ECONOMIC AND LABOR MARKET RESPONSES TO DEMOGRAPHIC CHANGES

by

Jiani Li

A dissertation submitted to the Faculty of the University of Delaware in partial fulfillment of the requirements for the degree of Doctor of Philosophy in Economics

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ABSTRACT

China is turning into an aging society and there is a growing percentage of older people in this country. Currently, the country has the world's largest older population (persons who are over or equal to the age of 65) and the United Nations also projects that there will be 366 million older population by the year 2050. It seems that the country is experiencing population aging on an unprecedented scale.

Generally speaking, population aging is assumed to have an adverse impact on economic growth since it will reduce the proportion of the population that is economically active. In addition, given the fact that institutional care and community-based care are far from satisfying the needs of older people, families have been the primary sources of care for the older population. The working-age labor force need to provide caregiving to their older parents and may choose to live near them, and thus it may affect the labor market outcomes of their working-age children.

For China, there is little empirical evidence exploring the magnitude of the population aging effect on economic growth or the labor market. In this study, I construct a city panel dataset where the data was observed every 5 years in 2000 to 2015. Specifically, I use the predicted variation in the rate of population aging across Chinese cities to estimate the impact of population aging on city level GDP per capita and labor market outcomes. I find that a 10% increase in the extent of population aging (extent is measured by the fraction of the population aged over or equal to 65 years) would decrease GDP per capita by 2.42 %. On the other hand, a 10% increase in the extent of population aging would increase the average wage by 1.67%. There is

heterogeneity in the effect across different periods and across different regions — with the effect more significant in less-developed cities. When decomposing the effect of population aging on economic growth into labor participation and labor productivity, I find that the effect of age composition mainly operates through the decrease in the labor-to-population ratio. When decomposing the effect by sector, I find there is a significant adverse effect on the secondary sector output, but there is no clear trend of how population aging would affect the development path of a city.

Chapter 1

INTRODUCTION

The age structure of a country's population is important for policymakers as it provides insights into the population trends and whether the country has enough human capital for future economic growth. For China, the age structure is trending to have a higher proportion of individuals in their later life stage and have a smaller proportion of working-age and younger population.

The change in the age structure is closely related to one population policy implemented by the Chinese government in the 1970s, which is the one-child policy. It was considered one of the strictest population policies ever implemented and it caused a significant decrease in the national fertility rate. Due to this policy, there is a relatively larger proportion of the population who were born before the policy compared to those born after the policy. As the larger group of people born before the policy reach the age of 65 and enter the group of older population[1], China is turning into an aging society. In addition, the decrease in the mortality rate for older people as well as parents' long-established preference for boys rather than girls are also associated with the dynamics of age structure in China. All these factors are expected to have a long-lasting impact and the old-age dependency ratio is predicted to keep increasing in the following two to three decades.

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[1] Throughout this study, older population refers to persons who are over or equal to the age of 65

First, population aging may affect the labor market. It reduces the labor-to-population ratio on the old-age population side (the other side is for those below 15 and are not eligible to work). Second, given the fact that family care has long been the primary source of health care for the older population (PRB, 2020), it may also affect the labor productivity of working-age people considering the need to take care of their elderly parents. On the other hand, young working-age people can take over older persons' jobs as they retire and there may have some new job openings in certain industries as the population ages. Older parents are also willing to support their working-age children to achieve their career goals since China's family members are more connected to each other. Taking these things into consideration, the effect of population aging on the labor market is uncertain.

Second, population aging is generally assumed to have adverse effects on economic growth. Since the labor force is a key factor in determining growth, having a relatively smaller labor force in the economy may slow down the growth rate. As the population ages, China is making a transition from enjoying a "demographic dividend" to potentially suffering from an inverted demographic pyramid (having a larger proportion of older people but a smaller proportion of working-age people and adolescents).

There is not much empirical study that examines the magnitude of the population aging effect using aggregate-level data of China. In this study, I follow the two-stage least squares regression method used in Maestas et al. (2016) to estimate the impact of age composition. Specifically, the predicted percentage change of the older population ratio is used as an instrument for the observed percentage change of the ratio, extracting the causal effect of population aging on the labor market and economic growth.

In the following parts of the study, Chapter 2 introduces the dynamics of the age structure in China, the reasons behind the change, and the potential impact of population aging on the labor market as well as on economic growth. Chapter 3 summarizes the findings of the existing literature. Chapter 4 describes the data. The regression specification and the way to construct the instrumental variable are discussed in Chapter 5. Chapter 6 presents the empirical findings using city-level as well as province-level data. Chapter 7 checks the robustness of the results and Chapter 8 presents conclusions.

Chapter 2

BACKGROUND

2.1 Dynamics of age structure in China

Many Chinese cities have already experienced growth in the size of their older population, and much of this was predetermined by historical trends in the fertility rate. Figure 2.1 shows the trend of China's old-age dependency ratio, which is the nationwide fraction of older people to the working-age population size. Specifically, the older population refers to those that are over or equal to the age of 65. The working-age population refers to those who are between the ages of 15 to 64 (including the age 15 and 64), who are considered potentially active workforce. The old-age dependency ratio has increased steadily since the 1970s, and the ratio exceeded 10% around the year 2000. In the year 2019, the old-age dependency ratio reached its highest point ever since, which is 16.3. It is predicted that the ratio will continue to increase in the following two to three decades, and the problem will become more pronounced over time.

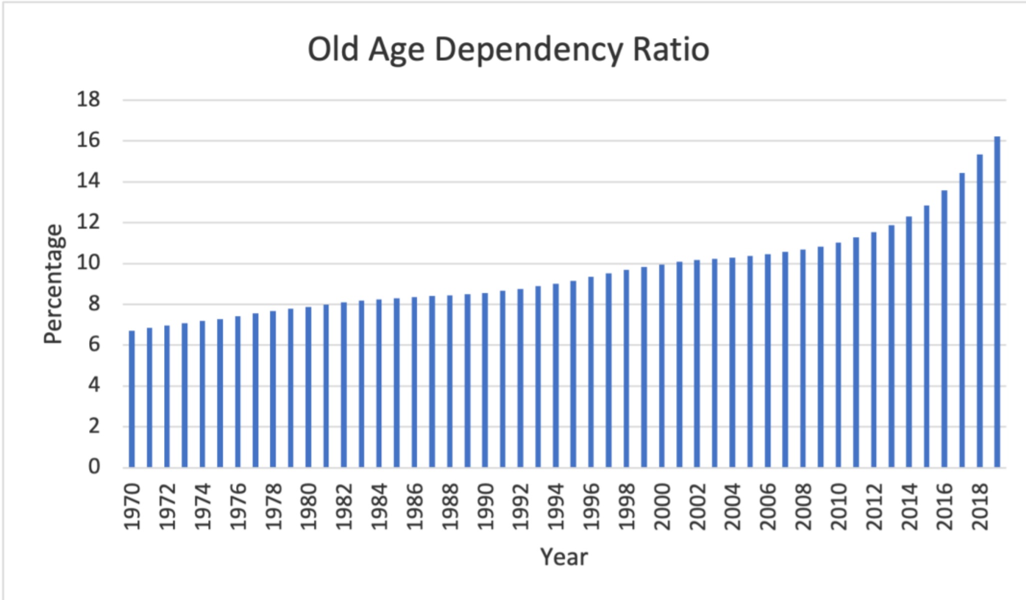

Figure 2.1: China's Nationwide Old-Age Dependency Ratio (persons aged 65 and older divided by the population aged 15 through age 64)

Another typical table to reflect the age composition of China over time is the population counts by broad age groups (see Appendix Figure A.1). Starting from 2000, there is a sharp increase in the population counts for people over 65 and it's also predicted that the fraction of older people will remain at a high level until the year 2100 (United Nations' World Population Prospects). In the meanwhile, we see that the population counts for all other age groups are expected to decrease over time.

2.2 Reasons Behind the Population Aging Problem in China

What caused the population aging problem in China? For China, the change in the population structure is closely related to the government's population policy in the past few decades. In the late 1970s, China implemented the one-child policy, requiring each couple only to have one child. It is considered one of the strictest population control policies and it was enforced through propaganda, fines, and even by force. A couple would be fined for tens of thousands of dollars if they broke the law and had an extra child. The fine amount is many times the average yearly income of many Chinese. If a couple were unable to pay the fine, they may lose their jobs and their children would be denied their rights and benefits of the country, like receiving education at very low cost~~s~~ in public schools. The government ensured serious consequences for not complying with the national population policy. On the other hand, the government rewarded couples who complied with the policy with benefits including extra salary, interest-free loans, better health care and extended maternity leave for women. It is straightforward to see the impact of population policy in Figure 2.2, which shows China's total fertility rate (defined as the total number of children that would be born to each woman). There was a sharp decrease in the fertility rate in the 1970s, when the one-child policy was implemented. And in the 1990s, the rate dropped below 2.1, which is the replacement rate (United Nations, 2015).

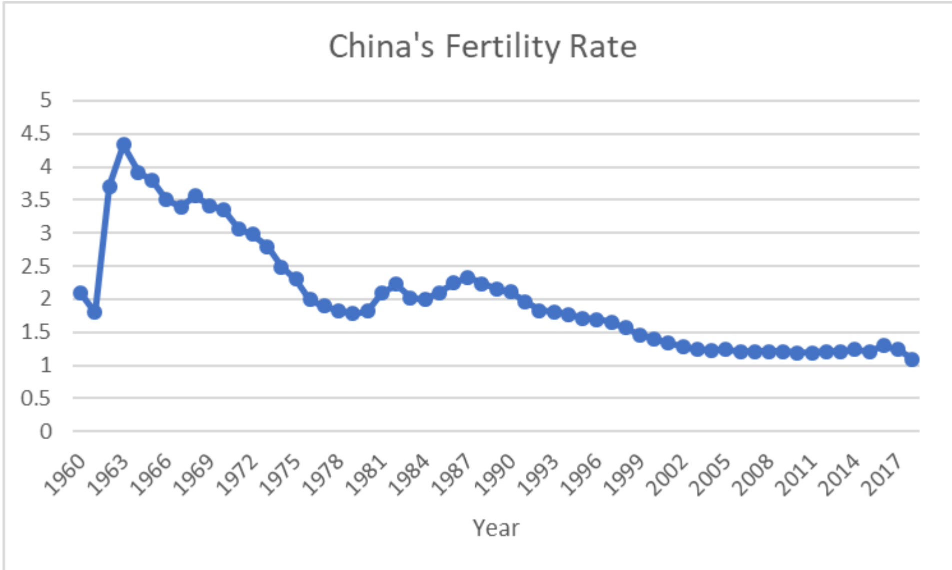

Figure 2.2: China’s Nationwide Fertility Rate

Another consequence of the one-child policy was the sex-selective abortions due to a long-established preference for boys rather than girls in China. To a varying degree of extent, Chinese couples and grandparents may consider boys to have "more value" than girls, and boys are likely to provide better support to their old parents when they grow up. After the one-child policy was implemented, sex-selective technology spread in China around the 1980s. These methods were used to tell the gender of the baby when women are pregnant. In some cases, where the family has a strong preference for sons, the couple would decide not to keep the fetus if they found they would have a baby girl. This led to an unbalanced sex ratio and further decreased the fertility rate in China. In addition, the “missing women of China” problem is projected to become worse and worse in the following several decades. According to United Nations’ World Population Prospects, China is projected to have around 244 million fewer women than men in 2050.

The one-child policy remained effective until 2013, when it was announced that certain couples, in which one member is the only child in his or her family, would be allowed to have two children. In 2016, the policy was further relaxed so that all couples were eligible to give birth to two children. Then in 2021, China began allowing couples to have at most three children. The Chinese government also provides a series of support measures ranging from tax breaks, admission to better schools for children, and longer and flexible work leave for women to encourage births. However, many couples, especially those who live in urban areas, may choose not to have a second child as the cost of living in big cities is very high in China. Although the Chinese government made great efforts to encourage births, data in Figure 2.2 shows that these changes have had little effect on the fertility rate and it has remained below 1.5 in recent years. As the relatively larger group of people born before the 1970s reached 65 and entered the older age group, the Chinese population is turning into an aging population.

Besides the one-child policy, the increase in life expectancy is another factor that can account for the increasing degree of population aging. As more diseases can be cured today than before, people tend to live longer lives. The average life expectancy for Chinese people was 66.41 years in 1980. It kept increasing in recent decades and increased to 71.25 years in 2000, and then it reached 76.96 years in 2020 (from World Bank open data). With other factors the same, increasing life expectancy will also lead to a larger proportion of the old-age persons in China.

To conclude, China's long-term low fertility rate and the increase in life expectancy together have contributed to the population problem, and it's generally predicted that the aging problem is one of the major threats the Chinese government needs to face within the following several decades.

2.3 Effect of Age Composition on China's Economy

The aging problem is reflected in the dynamics of China's population pyramids. Figure 2.3 shows China's demographic pyramid in 1990 and 2020, and also the projection made by United Nations for 2030 and 2050 (uncertainty is shown in lighter shades for 95 percent confidence intervals). The graph has a trend to transition from a standard pyramid (wider base bars and narrower top bars) to an inverted pyramid (narrower bottom bars and wider top bars). A standard population pyramid shows a larger percentage of the population in the younger age cohorts, whereas an inverted pyramid means that fewer young people need to support a growing, aging population, which is the current situation in China.

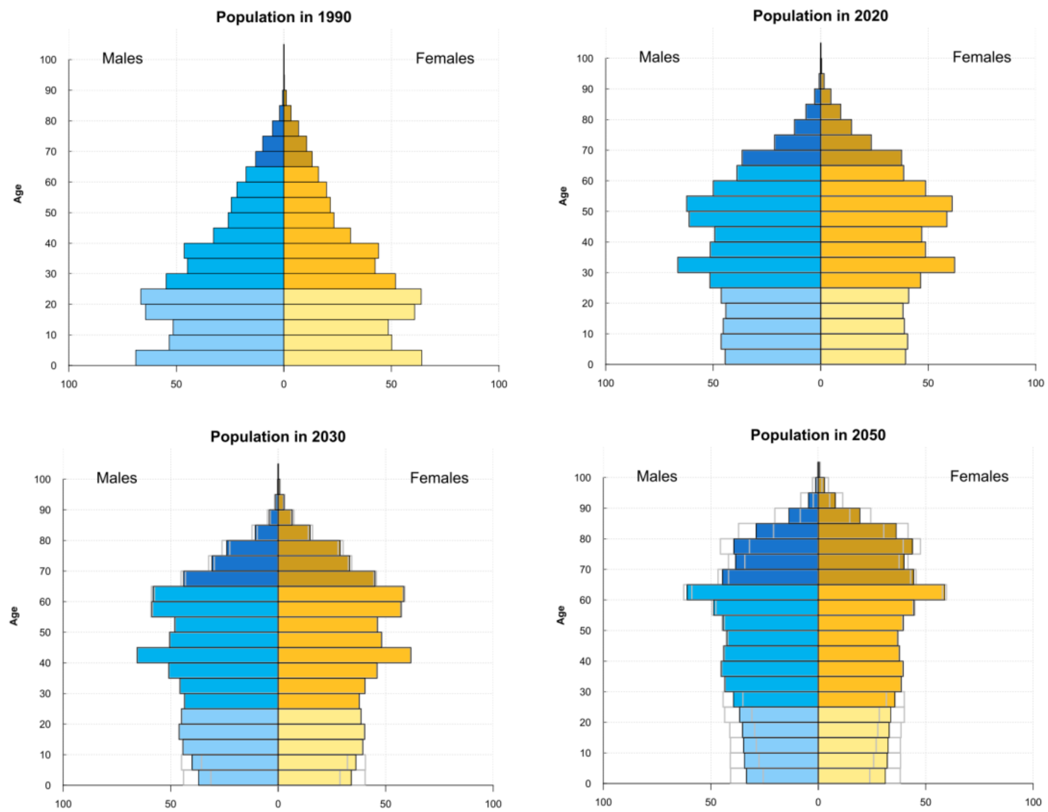

Figure 2.3: China's Population Pyramids (from United Nations Projection)

Before finally causing population aging that may be unfavorable to economic development, the low fertility rate in China had contributed to a rapid increase in the workforce since the 1970s. This is called the 'demographic dividend' by economists. During the majority of its economic reform period, the favorable demographic structure provided China with a sufficient supply of labor, human capital improvement, and radical resource reallocation through labor mobility. These conditions allowed China to harness its demographic dividend and have unprecedented economic growth. However, traditional growth sources may be depleted as China transforms into an aging society in recent years. The increasing old-age dependency ratio and the disappearance of the demographic dividend may cause a slow down in the future economic growth.

There are typically two reasons why population aging may slow down the economic growth rate. First, since older people are in general less economically productive than working-age people, a country with a larger ratio of older to younger persons may experience slower economic growth. In addition, the changes in the population composition may also affect the labor market outcomes. Having more older people to take care of, each working-age person may be burdened by the need to take care of his family members. This may also cause a decrease in the productivity of working-age people. Maestas et al. (2016) found evidence to support this view. Using U.S. state-level data, they found that as the population ages, it would cause a decrease in the productivity of workers.

In China, a typical example to illustrate the second point is the 4-2-1 family structure, which is becoming more and more prevalent in China today (Figure 2.4 shows this family structure). Specifically, the 4-2-1 family structure consists of four older people (grandparents), two parents (working-age people who were born before the one-child policy was in effect), and only one child (who was born after China implemented the population policy). Since the implementation of the one-child policy, the number of one-child families has increased significantly in China. As more and more of these children reach their marriageable age, there will likely be an increasing number of 4-2-1 families in China in the coming years.

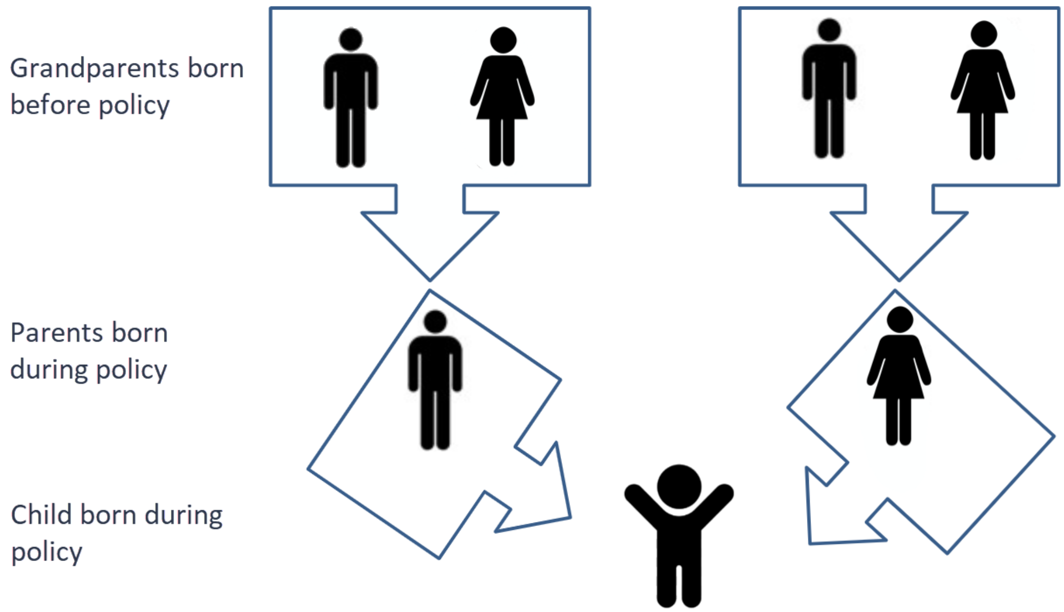

Figure 2.4: Four-Two-One Family Structure in China

Jiang and Sánchez-Barricarte (2011) have found that the four grandparents are likely to coexist for 16 years after the birth of their grandchild. After one grandparent passes away, the remaining three will on average spend another 8 years together. In the end, after another passes away, the surviving two old grandparents will on average coexist for another 5 years. Thus, for the middle generation of a 4-2-1 family, they need to take care of both their older people and their child for a fairly long period of time. Instead of having multiple siblings to support the older parents, working-age people in China will need to support and take care of four old parents on their own. In 4-2-1 families, it is generally believed that the pressure may be severe on the working-age middle generation.

2.4 Effect of Age Composition on China's Labor Market

For now, the effects of age composition on labor force outcomes for prime-age workers are uncertain. On the one hand, as older workers retire, the young workforce can take over their job positions. And the aging population may also lead to additional job openings in specific industries (like healthcare). In this way, more younger workers may be induced to increase their labor supply. On the other hand, as mentioned in section 2.3, caring for aging family members may take up many younger workers' time, which could lower their labor supply. And considering the need to take care of their children or/and older people, prime-age workers may have less incentive to migrate to higher-earning jobs and choose to work for a firm or organization near their home. This way, the need of caring for older parents may hinder their career development.

Chapter 3

LITERATURE REVIEW

Studies dealing with the effect of aging on economic growth use either a cross-country panel dataset or a single country's dataset.

Bloom et al. (2010) construct a cross-country panel dataset where the data was observed every 5 years in 1960 to 2000. The regression analysis shows that the major drivers of economic growth are the rising labor force-to-population ratio, increased trade openness, and overall improved health (proxied by the average life expectancy). They find that a higher proportion of working-age people can provide an opportunity for a potential economic boom on the labor supply side. However, whether this potential is realized or not depends on the country's policy environment. The interaction term between the policy environment measure and the growth rate of the labor share is included in the regression model, and the coefficient on this term is significantly positive. This suggests that the better the policy environment, the better a country will develop using the “demographic dividend”, which is the growth of the working-age share of the country’s population.

Up to now, the population aging problem has been a prevalent problem in high-income economies. In view of that fact, previous papers use data from high-income economies to analyze the impact of age composition. Maestas et al. (2016) use the two-stage least squares method to analyze the effect of population aging on state-level GDP per capita in the United States, where population aging has been long underway. The state-level data in 1980, 1990, 2000 and 2010 is used for analysis. The predicted variation in the rate of population aging is used as an instrumental variable for the actual rate of population aging across states. The estimate shows that a 10% increase in the fraction of the older people decreases the GDP per capita growth rate by 5.5%. And population aging will have a negative impact on both the labor-to-population ratio and labor productivity. Cooley and Henriksen (2018) find similar results using the data of the U.S. and Japan in the years before the financial crisis. They find that population aging and an increase in life expectancy can partly explain the slower growth, falling productivity growth, and lower economic growth. These changes are due, in part, to the decrease in labor supply, both on the extensive and intensive margin. Favero and Galasso (2015) suggest that demographic factors are related to lower economic growth but not lower interest rates in Europe. However, Acemoglu and Restrepo (2017) present contrary results where they don’t find a significant negative effect of population aging on economic growth, but the changes in age structure are correlated with the adoption of advanced autonomous technology.

Other research looks into the impact of the "demographic dividend" on the economic growth of East Asian countries in recent decades. They generally find that when a larger proportion of the population reach the prime age for working and saving, a country’s economy benefits. Bloom and Finlay (2009) analyze the impact of demographic factors on growth in 1965 to 2005. To address the concern of reverse causality, they instrument population and labor force growth with the lag of population and labor growth, as well as the lag of infant mortality rate and the lag of fertility rate. They find that the economic growth pattern between the two time periods, 1965–1990 and 1990–2005, is very different. But from the regression results, demographic factors are a key explanatory variable of economic growth in East Asia. Apart from that, education, trade openness and the degree of democracy (Freedom House Polity Index) are also positively correlated with growth.

Chapter 4

DATA

4.1 Research Question

Inspired by Maestas et al. (2016), I apply similar econometric methods to analyze the effect of population aging in China and include an expansion of the outcome variables. My research question is: what is the impact of age structure on GDP per capita and labor market outcomes in China? The three labor market outcomes examined include the labor participation rate, labor productivity and the average wage level. Besides, I use a more detailed geographic classification (city-level data) than the previous studies that used province-level data to capture the effect, using the variation in the rate of population aging across Chinese cities to estimate the effect of population aging. By doing this, a larger sample size is obtained, which will help get more accurate estimates (besides using city-level data, I also estimate regressions using province-level data and include the regression results in section 6.3).

4.2 Data Sources

To construct measures of the age structure in a city, I obtained city population counts by 5-year age groups from two data sources: China's population census (conducted in the years 2000 and 2010) and the 1% nationwide population survey (conducted in the years 2005 and 2015). Generally, around two years after the census or survey, most provinces would make the data available to the public. I collected the age distribution data from the publication of each province and then combined them to get a panel data set. Note that only the resident population is counted for a given city in a given year, and the resident population refers to those who have stayed in the city for at least six months in that year. Over the 15 years that I analyzed, the geographical division for Chinese cities has changed for some regions. It may have happened that a certain city was further divided into several smaller cities, each taking up a smaller region than the initial city. In the regressions, I drop the cities having the above-mentioned characteristics. Only those cities that have a nearly fixed boundary over the time period are kept for analysis.

For the outcome variables (GDP data and data measuring labor market outcomes), I collect the data from Chinese cities' statistical yearbooks for the years 2000, 2005, 2010 and 2015. For the control variables (industry composition for the labor force), I collect the data from the CEIC database.

4.3 Data Description

Table 4.1 shows the summary statistics for the variables included in the regressions. I construct 5-year percentage changes for GDP per capita and the average wage. The percentage changes are also calculated for the true and predicted fraction of the older population. Specifically, the changes are constructed over three 5-year periods: 2000 to 2005, 2005 to 2010, and 2010 to 2015. The first four rows of Table 4.1 show the statistics for the percentage changes with all years of population survey pooled. The mean percentage change in the fraction of the population over the age of 65, which is the main variable of interest, is 12.0%. The mean predicted percentage change in the fraction of older people is 11.7%, which is close to the mean actual percentage change. The mean percentage change in the GDP per capita is 63.1% and the mean percentage change in the average wage is 54.8%.

In the remaining part of Table 4.1, statistics are also shown for the fraction of workers in different industries. With the four years of population survey pooled, the largest proportion of the workforce is in the manufacturing industry, which is in line with the fact that China is the world's leading manufacturer (especially for chemical fertilizers, cement and steel). Around 15% of the labor force are working in the education and entertainment industry, which is the second-largest industry. The public management industry ranks third in terms of the fraction of the labor force. All the other 12 industries each account for around or less than 5% of the total labor force. At the end of Table 4.1, I also list the sector-specific output as a percentage of total output. The secondary sector on average accounts for the largest proportion, which is 46.8%. The tertiary sector on average accounts for 35.3% of total output, and the remaining 17.7% is related to the production in the primary sector.

Table 4.1: Summary Statistics

Variable	Mean	Std. Dev.	Min	Max
Percentage change in the fraction of old people (%)	11.968	5.684	-4.323	31.038
Predicted percentage change in the fraction of old people (%)	11.722	5.57	-3.582	30.122
Percentage change in GDP per capita (%)	63.14	13.339	30.105	102.672
Percentage change in average wage (%)	54.83	16.755	20.075	88.869
Fraction of workers by industry (%)				
Agriculture	5.893	11.811	.028	66.399
Mining	6.261	9.994	.009	58.556
Manufacturing	26.72	12.82	3.235	73.293
Utility service	2.926	1.326	.075	8
Construction	7.974	5.969	1.297	50.075
Environmental management	1.464	1.183	.031	12.684
Transportation	4.33	2.183	.769	12.9
Retail	6.224	3.303	.783	19.016
Finance	3.184	1.086	.321	8.047
Real estate	.877	.796	.023	8.974
Residential service & other services	1.49	1.874	.026	13.65
Social welfare	4.737	1.668	.636	10.329
Education & entertainment	15.039	6.373	2.154	33.554
Information technology & science	1.242	1.103	.075	7.586
Public management	11.64	4.962	1.366	28.973
Sector output as percentage of total output (%)				
Primary Sector	17.752	10.427	.4	51.8
Secondary Sector	46.843	11.765	15.7	89.7
Tertiary Sector	35.384	7.922	8.5	65.25

Chapter 5

IDENTIFICATION STRATEGY

5.1 Two-Stage Least Squares Regression

To analyze the causal effect of population aging on economic growth and labor market outcomes, the following regression equation is applied:

$$\ln y_{j,t+5} - \ln y_{j,t} = \varphi_t + \beta \left[\ln\left(\frac{A_{j,t+5}}{N_{j,t+5}}\right) - \ln\left(\frac{A_{j,t}}{N_{j,t}}\right)\right] + X'_{jt}\delta_t + \left(\varepsilon_{j,t+5} - \varepsilon_{j,t}\right) \quad (1)$$

For city j, at year t:

- $y_{j,t}$: outcome variable
- $A_{j,t}$: number of individuals aged over or equal to 65
- $N_{j,t}$: number of individuals aged over or equal to 15
- $X_{j,t}$: control variables

The dependent variable is the change in the log of the outcome variable from year t to year t+5 in city j, which is also the percentage change in the outcome variable. Variables measuring economic growth and labor market measures are used as the outcome variables in Equation (1), where the object is to estimate the effect of population aging on them. Since it has been found that initial industry composition would affect the employment and wages of the population (Maestas, Mullen and Powell, 2013), I include each city's industry composition for the labor force (the log of the fraction of workers in each industry) as control variables ($X_{j,t}$). Specifically, China's labor market can be categorized into 15 industries and the details for this classification are shown in Appendix Table A.2. The log of the fraction of workers in each industry is used as the control variable in the regression equation. Time fixed effects (φ_t) are also included in the equation. Last but not least, since there may exist some unobserved components in the outcome variable that are correlated within a cluster, the standard errors are clustered at the city level.

I use the ratio, $A_{j,t} / N_{j,t}$ in the regression equation as a proxy for population aging. It quantifies the burden that old-age people put on the working-age people. In contrast to using the old-age population share as the main independent variable, which is also a popular proxy used in literature, the old-age dependency ratio takes one situation into consideration where an increasing old-age population share coincides with an increasing working-age population share. In that case, the positive effect of the increasing working-age population may mitigate the negative impact of the population aging problem on economic growth. In the regression equation, by including the old-age dependency ratio, this situation is reflected by a lower value of the independent variable compared to having the old-age population share in the equation. Specifically, the expression in square brackets is the variable of interest and it is equal to the percentage change in the extent of population aging. Moreover, by having the log-difference specification for both main independent and dependent variables, it normalizes the comparison across different cities in China. Then β represents the elasticity of the outcome variable with respect to population aging.

While Equation (1) relates changes in city population aging to city economic growth changes, there are some confounding factors, such as migration and mortality rates. When a city experiences an economic decline, the residents may tend to migrate out of the city they live in. Prime-aged workers are more likely to migrate to other cities having better economic conditions, while older people may choose to stay given the smaller lifetime return to moving. In this case, we would find those aging cities have slower economic growth rates, though this relationship is not causal. Migration may increase the magnitude of the age composition effect on economic growth. Besides, city economic conditions may affect mortality rates and then alter the age composition of a city. Cutler and Meara (2001) show the negative effect of economic conditions (early in life) on individual mortality rates. As large and fast-growing cities can provide better medical care to their residents, it will lead to a reduction in the mortality rate. In addition, they also show that the mortality rate reduction is concentrated among the older population. In this way, cities having better economic conditions may have a larger group of older people, and thus experience an increase in the old-age dependency ratio of the city. Considering this aspect, the magnitude of the estimated effect may be decreased in the OLS regression. To conclude, these confounding factors would all lead to the point estimate in Equation (1) not capturing the causal effect.

To address potential simultaneity, I use two-stage least squares regression. The Bartik instrument is applied in this study, which is a common instrument that uses lagged stocks of a variable at a regional or categorical level, combined with aggregate flows to predict the values of the endogenous variable (Goldsmith-Pinkham, 2020). In the context of this paper, the instrument is the predicted value of the variable of interest, which is the predicted change in the log of the fraction of the city population aged 65+, i.e. $\ln \frac{\widehat{A_{j,t+5}}}{\widehat{N_{j,t+5}}} - \ln \frac{A_{j,t}}{N_{j,t}}$. It is similar in spirit to the instrumental variable used in Maestas et al. (2016), Bartik (1991) and Blanchard and Katz (1992).

To derive the instrumental variable, I follow several steps to get the first predicted term in the variable expression. I define $M_{i-i+4,j,t}$ as the number of people aged between i to $i+4$ in city j in year t (the age i and $i+4$ are included in the population count). Then $\widehat{A_{J,t+5}}$ and $\widehat{N_{J,t+5}}$ can be expressed as the sum of predicted population counts for 5-year age groups, respectively:

$$\widehat{A_{J,t+5}} = M_{\widehat{65-69,J},t+5} + M_{\widehat{70-74,J},t+5} + \cdots + M_{\widehat{85plus,J},t+5} \tag{2}$$

$$\widehat{N_{J,t+5}} = M_{\widehat{15-19,J},t+5} + M_{\widehat{20-24,J},t+5} + \cdots + M_{\widehat{85plus,J},t+5} \tag{3}$$

The final step is to derive the predicted population count of each 5-year age group. It can be constructed using the method below. For example, the predicted number of those aged between 15 to 19 in city j in year t+5 is:

$$M_{\widehat{15-19,J},t+5} = M_{10-14,j,t} * \frac{M_{15-19,t+5}}{M_{10-14,t}} \tag{4}$$

where $\frac{M_{15-19,t+5}}{M_{10-14,t}}$ is the province-level survival rate, which is the ratio of the province population aged 15-19 to the cohort's population size in the prior census (5 years ago). And $M_{10-14,\mathrm{j},t}$ is the actual population size for those aged between 10 to 14 in city j at time t.

Following equation (4), I can get predicted population counts for most groups: from $M_{\widehat{15-19,J},t+5}$ all the way to $M_{\widehat{80-84,J},t+5}$ (the predicted population counts for those aged between 80 and 84). But there is one special case, which is for those who are over the age of 85. The formula to get the predicted value for that group is:

$$M_{\widehat{85plus,J},t+5} = M_{80plus,j,t} * \frac{M_{85plus,t+5}}{M_{80plus,t}} \tag{5}$$

The population counts are unbounded from the right-hand side to solve for $M_{\widehat{85plus,J},t+5}$. After solving for all the predicted terms on the right-hand side of equation (2) and (3), I plug them back into the formula for the instrumental variable, i.e. $\ln\frac{\widehat{A_{J,t+5}}}{\widehat{N_{J,t+5}}} - \ln\frac{A_{j,t}}{N_{j,t}}$. Then I can ultimately get the value for the instrumental variable.

5.2 Decomposing the Effect

To understand the mechanisms driving changes in the GDP growth rate, I also examine specific decompositions of GDP per capita. Specifically, in Equation (6), GDP per capita can be decomposed into GDP per worker (labor productivity) and the labor to population ratio. By using GDP per worker and labor to population ratio as two additional outcome variables (i.e., replace the outcome variable in Equation (1) with these two terms respectively and re-estimate the regressions), I can further check how much of the effect of population aging on economic growth operates through each channel.

$$\ln(GDP\ per\ capita) = \ln\frac{GDP}{N} = \ln\frac{GDP}{L} + \ln\frac{L}{N} \quad (6)$$

where

- N: total population
- L: total labor force

Chapter 6

EMPIRICAL RESULTS

6.1 Effect of Population Aging on Economic Growth

6.1.1 Aggregate Effect and Heterogeneous Effect by Year

Table 6.1 shows the first-stage estimates. The dependent variable is the actual percentage change in the fraction of persons over or equal to the age of 65, i.$e.$ $\ln\frac{A_{j,t+5}}{N_{j,t+5}} - \ln\frac{A_{j,t}}{N_{j,t}}$. And the main independent variable is the instrumental variable (predicted percentage change in the fraction of older people[2]). The estimates using the full sample are shown in the first column, and the estimates separately for each 5-year period are shown in columns 2 to 4. We can see that the instrumental variable used is highly correlated with the endogenous variable, and this correlation also holds for each five-year period.

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[2] Older people refers to those who are over or equal to the age of 65

Table 6.1: First-Stage Regression Estimates

	Dependent Variable: $\Delta \ln (A/N)$			
	(1) Full Sample	(2) 2000-2005	(3) 2005-2010	(4) 2010-2015
$\Delta \ln \widehat{(A/N)}$	0.849***	0.848***	0.734***	1.042***
	(0.0288)	(0.0713)	(0.0421)	(0.0368)
2005.year	-0.00545			
	(0.0152)			
2010.year	0.0163			
	(0.0178)			
N	434	151	167	116

Notes: The main effect using the full sample is presented in column (1) and the effects separately for each 5-year period are presented in column (2) to column (4). The log of the fraction of workers in different industries are included as control variables for all regressions (effects are omitted in the table). Year dummies for the year 2005 and 2010 (for the second and third 5-year time period) are included in the full sample regression. Standard errors adjusted for clustering at the city level.
* p<0.1.
** p<0.05.
*** p<0.01.

Table 6.2 shows two-stage least squares regression estimates. The dependent variable is the change in log per capita GDP, and the right-hand side variable of interest is the percentage change in the fraction of older people. Specifically, the point estimates represent the elasticity of economic growth with respect to population aging. The estimates for the entire time period 2000-2015 are shown in the first column, and the estimates separately for each 5-year period are shown in columns 2 to 4. The effects of control variables (industry composition of the labor force) are omitted in Table 6.2[3]. The regression estimates indicate that cities experiencing growth in the

[3] The complete regression results are shown in Table A.3 in the appendix.

fraction of individuals ages 65+ also experience slower growth in per capita GDP. Using the entire sample, I find that a 10% increase in the fraction of the older population would lead to a decrease in economic growth by 2.42%. Limiting the sample to one five-year period at a time, I also find a statistically significant effect in the periods 2000 to 2005, and 2010 to 2015. Especially for the time period 2010 to 2015, I find that a 10% increase in the fraction of the older population would lead to a decrease in economic growth by 3.69%. This estimate is larger in absolute value than the effect using the full sample. It implies that the impact of population aging on economic growth tends to intensify as time goes by. In addition, the coefficient of the time fixed effect for the last 5-year period is -0.120, implying that Chinese cities overall have a slow-down in their economic development in 2010 to 2015.

Table 6.2: Two-stage Least Squares Regression on GDP Per Capita

	Dependent Variable: Δ ln (GDP/N)			
	(1) Full Sample	(2) 2000-2005	(3) 2005-2010	(4) 2010-2015
Δ ln (A/N)	-0.242***	-0.203**	-0.120	-0.369***
	(0.0870)	(0.0830)	(0.112)	(0.109)
2005.year	-0.0143			
	(0.0263)			
2010.year	-0.120***			
	(0.0322)			
N	434	151	167	116

Notes: The main effect using the full sample is presented in column (1) and the effects separately for each 5-year period are presented in column (2) to column (4). The log of the fraction of workers in different industries are included as control variables for all regressions (effects are omitted in the table). Year dummies for the year 2005 and 2010 (for the second and third 5-year time period) are included in the full sample regression. Standard errors adjusted for clustering at the city level.

* p<0.1. ** p<0.05. *** p<0.01.

In addition to two-stage least squares regression, I also estimate an OLS regression and instrumental variable regression with no control variables in the equation. The estimates are shown in Table 6.3. By comparison, the instrumental variable estimates are smaller in magnitude than the OLS estimates. One potential explanation for this is that younger individuals are induced to migrate to faster-growing areas, enlarging the effect in the OLS regression. Although there is an opposite effect on the regression estimates when taking the mortality effect into consideration. The migration factor outweighs the other factors. Besides, by comparing column(2) with column(3), I can find that only a very small portion of the effect is captured by the control variables. There is not much difference between the two estimates in column (2) and (3).

Table 6.3: Comparison of OLS versus Instrumental Variable Estimates

	Dependent Variable: $\Delta \ln (GDP/N)$		
	(1) OLS	(2) IV no control	(3) IV
$\Delta \ln (A/N)$	-0.316^{***}	-0.266^{***}	-0.242^{***}
	(0.0499)	(0.0701)	(0.0870)
N	434	434	434

Notes: The log of the fraction of workers in different industries and year dummies are included as control variables for all regressions (effects are omitted in the table).Standard errors adjusted for clustering at the city level.
* p<0.1.
** p<0.05.
*** p<0.01.

6.1.2 Heterogeneous Effects by Region

Besides estimating regressions using the whole sample, I also divide the sample into different groups and estimate 2SLS regressions on each group. I apply two division rules, and each rule divides Chinese cities into two segments. One is a more developed segment, and the other is a less developed segment and relies more on agriculture. It may be that the impact of age composition is different across cities with different economic conditions.

The first division rule is based on the fact that China is divided into four major economic regions the eastern region, the northeast region, the central region, and the western region. The study is focused on cities in the mainland of China and the details about this division rule are shown in Figure A.2 and Table A.1 in the appendix.

Due to geographical and policy factors, there are regional differences in the economic growth rates, population density as well as drivers of growth in different parts of China. And those differences lead to different economic development patterns in the above-mentioned four parts of China. Moreover, the average GDP per capita is significantly larger in the eastern area than in the other three, and cities in the eastern area are generally considered to have been benefiting from the newest technology and have turned into a more developed region. Thus, I put the cities in the central, western, and northeastern areas in one group and put those in the eastern region in another group, which is my first division rule to check for the heterogeneity effects of population aging.

Second, I divide Chinese cities into two groups based on City Tiering. City Tiering is based on the Ranking of Cities' Business Attractiveness compiled by the Rising Lab of Yicai Media Group. The City Tiering for Chinese cities combines data from nearly 200 mainstream commercial big brands, big data from about 20 Internet companies and data institutions. It is calculated and ranked by aggregating five first-level dimension indices, including Concentration of Commercial Resources Index, City as a Hub Index, Urban Residents' Activity Index, Lifestyle Diversity Index, and Future Potential Index, as well as nearly 20 second-level dimension indices and nearly 80 third-level dimension indices (CEIC database). I put cities in the first-tier and second-tier as one group, which are considered to be more developed areas. I put the remaining cities, which are the cities that belong to the third-tier and after, in another group. The second group includes cities that are less developed than the first group.

I estimate regressions for different groups separately. The two-stage least squares regression results are shown in Table 6.4. Column (1) reproduces the aggregate effect of population aging on growth. Columns (2) to (5) present the estimates in each region or group. From column 2 and column 5 in Table 6.4, I find that the point estimates are not significant in more developed areas (the eastern areas and first/second-tier cities), but a significant impact of population aging is still found in less-developed regions. In the western, central and northeastern regions, a 10% increase in the fraction of the population aged over 65 causes a 2.31% decrease in the GDP per capita growth rate. Similarly, there is also a significant effect for cities belonging to the third-tier or below the third-tier.

There are potentially two reasons to account for the different impacts between developed and less-developed cities. First, it is related to the main industries that a city relies on. Besides age composition, there are other significant drivers of economic growth in the developed area, for example, capital stock and technological advancement. Then age composition may play a less significant role in determining economic development, and developed cities suffer less from population aging. On the other hand, less-developed cities rely more on labor-intensive industries. Then population aging will have a greater influence among those cities. Second, the aging population may lead to additional job openings in some industries like healthcare in big cities. While this rarely happens in the less developed area.

Table 6.4: Heterogeneous Effect of Population Aging by Areas

	Dependent Variable: Δ ln (GDP/N)				
	(1) Full Sample	(2) West & Central& Northeast	(3) East	(4) Third-tier and after	(5) First- & Second-tier
Δ ln (A/N)	-0.242***	-0.218**	-0.216	-0.231**	-0.153
	(0.0870)	(0.100)	(0.164)	(0.0934)	(0.144)
2005.year	-0.0143	-0.0156	-0.0106	-0.0282	-0.0124
	(0.0263)	(0.0332)	(0.0563)	(0.0348)	(0.0586)
2010.year	-0.120***	-0.133***	-0.113	-0.148***	-0.0999
	(0.0322)	(0.0451)	(0.0709)	(0.0433)	(0.0758)
N	434	268	166	290	144

Notes: The main effect using the full sample is presented in column (1). The effects separately for different regions of China are presented in column(2) and column(3). The effects for cities in different levels are separately presented in column(4) and column(5). The log of the fraction of workers in different industries are included as control variables for all regressions (effects are omitted in the table). Year dummies for the year 2005 and 2010 (for the second and third 5-year time period) are also included in the regression. Standard errors adjusted for clustering at the city level.

* p<0.1.
** p<0.05.
*** p<0.01.

6.1.3 Effect on Sector-Specific Output

It may happen that the effect of population aging is different across three main sectors, depending on the sector-specific skill demands, labor force participating in different sectors and the structure of the workforce. To explore this, I estimate the main regression equation (Equation 1) separately by sector. The dependent variable is the sector-specific GDP per capita and the set of independent variables remain the same as before. The regression results are presented in Table 6.5.

Table 6.5: Effect of Population Aging on Sector-Specific Output

	Dependent Variable: $\Delta \ln(sector\ specific\ GDP\ per\ capita)$		
	(1) Primary Sector	(2) Secondary Sector	(3) Tertiary Sector
$\Delta \ln(A/N)$	-0.108	-0.251**	-0.140
	(0.125)	(0.108)	(0.110)
2005.year	-0.00584	-0.0396	0.0231
	(0.0567)	(0.0432)	(0.0488)
2010.year	0.0392	-0.340***	0.0721
	(0.0646)	(0.0537)	(0.0548)
N	427	427	427

Notes: The effects on the primary, secondary and tertiary sector GDP per capita are respectively presented in column (1) to (3). The log of the fraction of workers in different industries are included as control variables for all regressions (effects are omitted in the table). Year dummies for the year 2005 and 2010 (for the second and third 5-year time period) are also included as control variables. Standard errors adjusted for clustering at the city level.

* p<0.1.
** p<0.05.
*** p<0.01.

The second column in Table 6.5 shows the effect of population aging on growth in secondary-sector output. I estimate that a 10% increase in the extent of population aging decreases growth in secondary-sector output per capita by 2.51%. The estimate is similar in scale to the main estimate for total output per capita in column (1) of Table 6.2. It implies that the effect of population aging is mainly driven by changes in the secondary-sector output. The other two columns show the effect of population aging on primary and tertiary sector output. Those estimates are not statistically significant.

In addition to regressing on sector-specific output, I also estimate regressions using the percentage of sector-specific output in total GDP. This measures how much the output of each sector accounts of the total GDP per capita. Given the current age structure of a city, it may happen that the city tends to shift to a different growth path or output structure as the population ages. The regression results are presented in Table 6.6. The set of independent variables remain the same as before. I find that none of the estimates are significant. This implies that as the fraction of the older population increases in a city, there is not a clear pattern of how the output structure would change for the city.

One potential explanation for the statistically insignificant regression results in Table 6.6 is due to the fact that the Chinese government is still playing an important role in determining the sectoral output structure and resources distributed to regions of China. The policy set by the government, aiming to boost the development of certain industries of sectors in a city, has a large impact on the output structure and growth path of the city. For the time period analyzed in this paper, which is from year 2000 to 2015, there are other more important factors considered by the government when setting the support policy for a certain region, for example, geographic conditions, natural resources and the impact on the nearby cities' development. The age composition of a certain city appears to be a trivial factor when the policy is made. In addition, certain policies can provide companies with many privileges when growing and also create many new job openings. Young working-age people have the incentive to migrate to the city that gains the policy support from the government. Thus the age structure of a city is not a primary consideration for the Chinese government when formulating policy. One typical example is Shenzhen, which is a Chinese city that became a special economic zone in 1980. Over the past four decades, Shenzhen has transformed from a small fishing village into a modern metropolitan area having a large proportion of young workers. The government's support policy played an important role in making this transformation.

Table 6.6: Effect of Population Aging on Percentage of Sector-specific Output in Total GDP

	Dependent Variable: $\Delta \ln(percentgae\ of\ sector\ output\ as\ of\ total)$		
	(1) Primary Sector Percentage	(2) Secondary Sector Percentage	(3) Tertiary Sector Percentage
$\Delta \ln(A/N)$	0.114	-0.0293	0.0816
	(0.116)	(0.0704)	(0.0942)
2005.year	0.00187	-0.0234	0.0393
	(0.0494)	(0.0353)	(0.0408)
2010.year	0.155***	-0.216***	0.197***
	(0.0548)	(0.0404)	(0.0441)
N	427	427	427

Notes: Sector-specific output as the percentage of total output are used as dependent variables. Effects on the primary, secondary and tertiary sector are respectively presented in column (1) to (3). The log of the fraction of workers in different industries are included as control variables for all regressions (effects are omitted in the table). Year dummies for the year 2005 and 2010 (for the second and third 5-year time period) are also included as control variables. Standard errors adjusted for clustering at the city level.
* p<0.1.
** p<0.05.
*** p<0.01.

6.2 Effect of Population Aging on the Labor Market

6.2.1 Decomposing the effect of Population Aging on GDP

By applying Equation (6), I decompose GDP per capita into GDP per worker (labor productivity) and the number of workers per capita (the labor to population ratio). Then I separately estimate the effect of population aging on these two terms and the results are shown in Table 6.7. I find that population aging decreases growth in the labor to population ratio. A 10% increase in the fraction of older people would lead to a 1.01% decrease in workers per capita. The effect of population aging on labor productivity, however, is not significant. This is in line with the findings of a previous study (Leigh 2009), where it is found that informal care for older people does have a negative effect on labor force participation, but the impact on other labor market outcomes (including work weeks per year and work hours per week) is quite small or doesn't exist.

Table 6.7: Decomposing the Effect on GDP

	(1) Fraction of population working $\Delta \ln (L/N)$	(2) GDP per worker $\Delta \ln (GDP/L)$
$\Delta \ln (A/N)$	-0.101**	-0.142
	(0.0412)	(0.0893)
2005.year	-0.0179	-0.00490
	(0.0156)	(0.0301)
2010.year	-0.00919	-0.122***
	(0.0199)	(0.0414)
N	413	413

Notes: The log of the fraction of workers in different industries are included as control variables for both regressions (effects are omitted in the table). Year dummies for the year 2005 and 2010 (for the second and third 5-year time period) are also included as control variables. Standard errors adjusted for clustering at the city level.
* p<0.1.
** p<0.05.
*** p<0.01.

The decrease in the average family size in China is one reason for the observed results. China has been trending to have smaller family size in the past two decades and family members are more connected to each other than before. Although the workforce may be burdened by the need to take care of the older people, older parents also provide support for their working-age children. Most of those grandparents in China still hold that it’s their duty to support their children even if their children have been adults for many years. In addition, the norm of leaving grandchildren with grandparents persists. In order to help their children seek career advancement, older people take an active role in caring for as well as raising grandchildren. Working-age parents feel a lot safer and less stressed to leave their children with grandparents, and this child-raising way makes the Chinese workforce much more comfortable balancing between work and life. In the end, the effort each working-age person puts into work is not greatly influenced by the need to support the older people. In some cases, working-age people can even put more time and energy into work since their parents take the lead caring for and raising their grandchildren.

Second, if one child takes the responsibility to provide care to the older parents, in most cases, it will free other children of the older parents from spending time taking care of them. Then it will merely have any effect on the labor market outcomes of the other children and for those who live away from their parents. By taking these two factors into account, it may explain why there is not a significant adverse effect on labor productivity as the population ages in China.

6.2.2 Effect of Population Aging on Average Wage

In section 6.2.1, I have found a negative impact of population aging on the labor to population ratio. In this section, I continue to examine the effect of the age distribution on average labor earnings per year (measured in Chinese yuan). I still apply the Bartik instrumental variable to help identify the effect, and Equation (1) is adjusted to have the percentage change in average real wage per year[4] as the outcome variable. Specifically, the regression equation using average wage level as the outcome variable is shown below:

$$\Delta \ln(average\ wage) = \varphi_t + \beta \Delta\, ln\left(\frac{A}{N}\right) + X'_{jt}\delta_t + \Delta\varepsilon \qquad (7)$$

where the ratio of $\frac{A}{N}$ represents the fraction of the older population. It is also a proxy for the extent of population aging in a given city.

Table 6.8 shows the two-stage least squares regression results. The estimates for the entire time period 2000-2015 are shown in the first column, and the estimates separately for each 5-year period are shown in columns 2 through 4. From the point estimates, I find that a 10% increase in the fraction of the older population would increase the average wage level by 1.67%. The point estimate for the time period 2000-2005 is not significant, whereas I find a positive relationship between population aging and average wage level increase in years 2005-2010 and 2010-2015. Table 6.9 shows the OLS estimates. When the OLS estimates are compared with the two-stage least squares estimates in Table 6.8, I find the OLS estimates overall are smaller in magnitude than the two-stage least squares estimates. In both regression specifications, the time fixed effects are not significant.

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[4] Average wage per year is calculated as total wage of staff and workers divided by average number of staff and workers in that year

There are potentially two reasons why the population aging would cause an increase in the average wage of workers. First, when the population ages in a given city, each working person needs to, on average, support more older people. As the medical expenses in China are still high for Chinese families, working-age people may be induced to work harder and earn higher income to cover the potential medical costs for their parents. Second, population aging is associated with a decrease in the labor force supply. With all other factors remaining the same, a decrease in the supply of workers will cause an increase in the average wage of workers.

Table 6.8: Two-stage Least Squares Regression on Average Wage

	Dependent Variable: $\Delta \ln(average\ wage)$			
	(1) Full Sample	(2) 2000-2005	(3) 2005-2010	(4) 2010-2015
$\Delta \ln (A/N)$	0.167^{***}	0.130	0.288^{**}	0.235^{***}
	(0.0549)	(0.0944)	(0.125)	(0.0908)
2005.year	0.00308			
	(0.0239)			
2010.year	-0.0146			
	(0.0299)			
N	433	151	166	116

Notes: The main effect using the full sample is presented in column (1) and the effects separately for each 5-year period are presented in column (2) to column (4). The log of the fraction of workers in different industries are included as control variables for all regressions (effects are omitted in the table). Year dummies for the year 2005 and 2010 (for the second and third 5-year time period) are included in the full sample regression. Standard errors adjusted for clustering at the city level.

* p<0.1.
** p<0.05.
*** p<0.01.

Table 6.9: OLS Estimates with Average Wage as the Outcome Variable

	Dependent Variable: $\Delta \ln(average\ wage)$			
	(1) Full Sample	(2) 2000-2005	(3) 2005-2010	(4) 2010-2015
$\Delta \ln(A/N)$	0.133***	0.0518	0.269***	0.206**
	(0.0480)	(0.0876)	(0.0938)	(0.0904)
2005.year	0.00515			
	(0.0239)			
2010.year	-0.00795			
	(0.0296)			
N	433	151	166	116

Notes: The main effect using the full sample is presented in column (1) and the effects separately for each 5-year period are presented in column (2) to column (4). The log of the fraction of workers in different industries are included as control variables for all regressions (effects are omitted in the table). Year dummies for the year 2005 and 2010 (for the second and third 5-year time period) are included in the full sample regression. Standard errors adjusted for clustering at the city level.

* p<0.1.
** p<0.05.
*** p<0.01.

6.3 Examining the Effect Using Province-Level Data

In addition to using city-level data, I also collected province-level data of China to examine the effect of age composition on economic growth and labor market outcomes.

The first-stage estimates (with the true percentage change in the fraction of the older population as the outcome variable, and predicted percentage change in the fraction of older people and control variables as independent variables) are shown in table 6.10. We find that the predicted change can strongly forecast the actual percentage change, which is in line with the conclusion when using city-level data.

But the coefficient estimates are generally a bit higher and closer to one than the first-stage estimates using city-level data.

Table 6.10: First-Stage Estimates Using Province-Level Data

	Dependent Variable: $\Delta \ln \left(\frac{A}{N}\right)$			
	(1) Full Sample	(2) 2000-2005	(3) 2005-2010	(4) 2010-2015
$\Delta \ln \widehat{(A/N)}$	1.031***	1.008***	0.791***	1.091***
	(0.0506)	(0.0534)	(0.245)	(0.0980)
N	92	30	31	31

Notes: The main effect using the full sample is presented in column (1) and the effects separately for each 5-year period are presented in column (2) to column (4). The log of the fraction of workers in three sectors and year dummies are included as control variables for all regressions (effects are omitted in the table). Standard errors adjusted for clustering at the province level.
* p<0.1.
** p<0.05.
*** p<0.01.

There are some differences between the raw city-level data and raw province-level data. The differences in data may account for the difference between first-stage estimates when using different levels of data. For cities, population counts for each 5-year age group are recorded from age 0-4 all the way to age 80-84. The last age interval is for those over the age of 85. On the other hand, province-level data has a more accurate count for the oldest population. The data contains population counts starting from age 0-4 all the way to age 90-94. The last count in province-level data is for those who are over the age of 95. Without combining people over the age of 85 together, I can generate a more accurate prediction for older people, and equation (2) and equation (3) will be updated to the following two equations.

$$\widehat{A_{J,t+5}} = M_{65\widehat{-69,J},t+5} + M_{70\widehat{-74,J},t+5} + \cdots + M_{95\widehat{plus,J},t+5} \tag{8}$$

$$\widehat{N_{J,t+5}} = M_{15\widehat{-19,J},t+5} + M_{20\widehat{-24,J},t+5} + \cdots + M_{95\widehat{plus,J},t+5} \tag{9}$$

It may happen that more accurate predictions for A and N are generated using province-level data. Then there is a higher probability of a closer match between the instrumental variable (predicted percentage change in old-age population) and endogenous variable (true percentage change in old-age population).

The two-stage least squares estimates using the change in the log GDP per capita as the dependent variable are shown in table 6.11, and the estimates using the change in the log of average wage are shown in table 6.12. I find that age composition has no significant effect on economic growth or average wage, which is different from the regression results I got by using city-level data. One reason for this is that there may exist aggregation bias. As I aggregate information on all cities in a province, the effect of age composition may be obscured and then lead to nonsignificant estimates. Although it involves less effort to collect and use province-level data for regressions, the results might be misleading. On the contrary, by using the finer-geographic classification (city-level data), the true effect of population aging will more likely be found.

Table 6.11: Two-Stage Least Squares Regression on GDP Per Capita Using Province-Level Data

	Dependent Variable: Δ ln (GDP/N)			
	(1) Full Sample	(2) 2000-2005	(3) 2005-2010	(4) 2010-2015
Δ ln (A/N)	-0.0781	-0.0465	0.140	-0.950
	(0.0714)	(0.0667)	(0.448)	(0.955)
Primary Sector	0.140***	0.0511	0.217***	0.0479
	(0.0388)	(0.110)	(0.0679)	(0.0617)
Secondary Sector	0.0155	0.0636	0.0391	-0.0489
	(0.0300)	(0.0553)	(0.0492)	(0.0655)
Tertiary Sector	0.105	-0.0411	0.162	0.0438
	(0.0969)	(0.148)	(0.128)	(0.173)
N	92	30	31	31

Notes: The main effect using the full sample is presented in column (1) and the effects separately for each 5-year period are presented in column (2) to column (4). The log of the fraction of workers in three sectors and year dummies are included as control variables for all regressions. Standard errors adjusted for clustering at the province level.

* p<0.1.
** p<0.05.
*** p<0.01.

Table 6.12: Two-Stage Least Squares Regression on Average Wage Using Province-Level Data

	Dependent Variable: $\Delta \ln(average\ wage)$			
	(1)	(2)	(3)	(4)
	Full Sample	2000-2005	2005-2010	2010-2015
$\Delta \ln (A/N)$	0.103	0.0826	0.612	-0.249
	(0.0692)	(0.0535)	(0.437)	(0.153)
Primary Sector	0.0546*	0.0504	-0.00328	-0.00504
	(0.0311)	(0.0629)	(0.0861)	(0.0343)
Secondary Sector	-0.0159	0.0638	-0.0429	-0.103***
	(0.0251)	(0.0426)	(0.0610)	(0.0345)
Tertiary Sector	0.122*	0.0201	0.105	0.0179
	(0.0708)	(0.109)	(0.147)	(0.101)
N	92	30	31	31

Notes: The main effect using the full sample is presented in column (1) and the effects separately for each 5-year period are presented in column (2) to column (4). The log of the fraction of workers in three sectors and year dummies are included as control variables for all regressions. Standard errors adjusted for clustering at the province level.

* p<0.1.
** p<0.05.
*** p<0.01.

Chapter 7

ROBUSTNESS CHECK

7.1 Different Age Thresholds Measuring the Extent of Population Aging

In the previous regressions, I chose the age 15 and 65 as the threshold when constructing the variable of interest (percentage change in the extent of population aging). Specifically, in Equation (1), $A_{j,t}/N_{j,t}$ is a measure of population aging in city j. And it is defined as the ratio of population counts over the age of 65 (including age 65) to the population counts over the age of 15 (including age 15). The threshold of 15 years is applied since it is the general minimum age set by the International Labor Organization for admission to employment. This convention sets the minimum age for work at 15 years (13 for light work) and the minimum age for hazardous work at 18 (16 under certain strict conditions). And the threshold of 65 is applied because people are generally considered economically inactive when they are over the age of 65. Age 15 and 65 are also applied when the old-age dependency ratio is calculated.

In China, the retirement age for workers is different for different occupations. Doctors and college professors tend to work longer time than workers in other professions, and farmers in rural areas may work until they are physically unable to do work. However, women working in urban areas are generally allowed to retire earlier than 65 according to the policy set by the Chinese government. To account for that, in addition to using the original threshold, I also set $A_{j,t}$ equal to the number of individuals who are over or equal to the age of 60 (with $N_{j,t}$ remaining to be the number of individuals who are over or equal to the age of 15) and re-estimated the regressions using this new set of thresholds. The two-stage least squares regression results using $A_{j,t}$ equal to 60 are presented in columns (3) and (4) of Table 7.1, and the regression results setting $A_{j,t}$ equal to 65 are reproduced in columns (1) and (2). When I compare the regression results using different measures of population aging, I find that the point estimates for the main variable of interest (Δ ln (A/N)) are similar in scale. Thus, I can conclude that the two-stage least squares regression results are robust to different thresholds used to construct the measure of population aging.

Table 7.1: Robustness Check on Age Thresholds

	(1)	(2)	(3)	(4)
	Set $A_{j,t}$ = 65		Set $A_{j,t}$= 60	
	GDP	Average Wage	GDP	Average Wage
Δ ln (A/N)	-0.242***	0.167***	-0.220***	0.163**
	(0.0870)	(0.0549)	(0.0820)	(0.0704)
N	434	433	434	433

Notes: The effects on GDP per capita and average wage using age 15 and 65 as thresholds are shown in column (1) and column (2) respectively. The effects using age 15 and 60 as thresholds are shown in column (3) and column (4) respectively. The log of the fraction of workers in different industries and year dummies are included as control variables for all regressions. Standard errors adjusted for clustering at the city level.

* p<0.1.
** p<0.05.
*** p<0.01.

7.2 Controlling for Trends in Initial Economic Conditions

Barro and Sala-i-Martin (1992) found convergence over time in the levels of per capita product and income across regions. They argue that poor regions tend to grow faster while rich regions tend to grow slower. Then the initial economic condition may have an impact on the future growth path of a region. To account for this, I include the log of per capita GDP in each city in the initial time period (period t) as an additional control variable and re-estimate the main two-stage least squares regressions. The regressions results are presented in Table 7.2.

Table 7.2: Robustness Check with the Inclusion of GDP in the Initial Time Period

	(1) GDP	(2) Average Wage
$\Delta \ln (A/N)$	-0.278***	0.183***
	(0.0865)	(0.0597)
N	434	433

Notes: The effects on GDP per capita and average wage are shown in column (1) and column (2) respectively. The log of GDP per capita in the initial period (period t), the log of the fraction of workers in different industries and year dummies are included as control variables for both regressions. Standard errors adjusted for clustering at the city level.

* p<0.1.
** p<0.05.
*** p<0.01.

The estimates for $\Delta \ln (A/N)$ in Table 7.2 are similar in scale to the previous two-stage least squares estimates in Table 6.2 and Table 6.8, thus initial economic conditions are not driving the results.

Chapter 8

DISCUSSION AND CONCLUSION

8.1 Main Conclusion

China's rapid population aging, driven by low fertility and mortality rates in recent decades, has raised many concerns about the available labor supply and well-being of the older population. A persistent question has been how will this demographic change affect labor market outcomes as well as GDP per capita? In this paper, I use the variation in the extent of population aging across Chinese cities from year 2000 to 2015 to estimate the impact of population aging.

To conclude, I find that a 10% increase in the extent of population aging (extent is measured by the fraction of population ages 65+) would decrease GDP per capita by 2.42 %, and the effect of age composition mainly operates through the decrease in the labor-to-population ratio. There is heterogeneity in the effect across different year periods and across different regions — the effect is more pronounced in less developed cities. Between year 2000 and 2015, China's old-age population share increased by 27.2%. Thus the point elasticity estimate implies that the growth in GDP per capita over that period was lower by 6.58% than it would have been without population aging. According to the prediction made by United Nations Population Division (UNPD) of the Department of Economic and Social Affairs, the older population share in China is expected to increase by 47.1% from 2020 to 2030 (the projection up to the year 2100 is shown in Figure A.3 in appendix). Thus the estimate in this paper indicates that population aging will reduce output growth per capita in the current decade by 11.4%. It corresponds to an annualized 1.2% decrease in GDP per capita growth if we compare it to the situation where there is no change in the extent of population aging. Similar effects will also be found during the period 2030 to 2060 as the Chinese population is still expected to age rapidly up to that time. After 2060, the fraction of older people in the country is predicted to stabilize, and then the population aging will no longer be a problem that causes the slow down of economic growth.

There are some differences between the magnitude of the population aging effects between China and the U.S. In Maestas et al. (2016), they use U.S. state-level data and find that a 10% increase in the fraction of older people decreases GDP per capita by 5.5%, whereas the counterpart adverse effect for Chinese cities is only 2.42%. One potential explanation for this is due to the different levels of population aging across two countries. Figure 8.1 shows the old-age dependency ratio of the U.S. and China from 1980 through 2020. It can be seen that the ratio of the U.S. has been above 20% since the 1980s, but the ratio of China kept below 15% until the year 2015. China has been experiencing a lower level of population aging compared to the U.S. This may explain why population aging has a smaller impact on GDP per capita in China. However, the negative impact of population aging may be more pronounced as China is predicted to have a comparable population aging level to the U.S. in the following few decades.

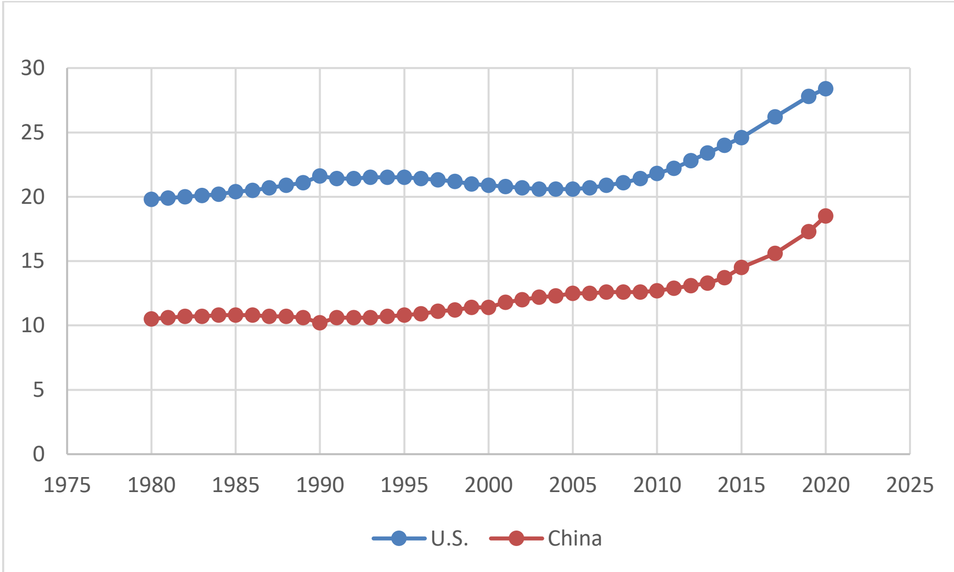

Figure 8.1 Old-age Dependency Ratio of U.S. and China (%)

As for the labor market outcomes, I find that the impact on labor productivity is not significant and I find a small positive impact of population aging on average wage level— a 10% increase in the extent of population aging would increase the average wage by 1.67%. However, there may be a negative impact on labor market outcomes in the future as there will be a decrease in the average number of surviving children each older person has. It is predicted that those who were born after the 1960s will on average have fewer than two adult children when they reach the age of 65 and enter the group of older population. The average number will continue to decrease with the prevalence of 4-2-1 families. At that time, the support given to the older parents may be more demanding for the working-age population. Working-age people may need to spend a fair amount of time taking care of their parents and then the population aging problem will have a negative impact on labor productivity in the future.

8.2 Some Policy Issues

Given the rapid population aging problem the country is facing, the Chinese government has said it would gradually implement an adjusted retirement scheme and postpone the official retirement age by the year 2025. At the province level, Jiangsu has already allowed individuals to postpone retirement on a voluntary basis in March 2022. It requires the consent from both the workers and their employees to adjust the retirement plan of a worker. Other provinces may also defer the retirement age following Jiangsu's footsteps. Up to now, it is still unclear how many workers may sign up to defer retirement. Many Chinese workers are worried that they could end up receiving less pensions in total after retirement. And given the need to take care of their grandchildren, workers may also be reluctant to defer retirement. It seems that only a minority group of workers may choose to defer retirement at this point. Official retirement age adjustment is aimed to boost labor participation of older workers and temper the negative effect of population aging. The question that remains is whether the Chinese government will take further actions to make that policy truly effective.

Another way to increase the proportion of the workforce in a society is to boost the fertility rate. In China, there is still gender inequality in the household where women are responsible for most of the family care housework. Inequality also exists in the workplace. Women on average receive lower pay compared to men and there is discrimination against women for hiring and promotion opportunities. These inequalities are considered as potential drivers of delayed marriage and a lower fertility rate. The Chinese government itself should be the one that has the most influence to address gender discrimination in the workplace. Aside from allowing families to have several children, ensuring that women are treated equally and given opportunities to develop in their careers could be a policy that helps China's birth rates rise.

The rapid population aging problem in China is also raising concerns about the well-being of the older population. The number of the oldest-old population in China, who are over the age of 80, will climb quickly after the year 2030 and increase to around 150 million by 2050 (Yi Zeng, 2012). Since they are the group of people who most likely need daily life care, there will be a drastic increase in the demand for elder-care services, and it will create challenges for the Chinese health care system. In addition, as China’s low fertility rate decreases the available amount of care provided by family members, other forms of caring for older people need to substitute for family-based care. However, institutional, home-based and community-based health care services are currently increasing but are still not widely available to the older population even in large cities, and there are also concerns regarding the quality of the services. For the Chinese policymakers, expanding access to those healthcare services may be one potential way to address the challenges created by the problems associated with the upcoming population aging. It will also improve the welling-being of Chinese people in their later stages of life.

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Appendix

TABLES AND FIGURES

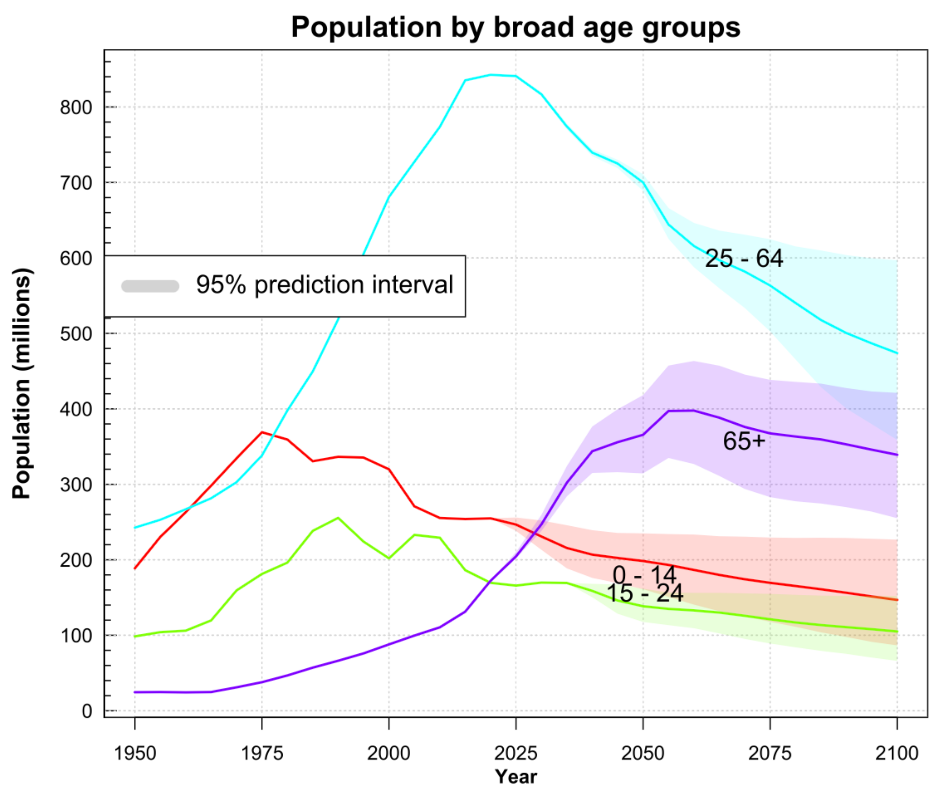

Figure A.1: Population by Broad Age Groups (from United Nations Projection, 2019)

Figure A.2: Four Major Economic Regions of China (Li et al, 2018)

Table A.1: Provinces Under Four Economic Regions in China

Eastern Region	Northeast Region	Central Region	Western Region
Beijing	Liaoning Province	Shanxi Province	Inner Mongolia
Tianjin	Jilin Province	Anhui Province	Guangxi
Hebei Province	Heilongjiang Province	Jiangxi Province	Chongqing
Shanghai		Henan Province	Sichuan Province
Jiangsu Province		Hubei Province	Guizhou Province
Zhejiang Province		Hunan Province	Yunnan Province
Fujian Province			Tibet
Shandong Province			Shanxi Province
Guangdong Province			Gansu Province
Hainan Province			Qinghai Province
			Ningxia
			Xinjiang

Table A.2: Definitions for Different Industries of China

Industry	Definition
Agriculture	Agriculture, forestry, pasture and finishing
Mining	Mining
Manufacturing	Manufacturing
Utility service	Electricity, gas and water supply industry
Construction	Construction
Environmental management	Geological and hydraulic management
Transportation	Transportation, warehousing, post and telecommunication
Retail	Wholesales and retail trade
Finance	Finance
Real estate	Real Estate
Residential service & other services	Residential service and other services
Social welfare	Healthcare, social security and social welfare
Education & entertainment	Education, culture, sports and entertainment
Information technology & science	Information technology & science
Public management	Public management and social organization

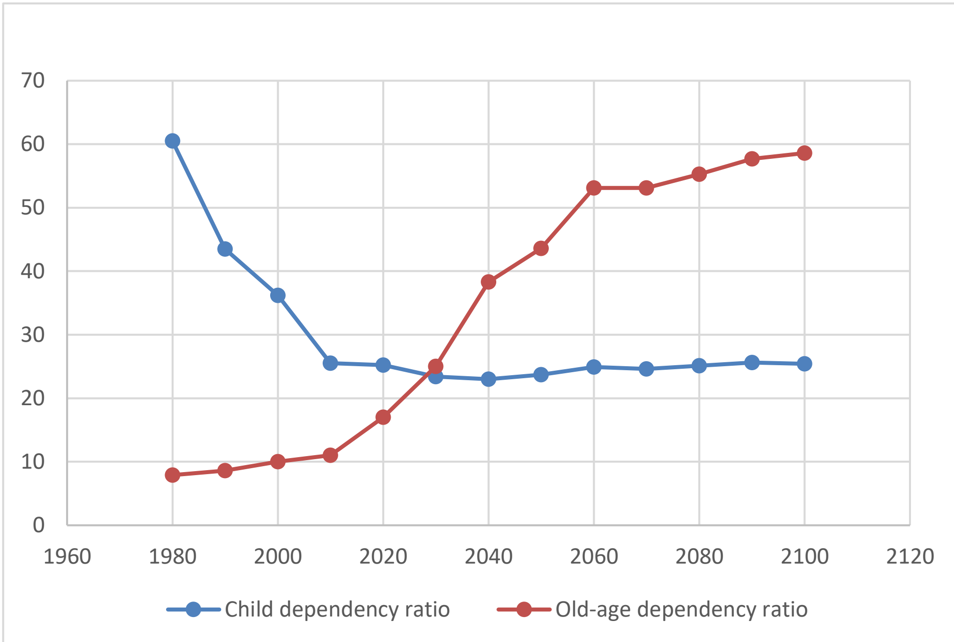

Figure A.3: Child and Old-Age Dependency Ratio in China (%, from United Nations Projection, 2019)

Table A.3: Two-stage Least Squares Regression on GDP Per Capita by Year

Dependent Variable: $\Delta \ln (GDP/N)$				
	(1) Full Sample	(2) 2000-2005	(3) 2005-2010	(4) 2010-2015
$\Delta \ln (A/N)$	-0.242***	-0.203**	-0.120	-0.369***
	(0.0870)	(0.0830)	(0.112)	(0.109)
2005.year	-0.0143			
	(0.0263)			
2010.year	-0.120***			
	(0.0322)			
Agriculture	-0.000573	-0.0168	0.0132	-0.00766
	(0.00692)	(0.0146)	(0.00957)	(0.00647)
Mining	-0.00299	-0.00590	-0.00191	0.000663
	(0.00324)	(0.00638)	(0.00795)	(0.00680)
Manufacturing	-0.0329**	-0.00847	-0.0193	-0.0740***
	(0.0159)	(0.0244)	(0.0262)	(0.0197)
Utility service	0.00575	0.0139	0.00158	-0.0283
	(0.0204)	(0.0154)	(0.0360)	(0.0216)
Construction	-0.0133	-0.0374**	-0.00499	-0.00477
	(0.0118)	(0.0184)	(0.0161)	(0.0146)
Environment	0.00945	0.0118	0.0292	-0.0307
	(0.0143)	(0.0158)	(0.0233)	(0.0231)
Transportation	-0.000846	-0.00379	0.00577	0.00274
	(0.0208)	(0.0253)	(0.0316)	(0.0363)
Retail	0.00221	0.0274	-0.00312	-0.00605
	(0.0103)	(0.0337)	(0.0149)	(0.0376)
Finance	0.0391	0.0727**	0.0110	0.0167
	(0.0331)	(0.0335)	(0.0480)	(0.0575)
Real estate	-0.0232*	-0.0198	-0.0174	-0.0228
	(0.0132)	(0.0164)	(0.0175)	(0.0298)
Services	-0.0178**	-0.0416*	-0.0197**	-0.00974
	(0.00753)	(0.0215)	(0.00984)	(0.0155)
Welfare	0.0114	-0.0835*	-0.00873	0.241***
	(0.0427)	(0.0465)	(0.104)	(0.0641)
Entertainment	0.0272	0.0268	0.0969	-0.153***
	(0.0464)	(0.0593)	(0.0757)	(0.0470)
Science	-0.00314	0.0141	-0.0187	-0.0316**
	(0.0117)	(0.0165)	(0.0178)	(0.0145)
Public	-0.0754**	-0.0822**	-0.0787*	-0.0614
	(0.0311)	(0.0413)	(0.0459)	(0.0650)
N	434	151	167	116