Life Expectancy, Human Capital and Economic Performance

by

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Abstract

In this paper, I examine the interactive effects among life expectancy, human capital investment and economic performance in China. This topic is of great importance since China is experiencing a problem of growing income disparities across its regions. I start with a theoretical model showing that longer life expectancy will lead to more human capital investment. As human capital plays a fundamental role in determining economic growth, regions with higher life expectancy tend to have more human capital investment. Hence, these regions will end up with a better economic performance in the following years. The empirical results provide evidence for this channel. In other words, different life expectancies at the beginning of an economic boom will subsequently affect later economic growth. I also address several problems using robustness checks. This paper's content is closely related to social issues such as economic inequality and human capital investment.

Contents

In this paper, the topic I choose to study is life expectancy, human capital and economic performance. All three parameters are highly correlated with social welfare in society. However, the relationship among these three variables is not totally clear. This paper is an attempt to give us a new angle to observe relationships among these variables.

1 Introduction

I open this research with a straightforward observation: a longer time horizon induces people to invest more in human capital. This point has drawn more and more attention, especially when we are experiencing an upward trend in life expectancy. Given their expected longevity, individuals choose the optimal years of schooling in order to maximize their lifetime utility. Jayachandran et al. (2009) point out that an investment that pays out a certain amount each year is more valuable if the stream of payouts lasts longer, all else being equal.

Hazan and Zoabi (2006) indicate that conventional wisdom suggests prolonging the period (life expectancy) in which individuals may receive returns on their investment spurs investment in human capital and causes growth. In fact, the idea dates back at least as early as Ben-Porath (1967). Hazan and Zoabi (2006) also indicate that this conventional wisdom is consistent with stylized facts about longevity, education, and economic outcome, each of which has been increasing monotonically since the middle of the nineteenth century.

In recent years, there has been much micro- and macro-level research studying the relationship among life expectancy, human capital investment and economic performance. There are several reasons. One reason is that dramatic changes have occurred in human capital investment levels and life expectancy. Generally people observe that, in many countries, a higher human capital level is accompanied with longer life expectancy. More specifically, the relationship began in the last century and has continued. Another motivation for this research comes from the fact that as a result of the rapid development of medical research and the building of modern health systems, people's life expectancy is much greater than in the last century. With extended time horizons people's lifetime decisions, such as human capital investment, have changed as well (Lorentzen et al. 2008). A third motivation is to reveal the effect of longer life expectancy on economic performance; in particular, the effectiveness of global efforts at combating poor health conditions in less developed regions (Acemoglu and Johnson 2006). As an extension, the effect of how improvements in life expectancy influence investment in education might shed light on how to reduce regional inequality in modern China. A better understanding of the educational consequences of life expectancy may also influence how policy makers choose to allocate scarce health resources. Moreover, policies related to this work might have relevance to other countries, such as India (Lorentzen et al. 2008).

As life expectancy is one of the most important dimensions of human welfare, it looms large in a person's life plan. When people make a lifetime decision, how many years the decision will affect matters significantly. If this idea applies at an individual level, then it is reasonable to infer it applies in a larger context. This is the reason I want to examine the effect of life expectancy on our human capital investment decisions. In particular, I analyze a mechanism that connects life expectancy and economic performance through the accumulation of human capital.

China's dramatic economic growth since 1978, when the economic reform began, along with wide regional disparities in growth, provide an important and useful episode for analyzing the effects of life expectancy and human capital on growth. In addition, as Fleisher et al. (2010) point out, the direct and indirect effects of human capital and especially their impacts on regional inequality in China have not been fully analyzed. Hence, fully understanding the human capital problem in China will be helpful for us to explain or predict the future performance of the Chinese economy.

My analysis relies on elements that can be reasonably approximated, such as years of schooling and illiteracy rates, as will be shown in Section 4. These data allow me to offer some quantitative results. In particular, I propose a channel that connects life expectancy and economic performance through human capital investment. By including a human capital variable in my regression, I find that life expectancy indeed affects economic performance via human capital investment.

This paper is organized as follows: Section 2 summarizes a selection of previous studies that consider life expectancy and human capital investment decisions. Section 3 introduces the hypothesis and economic models employed to analyze the Chinese data described in Section 4, which also reports and discusses the empirical results. Section 5 discusses the robustness of the results while conclusions can be found in Section 6.

2 Literature review

There exist three strands of literature related to my topic: the relationship between life expectancy and human capital investment, and that between life expectancy and economic performance. The third is human capital and economic performance.

2.1 Life expectancy and human capital investment

Life expectancy might impact people's human capital investment decisions. The idea dates as back at least to Ben-Porath (1967), which provides a theoretical perspective that longer life expectancy encourages more human capital investment.

Regarding empirical work, Miguel and Kremer (2004) evaluate a Kenyan project in which mass treatment is school-based. The project was designed to eliminate intestinal helminths in Kenya. Identifying as a natural random experiment, deworming drugs were randomly phased into schools. This program led a 7.5 percentage point average gain in primary school participation in treatment schools, which were provided deworming drugs, reducing overall school absenteeism in treatment schools by at least one quarter. Moreover, it was cheaper than alternative ways of boosting school participation.

Nicolini (2004), an economic history paper, follows the intuition of the life-cycle theory and claims that the increase in adult life expectancy will impact farmer's investment decisions. As a result, it caused more investment in nitrogen stock and land fertility, generated an increase in agricultural land, and higher productivity. The data he employs are mortality rates, investment, and agricultural production in 18th century England.

Bleakley (2007) studies hookworm disease empirically in the American south starting around 1910, when 40 percent of school-aged children in the American south suffered from hookworm infection. He finds that areas with higher levels of hookworm infection experienced greater increases in school enrollment, attendance and literacy after the intervention.

Castelló-Climent and Doménech (2008) take into account economic status, which would influence life expectancy and human capital investment. They conclude that inequality in the distribution of income or wealth may be harmful for human capital accumulation since individuals who are born into poor families have low life expectancy. As a result, the time they expect to benefit from the returns to education is very short, and they will devote little time to accumulating human capital.

Jayachandran and Lleras-Muney (2009) construct a theoretical model first and show empirically that time horizons affect people's educational decisions. They examine a sudden drop in maternal mortality risk between 1946 and 1953 in Sri Lanka. They find that the 70% reduction in maternal mortality risk over the sample period increased female life expectancy at age 15 by 4.1%. As a result, female literacy increased by 2.5%, and female years of education increased by 4.0%. They also find that for every extra year of life expectancy, literacy increases by 0.7 percentage points (2%), and years of schooling increase by 0.11 years (3%).

Fortson (2011) employs data from Demographic and Health Surveys conducted in fifteen sub-Saharan Africa countries. She estimates the relationship between regional HIV prevalence and the change in individual human capital investment over time. She finds a life expectancy decline due to HIV, and that this decline would be expected to reduce educational attainment among children. Her results show that relative to a base case with no HIV, regional HIV prevalence of 10% is associated with a decline in completed schooling of about 0.5 years, a 6 percentage point decrease in the probability of attending school, and an 8 percentage point fall in the probability of completing primary school.

Sun et al. (2012) study a similar problem to that of Jayachandran et al. (2009). Based on data from China's 31 provinces over 2002–2009, they find that, ceteris paribus, when the maternal mortality risk decreases by 0.1 percentage points, the female illiteracy rate drops by 6.1 to 12.8 percentage points.

In addition, there are some papers that have explored this topic theoretically (Kalemli-Ozcan, Ryder, and Weil 2000; Soares 2005; Murphy and Topel 2006) and generally support the idea that longer life expectancy will have a positive effect on human capital investment.

2.2 Life expectancy and economic performance

Sala-i-Martin et al. (2004) find that life expectancy seems to be one of the most robust factors affecting growth rates. In contrast, Acemoglu and Johnson (2007) find that life expectancy has no statistically significant effect on total GDP across 75 countries. Instrumenting for changes in life expectancy with exogenous changes to mortality resulting from the introduction of new health technologies, they find that increases in life expectancy have either an insignificant or a small negative effect on per capita GDP.

Lorentzen et al. (2008) study a variety of cross-national and sub-national data, and find that high adult mortality reduces economic growth by shortening time horizons. Dealing with endogeneity issues, they find that a greater risk of death during the prime productive years is associated with higher levels of risky behavior, higher fertility; and, especially, lower investment in physical capital. In their cross-national regressions, adult mortality explains almost all of Africa's growth tragedy.

Cervellati and Sunde (2011) investigate the hypothesis that the causal effect of life expectancy on income per capita growth is non-monotonic. Results from different empirical specifications and identification strategies show that the effect is non-monotonic, negative (or insignificant) before the onset of the demographic transition, but strongly positive after its onset.

2.3 Human capital investment and economic performance

Much evidence has shown that human capital is an important factor determining economic performance. The human capital theory can be traced back to the 1960's and 70's, when Schultz (1960, 1961), and Becker (1962), offered new perspectives on the concept and formation, and its role of human capital in the economy. From then on, many theoretical models and empirical analysis have followed their idea and examined the specific effect.

Talking about the China's economic growth in recent years, many researchers also point out that human capital plays an important role (Heckman 2005, Fleisher et al. 2010). Chi (2008) provides a good summary on this topic.

2.4 Critique of current research

2.4.1 Problems with cross-country data

As summarized previously, most current research studying life expectancy and economic performance is based on cross-country evidence. This analysis, however, suffers from several problems.

Fleisher et al. (2010) find that although it has long been believed that human capital plays a fundamental role in economic growth, studies based on cross-country data have produced surprisingly mixed results. One reason they provide to explain this uncertainty is that the impact of education has varied widely across countries because of very different institutions, labor markets and education quality, making it hard to identify an average effect.

First of all, rates of return to education vary significantly across countries. Because the benefit from additional years of schooling might be very different across various countries, direct comparison across countries is uninformative. Mincer equations should be introduced here to better capture the rates of return in different countries.

Furthermore, education quality differences across countries are also big. The impact of one additional year of schooling is likely to differ between, for example, Canada and Argentina. If we just use years of schooling in different countries, which are often used in the current literature, to proxy human capital levels in these countries, then the quality of those years must also be considered. It is, however, not a trivial problem to measure different educational quality across countries.

Culture, foreign aid and government policy also play an important role in determining people's human capital decisions. Like education quality, these variables are usually difficult to control or proxy in empirical analysis. Therefore these variables similarly undermine regression results as well.

The critique of using cross-country data is similar to the critique of studies on the resource curse issue. Many pioneering papers such as Sachs and Warner (1995) and Gylfason (2001) find a negative relationship between resource abundance and economic performance based on cross-country evidence, while Papyrakis et al. (2007) study the same problem from a US-state level. As Barro and Sala-i-Martin (1995) demonstrate, a merit of state level analysis is that whereas countries often differ in dimensions—such as language, the quality of institutions, and cultural characteristics—that are difficult to control for in growth regressions, these differences are likely to be smaller across regions within a country. As a result, state or provincial level analysis would be more reasonable, especially related to human capital, for which the variation is bigger across countries.

2.4.2 Problems with cross sectional regression

Most of current research employs cross sectional data. One of the reasons is that it is harder to access panel data for different countries.

A representative regression in the current literature is Lorentzen et al. (2008), which regress 89 countries' average growth rates on average mortality or infant mortality rates from 1960 to 2000 and several other control variables. Another example is Chakraborty (2004), which regresses GDP per worker in 1990 on life expectancy in 1970 and other variables. There are many other similar cross sectional cases.

However, as it requires a relatively long time for growth to reflect human capital investment changes, panel data regression instead of cross sectional data regression would be more persuasive for this topic. Moreover, allowing a several year lag for human capital to affect economic performance is suggested. This is also proposed by Bhargava et al. (2001).

2.4.3 Neglected human capital channel

The paper written by Lorentzen et al. (2008) is the only paper that investigates the human capital channel problem on this topic. At the same time, they also test the channel of physical capital investment. They run two regressions and provide a short discussion of the results. However, their results are not significant under cross-country analysis.

Most current papers have not seriously tested the hypothesis that life expectancy has a significant effect on economic growth through the human capital channel. However, given that so much of the evidence reviewed in this section shows that life expectancy affects human capital investment, there is sufficient reason to infer that a human capital channel exists between life expectancy and economic performance.

2.4.4 Dispute about the effect of life expectancy on economic performance

Some articles uncover a negative or ambiguous relationship between life expectancy and economic performance.

Acemoglu and Johnson (2007) find that life expectancy has no statistically significant effect on total GDP after empirical analysis across 75 countries. There are, however, two problems with their paper. The channel between life expectancy and economic performance is human capital, yet the authors fail to consider a lagged effect of this relationship. Second, cross-country analysis suffers the problems mentioned earlier:

different rates of return to human capital, and different culture or government policies in different countries.

Cervellati et al. (2011) find an ambiguous, non-monotonic relationship between life expectancy and per capita growth in income. Their conclusion is that there is possibly a negative effect before a demographic transition but positive after its onset.

In this paper I will provide a new perspective on this issue based on evidence from China's provincial level data.

3 Hypothesis and mathematical model

3.1 Hypothesis

Being one of the biggest developing countries in the world, China's economic growth provides us with an opportunity to analyze the relationships among life expectancy, human capital and economic growth.

China is currently suffering a regional disparity problem. In 1982, the ratio of the richest province's GDP to that of the poorest province was 38:1 while this jumped to 90:1 in 2010. In 2010, the ratio of highest per capita GDP to the lowest per capita GDP was 5.8:1. Some researchers attribute this problem to human capital (Heckman 2005; Chi 2008), but most do not further attribute this to life expectancy. This disparity is a very important issue. With such a persistent and huge gap, not only would we expect it to create many social problems in the short run, but it might also impede economic growth in the long run, as has happened in some Latin American countries.

In addition to regional economic disparities, human capital varies greatly across provinces. If we measure human capital by average years of schooling and illiteracy rates, we find that in 2010, the average years of schooling in Beijing was 11.47 and the illiteracy rate was 1.7%. This compares with an average of 5.27 years of schooling and an illiteracy rate of 24.42% in Tibet for the same year.

Some people might argue that different rates of return to education provide an explanation for different levels of human capital investment. However, according to Heckman (2005), rates of return to human capital are high in China, both in rural and urban regions. His empirical results indicate that different human capital levels across regions do not mainly result from different rates of return; therefore life expectancy, the length of the return to investment, should matter.

Moreover, there are also substantial variations in life expectancy across provinces. As an example, in 1981, the life expectancy at birth in Shanghai was 72.91 years compared with 60.0 years in Xinjiang.

Observing these facts and drawing from the literature, I hypothesize two claims: First, at the provincial level in China, different life expectancies in the beginning of the economic boom lead to different levels of human capital investment. Second, these different levels of human capital investment will result in differences in economic performance. In other words, provinces with relatively higher life expectancies encourage people to invest more in human capital, leading them to out-perform those provinces with lower life expectancies. My mathematical model in the next sub section will provide theoretical evidence to support these two hypotheses. My study will also provide empirical evidence on the issue based on Chinese provincial data. As in my earlier example, people who live in Shanghai and Xinjiang will invest differently in human capital (education), which will eventually affect the economic performance in the long run. While the effects may not be immediate, they will materialize after several years (Lorentzen et al. 2008).

One noteworthy point for better understanding my hypothesis is the argument of some literature that life expectancy itself does not directly affect economic outcomes such as GDP and per capita GDP (Acemoglu and Johnson 2007). As a result, it is reasonable to hypothesize that increase in life expectancy will encourage human capital accumulation first, which in turn effects economic outcomes.

This following channel will speak to my hypothesis, in which I attribute the disparities in China to the huge gap in human capital levels. After China's Cultural Revolution (1966-1976), individuals were more capable of making educational investment decisions. In 1982, the Chinese government set compulsory education as a political objective in the new Constitution. Moreover, in 1985, the Chinese Congress pursued this goal by passing the Compulsory Education Law of the People's Republic of China, which enforced a 9-year compulsory education system.

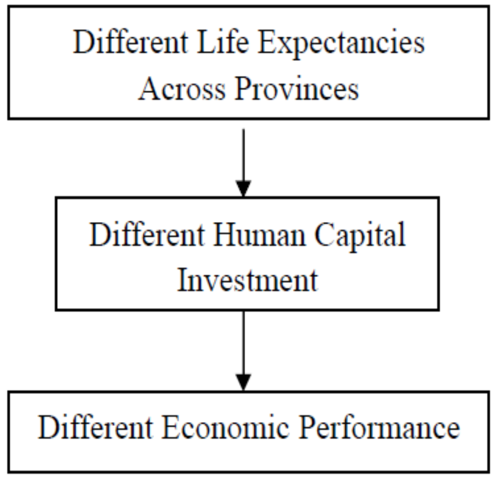

Figure 1: Channel from life expectancy to economic performance

There is clearly a bidirectional relationship between life expectancy and economic performance: with better economic performance, we would expect longevity to increase due to a better healthcare system. I address this problem using the following two techniques: first, I employ earlier life expectancy data and later economic performance data to avoid causal effects; second, I use an instrumental variable method in my regression to address endogeneity.

3.2 Model

The following presents a model to analyze the relationship between life expectancy and human capital. As the literature review has shown, there exists much theoretical and empirical research discussing this relationship. The basic hypothesis is that longer life expectancy induces people to invest more in human capital because their time horizons are extended and thus their benefits from investing in human capital are greater. I also hypothesize that, as human capital investment and accumulation play a significant role in economic performance, it naturally follows that life expectancy should eventually affect economic performance through human capital investment. I extend this logic to an analysis of Chinese provincial economies, which have significant variation in life expectancy, human capital and economic performance.

In the following mathematical model, I show that life expectancy has an impact on individuals' decisions where people with different life expectancies will invest various amount in human capital.

I start my analysis by assuming that there are two provinces where people have different life expectancies. For Province 1, the life expectancy is T_1. For Province 2, the life expectancy is T_2, where $T_1 > T_2$.

Individuals in each province choose the amount they invest in human capital (years of schooling), indicated by s_1 and s_2. $y(s,t)$ and $c(t)$ denote discounted income and cost streams, t is the age. Without loss of generality, I assume that $\partial y / \partial s > 0$, $\partial y / \partial t \,|_{t=s} > 0$ and $\partial c(t) / \partial t > 0$.

They face the following two choices:

$$\max_{s_1} Y_1 = \int_{s_1}^{T_1} y(s_1,t)\,dt - \int_0^{s_1} c(t)\,dt$$

$$\max_{s_2} Y_2 = \int_{s_2}^{T_2} y(s_2,t)\,dt - \int_0^{s_2} c(t)\,dt$$

FOC(s_1): $$\int_{s_1}^{T_1} \frac{\partial y(s_1,t)}{\partial s_1}\,dt = y(s_1,s_1) + c(s_1)$$

FOC(s_2): $$\int_{s_2}^{T_2} \frac{\partial y(s_2,t)}{\partial s_2}\,dt = y(s_2,s_2) + c(s_2)$$

Define:

$$F(s_1) = \int_{s_1}^{T_1} \frac{\partial y(s_1,t)}{\partial s_1}\,dt - y(s_1,s_1) - c(s_1)$$

Define:

$$F(s_2) = \int_{s_2}^{T_2} \frac{\partial y(s_2,t)}{\partial s_2}\,dt - y(s_2,s_2) - c(s_2)$$

Denote s_2^* the solution for FOC(s_2)=0, and put s_2^* into $F(s_1)$ we can get:

$$\int_{s_2^*}^{T_1} \frac{\partial y(s_2^*,t)}{\partial s_2^*} dt - y(s_2^*, s_2^*) - c(s_2^*) > 0$$

Because $T_1 > T_2$ and F(s) is monotonically decreasing in s, in order to satisfy the FOC=0 it must be the case that $s_1^* > s_2^*$ to ensure $F(s_1^*) = 0$.

As an illustrating example, suppose there are two neighboring provinces, the first with 72 years life expectancy and the second with 62. Ceteris paribus, people in the first province will choose to undertake more years of schooling, as shown in the previous mathematical model. Eventually this increase in human capital investment will result in a higher economic performance for the first province.

As this model shows, longer life expectancy encourages more investment in human capital. The intuition is straightforward: when people are able to enjoy more benefit from education because of their longer lifetimes, it will be optimal for them to invest more in human capital, despite the higher cost. The results of this model also correspond with the stylized facts I mentioned in Section 1: the trends are the same for education and life expectancy.

4 Data and empirical results

4.1 Data

In this part, I will introduce the data I employ in my empirical analysis.

The life expectancy data I use to analyze this issue empirically come from the Third National Population Census of China, compiled by the Chinese Academy of Social Sciences and published in the Almanac of China's Population (1988)[1]. The Third National Population Census of China was taken in 1981.

The measures of life expectancy are calculated in the standard way from age-specific mortality rates measured at a given point in time; in this case the time is 1981. The data that the government collected include the number of births in 1981, number of deaths in 1981 and more longitudinal data (Jiang 1990). One of the founders of this census was Prof. Zhenghua Jiang, who published a working paper in the Stanford Institute for Population (Model Life Tables for China, 1990) when he was a visiting scholar there. In that paper he introduced, in detail, the methods used to calculate life expectancy in the Third National Population Census.

To measure human capital investment I employ years of schooling, as is often done in the current literature. In Section 5, as part of the robustness check, I also employ illiteracy rates as an alternative proxy for human capital investment. The primary source for schooling and illiteracy data is the China Statistics Yearbook, a major source of public data in China. I also refer to a related paper (Chen et al. 2004) to deal with some missing data in early years.

For provincial economic performance, I will also apply two kinds of measurement. The first is total GDP in each province for the corresponding years; the other is provincial per capita GDP.

[1] The Almanac of China's Population has been publishing data from the Third National Population Census of China since 1988, which is the earliest publicly available source for these data.

Some papers use the enrollment rates as an indicator of human capital (Jayachandran et al. 2009, Fortsen 2011). However, primary school enrollment is not a good indicator in the Chinese context for the following reasons. First, it is a political goal for lower levels of government to raise their region's enrollment rates. Hence, local government has a strong incentive to over-report this figure. Second, in other countries, attrition is not a huge problem. But in China, attrition rates are relatively higher, especially in rural areas. Since enrollment rates are the political goal rather than attrition rates, local officials do not have strong incentive to lower the rates of attrition. In addition, there are not any publicly published data on regional attrition rates.

In these regressions, because of limited data availability, the life expectancy data I employ are life expectancy at birth, rather than life expectancy at an early adult age. However, this will not undermine my empirical analysis for the following reasons. First, there exists a strong correlation between the life expectancy at birth and the life expectancy whenever people make their educational investment decisions. Moreover, life expectancy at birth is also widely used by previous research (Acemoglu and Johnson 2007; Lorentzen et al. 2008; etc.) when studying the effect of life expectancy on human capital investment.

4.2 Empirical method and results

In this part, to show that life expectancy does affect economic performance through the human capital investment channel, I will run a series of regressions with the life expectancy variable and then run a second series adding the human capital levels variable. If we observe that the life expectancy variable has a significant effect on economic performance at first, and it turns out to be insignificant in the second series of regression, then it will be reasonable to infer that adding this human capital variable captures all the explanatory powers of life expectancy. In other words, the channel I hypothesize in Section 3 will be proved if these results come out. An alternative approach would be to start with a generally accepted standard model explaining regional disparities, and then add the life expectancy variable.

In my model, the life expectancy variable I employ is determined before education, so causation is not likely to run in the opposite direction. As an example, life expectancy in 1981 might affect human capital investment in 1988, which will determine the economic performance in 1995, but the opposite direction of correlation should not hold.

First of all, I study the simple relationship between life expectancy and human capital levels with solely regressing human capital (years of schooling) by life expectancy; the following table shows the results.

	Dependent Variable: Years of Schooling	
	Years of Schooling 1987-2010	Years of Schooling 1987-2010
Life Expectancy 1981	0.2154495*** (0.0113575)	0.2180403*** (0.0366991)
R^2	0.3415	0.3744
Life Expectancy 1981	0.234851*** (0.0124739)	0.2381156*** (0.040083)
R^2	0.3305	0.3843
Number of Observations	696	696

Table 1: Simple regression results for life expectancy and human capital levels

Standard errors reported in parenthesis

***: Significant at 1% level **: significant at 5% level *: significant at 10% level

From this table we can see that there is a positive, strong relationship between life expectancy and years of schooling. This suggests that life expectancy might affect human capital investment.

The following econometric approach exploits the relationship between life expectancy and human capital investment. At first I estimate the following benchmark regression model where the dependent variable is the logarithm of provincial GDP in certain years. The model also uses, as independent variables, provincial GDP in 1981 to control for initial economic conditions and the provincial FDI (Foreign Direct Investment) level.

Here are the regression model and results:

$$\ln gdp_{it} = \alpha\, fdi_{it} + \beta lifeexpectancy_{it} + \gamma \ln gdp_{1981} + u_{it}$$

10 year lag	lnGDP 1990, 2000, 2010	lnGDP 1990, 2000, 2010
Life Expectancy 1981, 1990, 2000	0.2635314*** (0.0354772)	0.1593377*** (0.0354157)
FDI 1981, 1990, 2000	0.0114*** (0.00250)	0.0114*** (0.00254)
lnGDP 1981		0.3956495** (0.14204)
Constant	-10.72307*** (2.415169)	-5.435933** (2.15147)
R^2	0.5997	0.6778
Number of Observations	90	90

Table 2: Regression results allowing a 10 year lag with the life expectancy variable

Standard errors reported in parenthesis

***: Significant at 1% level**: significant at 5% level *: significant at 10% level

Secondly, to verify my hypothesis, I add the human capital variable into this benchmark regression model:

$$\ln gdp_{it} = \alpha\, fdi_{it} + \beta lifeexpectancy_{it} + \gamma \ln gdp_{1981} + \delta humancapital_{it} + u_{it}$$

10 year lag	lnGDP 1990,2000, 2010	lnGDP 1990,2000, 2010
Life Expectancy 1981, 1990, 2000	0.0218098 (0.031438)	-0.0320555 (0.0409196)
FDI 1981, 1990, 2000	0.00323*** (0.00113)	0.00670*** (0.00171)
lnGDP 1981		0.3795202*** (0.1306684)
Years of Schooling 1981, 1990, 2000	1.024444*** (0.0632684)	0.8826963*** (0 0863353)
Constant	-1.586585 (1.821363)	-1.298422 (2.163295)
R^2	0.6735	0.7478
Number of Observations	90	90

Table 3: Regression results allowing a 10 year lag, including the human capital variable

Standard errors reported in parenthesis

***: Significant at 1% level**: significant at 5% level *: significant at 10% level

With provincial life expectancies in the first series of regression, I obtain a significantly positive coefficient for life expectancy. However, when I add a human capital variable (average years of schooling here, and illiteracy rates in the robustness section) into this regression, I find a significant coefficient on the human capital variable but an insignificant coefficient on the life expectancy variable.

To supplement the validation of my hypothesis, I substitute the provincial per capita GDP for provincial GDP as the dependent variable. As the following results show, we can observe almost the same effect again.

10 year lag Per capita GDP	lnPGDP 1990,2000, 2010	lnPGDP 1990,2000, 2010	lnPGDP 1990,2000, 2010	lnPGDP 1990,2000, 2010
Life Expectancy 1981, 1990, 2000	0.1447799*** (0.028636)	0.1401443*** (0.0324324)	-0.0488712 (0.0322217)	-0.05374 (0.0327263)
FDI 1981, 1990, 2000	0.00938*** (0.00236)	0.00933*** (0.00239)	0.00471*** (0.00141)	0.00685*** (0.00166)
lnPGDP 1981		0.0599546*** (0.2212756)		-0.139012 (0.1696149)
Years of Schooling 1981, 1990, 2000			0.9240033*** (0.0715661)	0.7674031*** (0.0764127)
Constant	-1.291779 (1.943457)	-1.350289 (1.996799)	5.217466*** (1.846276)	7.531079*** (1.809699)
R^2	0.4963	0.4927	0.7298	0.7426
Number of Observations	90	90	90	90

Table 4: Per capita GDP regression results allowing a 10 year lag

Standard errors reported in parenthesis

***: Significant at 1% level   **: significant at 5% level *: significant at 10% level

I also run regressions allowing a 20 year lag for life expectancy impacting human capital investment decisions, where the dependent variable is the logarithm of provincial GDP in 2000 and 2010, and the independent variables are provincial life expectancies in 1981 and 1990, FDI in 2000 and 2010, and initial GDP in 1981. The coefficient on life expectancy is 0.15 on average, which has a huge impact on GDP.

20 year lag GDP	lnGDP 2000, 2010	lnGDP 2000, 2010	lnGDP 2000, 2010	lnGDP 2000, 2010

Life Expectancy 1981, 1990	0.1437738*** (0.0365556)	0.0959738*** (0.0364644)	-0.0265538 (0.0437846)	-0.1083326** (0.0458563)
FDI 1990, 2000	0.0103*** (0.00227)	0.00737*** (0.00235)	0.00273* (0.00157)	0.00291* (0.00162)
GDP 1981		0.0038928*** (0.0014594)		0.0062072*** (0.0015653)
Years of Schooling 1990, 2000			0.9657499*** (0.0960343)	0.9492368*** (0.0980944)
Constant	-1.613281 (2.435022)	1.105148 (2.34223)	2.281557 (2.622402)	6.962007*** (2.565113)
R^2	0.5640	0.6140	0.5247	0.7042
Number of Observations	60	60	60	60

Table 5: Regression results allowing a 20 year lag

Standard errors reported in parenthesis

***: Significant at 1% level **: significant at 5% level *: significant at 10% level

As I add human capital into the former regression model, we find that the coefficient on life expectancy turns out to be insignificant, or even negative.

Finally, if I replace provincial GDP with per capita GDP in my panel regression, I get similar results as well.

20 year lag Per capita GDP	lnPGDP 2000, 2010	lnPGDP 2000, 2010	lnPGDP 2000, 2010	lnPGDP 2000, 2010
Life Expectancy 1981, 1990	0.1437738*** (0.0365556)	0.0959738*** (0.0364644)	-0.0265538 (0.0437846)	-0.1083326** (0.0458563)
FDI 1990, 2000	0.0103*** (0.00227)	0.00737*** (0.00235)	0.00273* (0.00157)	0.00291* (0.00162)
PGDP 1981 (lnPGDP1981)		0.0038928*** (0.0014594)		0.0062072*** (0.0015653)

Years of Schooling 1990, 2000			0.9657499*** (0.0960343)	0.9492368*** (0.0980944)
Constant	-1.613281 (2.435022)	1.105148 (2.34223)	2.281557 (2.622402)	6.962007*** (2.565113)
R^2	0.5640	0.6140	0.5247	0.7042
Number of Observations	60	60	60	60

Table 6: Per capita GDP regression results allowing a 20 year lag

Standard errors reported in parenthesis

***: Significant at 1% level **: significant at 5% level *: significant at 10% level

The following shows another set of regressions in which I exploit all available data. The GDP, per capita GDP, FDI and years of schooling variables are yearly instead of decennial as used in the above regressions. I also include a coastal dummy variable, which equals to 1 if a province is adjacent to the sea, otherwise 0. Since life expectancy data are only surveyed and reported every decade in China, I cannot substitute yearly data in the following regressions. It is, however, still useful to trace the channel by running similar regressions.

Here are the regression model and results:

$$\ln gdp_{it} = \alpha\, fdi_{it} + \beta coastal_i + \gamma\, lifeexpectancy_i + \delta gdp_{1981} + u_{it}$$

	lnGDP 1987-2010	lnGDP 1987-2010	lnGDP 1987-2010	lnGDP 1987-2010
Life Expectancy 1981	0.1788141*** (0.0337761)	0.1573403*** (0.0452144)	0.135418*** (0.0406804)	0.0844012 ** (0.033318)
FDI 1987-2010			0.0233*** (0.0122)	0.0226*** (0.0122)
Coastal		0.2704032 (0.3741751)	-0.5195008 (0.33888)	0.7208623*** (0.2585497)
GDP 1981				0.0043046*** (0.0012203)

Constant	-4.475668** (2.267626)	-3.129699 (2.950202)	-1.809866 (2.654498)	0.9953071 (2.114275)
R^2	0.2381	0.2427	0.4564	0.5095
Number of Observations	696	696	692	692

Table 7: Yearly data regression results

Standard errors reported in parenthesis

***: Significant at 1% level **: significant at 5% level *: significant at 10% level

$$\ln gdp_{it} = \alpha\, fdi_{it} + \beta coastal_i + \gamma\, lifeexpectancy_i + \delta gdp_{1981} + \eta humancapital_{it} + u_{it}$$

	lnGDP 1987-2010	**lnGDP 1987-2010**
Life Expectancy 1981	-0.0847856** (0.0419948)	-0.161284*** (0.0363271)
FDI 1987-2010	0.00328*** (0.000481)	0.00332*** (0.000485)
GDP1981		0.0070861*** (0.0014379)
Coastal	0.3306147 (0.3471043)	-0.0132674 (0.2789331)
Years of Schooling 1987-2010	1.040136*** (0.0140286)	1.04157*** (0.0140021)
Constant	5.533572** (2.735218)	9.756503*** (2.298399)
R^2	0.5730	0.6834
Number of Observations	692	692

Table 8: Yearly data regression results, including the human capital variable

Standard errors reported in parenthesis

***: Significant at 1% level **: significant at 5% level *: significant at 10% level

Similarly, without human capital variable in the regression, the life expectancy variable shows a significant and positive effect to yearly GDP while the coefficient becomes significantly negative after I add a human capital variable into the regression. Thus, the channel I propose still holds if I change several variables to yearly data.

5 Robustness checks and extensions

In this part, I provide some robustness checks and extensions for my empirical analysis.

5.1 Endogeneity problem

Because of the possibility of endogeneity, which means there might be simultaneity biases (e.g. human capital and life expectancy are determined by average health), I will try to use the geographic size for every province as an instrument for the life expectancy variable, with an assumption that the larger a province is, the harder it is for local governments to provide public health services. Hence, life expectancy would be negatively related to geographic size. However, the geographic size itself does not affect economic performance. I find similar results from 2SLS regressions when I instrument life expectancy with geographic size.

Here are the 2SLS results:

Relationship between Life Expectancy and Geographic Size		
	Life Expectancy 1981	

Geographic Size	-0.000679*** (0.0000286)	
R^2	0.4482	
Number of Observations	692	
IV Regressions Results		
	lnGDP 1987-2010	lnGDP 1987-2010
Geographic Size	-0.000118*** (0.0000232)	0.000102*** (0.0000180)
FDI	0.0190*** (0.00133)	0.0105*** (0.00105)
GDP1981	0.0045312*** (0.0005793)	0.0063455*** (0.0004341)
Constant	7.017001*** (0.1560248)	1.705273*** (0.2305651)
Years of Schooling		0.610547*** (0.025131)
R^2	0.4536	0.6931
Number of Observations	692	692

Table 9: IV regression results

Standard errors reported in parenthesis

***: Significant at 1% level **: significant at 5% level *: significant at 10% level

Several conclusions can be drawn from these results. First, from the first stage regression, we can observe there is a significantly negative relationship between life expectancy and geographic size. Second, in the second stage regressions, the results are similar to what I have got in Section 4. The coefficient of geographic size is significantly negative without the human capital variable but positive with it.

5.2 Life expectancy data

Some observers might express reservations about the quality of my data on life expectancy. To address this concern, I will substitute life expectancy with infant mortality rate, as the main explanatory variable. The infant mortality rate is used in some literature such as that Lorentzen et al. (2008). As these research points out, there is a strong negative relationship between infant mortality rate and life expectancy since life expectancy and infant mortality rate are both highly related to the efficiency of the public health system.

Therefore, in this extension, I employ the infant mortality rate to replace the life expectancy variable that I use earlier. The provincial infant mortality rates in 1981 are also from the China's Third National Census.

Regression results:

	lnGDP 1987-2010	lnGDP 1987-2010
Infant Mortality Rate 1981	-0.076426* (0.04147)	0.105246** (0.0044853)
FDI 1987-2010	0.00224*** (0.00121)	0.00339*** (0.000499)
Coastal	-0.5204882** (0.2090804)	-0.5103781** (0.2231021)
GDP 1981	0.0040108*** (0.001032)	0.0065377*** (0.0011061)
Years of Schooling 1987-2010		1.038034*** (0.0145683)
Constant	7.009348*** (0.2959858)	-1.358172*** (0.3402084)
R^2	0.4882	0.6488
Number of Observations	692	692

Table 9: Regression results of infant mortality rates

Standard errors reported in parenthesis

***: Significant at 1% level **: significant at 5% level *: significant at 10% level

When I replace the life expectancy variable with the infant mortality rate in the regression models, I also find a significantly negative relationship between the infant mortality rate and economic performance at first, and a positive relationship when I add human capital variables. Note that the higher the infant mortality rate is, the lower life expectancy at birth will be.

5.3 Illiteracy rate data

As mentioned in Section 3, I can also use other indicators of educational investment as the dependent variable. Illiteracy rate is another variable usually employed in the literature on related topics (Bleakley 2007). It is also a good measurement of human capital level. Here the definition of illiteracy rate is the proportion of people 15 years of age and older who cannot read and write.

If I use illiteracy rates instead of years of schooling to proxy human capital in the model of Section 3, I find consistent results as well.

	lnGDP 1987-2010	lnGDP 1987-2010
Life Expectancy 1981	-0.0847856** (0.0419948)	-0.1388538*** (0.0290768)
FDI 1987-2010	0.00328*** (0.000481)	0.00101*** (0.00069)
Years of Schooling 1987-2010	1.040136*** (0.0140286)	
Illiteracy Rates		-0.1179848***

1987-2010		(0.0026778)
GDP 1981	0.0043046*** (0.0012203)	0.0043747*** (0.0010459)
Coastal	0.3306147 (0.3471043)	0.2162865 (0.2221398)
Constant	5.533572** (2.735218)	17.80078*** (1.856313)
R^2	0.5730	0.7064
Number of Observations	620	620

Table 10: Regression results of illiteracy rates

Standard errors reported in parenthesis

***: Significant at 1% level **: significant at 5% level *: significant at 10% level

The results are similar when I proxy human capital by the illiteracy rate. These results are not only of high economic importance, but also statistically significant.

Again, this reaffirms to two points. First, life expectancy does have a significant effect on individual's educational investment. Second, the channel we hypothesize still exists when we employ illiteracy rate as an alternative.

5.4 Migration problem

A migration problem might affect years of schooling data. An example of this occurs when a person is born in one province, but receives higher education in Beijing where he finds a job after graduation, and his *hukou* moves to Beijing as well. Then his years of schooling will be considered as a resident in Beijing instead of his home province. As a result, these migration cases should be considered in the dataset. Hence, I exclude the 4 municipalities in China, which are the largest and have the most universities: Beijing, Tianjin, Shanghai and Chongqing. Moreover, none of the current literature studies the migration problem I am trying to address.

The results below show that my hypothesis still holds when I exclude these 4 municipalities.

	lnGDP 1987-2010	lnGDP 1987-2010
Life Expectancy 1981	0.1447657*** (0.0415432)	-0.0494253*** (0.0389231)
FDI 1987-2010	0.00217*** (0.00132)	0.00319*** (0.00050)
Coastal	-0.3264257 (0.3551963)	0.8967363*** (0.3297067)
Years of Schooling 1987-2010		1.058031*** (0.0146323)
Constant	-2.410511 (2.710572)	3.143041 (2.534663)
R^2	0.4553	0.7459
Number of Observations	620	620

Table 11: Regression results excluding 4 municipalities

Standard errors reported in parenthesis

***: Significant at 1% level **: significant at 5% level *: significant at 10% level

6 Conclusion

This paper contributes to the existing literature in several aspects. First, with much evidence on an individual level, longer life expectancy will lead to more human capital investment. I show that if we look at an aggregate level, people will invest more in human capital and consequently improve the economy through my empirical analysis. This channel has not been completely revealed before. Second, I provide a unique perspective to understand the regional inequality problem that has happened and continues in China. In a larger sense, this paper offers policy makers some aid in lowering the level of future disparities. Again, the economic magnitude of economic performance differences associated with the difference in life expectancy is large.

Given the low cost of deworming drugs, Bleakley (2007) suggests pursuing deworming drugs in poor regions. An improvement in health conditions might thus be a cheaper method to encourage human capital investment in rural or less developed places in China. In other words, to reduce the gap of human capital in the long run, the Chinese government might find that improving the healthcare system is a useful approach.

My results also have implications for China's future regional inequality issue. The inequality may still exist and may be increasing rather than decreasing since the gap of human capital continues to widen (Chi 2008). In addition, with life expectancy data, we can forecast the accumulation of human capital in specific provinces or regions in China and predict the economic performance based on these human capital predictions.

As I mentioned in the introduction, my research could also be extended to other developing countries, such as India, who are also suffering a regional disparity problem.

In summary, this paper combines findings from two separate literatures: life expectancy effects on human capital investment; and human capital investment effects on economic performance. I find that, within a Chinese context, life expectancy impacts human capital investment, which determines long run economic performance.

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