The Economic Characteristics of an Ageing Society: A Study Based on a General Equilibrium Model

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The Economic Characteristics of an Aging Society: a Dynamic Computable General Equilibrium Analysis

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Abstract

China is experiencing rapid population ageing. The elderly 65 and older accounted for 13.5 percent of the total population in 2020. It will continue to increase to 40 percent in 2100. What's the economic implication of population aging? Most research has focused on the macro economic effects of declining labor force and increasing elderly. There is insufficient research on the changes in demand for goods and services brought about by population ageing. The research on the impact of such changes on the economy under the computable general equilibrium (CGE) framework is even rare. This paper attempts to fill the research gap in this area.

Using a dynamic CGE model of the Chinese economy, in the baseline scenario we projected China's economic growth path over the period of 2019 to 2100. We assumed that there is no change in the age specific consumption demand even though there is population ageing which is reflected by the declining working age population and the increasing elderly population. The simulation results revealed that China has to rely on technology improvement and capital stock increases to support its economic growth. The increasing elderly will put high pressure on China's general government budget balance.

Starting with the baseline described above, we constructed a policy scenario that deviated from the baseline due to ageing-induced changes to household and government consumption preferences for education, health and aged care services. With ageing, demand shifts against education and towards health and aged care services. The simulation results show that the effects on the macro economy of age-structure driven changes are negligible, even though the changes will affect the industrial outputs and cause small adjustments of economic structure. The increased demand for medical and aged-care services will exceed the decreased demand for the education, thus drive up the general government budget deficit.

Key Words: Population ageing, Age specific consumption pattern, CGE model, Economic structure, Economic growth

JEL classification: J11, J26, C68

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1. Introduction

China is experiencing rapid population ageing. The population aged 65 and older accounted for 13.5 percent of the total population in 2020 compared to around 8.87 percent in 2010. It will continue to increase to 40 percent in 2100 according to the medium variant population projection conducted by Shanghai Academy of Social Sciences (Zuo, 2021). There exists many research investigating the economic implication of declining working age population and increasing elderly. There is insufficient research on the changes in demand for goods and services brought about by the dramatic age structure change. The research on the impact of such changes on the economy under the CGE framework is even rare. This paper attempts to fill the research gap in this area.

1.1 Low fertility rate and population ageing in China

The total fertility rate (TFR) in China has changed significantly, from a high fertility rate stage in the 1950-60s, to a dramatic declining stage in the 1970s-80s, further to a low fertility rate stage from the early of the 1990s. The long and sustained low fertility rate in China will bring negative population growth and population ageing in the longer term.

1.1.1 Low fertility rate and negative population growth

According to China's Seventh Population Census, the TFR is 1.3 children per woman in China in 2020, which signals that China has entered the "lowest low ferity rate period"[1]. The population growth rate is 0.12% in 2020, close to zero growth. An estimation based on the birth number in the first half year of 2021 shows that the total birth number will be below 10 million in 2021 meanwhile the total death will be more than 10 million. This means that China will start to experience negative population growth from 2021. Based on the population projection conducted by Shanghai Academy of Social Census, if the TFR is 1.1 (low variant), 1.6 (medium variant) and 2.1 (high variant) in China by the end of this century, then total population will reduce to 595 million, 827 million and 1.089 billion, respectively comparing with the 1.402 billion in 2020.

In recent years, the Chinese government has relaxed its several decades long one-child policy and replaced it with a two-child policy in 2015. But the new policy didn't yield the expected

[1] TFR 2.1 is regarded as a replacement level fertility rate. Replacement level means that the total number of the next generation is just the same as the total number of this generation. TFR 1.3 means that the total number of next generation is only 60% of the total number of this generation.

result and the fertility rate has kept declining. The Chinse government therefore further adjusted its population policy and started a three-child policy in July 2021[2]. Meanwhile, related subsidies and child care services have been provided to help reduce family's cost of raising children.

Fertility decline is a common trend in countries around the world. According to the data released by the United Nations (2019), the global total fertility rate (TFR) has dropped from an average of 5.02 children per woman in 1960-65 to 2.47 children in 2015-20, a drop of more than half. In high income and upper middle-income countries, TFR has fallen to 1.67 and 1.90, respectively, well below the replacement level fertility rate (2.1). Some countries' TFR has fallen below the very low fertility rate (1.5) or the extremely low fertility rate (1.3). This has led to concerns about the political, economic and social consequences of shrinking and aging populations. The fact is TFR in lower middle-income and low income countries has been declining as well. The main force driving the decline of global fertility is the modernization process represented by urbanization, industrialization, post-industrialization and the extensive and profound social changes it promotes. The modernization process will not be reversed, nor will the trend of fertility rate decline.

European countries and some East Asian countries, such as Japan, South Korea and Singapore have successively implemented policies to encourage fertility, but the impact on fertility is very limited. Low fertility rates and shrinking population will be the main trends of China's population dynamics in the future.

1.1.2 Population ageing

Population ageing is a natural consequence of low fertility rates and increasing life expectancy. According to China's Seventh Population Census, the number of elderly people aged 60 and over in China reached 264 million, accounting for 18.70% of the total population; among them, there were 191 million population aged 65 and over, accounting for 13.50% of the total population.

[2]In July 2021, the Central Committee of the Communist Party of China and the State Council issued the "Decision on Optimizing the Fertility Policy to Promote Long-term Balanced Development of the Population" (see Chinese government website: www.gov.cn/zhengce/2021-07/20/content_5626190.htm. In Augustthe National People's Congress passed the second amendment to the "Population and Family Planning Law of the People's Republic of China" (see the National People's Congress website: ww.npc.gov.cn/npc/c30834/202109/9ab0af08773c465aa91d95648df2a98a.shtml).

The forecast conducted by the Shanghai Academy of Social Sciences shows that the proportion of the population aged 65 and over will continue to increase under the low, medium and high scenarios, and China will become a "super-aging society" in 2032 when the share of the population aged 65 and over will be more than 20%. By the end of the 21st century, the population aged 65 and over in the low, middle and high scenarios will increase to 51.65%, 40.05% and 32.01% respectively. The proportion of the oldest population aged 80 and above (the oldest old) among those aged 65 and over will be 58.12%, 54.06% and 51.68%, respectively. That is, in every two elderly people, there will be one person who will be over 80 years old.

The migration of China's young and middle-aged population from rural to urban areas, as well as the migration from northeastern, central and western regions to eastern coastal areas, will make the aging problem of those emigrating areas, especially those rural areas, more severe. It will bring serious challenges to China's institutional arrangement of basic social security and public services provided by local governments.

1.2 The characteristics and economic impact of an aging society

Population aging will have a long-term and profound impact on future economic and social development. In this section we will discuss the economic impacts of population ageing from both supply side and demand side. Then from section three we will use a CGE model to quantitatively simulate the economic impact of an aging society.

1.*2.1 The characteristics and economic impact of an aging society: a supply side perspective*

Most research examines the economic impact of population aging from the supply side. First, population aging will reduce a country's labor supply, increase labor scarcity and labor costs, resulting a lower competitiveness of its labor-intensive products in the international market, and thus promote the adjustment of industrial structure. Second, according to the life cycle hypothesis (Modigliani, 1966), the labor income of the elderly population is smaller than their consumption expenditure. The related deficit needs to be made up through public or intra-household transfer payments, or through personal property income, or reduction of personal saving. Therefore, population ageing will reduce the domestic saving rate and investment rate. As a result, the driving force of economic growth will shift from traditional production factors such as capital and labor to innovation and technological progress (Romer, 1986, 1990, Cai, 2009, Tian, etc. alt, 2006; Zuo and Yang, 2006). Third, population aging makes economic

growth more dependent on human capital, technological innovation and technological progress. However, population aging may weaken the national innovation ability, economic vitality and technological progress potential, thereby reducing the actual growth rate and potential growth rate of the economy (Simon, 1983; Liang and Huang, 2018).

In this paper, the age specific population information from 2019 to 2100 generated by our population module will be put into our CGE model as exogenous variables. Through this way, we will quantitatively examine the economic impact of population ageing from supply side.

1.2.2 *The characteristics and economic impact of an aging society: a demand side perspective*
However, population aging not only affects the economic growth from the supply side, but also from the demand side. Final demand can be disaggregated into consumption, investment and net export (export subtracts the import). As we pointed out in the previous section, population ageing will reduce the saving rate and investment rate, therefore generate negative effects on the investment demand. Population ageing will also increase the labour cost through the declining labour supply, reduce the competitiveness of the labour intensive manufacturing goods in the international market, and thus reduce export.

A decline in the saving rate in an aging society means a corresponding increase in the consumption rate. However, such an increase in consumption rate cannot bring about a rapid increase in consumption demand. This is because if total consumption demand is the product of total population and per capita consumption demand, then the increase rate of total consumption demand is the sum of population growth rate and the increase rare of per capita consumption demand. But in an ageing society, the former is negative and will bring negative contribution to the increase of consumption demand. Since 2010, China's population aging has driven the growth rate of per capita GDP to slow down, and the growth rate of per capita consumption has also slowed down accordingly. Relevant data from countries around the world also reveal similar trends. As Peterson (2017) pointed out, based on data from the World Bank, during 1990-2015, the population growth rate and per capita GDP growth rate of low- and middle-income countries were 1.46% and 3.04%, respectively, while those of high-income countries were 0.68% and 1.37%, respectively. The latter's population growth rate and per capita GDP growth rate are less than half of the former.

1.3 Introduce age specific consumption pattern into model

Empirical data on consumption also suggests that consumption of some products varies with age, therefore ageing also has an impact on consumption in different sectors. For example, the school-aged population has a greater demand for school education, the young and middle-aged population has a greater demand for durable goods such as housing and automobiles, and household appliances, while the elderly population has a greater demand for medical care and aged-care service. But general demographic economic models, including CGE models, treat each consumer as a homogeneous consumer, regardless of their age and differences in age-dependent consumption behavior. In this sense, such models fail to fully reflect the impact of population aging and changes in population age structure on the demand side of the economy. In this study, we introduce changes of the age-dependent consumption behaviour into our CGE model and simulate the effects of population ageing not only from supply side but also from the demand side.

The section two describes the changes of the age specific consumption pattern in China. In section three, we introduce our methodology and modelling framework. The baseline scenario and simulation results are discussed in the section four. Section five includes the policy simulation and results analysis. Conclusions are discussed in the section six.

2. Changes of the age specific consumption patterns in China

By introducing an age specific profile of consumption into CGE model, this study will investigate the effects of the changes of population age structure on the consumption demand for different sectors. This is the major difference of this study with others in this area. But the main problem for doing this study is that it is very difficult to obtain the consumption data by age and sector.

Firstly, existing research obtains the consumption data generally from large-scale household tracing survey such as CHARLS, CFPS, CHIP and etc. However, in such survey, there is only record of consumption expenditure of household as a total, no record of individual family member’s consumption information. Therefore, there is a need to decompose the information of household consumption and family member’s age into individual consumption information of different aged-family member by using M&W model (Mankiw & Weil, 1989).

Secondly, the household tracking survey data generally only records the consumption expenditure borne by households, but does not record the corresponding part paid by social insurance or government public finance. Therefore, when studying the age specific consumption pattern, it is necessary to combine the household consumption data with the statistical data released by the national statistical department, or to estimate the relevant data of public consumption based on a certain assumed proportion of household consumption.

Thirdly, the sectoral classification of consumption goods in the Household Tracking Survey differs significantly from the sectoral classification in the Input-Output (IO) Table which is the main data source of the CGE model, as the latter has as many as 142 sectors. Even after aggregation for simplification purposes there are still 45 sectors, while in the household surveys, there are generally only have eight sectors. In this study, we selected four sectors: education, health and medical care, social work and residential services[3] which are easier to match between these two databases. The other reason is that the consumptions of these four sectors have significant age-dependent.

In this study, we use the CFPS2016 data collected by Institute of Social Science Survey at Peking University for the age specific consumption for education, health and medical care data. The aged-care service is from 2011-2012 survey data of the China Health and Retirement Longitudinal Study (CHARLS). Some data on household and government education expenditure are also from 2017 China Education Statistical Yearbook and China Population and Employment Statistical Yearbook.

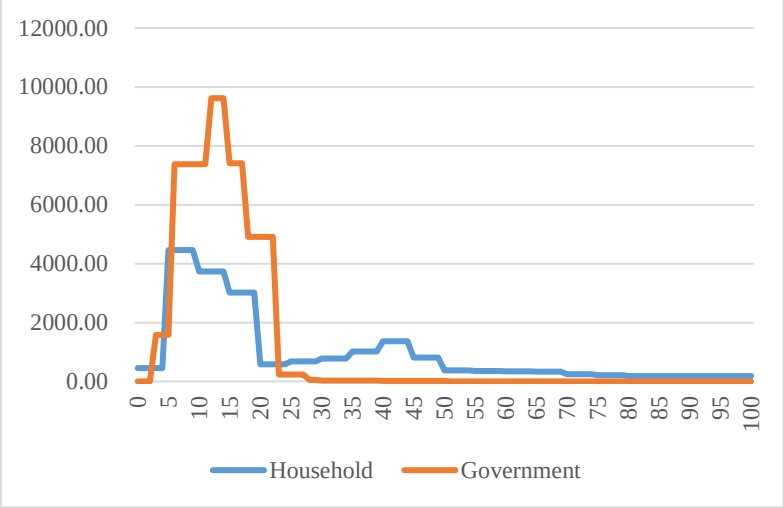
2.1 Age specific consumption pattern of selected sectors in China

Figure 1 shows per capita expenditure on education of household and government by different

[3] In China IO table, aged-care services is included in health and medical care, social work and residential services sectors. When estimating the related consumption of aged-care, we disaggregate the aged-care consumption data from Household Tracking Survey into two parts: medical care consumption and living care consumption. The medical care consumption matches the health and medical care sector in the IO table. The living care consumption matches two sectors: social work and residential service. Based on certain portion, we disaggregated the living care consumption into social work and residential service. In China the majority of elderly live at home and rely on family members to provide aged-care service. In estimating the consumption of home based living care, we also takes into account that a considerable proportion of home care is provided by family members or purchased through the informal market. These services obtained without formal market transactions are obviously not included in the official statistics, so it is "implicit services" and need to be distinguished from "explicit services" purchased through the formal market. In the future, due to the declining family size and implementation of aged-care insurance, some implicit services will gradually turn to explicit services, which is also an important reason for the rapid growth of demand for explicit aged-care services in China.

age group in China in 2016. The expenditure of both household and government vary dramatically for different age group. The age group of 5 and 19 has the highest education expenditure from household. After age 20, the expenditure on education become small and from age 30 to 44, there is slight increase in the spending on education. After age 70, even though there is still some education expenditure from household, the amount is very small, only around 200 RMB per person. Government's expenditure on education starts to increase from age group 6, and age group 12-16 receive the highest education expenditure from government. The education expenditure from government drops sharply from the age group of 23 which is less than 600 per capita and further down to less than 40 RMB on the age group of 27. There is no education expenditure from government on the age group of 51 and over.

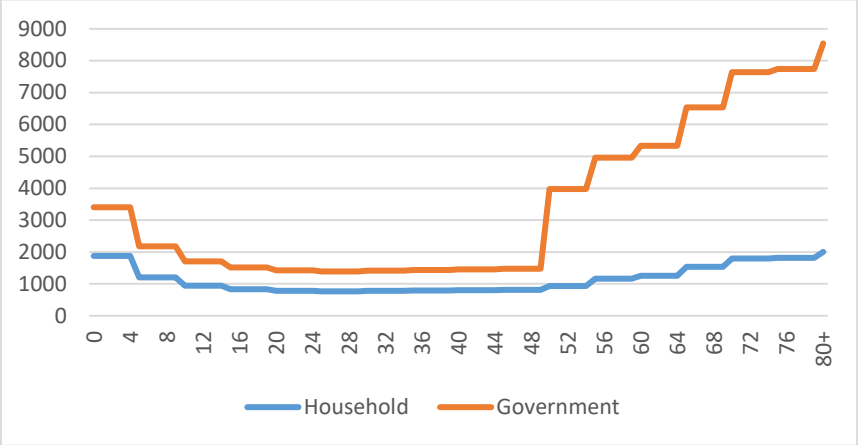
Figure 1: Education expenditure of household and government by age group in 2016
(Per capita, RMB)



Source: Authors' calculation based on the survey data CFPS2016 and 2017 China Education Statistical Yearbook and 2017 China Population and Employment Statistical Yearbook

The expenditure on health and medical service by age group (Figure 2) presents different pattern compared with the expenditure on education. The expenditure on health and medical service is lowest among the age group of 16 to 50. It increase gradually when the age increases. The elderly aged 80 and over has the highest expenditure on health and medical service. We also notice that in China government expenditure per person on health and medical care is much higher than household.

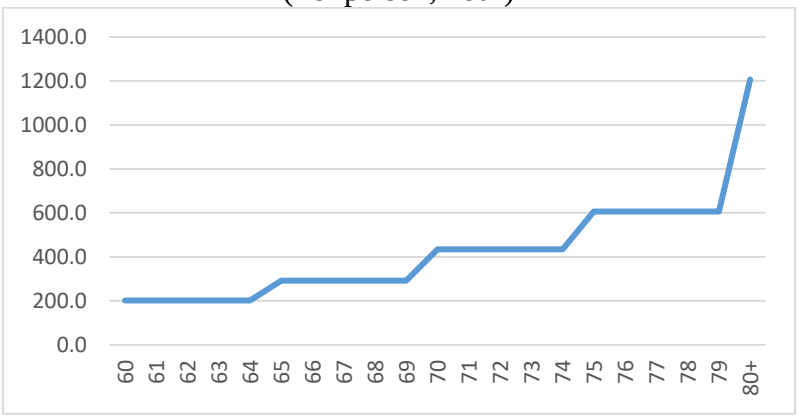
Figure 2: Expenditure on health and medical service from household and government by age group in 2016 (per capita, RMB)



Source: Authors' calculation based on the survey data CFPS2016

Figure 3 displays the time spent on the aged-care service of disabled elderly in China. In average per disabled elderly of aged 60 needs around 200 hours a year, while the elderly aged 80 needs 1200 hours in average which is six time more than the elderly aged 60. Both Figure 2 and 3 implies that when a country's population becomes old, the demand for health, medical service and aged-care service will increase dramatically. In next section we will calculate how the demand for education, health, medical and aged-care service changes when a population is ageing using the data from the medium variant population projection conducted by Zuo et.al. (2021).

Figure 3: Time spent in aged-care of disabled elderly by age group in 2016 (Per person, hour)



Source: Authors' calculation based on the 2011-2012 survey data of CHARLS

2.2 Population ageing and changes of age specific consumption pattern

We use the education sector as an example to illustrate how population ageing affect the education demand. We assume no change in the education expenditure per person from 2016 to 2100 and we only calculate the effect of age structure change on the education demand.

First, we assume that age cohort 25-29 is a “standard” cohort for the education demand. Then we calculate the ratio of other cohorts relative to the “standard’ cohort, we call these ratios are “EA” index.

$$EA_a = \frac{EXP\_EH_a}{EXP\_EH_{25-29}} \qquad a \geq 0 \qquad (1)$$

While EA_a is the Education index by age cohort ranging from 0 to 100 and over. EXP_EH_a is the household expenditure spending on education by age cohort. EXP_EH_{25-29} is the household expenditure on education for age cohort 25-29.

Using 2016 data of EXP_EH_a we calculated the EA_a index. The result is consistent with the line shown in the Figure 1. Ago cohorts 6-10, 11-14 and 15-17 have the highest *EA* index.

Secondly, we calculate the share of population AGE_{at} over total population based on the population date from the medium variant population projection using the following formula:

$$AGE_{at} = \frac{POP_{at}}{\sum_a POP_{at}} \qquad a \geq 0 \qquad (2)$$

While POP_{at} is the size of population of age cohort a in year t. With the rapid ageing, the share of old population aged 65 and over will keep increasing. For example, the share of population aged 70 is 0.0083 in 2020, it will increase to 0.0127 in 2050 and 0.0144 in 2090.

Thirdly, we time “*EA*” index by the “AGE” share in year t, and then and sum up the product of all age cohorts in year t. We then get the household Education- Age index “*EH_AGE*” in year t.

$$EH\_AGE_t = \sum_a (EA_a * AGE_{at}) \qquad (3)$$

Figure 4a displays the Education-Age index for household “*EH_AGE*” from 2012 to 2100. Under the assumption that the household education expenditure for each age cohort maintains its 2016 level (in other word, household age specific education expenditure keeps its 2016 pattern), the age structure change will drive the household demand for education to decline from 1.20 in 2012 to 0.83, which is a 31% decrease. Similar trend can be seen in the Figure 4b which shows the Education-Age index for Government “*EG_AGE*” over the period of 2012 to 2100. The index will decline from 81.3 to 53.5 which is a 34 percent decrease. Since the

government expenditure on education for the young cohorts are much higher than the household does, the effects of population ageing on the education demand is relatively larger for government than for household.

Figure 4a: Changing education demand 2012-2100 -Household

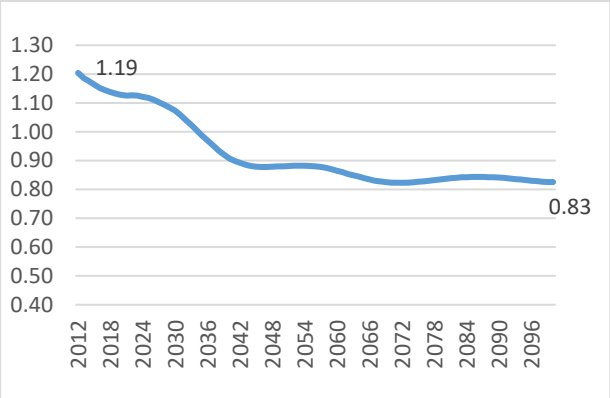
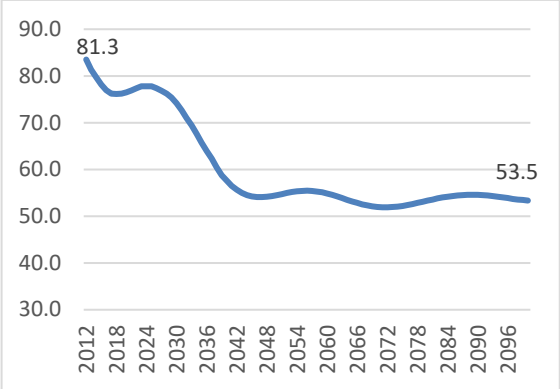


Figure 4b: Changing education demand 2012-2100 -Government



Source: Authors calculation.

Using the same approach we calculated the index of health-medical services for both household and government, "*HM-AGE*" from 2012 to 2100. Figures 5a and 5b are the results. With the rapid population ageing, the demand for health and medical services will increase. The *HMH-AGE" index* for household will increase from 1.30 to 1.70. For government the index will double from 2.63 in 2012 to 5.29 in 2100. The dramatic increase of the demand for health and medical services as a result of the rapid population ageing will put high pressure on the government financial system.

Figure 5a: Changing demand for health and medical services 2012-2100 - Household

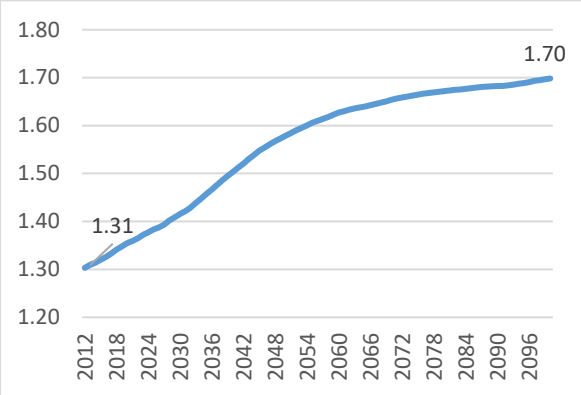
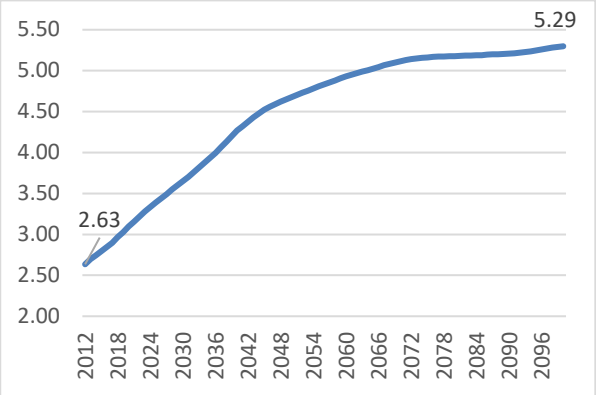


Figure 5b: Changing demand for health and medical services 2012-2100 - Government

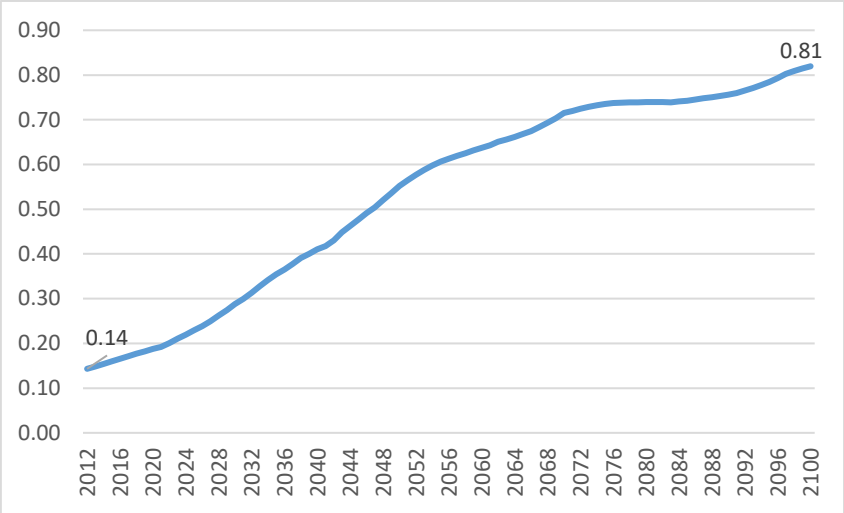


Source: Authors calculation.

The calculation of the index for aged-care service is more complicated. Based on the time spent

in aged-care service of disabled elderly by age group in 2016 (see Figure 3), the average hour wage of the employee in the aged care sector (in our model, Residential Service and Social Work sectors provide aged-care services), we calculate the expenditure on the aged-care service by age group in 2016. We assume the pattern of the aged-care expenditure between 2012 and 2100 are the same, we then use the same formulas to calculate the aged care index from 2012 to 2100 (please see the details of the calculation of the aged-care service in the Appendix). Please notice that since we have no data about the government spending on aged-care service by age group, so the aged-care index for household and government is the same. Figure 6 shows that the rapid population ageing will drive the aged care service to increase fast. By the end of this century, the aged-care index will be nearly 5 times higher than in 2012.

Figure 6: increasing demand for aged-care service, 2013-2100



Source: Authors calculation.

3. Methodology and modelling framework

3.1 CHINAGEM model and its core theory, structure and dynamic mechanism

The model we used in this paper is a revised version of CHINAGEM – a recursive dynamic computable general equilibrium model of the Chinese economy. The original database of the CHINAGME model includes 142 sectors and its base data reflects the 2012 input-output structure of the Chinese economy. For the purpose of this study, we aggregate the 142 sectors into 45 sectors. The core CGE structure of CHINAGEM is based on ORANI, a static CGE model of the Australian economy (Dixon et al 1982). The dynamic mechanism of CHINAGEM is based on the MONASH model of the Australian economy (Dixon and Rimmer, 2002). The CHINAGEM model captures three types of dynamic links: physical capital accumulation;

financial asset/liability accumulation; and lagged adjustment processes in the labour market.
In CHINAGEM, production is modelled using nested constant elasticity of substitution (CES) and Leontief production functions which allow substitution between domestic and imported sources of produced inputs and between labour, capital and land. The production functions are subject to constant returns to scale. Household demand is modelled by the Extended Linear Expenditure System (ELES). Trade is modelled using the Armington assumption for import demand and a constant elasticity of transformation (CET) for export supply. China is considered as a small open economy in import markets with foreign import prices determined in world markets. Exports are demanded according to constant-elasticity demand curves for most commodities. In the model, capital stock is accumulated through investment activities (net of depreciation). Investors respond to changes in the expected rate of return.

The revised CHINAGEM model also includes a detailed pension module which describes the current pension schemes in China[4]. It also include a government account which record the government general revenue, expenditure and balance[5]. The introduction of the pension module and government account enable the CHINAGEM model to track the change of the pension fund and government budget balance against the backdrop of the rapid population ageing in China.

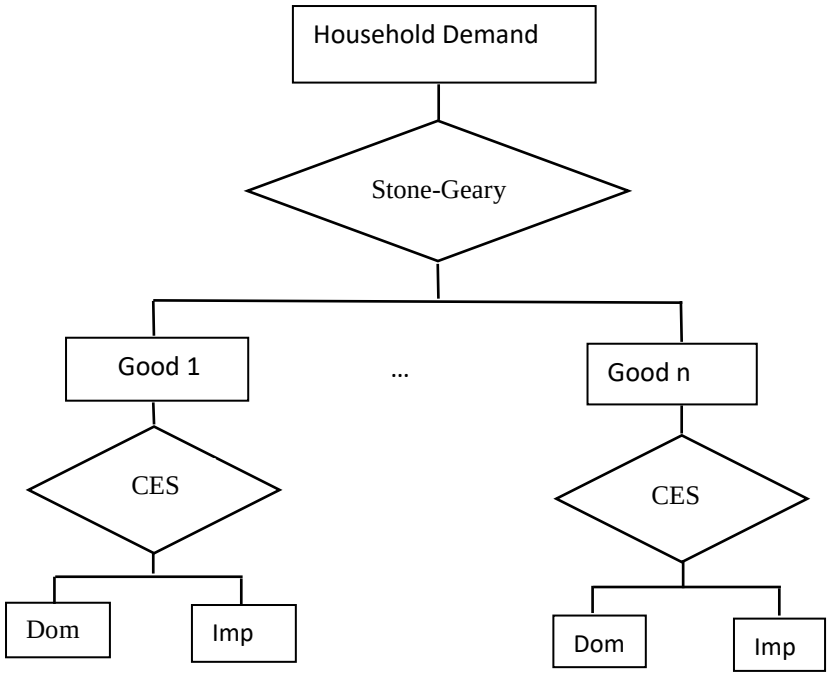
3.2 Household consumption function

Since in this study we focus on the effects of age structure induced change in consumption, so we explain the household consumption equation in detail. In the CHINAGEM model, demands for commodities by households are derived from a two-level utility function (Figure 7). In the first level, the bundle of commodities is chosen, according to the Stone-Geary utility function[6] (Stone, 1954 and Geary, 1950-1951). Then in the lower level, the mixture between domestically produced and imported commodities is chosen based on the constant elasticity substitution (CES) function.

In this study, we will only focus on the first level of utility function based on the assumption that the age structure change will not affect household's consumption preference for domestic or imported goods.

[4] Please refer to Zuo et. al.(2020) for the detailed Pension module.
[5] Please refer to Zuo et. al.(2020) for the detailed explanation of government account.
[6] This is also known as the Klein-Rubin utility function following Klein and Rubin (1948-49).

Figure 7: the structure of household demand in CHINAGEM



After solving the utility maximizing problem of the first level of Stone-Geary utility function[7], we obtain the percentage-change equation of the composite household demand for a commodity:

$$x3(c) - pop = EPS(c) * (w3tot - pop) + \sum_k (ETA(c,k) * p3(k)) + a3com(c) - ave\_a3com \quad (4)$$

This equation shows that household demand for commodity c is a functions of: the expenditure elasticity of demand for commodity c, $EPS(c)$; the household total expenditure, $w3tot$; population (pop); the price elasticity of demand for commodity c with respect to commodity k, $ETA(c,k)$ and the price of commodity k, $p3(k)$ and variables reflecting household preferences, $a3com(c)$ and ave_a3com. The variable $a3com(c)$ is the household preference for commodity c and $a3com(c)$ is the average household preference for all the commodities. $a3com(c)$ can be used to shock the household preference changes for a specific commodity caused by various factors for example, government subsidies or tax on certain commodity consumption, non-economic factors such as habit, food quality, product availability, the tendency to support local products, the availability of information and knowledge and etc..

[7] For the details of deriving the percentage-change equations for household demand for a commodity, please see Dixon and Rimmer (2002).

Population ageing causes the rise of the proportion of elderly population who need more health and medical care and aged-care service and the fall of the proportion of young population who need more education. The resulting changes in the consumption of education and medical and aged-care service can be reflected by the changes of the preference variable $a3com$ in the above household demand equation in the CHINAGEM model.

4. Development of baseline scenario and simulation results

To analyze the economic effects of changes in household demand resulting population ageing, we first develop a baseline scenario - a business as usual without introducing household demand changes[8]. Then we conduct a policy simulation - alternative forecast with the changes of the household demand. The effects of the policy change are measured by deviations of variables in the alternative forecast from their baseline levels.

4.1 The growth path of macro economy in the baseline scenario

To develop the baseline scenario, using the data from China Statistical Yearbooks and World Bank Development Indicators database, we first update the model's database to 2018. Then for the forecast period 2019 to 2100 we assume that the growth pattern of the Chinese economy will follow its historical trend but at progressively lower rates. For example, while the annual growth rate of total factor productivity will decline from 4.17 percent in 2017 to 3.8 percent in 2020, and further drop to 3.49 percent in 2030, 3.3 percent in 2050, 2.65 percent in 2080 and 1.78 percent in 2100.

The growth rates of employment in each industrial sector in the baseline scenario are endogenized and determined by the exogenous macro variables such as investment, export, and GDP, and the growth rate of total labour force (refer to Table 1 for the baseline results). The growth rate of the exogenous variable such as total labour force is calculated based on the growth rate of working-age population and the aggregate labour force participation rate. The annual growth rate of working-age population is from medium variant of population projection conducted by Zuo et. al. (2021). We assume that the cohort labour force participation rates will remain at their 2015 levels until 2100.

Table 1 shows that China will experience persistent labour force declining in the future. The

[8] For more detail about how the business-as-usual scenario is developed for the CHINAGEM model, please see Mai, et. al (2006).

labour force will decline at a rate of 0.34 percent in 2020 and further down to 0.62 percent in 2030. It will further drop at a rate of 1.43 in the middle of the century and at 0.92 percent at the end of the century. The baseline simulation shows that with the continuously declining labour force, China has to rely on the capital stock growth and total factor productivity improvement to sustain its economic growth.

Table 1: Summary of baseline calibration*

	2020	2030	2040	2050	2080	2100
Exogenously specified variables						
Annual growth rate (%)						
Investment	5.84	4.60	3.45	2.46	2.06	1.8
Export	7.49	6.31	5.28	4.46	3.4	2.7
Total factor productivity	3.8	3.49	3.36	3.3	2.65	1.78
Labour force	-0.34	-0.62	-1.10	-1.43	-1.29	-0.92
Endogenously solved variables						
Annual growth rate (%)						
Capital stock	5.51	5.09	4.19	3.16	2.07	1.76
Real GDP	6.70	5.77	4.81	4.04	2.81	2.0
Real wage rate	6.85	6.22	5.80	5.40	4.04	2.86
Real household consumption	7.29	6.31	5.24	4.59	2.81	1.90
Import	7.03	6.57	6.40	5.29	3.82	3.0

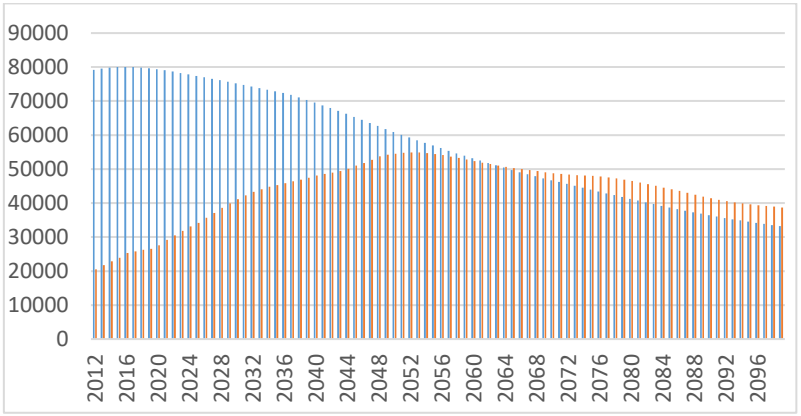
Source: Baseline simulation results. ***** Only selected years results are displayed in this table.

4.2 The change of the pension fund and government budget balance

The rapid aging in China drives the number of retired people to increase fast while the number of labour force to decline dramatically. Figure 8 shows that in the middle of the century, the labour force will decline to 609 million, which is a 23 percent drop from its 2012 number (792 million). By the end of the century, the labour force will further decline to 332 million, which is less than half of its 2012 number. Meanwhile, the elderly population who are eligible for receiving pension will increase to 545 million in the middle of the century, which is a 166 percent increase from its 2012 number. Since the total population in China is declining, the number of elderly population will reach its peak at around 2053 and then begin to decline (but the share of elderly population will continue to grow because of the population ageing). By the end of the century, there will be 387 million pensioners. Figure 1 also shows that in the year 2046 the number of pensioners will surpass the number of labour force. By the end of the

century, the number of pensioners will be 17 percent higher than that of labour force.

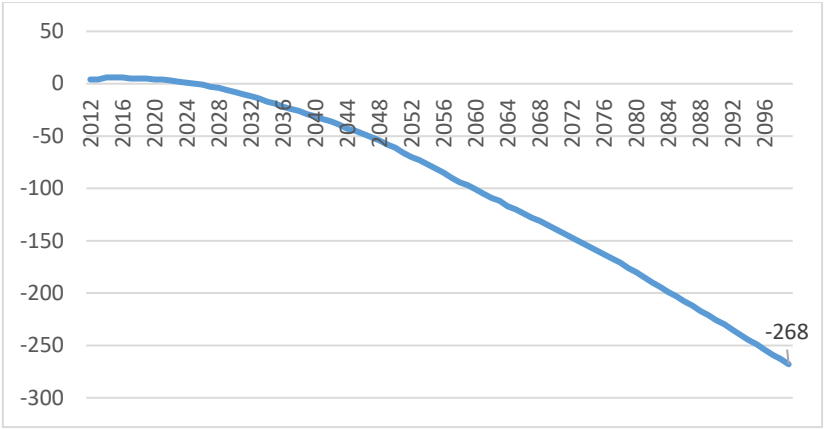
Figure 8: Declining labour force and increasing pensioners, 2012 to 2099 (10,000 persons)



Source: Population projection and baseline simulation result

The increase of pensioners and the decline of labour force will put high pressure on China's pension fund. Figure 9 shows that if the current pension system remains in China, then the stock of pension fund will run out of surplus and turn to negative in 2026 and the deficit will accumulate rapidly. The accumulated deficit will account for around 268 percent of GDP in 2099.

Figure 9: Stock of pension fund as share of GDP (%), 2012 to 2099

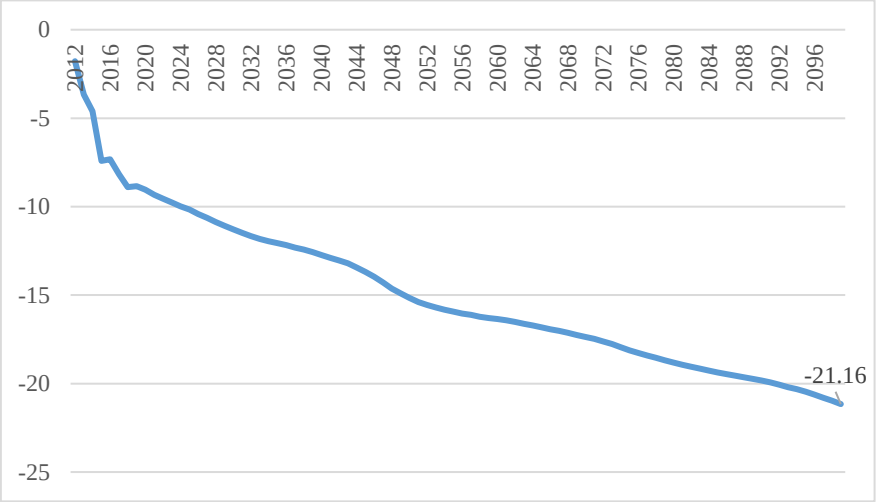


Source: Baseline simulation results

In China the government general budget balance has been in deficit since 2012, however the share of the deficit over GDP has been controlled under 6 percent. With the rapid accumulation of debts of pension fund, the government general budget deficit will increase very fast. If the government chooses to pay the pension debts every year, then the share of government general budget deficit over GDP will increase to 15 percent in 2050 (Figure 10), and further increase

to 21 percent by the end of the century, which implies that the economy cannot sustain under such big deficit. The Chinese government has to find ways to reform its current pension system and sustain its economic growth.

Figure 10: Government general budget deficit as share of GDP, 2012 to 2099 (%)



Source: baseline simulation results

4.3 The performance of sectors

In the baseline scenario we didn't introduce the age specific consumption pattern when we forecast the Chinese economy from 2020 to 2100. We assume that there is no change in the age specific consumption demand even though there is population ageing which is reflected by the negative growth of the labour force and the increase of the elderly population. The growth of household demand for different commodity and the growth of the output of the each industrial sector are endogenously determined by exogenously defined growth of labour force, total factor productivity, investment, export and economic structure embedded in the model's database.

Table 2 shows that the annual growth rates of output, employment and household demand of the three aggregated sectors are consistent with those of macro-economy. Among the three aggregated sectors in the economy, the output of service sectors will grow faster than both industry and agricultural sectors while the grow rate of the agriculture will be the slowest. This pattern is consistent with the development path of most developed economy. For the four selected individual sectors which are more sensitive to the age structure change than the other sectors– Residents service, Education, Health and Social work, their output growth rates are very similar and their growth rates are all consistent with the macro-economy. This is because we didn't introduce age specific consumption demand in the baseline scenario. The growth rate

of employment. The growth rates of employment and household demands of these four individual sectors are very similar as well.

Table 2: Summary of selected sector results in the baseline scenario (Annual growth rate %)*

Sectors	2020	2030	2040	2050	2060	2080	2100
Output							
Agriculture	4.72	4.25	3.73	3.29	3.10	2.42	1.51
Industry	6.39	5.67	4.79	3.95	3.63	2.87	2.03
Service	7.07	6.04	5.00	4.20	3.72	2.84	2.02
Residents service	6.40	5.60	4.56	3.96	3.45	2.47	1.64
Education	7.30	6.48	5.44	4.75	4.10	2.96	1.98
Health	7.36	6.55	5.45	4.77	4.07	2.93	2.00
Social Work	7.35	6.26	5.17	4.52	3.84	2.75	1.85
Employment							
Agriculture	-0.63	-0.83	-1.21	-1.58	-1.48	-1.63	-1.53
Industry	0.61	-0.43	-0.99	-1.45	-1.28	-1.23	-0.84
Service	0.01	-0.25	-0.83	-1.15	-1.14	-1.09	-0.67
Residents service	1.66	0.76	0.04	-0.29	-0.57	-0.85	-0.64
Education	0.37	-0.38	-0.99	-1.13	-1.35	-1.53	-1.19
Health	0.01	-0.71	-1.33	-1.41	-1.66	-1.82	-1.37
Social work	1.01	0.90	0.29	0.04	-0.29	-0.57	-0.41
Household consumption							
Agriculture	4.11	3.69	3.16	3.06	2.72	2.13	1.52
Industry	5.90	5.41	4.53	4.14	3.52	2.59	1.86
Service	9.09	7.40	6.06	5.11	4.31	3.04	1.97
Residents service	6.38	5.55	4.48	3.90	3.38	2.36	1.51
Education	7.38	6.90	5.86	5.10	4.47	3.19	2.09
Health	7.42	6.77	5.61	4.92	4.21	3.01	2.06
Social work	7.78	6.07	4.82	4.15	3.51	2.39	1.54

Source: Baseline simulation results. ***** Only selected years results are displayed in this table.

5. Policy scenario and results analysis

In this section we will introduce the age specific consumption demand but keep the population projection the same as in (medium variant) the baseline scenario. In other words, in the baseline scenario, the change of population size in each age group and the change of age structure is from the medium variant population projection, but we ignored the consumption demand

change caused by the age-structure change. But in the policy simulation, we will add the consumption demand change given the same population profile as the baseline scenario. In this way, we can simulate the effects of population ageing on the sector demand and macro economy.

5.1 Shocks of the age specific consumption demand changes

As we discussed in the subsection 3.2, there is a taste preference variable in the household consumption function. This variable is commodity specific and it can be used to simulate the household preference changes for a specific commodity caused by various factors for example, government subsidies or tax on certain commodity consumption, non-economic factors such as population age structure change or rapid urbanization. As we explained in section 3, the consumption demand for some commodities such as education, health and medical service, and aged-care service are age-dependent. The rapid population ageing will cause the consumption demand change for these commodities, and these changes can be captured by the taste preference variable *a3com* in the CHINAGEM model.

Using the index we obtained in the sub-section 2.2, we calculated the shocks for *a3com* in the policy simulation, which reflect the consumption preference change for the selected commodities. For the commodity Education, the shock for the first policy year 2013 is just the percentage difference of the index EH_AGE_{2013} and EH_AGE_{2012} . The formula is $(EH\_AGE_{2013} - EH\_AGE_{2012})/EH\_AGE_{2012})$*100. Using the same formula, $(EH\_AGE_t - EH\_AGE_{t-1})/EH\_AGE_{t-1})$*100, we get the shocks for the rest of years 2014 to 2100. Same approach is used to calculate the shocks for the commodities: Health and Medical care service, the Residence Service and Social Work which are used for the aged-care service.

The consumption demand for the education, health and medical service is not only from household but also from government. Our model does not have specific theory to explain the aggregate government consumption demand. In this research we assume that the aggregate government consumption demand follows the aggregate household consumption demand. For each specific commodity, the consumption demand is not only affected by the total government demand, but also affected by exogenous a shift variable[9]. This shift variable can be used to

[9] In the CHINAGEM model, we call these variables shift variables. They are normally exogenous variables and can be used to shock the changes caused by policies and other non-economic factors.

shock demand changes caused by the government subsidy or tax on certain commodity, or population age structure change, and etc. we shock this shifter variable to reflect the changes of the government consumption demand for education, health and medical service and aged-care service resulting from population ageing. The same approach was used to calculate these shocks as we did for the household consumption demand.

5.2 Policy simulation results analysis

5.2.1Macro results

The policy simulation results shows that the effect of the consumption demand change as a result of rapid population ageing is small. By the end of this century, real GDP will be only 0.14% lower than that of the baseline scenario (Figure 11a). The one reason is that the values of the three sectors we modelled in the simulation – education, health and medical service and aged care service are very small in China's economy (The value added of education, health and medical care, and the aged-care parts in the social work and residential service only account for 3.5%, 1.9%, 0.06% and 0.95%, respectively, in China's IO table in 2012). The second reason is that falling demand for education and rising demand for medical and aged-care service resulting from an aging population have opposite effects on the economy. Therefore, the combined effects on the economy becomes small.

Figure 11: Macro results of policy simulation
- Cumulative deviation from baseline scenario (%)

Source: Policy simulation results

We noticed that the employment fluctuates around the baseline scenario but is back to the baseline level at the end of simulation period. This is because of lagged wage adjustment mechanism in our model[10]. If the policy shocks causing the employment deviates from its

[10] Please refers to Dixon and Rimmar (2002) for the details of the dynamic lagged wage adjustment mechanism.

baseline level then the real wage will adjust to bring the employment back to its baseline level. Figure 11a shows that the real wage has to adjust downwardly to bring the employment back to its baseline level. By the end of the simulation period, the real wage will be -0.58% lower than that of the baseline scenario. This implies that the changed consumption demand caused by the rapid ageing reduces the employment. Therefore the real wage has to reduce to bring the employment back to its baseline level. Without the adjustment of the real wage, the employment will reduce further.

The age structure change will also bring the capital stock to growth slower than that of the baseline scenario. By the end of this century, the capital stock will be 0.22% lower than that of the base case.

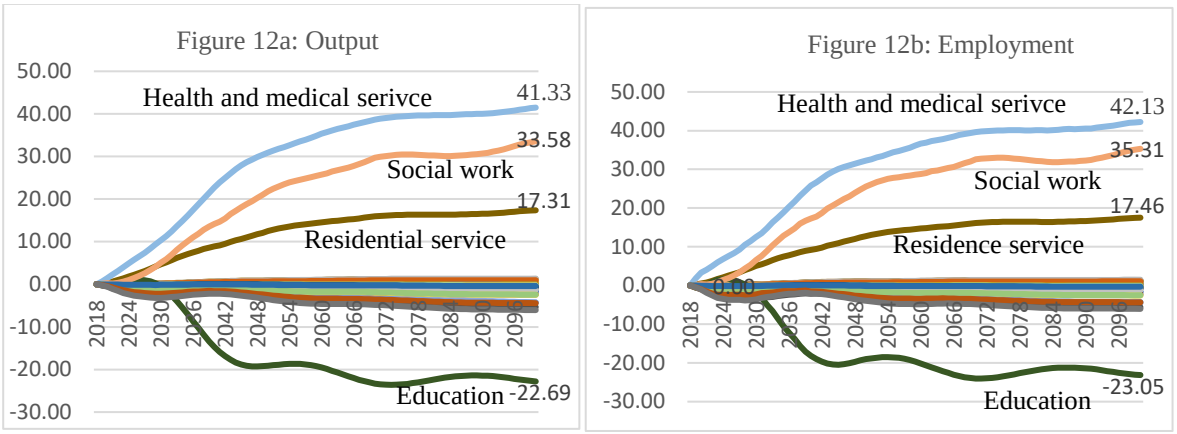
Figure 11b shows the effects of age structure change on the expenditure side of the real GDP. Similar as the effects on capital stock and employment, the effects on investment and household consumption are negligible. By the end of this century, investment and household consumption will be 0.36% and 0.27% lower than those in the baseline scenario, respectively. The lower consumption is caused by the declining demand for education as a result of population ageing, although the demand for health, medical service and aged-care service has increased (due to the larger share of education in the economy than that of health, medical service and aged-care service, the negative effects of declining demand for education exceeds the positive effects of rising demand for medical care and aged-care service).

5.2.2 Industry results

Except for the four age-dependent sectors, the effect of population ageing on the output of other sector is a very small negative (Figure 12a). The demand shifting away from education and towards health and medical service and aged-care service due to the age structure change will impose significant effect on those sectors. The output of education sector will be 23% lower than that of the baseline scenario, while the output of health and medical service, social work and residential service which provide aged-care service will be 41%, 34% and 17% higher than their baseline level, respectively. Similar results can be seen for the employment of industries (Figures 12b).

Figure 12: Industry results of policy simulation

- Cumulative deviation from baseline scenario (%)

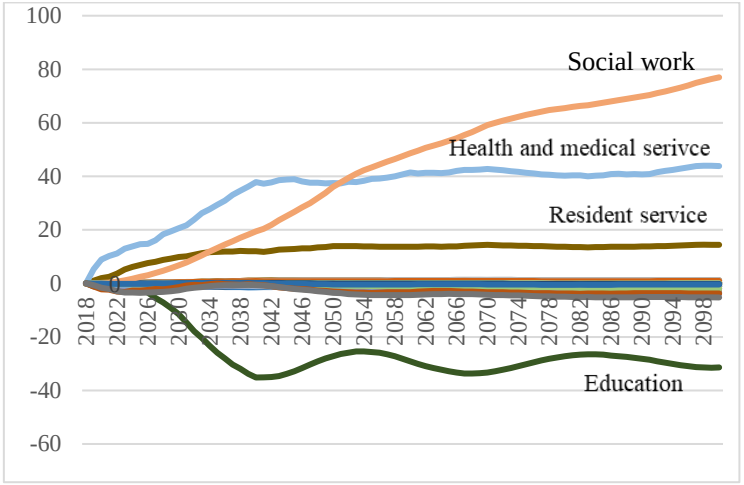


Source: Policy simulation results

We also notice that the age structure change also make significant changes to the investment demand for the four sectors comparing with other sectors. Figure 13 shows that by the end of century, investment demand for the education sector will be 31% lower than that of the baseline case. While the investment demand for health and medical service, social work and residential service will be 44%, 77% and 14% higher than those of the base case, respectively.

Figure 13: Industry results of policy simulation: Investment

- Cumulative deviation from baseline scenario (%)



Source: Policy simulation results

The consumption demand from both household and government for the products of these four sectors will also change dramatically while the demand for other products will be decline only slightly. Figure 14 shows that by the end of the century, with age structure change, consumption

demand for education from household and government will be 28% and 33% lower than their base case, respectively. While the household demand for social work will be 38% higher (Figure 14a) and the government demand for social work will be doubled by the end of the century comparing with the baseline case (Figure 14b). The demand for health and medical service from both household and government will also increase significantly (Figure 14a and 14b). The household demand for residential service will be 18% higher than that of base case (Figure14a).

Figure 14: Industry results of policy simulation
- Cumulative deviation from baseline scenario (%)

Figure 14a: Household consumption

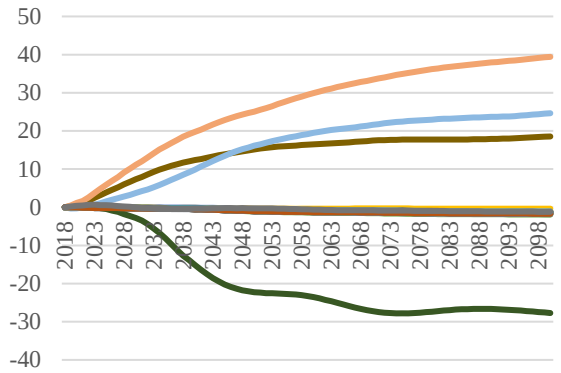
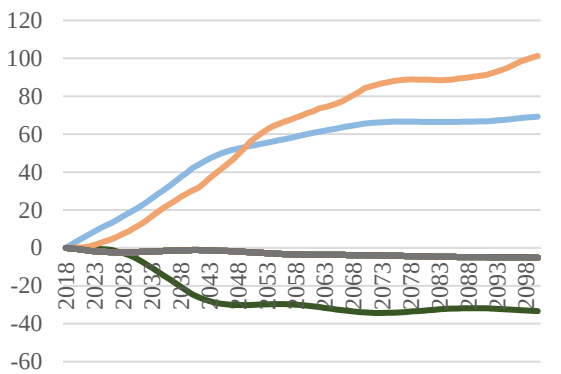


Figure 14b: Government consumption

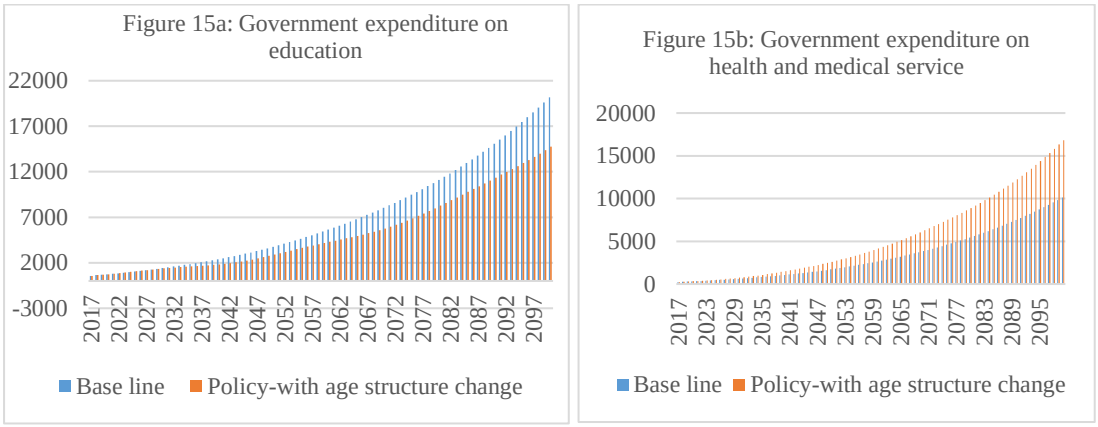


Source: Policy simulation results

5.2.3 The effects on government expenditure

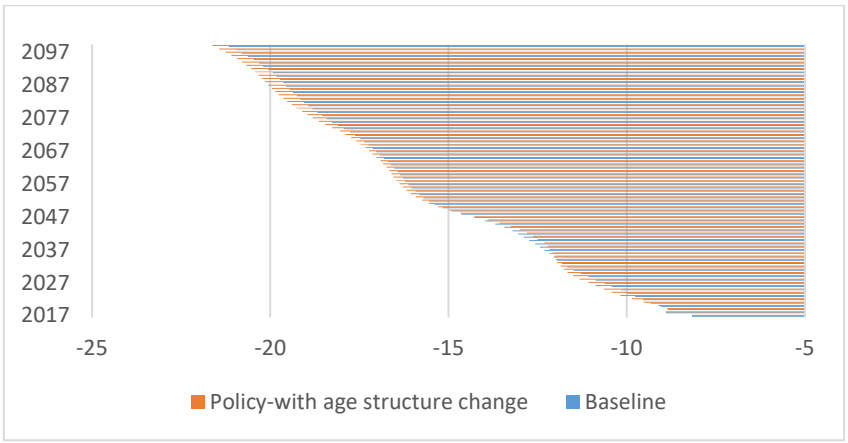
The demand shift away from education and towards health, medical service and aged-care will also affect the government public expenditure. We notice that by the end of this century, the government general expenditure on education will fall to less than 15000 million RMB comparing with more than 20000 million RMB in the base case of without age structure change (Figure 15a). While the expenditure on health and medical service will increase to nearly 170000 million RMB, a 66% rise comparing with the base case (Figure 15b). The increase of the expenditure in health and medical service will exceed the fall of the expenditure in education and result a slight rise of government general budget deficit, from 21.16% in the baseline to 21.62% of GDP in the policy simulation (Figure 16).

Figure 15: the government expenditure on education, health and medical service (millions RMB)



Source: Baseline and policy simulations

Figure 16: Government general budget deficit as share of GDP, 2017-2099 (%)



Source: Baseline and policy simulations

6. Conclusions

China's population is ageing. This paper first discusses the economic characteristics of an aging society. Then using a dynamic CGE model of the Chinese economy - CHINAGEM, this paper quantitatively analyze the economic impacts of not only the declining labour force and rising elderly population from supply side, but also the age structure induced change on consumption demand for several age-dependent goods and services over the period of 2019 to 2100.

In the baseline scenario, our simulation revealed that given the rapid ageing, China has to rely on technology improvement and capital stock increases to support its economic growth. The increasing elderly population will put high pressure on China's general government budget balance.

Then we constructed a policy scenario that deviated from the baseline due to ageing-induced changes to household and government consumption preferences for education, health and aged care services. With ageing, demand shifts against education and towards health and aged care services. The simulation results show that

- The effects of age-structure driven changes on the macro economy are negligible;
- The changes will affect the outputs, employment, investment and consumption of shocked sectors dramatically while the effects on other sectors are very small.
- The increased demand for medical and aged-care services will exceed the decreased demand for the education, thus drive up the general government budget deficit.

Please note that the above findings are based on the shocks on four sectors: education, health and medical care, residential service and social work. These are small sectors in China's economy. The effects of consumption change of these sectors on the macro economy are also small. Due to the data limitation, we did not include other age-dependent sectors such as housing, tourism and automobile into this study.

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Annex: About aged-care data calculation

A1: Data sources

In the 2011-2012 survey data of the China Health and Retirement Longitudinal Study (CHARLS), 7303 samples were obtained from the elderly population aged 60 and over at the survey time. Among the samples, 50.2% were male and 49.8% were female; 38.2% were aged 60-64, 24.6% aged 65-69, 17.5% aged 70-74, 11.5% aged 75-79 and 8.2% aged 80 and over; 23.9% with urban *hukou*, 75.4% with rural *hukou*, and 0.7 per cent were registered unified residents or no *hukou*.

A2: Construction of comprehensive self-care ability index for the elderly population

In order to analyze and forecast the aged-care needs of the elderly population, a comprehensive self-care ability of the elderly needs to be assessed first. If we only use Daily Life Activities (ADL) as the criteria of the elderly's self-care ability, the lack of self-care ability due to difficulties of Instrumental Daily Life Activities (IADL, such as housework, cooking, shopping, financial management, etc.) , the cognitive impairment and emotional instability (the elderly would need cognitive training, emotional counselling and accompany) will not be fully covered. There is a need to build broader indicators of comprehensive self-care ability for the elderly population.

As there is no national service needs assessment system for the elderly, we constructed the evaluation index system of the comprehensive self-care ability for the elderly population (see table 1) according to the grading standard and weight setting of “Shanghai Unified Needs Assessment Standard for Elderly Care (trial) 2.0”. Shanghai is one of the pilot cities of aged-care insurance in Chin with some adjustments based on the content of the CHARLS questionnaire.

Table A1: Comprehensive Self-care Ability Evaluation Index for the Elderly Population

Level I indicators	**Level II indicators**	**Weight**
(A) ADL	A_1 Dressing	0.075
	A_2 Bathing	0.075
	A_3 Eating	0.075
	A_4 Getting into or out of bed	0.075
	A_5 Using toilet	0.075
	A_6 Controlling urination and defecation	0.075

(B) IADL	B_1 Household chores	0.04
	B_2 Preparing hot meals	0.04
	B_3 Shopping	0.04
	B_4 Managing Money	0.04
	B_5 Taking medications	0.04
(C) Cognition	C_1 Self assessment of recent memory	0.05
	C_2 Word recalling	0.05
	C_3 Cognitive ability	0.1
(D) Emotion and Behavior	D_1 Emotion	0.1
	D_2 Communication	0.05
Total		1.0

According to the evaluation index of the old people's comprehensive self-care ability in Table A1, according to the evaluation standard in "Shanghai Service Needs Assessment Table for the Elderly" calculated by 100 points , 0-6 points are divided into the comprehensive self-care ability without difficulty; 6.1-18 into mild difficulty; 18.1-30 into moderate difficulty; 30.1-100 into severe difficulty.

A3. Current situation and projections of aged-care for the elderly population

A3.1 Disability rate of the total elderly population

According to the survey data of CHARLS (2011), the comprehensive self-care ability of the elderly was divided into four states: "no difficulty", "mild difficulty", "moderate difficulty" and "severe difficulty". Considering that the elderly with institutional care might have a higher disability rate than those with care at home, it is assumed that the disability rate of the total elderly population is 20%.

A3.2 Comprehensive self-care ability and the caring time required of the elderly population

Assuming that the elder population with moderate and severe difficulties in comprehensive self-care ability require the same caring time as those with ADL moderate and severe difficulties at home, the overall caring time required by the disabled elderly population and the average caring time by age group can be estimated (see Table A2).

Table A2 Comprehensive Self-care Ability and Caring Time Required of the Elderly Population by Age group[11](2011, hour/month)

Comprehensive Self-care Ability	**60-64**	**65-69**	**70-74**	**75-79**	**80+**	**Total**
No difficulty	6.6	10.4	12.6	16.9	39.6	11.6
Mild difficulty	29	39.8	47	48.3	95.2	44.7
Moderate difficulty	88.9	108.5	128.2	147.8	167.4	122.6
Severe difficulty	258.9	282.4	305.9	329.4	352.9	329.1
Total	15.1	24.4	34.6	39.7	100.4	30.6

A3.3 Mode, efficiency and cost estimates of aged-care delivery

Aged-term care can be divided into three different ways by service provider and place: informal care at home, formal care at home and institutional care. Informal care at home is mainly provided by family members, and also includes informal services obtained or purchased by the family; formal care at home is door-to-door services purchased by the family through formal market; and institutional care is the care service provided in nursing institutions for the elderly people. Among the 45-sector input-output tables used in the CGE model, informal care at home is not included and is a kind of "hidden" service; formal care at home and institutional care are respectively included in the sectors of "residential services "," social work" and "health", and are "explicit" services. Since neither the level of specialization nor the scale effect of formal care at home and institutional care are superior to those of informal care at home, the formal care at home and institutional care services are more efficient. Thus, the same amount of services may take varying amounts of time if they are provided by different forms of care. It is assumed that the efficiency ratio of informal care at home to formal care at home is 0.7, i.e. the amount of services provided per hour of informal care at home is same with the services provided through 0.7 hours of formal care at home; the efficiency ratio of informal care at home to institutional care is 0.35, i.e. the amount of services provided per hour of informal care at home is same with the services provided in 0.35 hours of institutional care, as shown in Table A3.

Table A3: Efficiency of Aged-care Service in Different Modes

Mode of LTC	**Service Amount**	**Service Time**
Informal care at home	the amount of services provided per hour of informal care at home	1 hour
Formal care at home	the amount of services provided per hour of informal care at home	0.7 hour
Institutional care	the amount of services provided per hour of informal care at home	0.35 hour

[11] As 97% of the caring time received in CHARLS survey data was for informal care at home, it is assumed that caring time here refers to those required under informal care at home.

In addition, we assume that in 2012, 90% of aged-care services were “hidden” or implicit services (informal care at home) and 10% were explicit services (formal care at home and institutional care). Among the 10% of the explicit services, 80% (8% of the total care service) are formal care services at home and 20% (2% of the total care service) are institutional care services.

A3.4 Explicit costs of aged-care provided by the household and the government.

Among the explicit costs, the part provided by the government refers to the services provided or covered by the government through aged-care insurance or civil relief, and the rest of the expenses are paid by the household. It is assumed that in 2012 the government and the household accounted for 30% and 70% of the cost respectively.

A3.5 Linking with the Input-Output table.

In the Input-Output table there are 45 aggregated sectors. Aged-care services involve three sectors: “residential services”, “social work” and “health”. The aged-care services provided by hospitals have been included in the relevant statistics of the health sector, and we have estimated the per capita medical consumption by age-group; therefore, in order to avoid double counting, in the per capita consumption of aged-care services, we no longer consider the long-term medical care and rehabilitation services provided by the "health" sector, but only the care services provided by the “residential services” and “social work” sectors. The cost of care services provided by “residential services” and “social work” sectors in 2012 was 53.65464 billion yuan and 67.0683 billion yuan respectively[12], accounting for 11.4% and 23.3% of the value of “residential services” and “social work” sectors respectively.

A3.6 Dynamic changes in the aged-care service costs.

Growth mechanisms for aged-care service costs include three parts. First, the raise in the proportion of the elderly population, especially those aged 80 and over, contributes to the increase in aged-care costs. Second, the increase in explicit costs (partially paid by the household) due to the smaller family size, the reduced capacity of family members to provide care, as well as the increased involvement of social security projects such as aged-care

[12] The formula is

$$\sum_{age=60}^{100} the\ number\ of\ elderly\ people\ at\ certain\ age * the\ explicit\ cost\ of\ care\ per\ person\ of\ that\ age$$

insurance and civil assistance. Moreover, the share of the household burden in the explicit cost falls and the share of the government burden rises accordingly. To this end, we assume that during the period 2012-2050: first, the proportion of explicit services in aged-care increases linearly from 10% in 2012 to 50% in 2050; second, the share of services in “residential services” and “social work” sectors in explicit service remained unchanged at 80% and 20%; third, the government's share of explicit services will increase linearly from the current 30% to 80% (including paid services provided by households. For example, care services provided by family members in Germany aged-care service can be compensated), and accordingly the share of explicit services provided by households will gradually decrease from the current 70% to 20%. These ratios remains unchanged after 2050. The changes in the per capita consumption of older persons in both sectors are shown in Figures A1 and A2.

Figure A1: Per capita consumption of elder population by age Group in the residential services sector

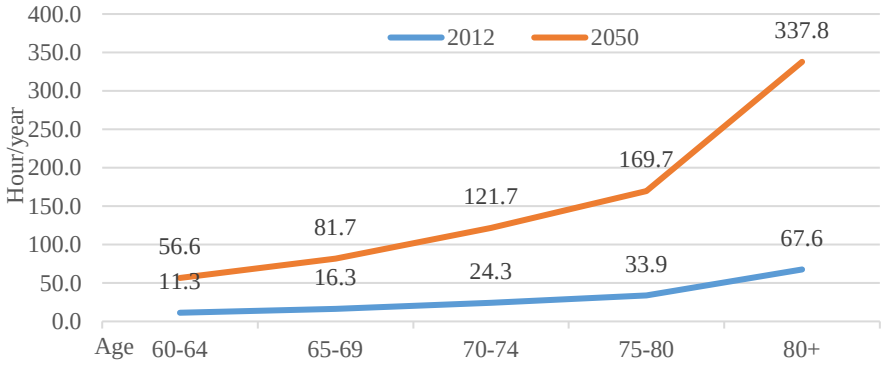

Figure A2: Per capita consumption of elder population by age Group in social work sector