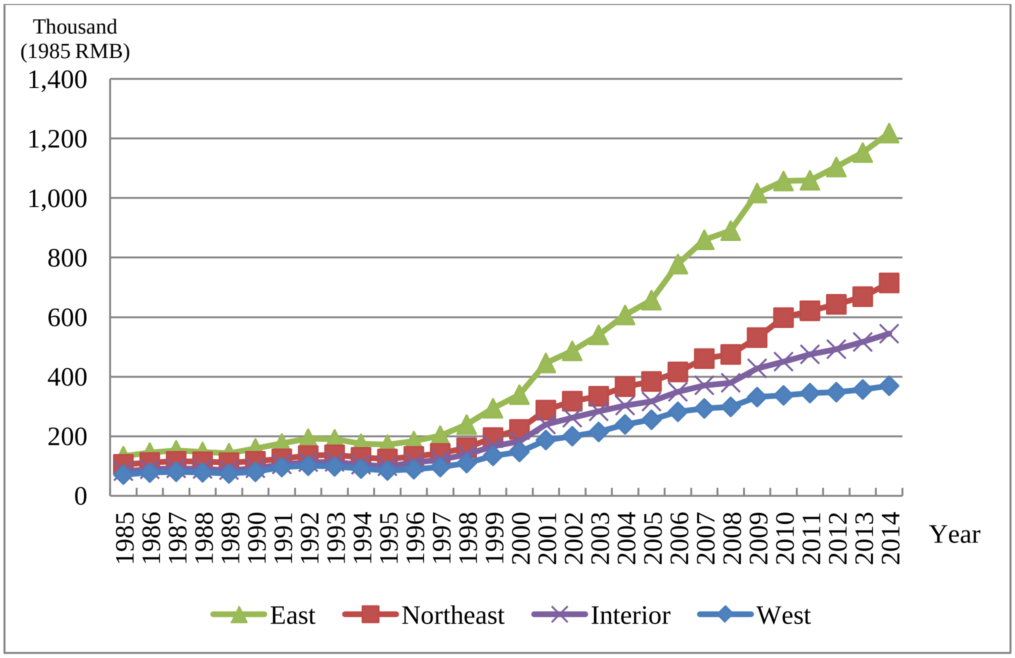

Figure 7 Expected Average Lifetime Income for A Newborn by Region

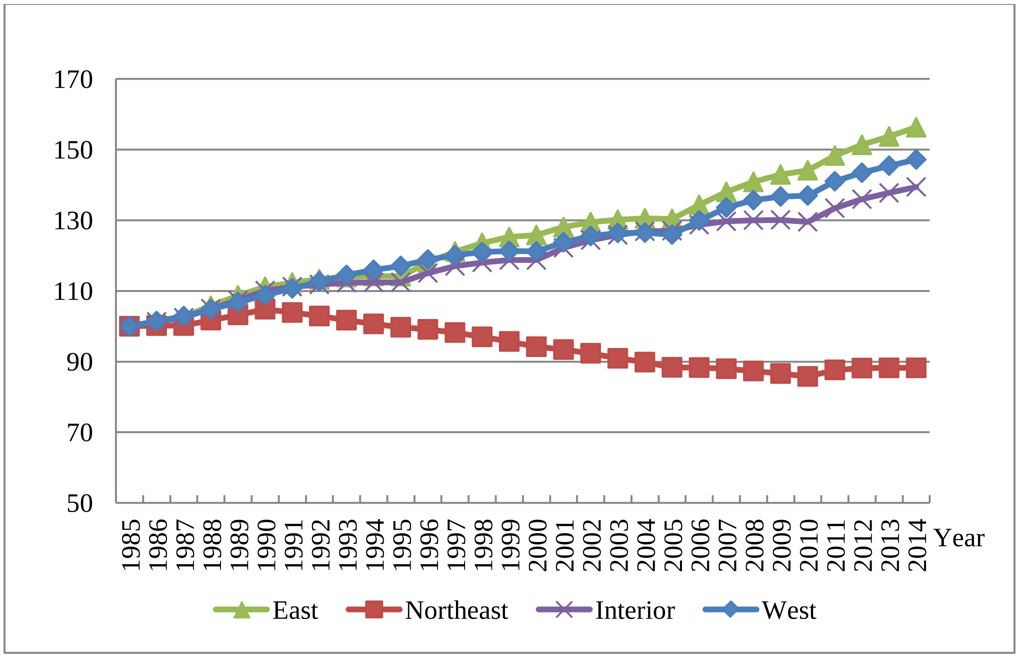

Figure 8 Cumulative Human Capital Divisia Quantity Index by Region

Note: The vertical axis is the cumulative growth rate with 1985 as 100.

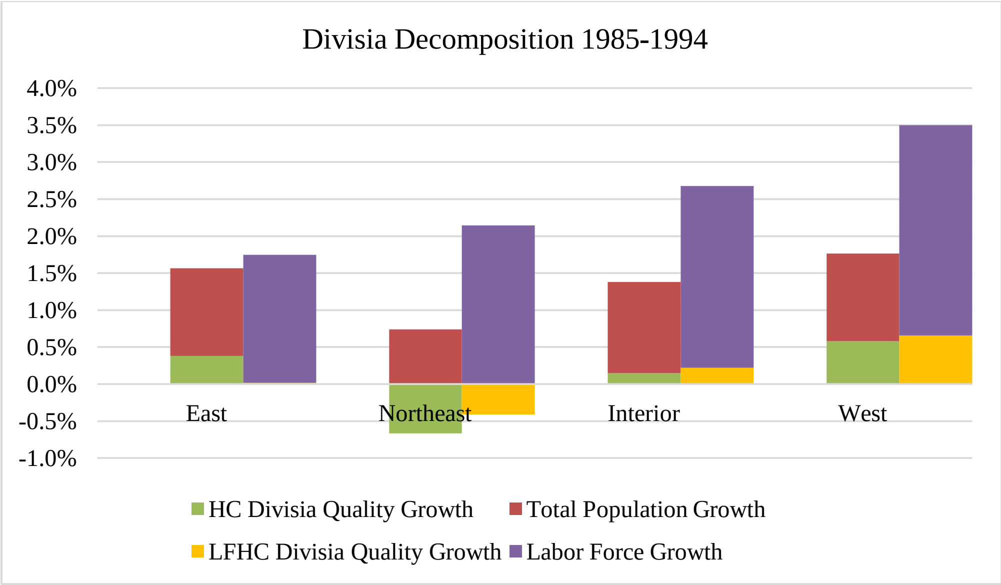

Figure 9 Divisia Decomposition 1985-1994

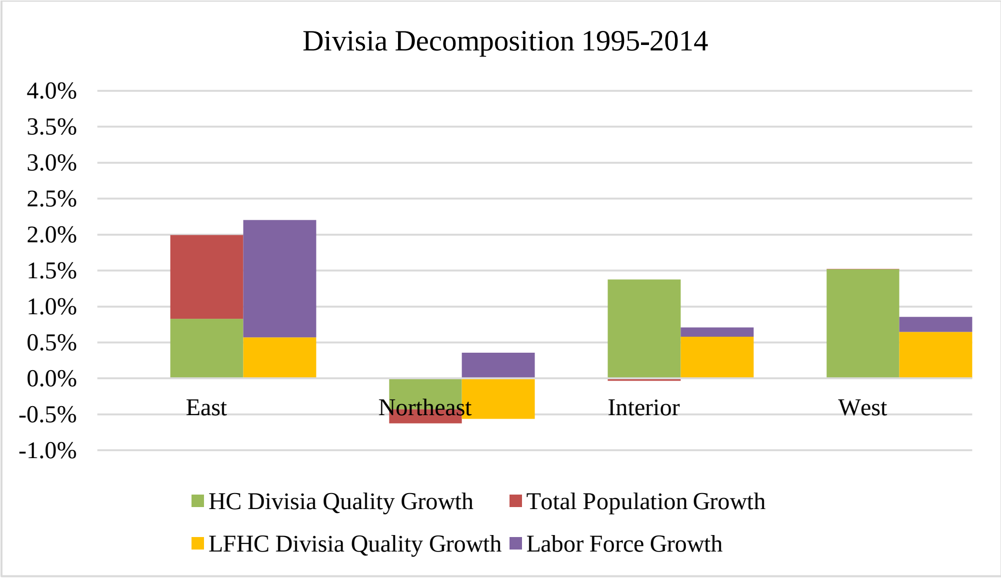

Figure 10 Divisia Decomposition 1995-2014

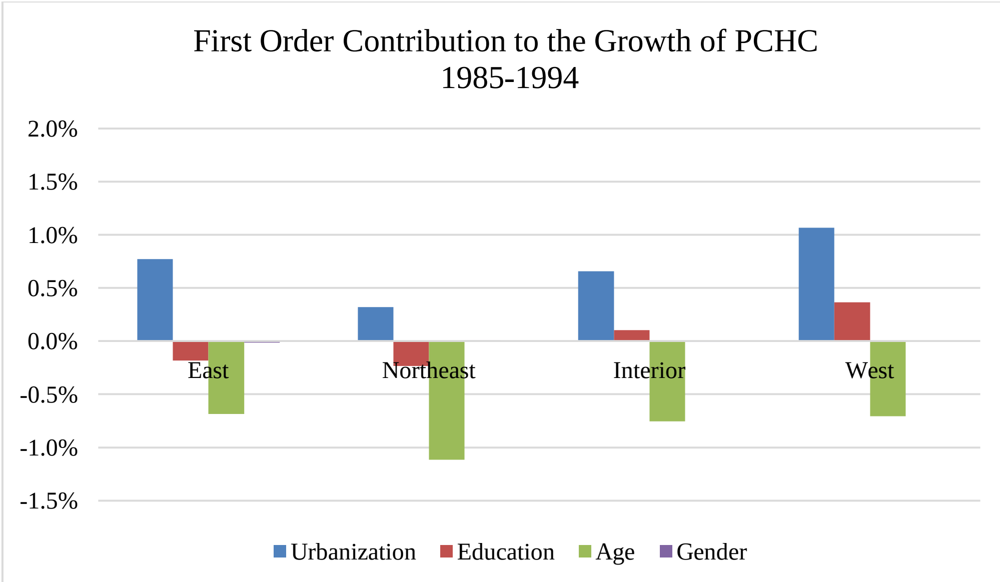

Figure 11 First Order Contribution to the Growth of PCHC 1985-1994

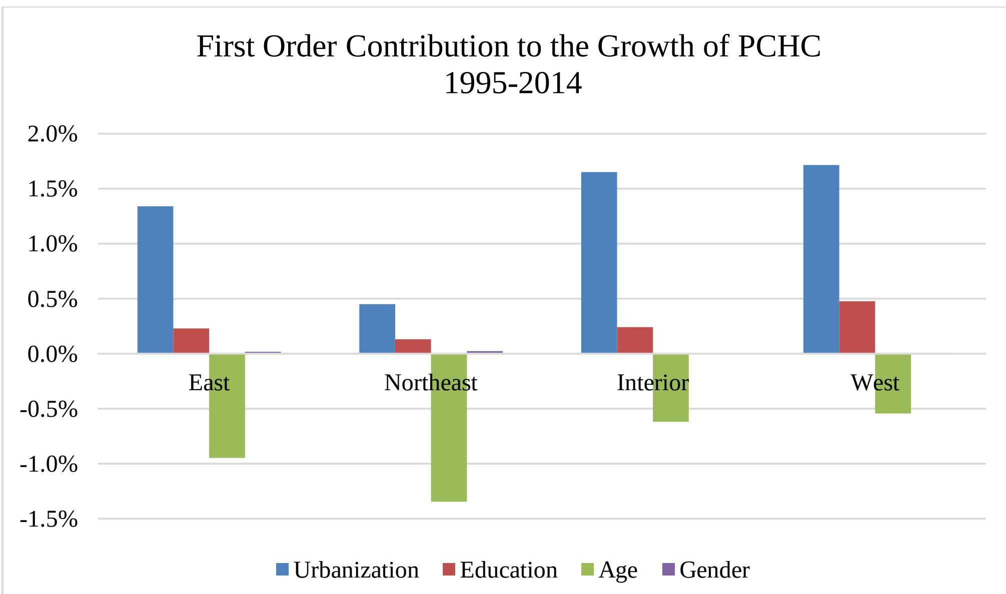

Figure 12 First Order Contribution to the Growth of PCHC 1995-2014

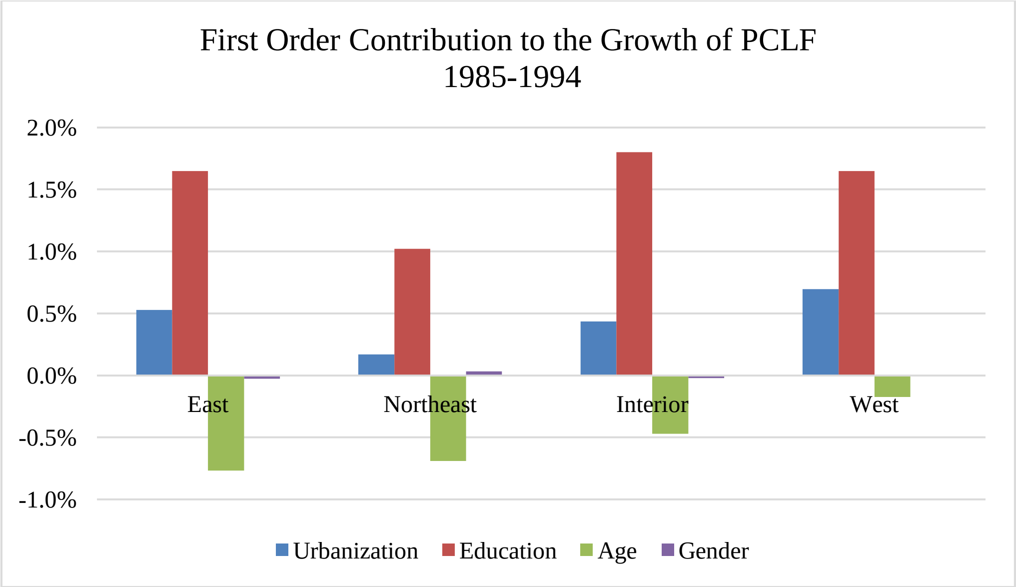

Figure 13 First Order Contribution to the Growth of PCLF 1985-1994

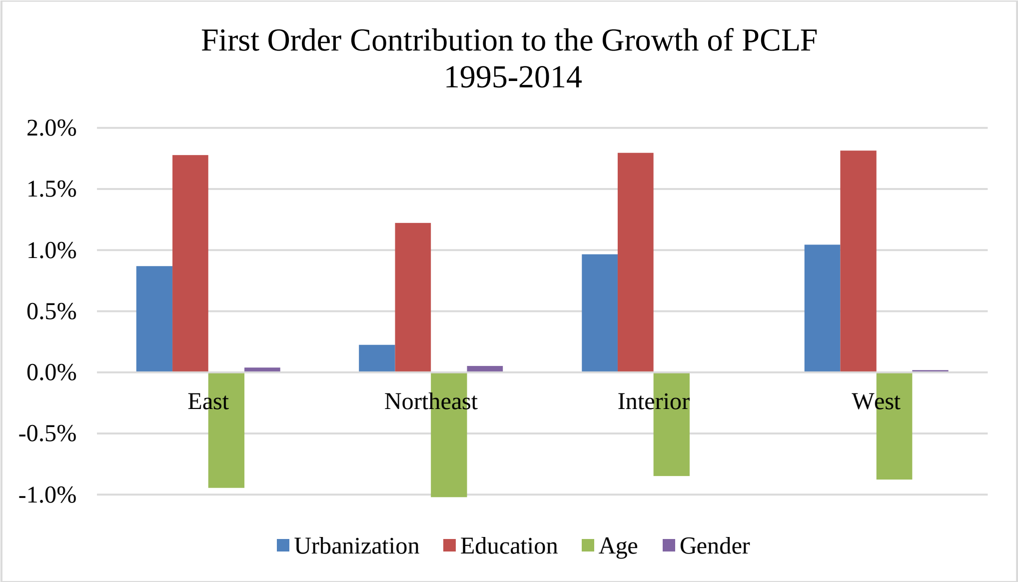

Figure 14 First Order Contribution to the Growth of PCLF 1995-2014

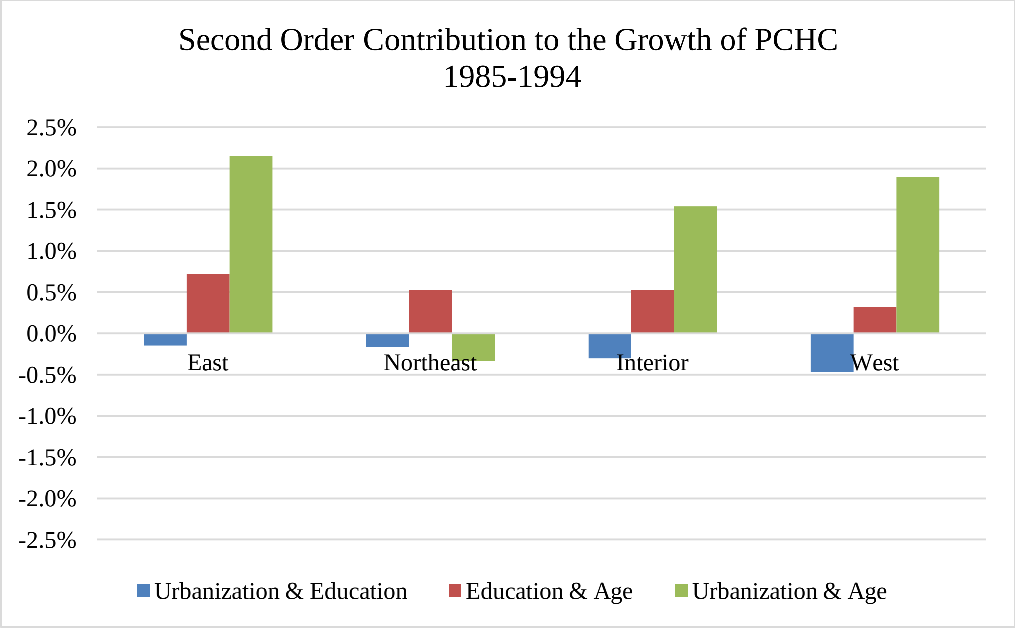

Figure 15 Second Order Contribution to the Growth of PCHC 1985-1994

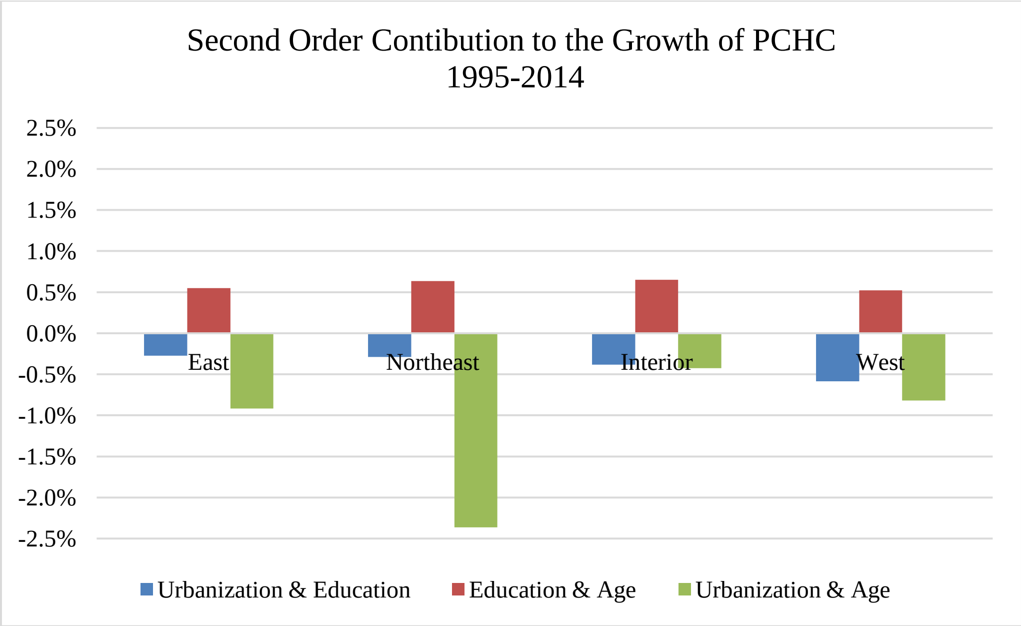

Figure 16 Second Order Contribution to the Growth of PCHC 1995-2014

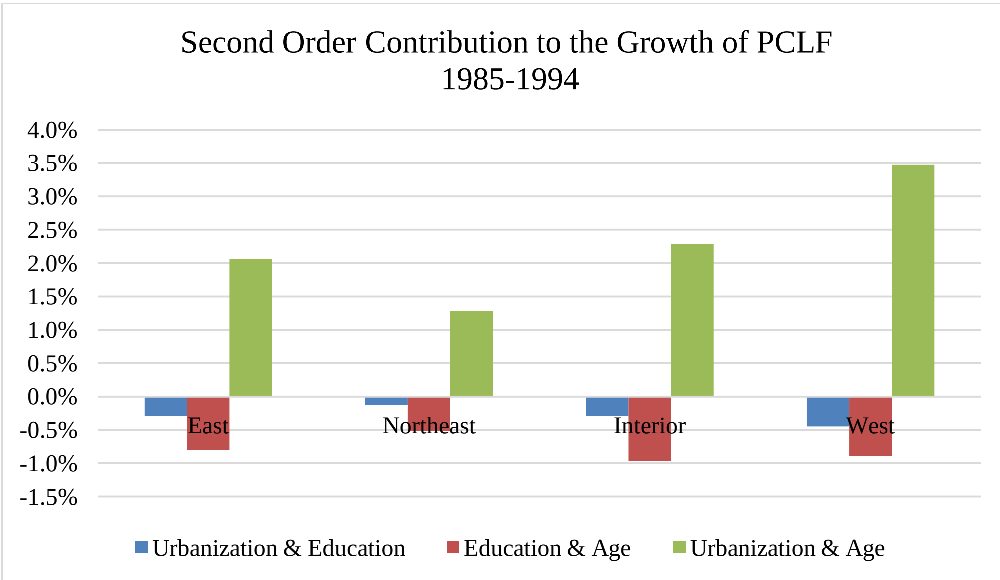

Figure 17 Second Order Contribution to the Growth of PCLF 1985-1994

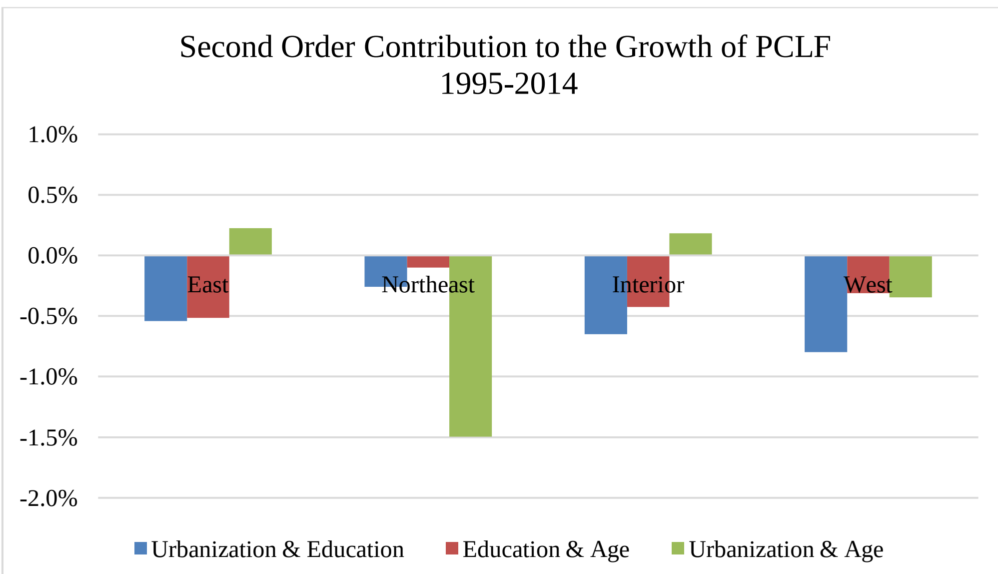

Figure 18 Second Order Contribution to the Growth of PCLF 1995-2014