The Impact of China's Demographic Transition on Economic Growth and Income Distribution: CGE Modeling with Top-Down Micro-Simulation

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Abstract: Demographic transition due to population aging is an emerging issue throughout the developing world, and especially in China, which has undergone demographic transition more rapidly than most industrial economies. This paper quantifies the economic and distributional effects in the context of demographic transition using the integrated recursive dynamic computable general equilibrium (CGE) model with top-down behavioral micro-simulation. The results show that the population aging slow down China's economy growth rate due to the exhausted of demographic dividend with high cost of labor force. The consequences from the poverty and inequality index indicate that population aging has a negative impact to the reduction of poverty while it is positive as refers to the equality during the process of demographic transition. The average age within a household has a noticeable contribution to total inequality. These findings suggest that measures for stimulating the second demographic dividend should be carried out to promote the economic growth as well as the reduction of poverty. The inequality within the same household groups while with different household age should be put more emphasize on. What's more, the social pension system should be improved, especially in rural China

Key words: Demographic Transition, Economic Growth, Income Distribution, CGE model

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1. Introduction

As the world's most populous country, China has experienced rapid economic growth over the past decades. China's abundance of cheap labour has made it internationally competitive in many low-cost, labour-intensive manufactures (Wang and Mayes et al., 2005). Scholars estimate that the demographic dividend accounts for one fourth of China's economic growth since 1978 (Wang and Mason, 2004; Cai, 2009).

However, due to the combined influence of the strict implementation of the one-child policy and of socio-economic development, China has completed a demographic transition from the interim pattern to the final pattern within approximately 30 years, a very short period of time when compared to most developed countries (Cai and Wang, 2010). According to the sixth national census in 2010 released by NBS (National Bureau of Statistics), the proportion of the population aged over 60 is 13.32 percent and the population aged over 65 accounted for more than 8.92 percent of the total population in China. China will enter a rapid ageing period, with the proportion of the old population doubling by 2030 and the total labor force declining by 2015 (United Nations, 2010). Meanwhile, the phenomenon of the labor shortage in eastern part of China and the increasing of the labor wages since 21th century has become a hot topic throughout China and it attracts a lot of debates among scholars on whether China has reached the Lewis turning point. The population aging and labor shortage phenomenon imply that China's demographic dividend will soon be exhausted (Wang and Mason, 2004) and it will turn into a demographic deficit with important adverse economic consequences (Peng and Mai, 2008).

These profound demographic changes are causing increasing concern about the sustainability of China's economic growth (Cai, 2009; Cai and Wang, 2005). Scholars and Chinese government officials worry that the looming demographic challenge may undermine China's ability to grow rich before its population grows old (Jackson and Howe, 2004).

There has been a great deal of theoretical and empirical research on the relationship between demographic transition with economic growth and income distribution for developed economies since 1990s when the population aging emerged to influence the economic and society. Generally speaking, the literature indicates that the aging of the population generates negative economy-wide effects that would slow economic growth. As refer to the relationship between demographic transition and income distribution, the empirical results are inconclusive as there is evidence both supporting a positive and a negative relationship. As the issue of population aging began to unfold at the beginning of the 21st century for developing countries, existing studies on the relationship between demographic transition with economic and income distribution mainly focus on developed countries and only a few studies referred to developing countries.

This paper aims to examine the economic and distributional effects of the demographic transition that is underway in China using an integrated recursive dynamic computable general equilibrium (CGE) model with a behavior micro simulation model. A CGE model is solved first by identifying the labor force into eight different segments and considering the demographic transition for the time period from 2010 to 2050. The economic impact would be quantified from the CGE model's results. To further identify the income distribution by demographic transition, the results from the macro model would then communicate with the micro behavior simulation model which accounts for the individual's heterogeneity. The latter is used to generate changes in individual's non-capital wages that is consistent with the results from the macro CGE model. Finally, the FGT index and Gini index are adopted to analyze the evolution of poverty and inequality for the next forty years as influenced by the shock of the demographic transition. In addition, regression-based inequality decomposition with the Shapley value decomposition method is further used to identify the relative contribution of demographic variables to income inequality.

The rest of the paper is organized as follows: section 2 concludes the literature reviews on demographic transition with economic growth and income distribution; section 3 qualitatively describes the demographic transition, economic growth and income distribution in China. Then we introduce both the CGE model and micro-simulation model in section 4 and section 5 respectively. Section 6 contains the empirical results on economic growth from CGE model and the variation tendency of income distribution in the context of demographic transition is analyzed in the following section 7 and finally, we present the conclusions of the whole paper and propose the policy implications arising from the results in the last section.

2. Reviews on Demographic Transition with Economic Growth and Income Distribution

In this section, we will briefly introduce the effects of demographic transition to economic growth and income distribution respectively based on the literatures reviews.

2.1 The Effects of Demographic Transition with Economic Growth

The impact of any demographic change can be split into supply effects (consequences for labor and capital) and demand effects (consequences for public and private consumption, international trade and domestic and foreign investment) (Poot, 2008). Generally speaking, the population transitions have been known to generate negative economy-wide effects (Kim and Hewings *et al.*, 2011). The negative effects of population ageing on economic growth are increasingly recognized (Peng, 2006; Golley and Tyers, 2006). Peng(2006)'s simulation results show that the labor force decline caused by population ageing will decelerate China's economic growth rate by two percentage points annually during the 2020s and by three percentage points annually during the 2040s. Conclude from the literature review, the demographic transition would affect the economic growth via different routes: 1) the total labor supply and labor productivity growth; 2) the structure of household consumption and 3) the institution's savings and investment behavior.

(1) The changes of production due to the reduction of total labor supply and modification of labor age structure. In one hand, the total labor supply as the factor input for production would be reduced with the population ageing that it have a negative impact on productive. In the other hand, the process of population ageing would change the age structure that influence the composition of the labor resource and thus the total factor productivity (TFP) would be modified accordingly. This is because of the different age groups would have different characteristics which would impact the work categories, the innovation, the cost of adopting new technology (OECD, 1998;Canton *et al*, 2002) that work on the TFP. What's more, the population age would slow down structural adjustment due to the less labor mobility for aged people (Poot, 2008).

(2) The reduction of total household consumption and changes of household consumption structure. The population ageing may reduce the total consumption in one hand and change the

consumption structure on the other hand. Different age population would have different consumption propensity. For example, the population with high ratio of children dependent, the educational expenditure would be enhanced within household and the population with high ratio of old people, the expenditure on health care would be increased accordingly.

(3) The changes of social savings and investment. The population age would have a negative impact on saving and the related investment as well. First, the old population themselves would have a low saving rate as no labor-income for old population. They have to use their savings and this may increase the cost of capital and lower investment (Poot, 2008). Second, the families with old people would enhance the burden for the family's labor force so that comparatively less saving would be accumulated. Third, the government would increase the transfer to the population pension for social security which would reduce the government saving correspondingly (Fu, 2012). And finally, foreign capital would flow to other countries because of the high cost of labor force which would rise significantly due to the population aging and labor shortage. Consequently, the reduction of savings and investment further increase uncertainties in capital accumulation in China, and destabilize economic growth (Li and Liu, *et al*, 2011).

However, there are also some researches claimed a different attitude that population ageing would have positive effect to productiveness. This can be account for the following reasons: 1) with the population transition, the senior labor force also increased, and an increasingly mature workforce will have higher levels of work experience and it may achieve higher levels of productivity than a younger workforce (Disney, 1996). 2) Population transition lead to less new born and young population, thus the education expenditure for young would fall and this may lead to subsequent productivity growth (Ermisch, 1995; Fougere and Merette, 1999). 3) The decrease of the labor force due to the population ageing cause a higher relative price of labor and therefore provides a greater incentive to innovate through capital investment or research and development (Romer, 1990).

2.2 The Effects of Demographic Transition with Income Distribution

With the deterioration of income inequality followed with the rapid economic growth and population aging, the researches on the population transition with income distribution became popular in the 1990s for developed countries. Moreover, the general trend of such researches regarding this relationship is inconclusive as there is evidence both supporting a positive and a negative relationship. *In one hand, some empirical researches indicate that population aging worsen the income inequality* (Ohtake and Saiyo, 1998; Deaton and Paxon, 1994). Deaton and Paxson (1995) analyze the relationship between population aging and inequality and conclude that population aging leads to greater inequality both for within-cohort inequality and between-cohort inequality. Their results fit the conditions of the Taiwanese economy and also predict increases in inequality in other fast-growing Asian countries. Followed by Deaton and Paxson (1995), Ohtake and Saito (1998) analyze how consumption inequality within a fixed cohort grows with age, using Japanese household micro data. Their results show that half of the rapid increase in the economy-wide consumption inequality during the 1980s was caused by population aging. Consumption inequality starts to increase at the age of 40 and younger generations face a more unequal distribution from the beginning of their life-cycle. Miyazawa (2005)'s analytical results reveal that the relationship between growth and inequality is at first positive and then may become negative as the population ages. *However, on the other hand some studies find that aging may have a negligible effect inequality* (Jantti, 1997; Bishop, Formby and Smith, 1997; Barrett, Crossley and Worswick, 2000; Schultz, 1997) *or even a positive effect on equality.* Chu and Jiang (1997) examine the effects of age structure on family income using the Gini coefficient and the results demonstrate that changes in Taiwan's demography reduced the inequality in family earnings between 1980 and 1990. By applying the Overlapping Families (OLF) Model, Lee and Mason (2003) find that population aging had little effect on income inequality. Morley (1981) expands Paglin (1975)'s method, which decompose the inequality by age structure and found that the younger age structure would widen the income inequality while the countries with serious population aging have a relative smaller inequality.

As the issue of population aging began to unfold at the beginning of the 21st century for developing countries, there are only a few existing studies on the relationship between demographic transition and income distribution that focus on developing world. China is among the few developing countries that have stepped into the aging population society. The researches on China's demographic transition with income distribution are start to emerging in recent years and the results regarding this relationship are still not clear. S*ome empirical researches indicate that population aging expand the income inequality*. Zhong (2011) investigates the relationship between population aging and income inequality in rural China by using the five years' panel data from CHNS (China Health and Nutrition Survey) and argues that a significant portion of the sharp increase of income inequality at the beginning of this decade can be attributed to demographic change. Dong, *et al* (2012) employ provincial level panel data between 1996 and 2009 and confirm that population ageing is a positive and significant factor contributing to income inequality. *But on the other hand, researches find that the demographic transition only account for a tiny fraction of inequality.* Cai, *et al* (2010) adopt the urban household survey data between 1992 and 2003 by employing the regression based inequality decomposition and find that the age have a negligible effect on inequality. Qu and Zhao (2008) investigate the relationship between inequality and population aging in rural China based on the life cycle model. They use three years' rural household surveys in China Household Income Project and apply analysis of variance and regression decomposition methods to decompose the consumption and income inequality in rural China into three parts: cohort effect, age effect and population aging effect. The results show that population aging only plays a small role on the inequality increasing in rural China. *There are few other studies that have comprehensively analyzed the relationship between income distribution and problems associated with population aging in China.*

2.3 Brief Summary

The population transitions have been known to generate negative economy-wide effects and it would affect the economic growth via (1) the changes of production due to the reduction of total labor supply and modification of labor age structure; (2) the reduction of total household consumption and changes of household consumption structure; and (3) the changes of social savings and investment. As the issue of population aging began to unfold at the beginning of the 21st century for developing countries, existing studies on the relationship between demographic transition and income distribution mainly focus on developed countries. Moreover, the general trend of such researches regarding this relationship is inconclusive as there is evidence both supporting a positive and a negative relationship.

China is among the few developing countries that have stepped into the aging population society. The researches on China's demographic transition with income distribution are start to emerging in recent years and the results regarding this relationship are still not clear. The existing studies mainly using the panel data and decomposing the inequality by aging and simulating the contribution of aging on inequality. However, demographic transition is a long process; the economic and social impact by population aging has not yet emerged throughout China. A review of the literature indicates that demographic transition (such as age structure transition, spatial structure change, and gender structure and human capital structure variation) have economic and social impacts by changing the supply of labor factor and affecting household consumption and investment demand. Then, it would affect household income and expenditure via two channels: 1) direct channel, affects the individual's employment and wage and 2) indirect channel affects the sensitivity of commodities' supply and price due to changing of productivity for economic growth. Finally, income distribution would be changed accordingly. The channel of the impact of demographic changing on income distribution is shown in Figure 1. Thus, it would be better to quantify the distributional effects in the context of demographic transition using the linkage between macroeconomic models (which quantify the demographic transition) with micro simulation models (that can quantify the income distribution from micro data).

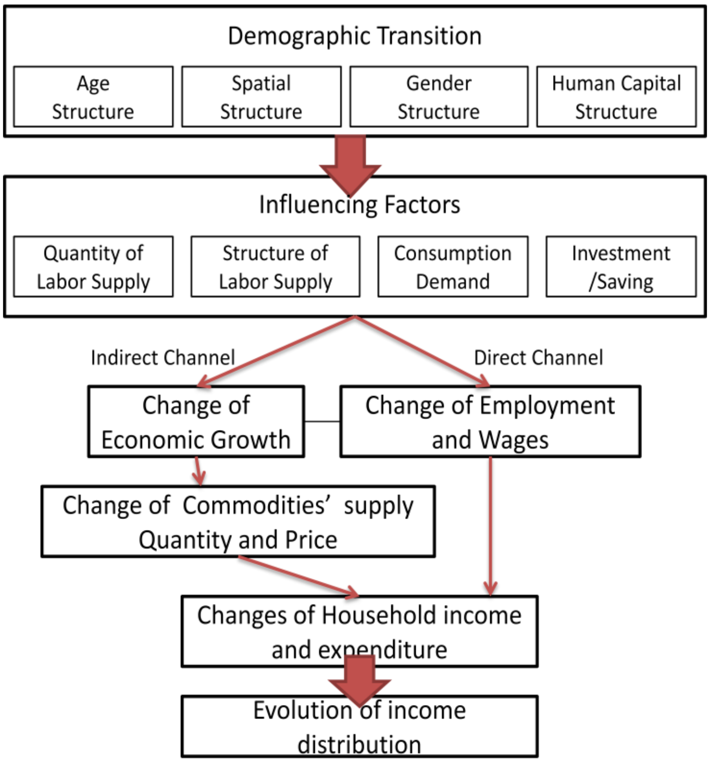

Figure1: The Channel of the Impact for Demographic to Income Distribution

CGE model is considered as one of the best modeling for the connecting the macro model with micro simulation model. This paper attempts to quantify the economic and distributional effects in the context of demographic transition using the integrated recursive dynamic computable general equilibrium (CGE) model with top-down behavioral micro-simulation.

3. Demographic Transition, Economic growth and Income Distribution in China

3.1 Demographic Transition in China

China has completed a demographic transition from the interim pattern to the final pattern within approximately 30 years, a very short period of time when compared to most developed countries (Cai and Wang, 2010). From figure 2 on China Population structure by age groups and sex, we can get the idea that, at the early stage of the founding of the People's Republic of China, China's population age structure presented a perfect pyramid shape: the young and new-born population account for an absolute proportion of the population and the elder population only has a small part of the total. According to the data from China's the first national census in 1953, for example, it shows that the share of population with the age over 15 year old is 36.28% of the total population and the population aged over 65 years only account for 4.41%. However, with the economic growth and the implement of birth control policy, the pyramid structure is being subversive that the elderly population is rising sharply. In 2010, the typical pyramid structure turns to be olive shape that the old and middle-age population increased rapidly. According to the data from the sixth national census in 2010 released by NBS, the proportion of the population aged over 60 is 13.32 percent and the population aged over 65 accounts for more than 8.92 percent of the total population in China. With the faster growth of population aging, China's aging labor force will start to fall in 2015 and the total population will begin to decline in 2025, as projected by the United Nations (2010). China will account for 23.5 percent of the world's old population who are over 65 years of age by 2030 and in 2050; the population age structure would turn to be inverted pyramid structure.

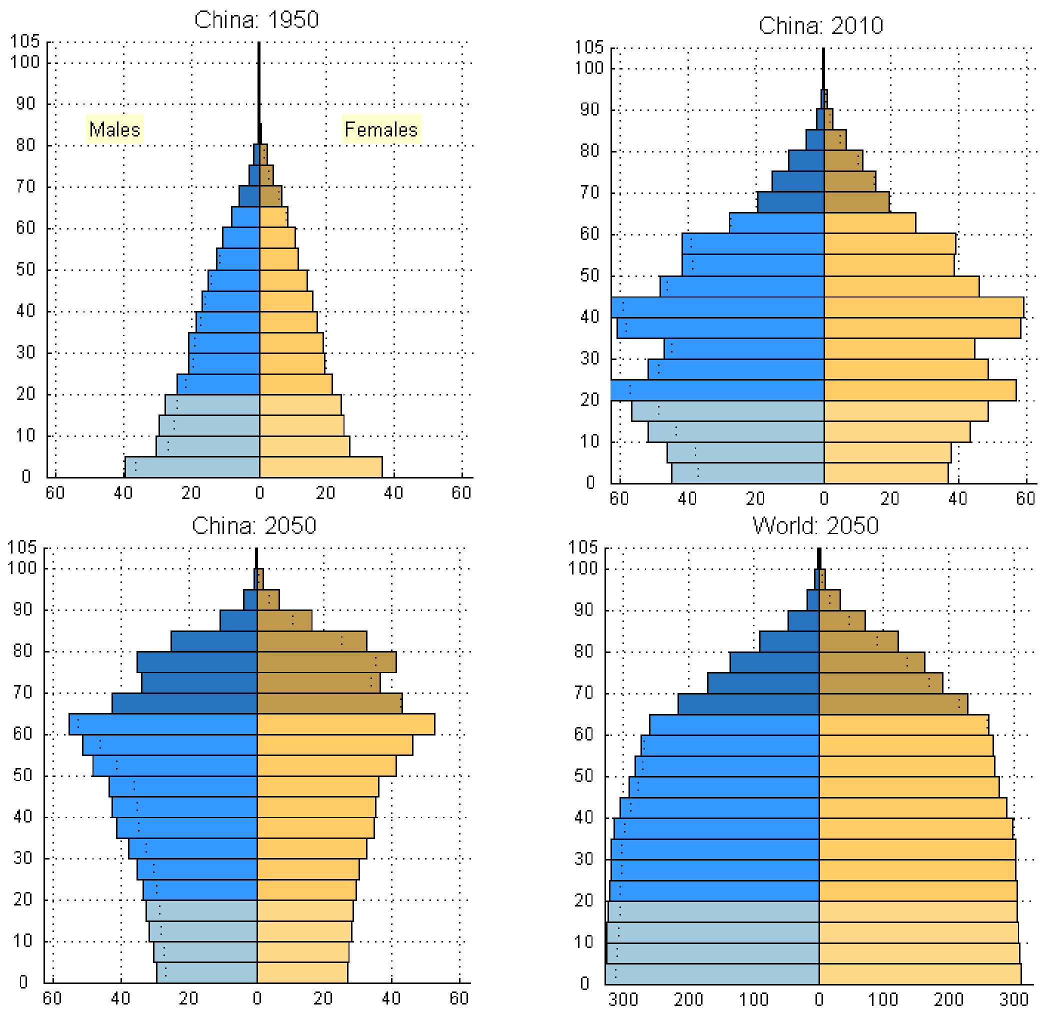

Figure2: China and World's Population by age groups and sex (absolute numbers)

The demographic change from the establishment of the People's Republic of China (PRC) to the present is revealed in Figure 3. Combined with China's economic growth and government policies as well as the variation tendency in figure 3, we categorize the demographic transformations according to the following time periods. **(1) 1949 – 1958,** the period immediately following the establishment of the new PRC. The birth rate was high and as a result, the population increased rapidly. This growth, especially the improved infant mortality indicators, was also facilitated by the success of the healthcare program and improved nutrition. The idea of "more people more power", and "more children as a guarantee for security in old age" served as the prevailing wisdom for the majority of Chinese households at that time. **(2) 1958 – 1963.** This is the period in which widespread famine, attributed to policy mismanagement and low agricultural production, plagued China, resulting in a 30-35 percent fall in the birth rate. The death rate rose higher than the birth rate and the population experienced 5 years of population decrease. **(3) 1963 – 1979:** a baby boom took place in the mid-1960s and the economy began to recover during this period. **(3) 1979- today**. The 'one child policy' was adopted in 1979 as the nation's basic policy to control the birth rate for policymakers realized that a huge population would outgrow the available resources, and has been very successful in reducing birth rates. China is now a 'post-transitional' society, where life expectancy has reached new heights, fertility has declined to below-replacement levels, and rapid population ageing is on the horizon.

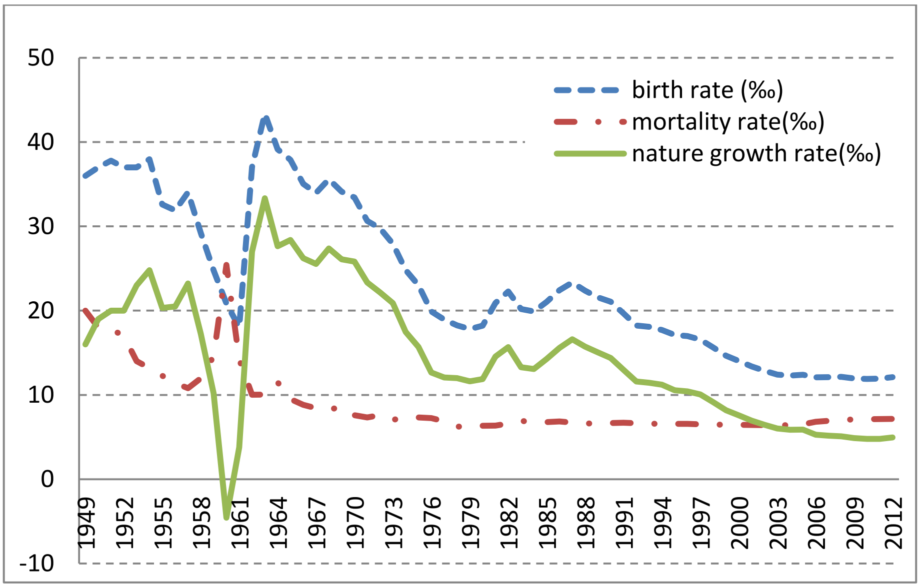

Figure 3: China's demographic transition from1949-2012

Data source: China Stock Market & Accounting Research Database

Based on the new definition provided by the United Nations' World Health Organization (WHO), a region or country in which the proportion of the aging population (aged over 65) is over 7 percent of the total population is known as an "aging society"; while it is called an "aged society" when the ratio of the elderly population reaches 14 percent and it is a "Hyper-aged society" if the old population is over 20 percent. According to this definition, China has been regarded as aging society since 2000. The proportion of over 65 year-aged populations is projected to reach 14% in 2025 (United Nations, 2010), at which point China will be regarded as an aged society. What's more, the growth rate of China is much lower than the average of the world and even for the more developed regions. All of which indicates that China will enter a rapid ageing period. That would be a disaster for economic growth if China can't adjust its industrial structure in a timely fashion.

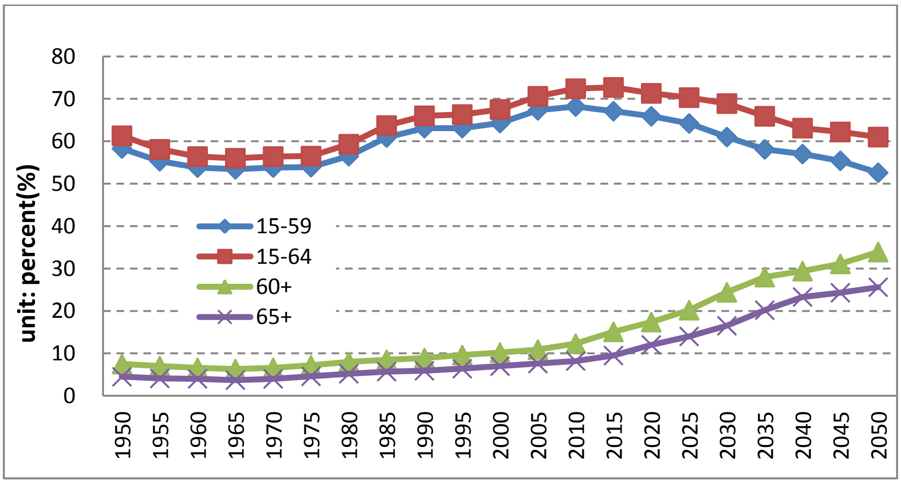

Figure 4: the evolution of the different age group proportion

Data source: World Population Prospects (2010) by United Nation

3.2 Economic growth and Poverty & Inequality Evolution in China

Over the past decades, China has experienced rapid economic growth and social changes. People's living standards have vastly improved. From the table 1 on China's GDP evolution since the reform and opening policy, the GDP at constant prices (take 2010 as the base year) in 1978 is 7472.76 billion yuan, which is 1103.8 billion dollors[2]; the GDP at constant prices in 2011 is 43147.72 billion yuan that is 63733.71 billion dollars and 5.77 times than the GDP in 1978. Meanwhile, the per capital GDP in China also increased sharply, from 5610.8 yuan(at constant prices) in the year of 1978 to 35181.2 yuan in 2011, which is 828.8 dollar and 4777.5 dollars respectively with an increase of 4.76 times from 1978 to 2011. For the composition of GDP, the tertiary industry has exceeded primary industry since the year of 1985. In 2011, the GDP composition for the primary industry, the secondary industry and tertiary industry are 10.0 percent, 46.6 percent and 43.4 percent respectively.

Table1: the GDP evolution and GDP composition in China (1978-2011)

	GDP (unit:100 million yuan)		Per capital GDP (unit: yuan)		Composition of GDP (unit: %)		
Year	current price	Constant Prices(2010)	current price	constant price(2010)	Primary industry	Secondary industry	Tertiary industry
1978	3645.2	74727.6	381.2	5610.8	28.2	47.9	23.9
1979	4062.6	77401.1	419.3	5815.6	31.3	47.1	21.6
1980	4545.6	80327.3	463.3	6031.2	30.2	48.2	21.6
1981	4891.6	82169.3	492.2	6166.9	31.9	46.1	22.0
1982	5323.4	81851.9	527.8	6153.9	33.4	44.8	21.8
1983	5962.7	82499.3	582.7	6218.1	33.2	44.4	22.4
1984	7208.1	86493.9	695.2	6526.4	32.1	43.1	24.8
1985	9016.0	95559.6	857.8	7194.5	28.4	42.9	28.7

[2] Note: calculate with the exchange rate in the year of 2011(per US dollar equals to 6.77 yuan)

1986	10275.2	100335.8	963.2	7532.9	27.1	43.7	29.1
1987	12058.6	105589.2	1112.4	7922.7	26.8	43.6	29.6
1988	15042.8	118336.0	1365.5	8881.5	25.7	43.8	30.5
1989	16992.3	128336.5	1519.0	9640.7	25.1	42.8	32.1
1990	18667.8	135480.6	1644.0	10196.9	27.1	41.3	31.5
1991	21781.5	144882.2	1892.8	10900.5	24.5	41.8	33.7
1992	26923.5	157002.1	2311.1	11794.2	21.8	43.5	34.8
1993	35333.9	181271.3	2998.4	13581.9	19.7	46.6	33.7
1994	48197.9	218611.8	4044.0	16383.5	19.9	46.6	33.6
1995	60793.7	252202.9	5045.7	18629.8	20.0	47.2	32.9
1996	71176.6	267964.4	5845.9	19827.2	19.7	47.5	32.8
1997	78973.0	271206.4	6420.2	20127.7	18.3	47.5	34.2
1998	84402.3	270100.6	6796.0	19948.8	17.6	46.2	36.2
1999	89677.1	265859.2	7158.5	19694.8	16.5	45.8	37.8
2000	99214.6	270955.6	7857.7	20095.1	15.1	45.9	39.0
2001	109655.2	277144.4	8621.7	20507.6	14.4	45.2	40.5
2002	120332.7	277628.2	9398.1	20630.8	13.7	44.8	41.5
2003	135822.8	283651.4	10542.0	21164.7	12.8	46.0	41.2
2004	159878.3	302215.1	12335.6	22630.9	13.4	46.2	40.4
2005	184937.4	315480.5	14185.4	23518.1	12.1	47.4	40.5
2006	216314.4	325771.3	16499.7	24413.4	11.1	47.9	40.9
2007	265810.3	349183.6	20169.5	26278.0	10.8	47.3	41.9
2008	314045.4	374790.5	23707.7	28318.2	10.7	47.4	41.8
2009	340902.8	375514.8	25607.5	28146.5	10.3	46.2	43.4
2010	401512.8	401512.8	30015.0	30015.0	10.1	46.7	43.2
2011	472881.6	431477.2	35181.2	32344.0	10.0	46.6	43.4

One of the great successes of China's economic reforms has been a dramatic reduction in the number of the poor population, especially in the early years of reform. Household income has grown rapidly in China since 1978, and individual Chinese are clearly much better off than they were 30 years ago. There were about 260 million poor people at the beginning of the reforms in 1978 and the incidence of poverty was quite high, at 33 percent. The poverty incidence decreased to 2.8 percent in 2010, with a total poor population of 26.88 million despite the introduction of a growing poverty standard (figure 5). In 2011, the central government of China further raised the official poverty line from an annual income of 1274 yuan in 2010 to 2300 yuan, which is equal to 1.8 dollar per day at 2005 constant PPP, and is larger than the World Bank's international poverty standard (1.25 dollar per day). Accordingly, the size of China's impoverished population under this new poverty line is forecast to exceed 100 million. Despite this, it is obvious that Chinese people's standard of living has been significantly improved and that poverty has been substantially reduced.

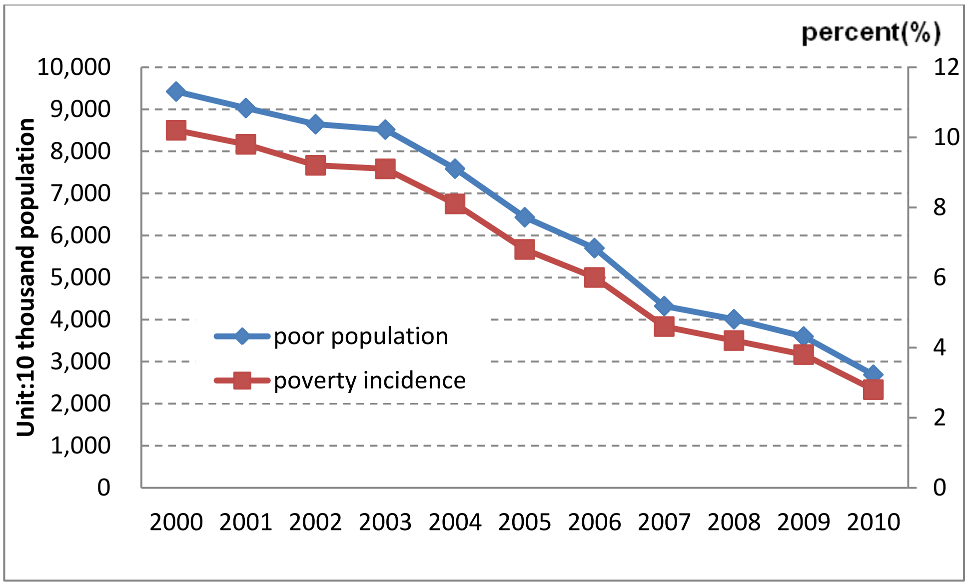

Figure5: the poverty scale and poverty incidence in China (2000-2010)

Data source: Poverty Monitoring Report of Rural China (2011)

However, over the same period the distribution of income has become much more unequal between rural and urban areas, coastal regions and inland regions, males and females and between different industry sectors. Take the trend of urban-rural inequality as an example, from the figure 6, we can get the idea that the absolute gap of urban-rural per capita income is enlarging since China's reform and opening up policy in 1978. In 2011, the per capita disposable income of urban households is 21809.78 yuan; it is 6977.29 yuan for rural households. Nevertheless, the ratio of urban-rural income shown fluctuations trends according to the different government policy preferential in different period.

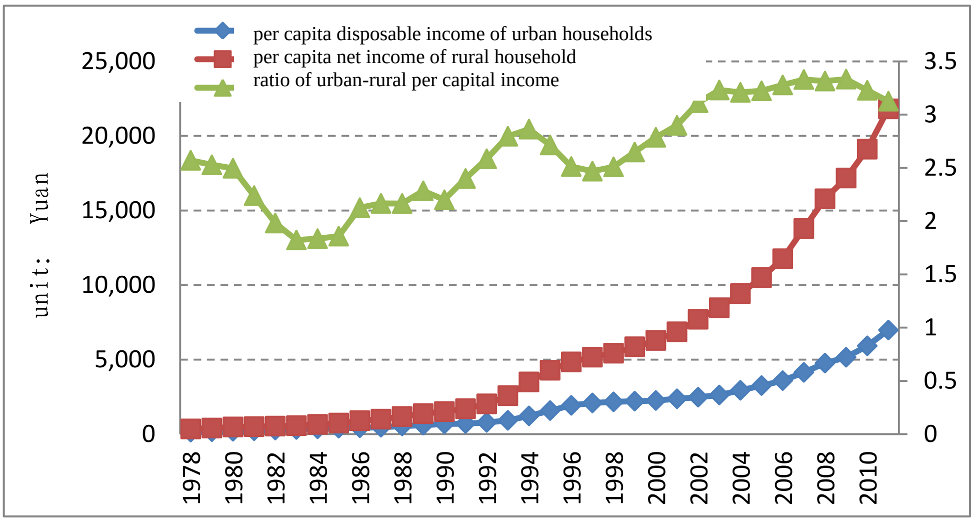

Figure 6: the per capita household income trends for urban-rural household(1978-2011) [3]

The Gini coefficient was only 0.16 before China's reform and opening up policies in 1978.

3 Data souce: China statistical yearbook data throughout different years

According to the National Bureau of Statistics' recent report, the Gini coefficient was 0.491 in 2008 and 0.474 in 2012, both of which cross the international Warning Line, which implies that China's inequality is becoming increasingly severe. Some of this inequality is attributed to policies that inhibited labor mobility because of the household registration system. Whither inequality in the context of demographic transition in the middle- and long-run period will be a hot topic in the near future.

4. CGE Model and its Database

Computable general equilibrium (CGE) models are a class of economic models that use actual economic data to estimate how an economy might react to changes in policy, technology or other external factors. It is widely used for policy analysis in many countries and organizations throughout the world. A CGE model consists of equations describing model variables and a database consistent with the model's equations. The equations tend to be neo-classical in spirit, often assuming cost-minimizing behavior by producers, average cost pricing, and household demands based on optimizing behavior. The dynamic CGE model adopted in this research is developed by the International Food Policy Research Institution (IFPRI) which is an extension of IFPRI's static standard model that was developed by Lofgren, Harris and Robinson (2002). The model is a recursive dynamic model that is solved one period at a time, which indicates that the behavior of the model's institutions is based on adaptive expectations, rather than on the forward-looking expectations which underlie inter-temporal optimization models (Thurlow, 2004). We will briefly introduce both of the within-period and between-period components of this model with the database in this section.

4.1 Within-Period Specification of the CGE Model

This part describes a one-period static CGE model. The structure of the model can be simply outlined in figure 7. The basic characteristics of this model are included in the following four parts: (1) the activities, production and factor markets; (2) the trade and commodities market; (3) the institutions income and expenditure; and finally (4) the macro closure and system constraint. We introduce each of the four parts here with the specification of this paper's objective.

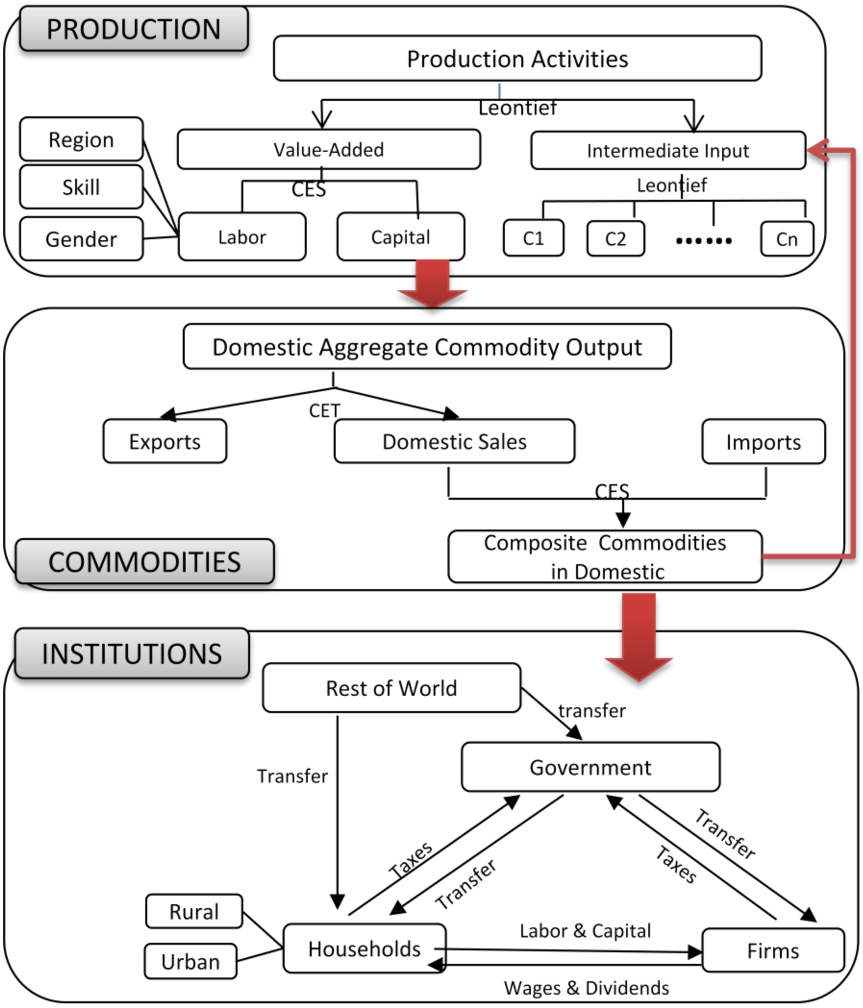

Figure 7: the structure of the CGE model

(1) The activities, production and factor markets

Consistent with the micro household survey data and taking into consideration the household's work and consumption sectors, this model classifies production activities into 12 activities sectors in all, including : 1) agriculture, forestry, animal husbandry & fishery; 2) mining; 3) manufacture of foods, beverage & tobacco; 4) manufacture on non-durable consumer goods; 5) other manufacture; 6) power, water, Gas, electricity processing industry; 7) construction; 8) transport, storage, post, information; 9) wholesale, retail trades and hotel; 10) financial intermediation; 11) real estate, leasing and business services; 12) other services.

Each producer is assumed to maximize profits to decide the distribution of the value-added and intermediate input for the production activities. At the top level, the technology is specified by a constant elasticity of substitution (CES) function of the quantities of value-added and aggregate intermediate input. The value added is divided into labor and capital; the former is further split by region, skill and gender for considering the demographic transition. Thus, there are eight segments for labor factor, those are: urban skilled male, urban skilled female, urban unskilled male, urban unskilled female, rural skilled male, rural skilled female, rural unskilled male, rural unskilled female. Value added itself is represented by a CES function with 8 labor segments and one capital input whereas the aggregate intermediate input is expressed as a Leontief function with a fixed share of disaggregated intermediate inputs.

(2) The trade and commodities market

In our research, we assume each individual activity produces a single commodity thus, there are 12 commodities sectors in all accordingly. Profit maximization drives producers to decide the distribution of their output commodities between the export or domestic markets. This decision is governed by a constant elasticity of transformation (CET) function in this model. Domestic demand is made up of the sum of demands for household consumption, government consumption, investment and intermediate inputs, etc. Domestic customers make their commodity purchasing decisions based on the desire to minimize costs, and are subject to imperfect substitutability between imported commodities and domestic output commodities, which is captured by a CES Armington function. Under the small-country assumption, China is assumed to face a perfectly elastic world demand and supply at fixed world prices. This implies that China's export and import won't change the international goods' prices based on this assumption.

(3) The institutions income and expenditure

In this model, institutions are represented by households, enterprises, the government, and the rest of the world. The household is disaggregated into rural household and urban household in our model. **Households** receive factor income and transfers income from government and enterprises. They expend their income to pay direct taxes, save and consume. Household consumption is allocated across different commodities according to a linear expenditure system (LES) demand function, which is derived from the maximization of a Stone-Geary utility function subject to a household budget constraint. The LES specification allows for the identification of supernumerary household income that ensures a minimum level of consumption. **Enterprises** receive factor incomes (mainly on capital factor) and allocate their incomes to direct tax, savings, and transfer to households who provide labor factors for production. The **government** collects taxes and receives transfers from the rest of the world and distributes its income to consumption and transfers to other institutions. Finally, for the **rest of the world,** transfer payment between the rest of the world and domestic institutions and factors are all fixed in foreign currency. The rest of the world also receives the exported commodities and provides the imported commodities.

(4) The macro closure and system constraint

The equilibrium of the model requires the goods markets equilibrium and the factor market equilibrium. **The goods markets equilibrium** requires that commodities demand is equal to commodities supply. Aggregate demand for each commodity consists of the institutions consumption spending, investment spending, and export demand. Aggregate supply comprises of domestic production and imported commodities. **The factor markets equilibrium** is dependent on how the relationship between factor supply and wages is defined. In this research, for the labor market, all the labor is set at full employment so that the wage is flexible to ensure that the labor demand and supply are equal in equilibrium. For the capital market, the capital is fixed sectoral employment with the sector-specific wages adjusted to ensure that the total capital demand is equal to total capital supply.

The model includes three macroeconomic balances: the current account (or the external balance), the government balance, and the Savings-Investment balance. The macro-closure rules set here is neoclassical closure. (1) For the current account, the foreign borrowing is exogenously set at a fixed level so that the exchange rate is endogenously defined by the model with a flexible exchange rate to adjust. (2) For the government account, the government income is not fixed and the entire tax rate (including factor tax, activity tax and commodities tax) as well as the government real consumption are held constant so that government saving is assumed to adjust to ensure that public expenditures is equal to receipts. (3) For the saving-investment balance, the model adopts savings-driven closure, in which the savings rate is fixed while the value of investment adjusts to keep the savings and investment equal in equilibrium. Finally, the consumer price index is chosen as the numeraire so that all prices in the model are relative to the weighted unit price of households' initial consumption bundle.

4.2 Between-Period Specification of the CGE Model

The between-period specification governs the dynamics of the CGE model in this research. Demographic change is a long process, the labor and population part of the dynamic model is exogenously updated to reflect demographic changes that are based on observed or separately calculated projected trends. The capital accumulation is endogenously formed in the dynamic model. These are achieved from the following perspectives.

(1) The capital factor growth. The process of capital accumulation is modeled endogenously with previous-period investment generating new capital stock for the subsequent period. The final sectoral allocation of capital in the current period is dependent on the capital depreciation rate and on the sectoral profit-rate differentials from the previous period.

(2) The household population growth. The population growth is exogenously imposed in the model based on the United Nations' World Population Prospects (2010), which was updated in 2011. However, these projections of population growth are not classified by rural and urban regions, this research will estimate the rural and urban population growth based on China's current urbanization rate (which is 52.57 percent in 2012) and suppose that the urbanization rate would reach 65 percent in the year 2030 according to the government's target and 80 percent in 2050 based on other developed countries' experience. Then, the annual growth rate of the urbanization rate is calculated for dynamic simulation. However, despite the change of the household population, the model is assumed to be unchanged in the marginal rate of consumption for commodities, which implies that new consumers have the same preferences as existing consumers.

(3) The labor supply growth. The same with household population growth, the labor supply is fixed exogenously according to the United Nations' World Population Prospects (2010). Because the labor factor is classified into eight different segments, labor supply changes will adjust based on gender difference, urbanization rate as well as human capital structure change. China's official retirement age is 60 for male and 55 for female. The labor force age in this model is set from 15 to 60 both for male and female. Labor force participation is set at 85% for male and 75% for female, and is based on the past situation.

(4) TFP growth and other exogenously set. The factor-specific productivity growth is imposed exogenously on the model based on observed trends for labor and capital, which is set at a 2% annual growth rate. Growth in real government consumption and transfer spending is also exogenously determined between periods, which is set at 8% and 10% annual growth rates respectively, and are based on previous trends.

4.3 Database for the CGE model

(1) Social accounting matrix and parameters

A social accounting matrix (SAM) is a comprehensive and economy-wide data framework that is the database of the CGE model. The SAM is built using the latest Input-Output table for the year of 2010, different kinds of yearbook as well as the national micro household survey data are employed for the SAM. There are 12 activities and commodities sectors, 8 segments of the labor force and two types of households in the SAM. To overcome the difficulty of collecting the data of 8 different types of labor factor inputs as value added on 12 different sectors, we employ the household survey data with econometrics model to calculate the ratio of the factor input distribution on 12 sectors. The wage difference between the 8 different labor segments is estimated by a wage regression with region dummy, skill dummy, gender dummy and their cross variable dummy as well as other individual and household characteristics for independent variables. After getting the predicted slopes of these dummy variables, the marginal wage difference of the 8 different types of the labor force can be calculated from the slopes. Then the wage differences for different labor forces can be induced based on the average wages by sector, which can be collected from the China Stock Market & Accounting Research Database.

The parameters that can be calibrated directly by the SAM and the model function is not introduced in this sub-section. We specify the parameters such as the elasticity in CET, CES and LES functions, which can be estimated by econometric methods. The overcome the complexity of estimating these parameters, we employ most of these parameters from the previous literature of other's studies or based on previous experience. For the substitution elasticity in the CES function, we mainly use Xie (2008)'s results who employs both the Bayesian Rules and Generalized Maximum Entropy method to estimate the substitution elasticity of 14 different sectors. The elasticity in the CET function and Armingtion function are manly from Zhai and Hertel (2005)'s results whose paper has the elasticity of 53 sectors. For the parameters in ELES function, the Frisch parameter is based on Frish (1959)'s own estimated results on different income quintile's households and we set the Frisch to -2 and -2.5 respectively for urban and rural households in our research. The demand elasticity for different commodities is adjusted according to Xie (2008)'s results which are calculated based on the 31 provinces' living expenditure both for rural and urban households.

(2) Scenarios for the macro model

To consider demographic transition within real economic development, four types of demographic changes are introduced for the basic scenario. 1) Population age structure change, which is the most important issue that this paper focuses on. 2) Population gender structure change. These two will be simulated based on World Population Prospects (2010) by the United Nations, which was published in 2011. 3) Human capital accumulation change. This is represented by the proportional changes for labor force with tertiary education to total labor force aging population. The share of the labor force with tertiary education was 19.52 percent and 2.63 percent respectively for rural and urban individuals in 2010, as reported by the China Statistic Yearbook. On the basis of China's past growth rate of the share of the labor force with tertiary education as well as the current situation for developed countries, the simulation for the tertiary education share change is assumed to double for rural individuals and increase by 1.5 times for urban individuals in 2030 and then further increase 1 times and 0.5 times for rural and urban individuals respectively to 2050. Calculate by this growth rate, the proportional for tertiary education labor force to total labor would reach to 20.09 percent in 2030 and 37.26 percent in 2050. 4) The population spatial change with urbanization. The current share of the urban population for China is 52.57 percent as of 2012 and is supposed to reach 65 percent in 2030, based on the Chinese central government's target and it is set to be 80 percent in 2050 followed the urbanization experience of most of developed countries. All these four demographic transitions are linked to the labor factor supply and population changes within the periods of the CGE model's dynamic part.

Two comparative scenarios are used for comparing the base scenario to quantify the real impact of population aging. One is the scenario without population age structure change and it is indexed as "NODE" scenario. In this scenario, the population age structure during the period of 2010 to 2050 would keep at the level in 2010 and hold the other three demographic transitions constant. The other is the scenario without population old that is indexed as "NOOD". In this simulation, the population age structure change from 2010 to 2050 follows the structure change from 1970 to 2010 and still keeps the other three demographic transitions unchanged. The results of the scenarios can identify the absolute impact of population aging by comparing the base scenario with the other two simulations.

Table2: the scenarios design in different simulations

Scenario	Scenario design
Base scenario	1. Labor supply and population growth is exogenous set based on the United Nations projection; 2. the urbanization is set to be 65% in 2030 and 80% in 2050; 3. The proportional with tertiary education labor force is set to reach at 20.09% in 2030 and 37.26% in 2050; 4. The work participate rate is 85% and 75% respectively for male and female; 5. The growth rate for TFP is set at 2%.
"NODE" scenario	1. the population age structure during the period of 2010 to 2050 is kept at the level in 2010 2. Holds the other three demographic transitions constant.
"NOOD" scenario	1. the population age structure change from 2010 to 2050 follows the structure change from 1970 to 2010 2. Keeps the other three demographic transitions constant.

5. Behavior Micro-simulation and Methodology

The recent development of macro-micro modeling frameworks which integrate the CGE model with a microeconomic model has proved useful in capturing the effect of macro shocks to micro distribution. As concluded by Debowicz (2012), there are mainly two different channels that can link the macro and micro model. One is integrating the selected information on representative household groups (RHG) into a macro CGE model; the other is through layering the micro-simulation model to the macro CGE model via individuals' behavior or non-behavior approach. From an empirical point of view, the RHG can be fully integrated into the macro model and it works well when a small number of groups in the model. But it does not allow researchers to take into account within-group changes in income distribution because the same groups in the macro model are assumed to be identified. For the non-behavior layering approaches which assume that all the households in a group are affected in the same way by the change of macro variables from macro model can eliminate the within-group differences induced by individual heterogeneity. In order to fully quantify the distributional effects caused by the shock of the demographic transition, we employ a layered behavioral methodology in a top-down fashion, which can capture the distributional differences both of the within-group and the between-group by considering the individual and household's heterogeneity.

Following the methodology in the paper of Bourguignon, Robilliard and Robinson (2003) and Debowicz (2012), the main idea of the linkage of our study is as follows: The CGE model with demographic transition is solved first to get the results on a vector of commodity prices and factor wages. Then, the micro-simulation model is used to generate the new changes on individual labor wages consistent with the equilibrium of aggregate markets in the CGE model in terms of the labor factor wages; the capital factor income and the household income from government transfers would be linked through a non-behavior method. Finally, the poverty and inequality indexes are adopted to evaluate the distributional impact by the shock of the demographic transition with the results from the micro simulation model. We discuss the micro simulation model in this section.

5.1 Specification of the Micro Income Model

(1) The model of household income determination

Consistent with the macro model, the micro household income is comprised of labor income, capital income, government transfer income and other incomes which can't be classified into any one category. Both the employed or self-employed wage income is classified as labor income, which provides the majority of the income for households. The labor income is linked to the CGE results with a layered behavioral methodology that can reveal individual heterogeneity. Other non-labor income, which can't be estimated by an individual behavior function and may only take a small part of the income, is linked to the CGE results through a non-behavior layering approach in which the income is changed with the same ratio within the same group segment according to the changes from CGE model.

The labor income can be represented by the function 4-1.

$$logW_i = a^s + b^s X_i + v_i \qquad (4-1)$$

Where, the W_i is the nominal labor income of working individual i; dependent X_i variables denotes the vector of the characteristic of the individual, household and regions. a^s and b^s are the intercepts and slopes in the logarithm of the wage, respectively. v_i is the residual term which describes the effects of unobserved earning determinants and possibly measurement errors.

The total household income can be defined as the following function 4-2. The non-labor income and a household specific consumer price index are described in function 4-3 and 4-4 respectively.

$$YH_h = \frac{1}{P_h}\left(\sum_{i \in h} W_{ih} IW_{ih} + Y_{0h}\right) \qquad (4-2)$$

$$Y_{0h} = Capi_h + Trans_h + Other_h; \qquad (4-3)$$

$$P_h = \sum_{\mathrm{k}=1}^{\mathrm{K}} \mathrm{S_{hk}} * \mathrm{p_k} \qquad (4-4)$$

Where, YH_h is the sum of the labor income for the members within a household. IW_{ih} stands for a dummy variable, which denotes the individual work status (1 for work, 0 for not work). To compare the real household income changes as a result of the demographic transition shocks, a household specific consumer price index (P_h) is introduced in the household income function to deflate the household income following Bourguignon et al. (2003)'s method. S_{hk} is the observed budget shares of a household's consumption for commodity k, and p_k denotes the price of various consumption goods k. The non-labor income is comprised of the capital income, land income, transfer income and other income. All these are calculated at the household level.

(2) Estimation of the model for the benchmark simulation

The parameters of the labor income function are estimated for transmitting the CGE results to the micro-simulation using a behavior method. Labor income is a non-linear function of the observed characteristics of individuals, households and regions. Consistent with the CGE model, this labor income function is defined independently across eight labor segments, which are classified by area (rural/urban), skill (with high education level) and gender (male/female). Therefore, eight separate regressions are run to estimate the parameters (a^s and b^s) of the labour income equation for each labour market segment. The subject of these regressions is the aging labour force, which may include the working-age population who do not participate in the workforce, which induces sample selection. To correct for the possibility of sample selection, we use the two-step Heckman procedure, which includes an inverse Mills ratio derived from a pre-probit model that estimates the work status of the individual.

For the individuals at work with a positive reported work, the income of the labor wages is calculated using the estimated parameters with the residual in the regression; while individuals who report work status but not labor income or who report null wages are estimated with a residual which is randomly attributed from a normal distribution with mean zero and a standard deviation that is capture by the estimated residuals with the observation with positive wages.

5.2 Communication between the CGE Model with Micro Simulation

From the CGE model, we get the idea that the household receives income from factor endowments (labor income and capital) and transfers from the government. The CGE model can report both the factor price changes and household income changes so the linkage can be done from two perspectives, through households and via the factor market. In this part, we explain the transmission channels of how the results of the CGE model are linked to the household income model. For the reason that the labor income is kept at the individual level in our study while the other income is kept at the household level, the labor income would use the factor price change from CGE model with a layered behavioral methodology, the non-labor income would adopt the household income change with different income categories from the CGE model through a non-behavior layering approach. The following section focuses more on the transmission channels for the communication from the CGE model to the labor income model.

After solving the dynamic CGE model for a period of 40 years from 2010 to 2050 in the context of demographic transition, new labor wage change is generated in each of the periods. The labor wage change in a specific simulation year is represent as $\widehat{W}_{r,s,g,p}$, here, r, s, g, p denote the region, skill level, gender and time period respectively and there are eight segments of labor force in all as mentioned in the previous section. The micro simulation model is applied to generate the changes for the individual's labor income consistent with the labor wage changes from CGE model. Let us call the set of the original macro labor wage as $f(x) = W_{r,g,s0}$, which is the consistency adjusted micro data with the sample weights for each of the labor segments. The macro targets in a specific simulation period vector is indicated as $f^*(x) = W^*_{r,g,s,p}$. Where,

$W^{*}_{r,g,s} = W_{r,g,s0} * (1 + \widehat{W}_{r,g,s,p})$ and the $\widehat{W}_{r,g,s}$ is taken as the percentage change from the base year of the macro simulation.

The parameter changes are assumed to be "neutrality" with respect to the individual characteristic. So only the intercepts of the labor income function would be adjusted to generate a proportional change of all the income in each of the labor segments irrespective of individual characteristics. Then, consistent adjusting involves finding a row vector $x = a_{r,g,s}$ to be consistent with the $f^{*}(x)$ macro target vector. Following Debowicz (2012)'s research, this problem can be solved using the Newton-Raphson's method, which is a root-finding algorithm that uses the first few terms of the Taylor series of a function in the vicinity of a suspected root to find successively better approximations to the root of a real-value function. This requires a Jacobian matrix (4-5) with all the possible combinations of partial derivatives of the element for the original macro labor wage, $\mathrm{f}(x)$. A detailed discussion of the specification for this methodology can be found in Debowicz (2012).

$$J = \begin{bmatrix} \frac{\partial W_{u,\mathrm{s,m}}}{\partial a_{u,\mathrm{s,m}}} & \cdots & \frac{\partial W_{u,\mathrm{s,m}}}{\partial a_{r,\mathrm{u,f}}} \\ \vdots & \ddots & \vdots \\ \frac{\partial W_{r,\mathrm{u,f}}}{\partial a_{u,\mathrm{s,m}}} & \cdots & \frac{\partial W_{\mathrm{r,u,f}}}{\partial a_{r,\mathrm{u,f}}} \end{bmatrix} \quad (4\text{-}5)$$

5.3 Introduction of the Micro Data

The household survey data we employ is from the Chinese Household Income Project (CHIP), which is carried out by the Institute of Economics, Chinese Academy of Social Sciences with assistance from the National Bureau of Statistics. CHIP has carried out the survey in 1995, 2002 and 2007. However, only the 1995 and 2002 data is public at present, and also because the question design for the income and expenditure sector in the 2002 survey is more consistent with our macro model, the CHIP (2002) data is used for our research. The CHIP (2002) data was collected through a series of questionnaire-based interviews conducted in rural and urban areas and covered 22 provinces in China. There are a total of 6,835 urban households, 9,200 rural households and 2,000 migrant households included in the survey with a total number of 37,969 individuals. Because the sampling for migrants is based on the place of residence of migrants, migrants living in a dormitory or workplace (such as a construction site) are excluded in the sample (Zhao and Qu, *et al*., 2010), and so we merge the migrant households with the urban households in our study.

In order to connect the CGE results with the base year of 2010, we update the labor income data of 2002 to 2010 using a method similar to that described in the previous section. Different with the way that updating the micro income data by the corresponding proportion from macro data (such as the work from Zhang, Wang, and Chen, 2012), the advantage for this method is that it can sustain the individual heterogeneity for the wage changes to overcome the consistent of the within group variance. Labor income is updated based on the sectors the individual worked for, and the macro data is collected from the China Stock Market & Accounting Research Database, which has the average wages in different sectors for both 2002 and 2010. Labor is classified by sectors, and each regression income model is done to estimate the parameters of different types of labor segments. Other income would be updated to 2010 based on the proportion changes between 2002 and 2010 from the data collected in the China Statistic Yearbook.

The dependent variables for the labor income regression function are the observed characteristics of the individual, household and region, which include the individual's age, education year, the sector the individual works in, the number of kids and labor force in the household, whether the individual is the household head and finally the region (east, middle or west of China).

In addition, because the computation of a Jacobian matrix and the solution of a linear system in each iteration makes the Newtonian technique costly, and as there would have to be two scenarios and 40 years each for all the simulation periods, it would not be a good idea to solve all 40 of the period simulations in a micro simulation model. In order to compare the income distribution by the demographic transition in a more practical manner, we choose the year of 2010, 2015, 2020, 2025, 2030, 2035, 2040, 2045 and 2050 as the year point with two scenarios to quantify the trend of the distribution impact in our research instead of the total simulation year. Besides, a new sampling weight which can reflect the demographic characteristics and their tendency at the five times point is measured based on the population projection from the UN.

6. Macro Economic Growth Tendency in the Context of Demographic Transition

In this section, we will describe the macro results on economic growth from the CGE modeling in the context of three scenarios.

In the base scenario, the GDP growth rate keeps at 9.21 percent during the period of 2010-2015; however, with the process of demographic transition and rapid population aging, the GDP growth rate is further reduced to 5.51 percent in the period of 2025-2030 and it is predicted to be only 3.08 percent during the period of 2045 to 2050. This indicate that with the demographic transition, the economic growth rate is slowed down

Compared with the base simulation, in the scenario of "NODE" (the population age structure keeps unchanged from 2010), the GDP growth rate is much more faster than the base scenario. For example, during the period of 2010 to 2015, the GDP growth rate is 11.61 percent and it keeps at 10.35 percent during the period of 2020 to 2025; while it is only 6.47 percent for base scenario during the same period. Though the GDP growth rate in this scenario still slow to 4.86 percent during the period of 2045 to 2050, it is faster than the base scenario.

In the scenario of "NOOD" (the population age structure changes based on the past years from 1970 to 2010, the GDP growth rate keeps at a faster growth rate compared with the other two scenarios. The results in table 3 indicate that the GDP growth rate from 2010 to 2035 keeps more than 10 percent and it still keeps with a growth rate of 7.42 percent during the period of 2045 and 2050. These demonstrate that the Chinese demographic dividend plays an important role for China's economic growth during the past decades. While the population transition with the population aging lead to the exhausting of demographic dividend with high cost of labor force, which slow China's economy growth rate if without any related stimulate policies.

Table 3: the GDP growth rate and GDP composition (2010-2050)

GDP GROWTH RATE (unit :%)

	period / scenario	2010-2015	2015-2020	2020-2025	2025-2030	2030-2035	2035-2040	2040-2045	2045-2050
GDP growth rate	BASE	9.21	7.56	6.47	5.51	4.69	4.34	3.86	3.08
	NODE	11.61	11.14	10.35	9.52	8.66	8.08	7.01	4.86
	NOOD	12.93	13.19	12.83	11.98	10.48	9.02	8.41	7.42

GDP COMPOSITION (unit :%)

Composition	Scenarios	2010	2015	2020	2025	2030	2035	2040	2045	2050
Consumption	BASE	50.57	48.93	47.82	46.79	45.81	44.82	43.97	43.17	42.35
	NODE	50.57	48.97	47.95	46.98	45.97	44.77	43.61	42.56	41.84
	NOOD	50.57	49.31	48.68	48.09	47.36	46.2	44.81	43.74	43.38
Investment	BASE	46.61	47.74	49.22	50.46	51.5	52.45	53.21	53.85	54.38
	NODE	46.61	47.43	48.63	49.65	50.59	51.57	52.39	52.85	52.33
	NOOD	46.61	47.3	48.37	49.31	50.27	51.48	52.77	53.65	53.69
Export	BASE	26.57	28.48	30.86	34.1	38.14	42.58	47	51.67	56.84
	NODE	26.57	28.98	32.8	38.43	45.42	52.67	59.52	65.74	70.36
	NOOD	26.57	28.5	31.41	35.94	42.19	49.45	57.08	63.49	67.62
Import	BASE	-23.75	-25.14	-27.9	-31.34	-35.45	-39.85	-44.18	-48.69	-53.58
	NODE	-23.75	-25.38	-29.38	-35.06	-41.98	-49.02	-55.53	-61.15	-64.54
	NOOD	-23.75	-25.1	-28.47	-33.35	-39.82	-47.13	-54.66	-60.89	-64.68
GDP		100	100	100	100	100	100	100	100	100

From the view of GDP composition, we can find that the pull effect for consumption and investment to GDP has little effect by the population ageing itself. The GDP composition in table 3 shows that the proportion of consumption to GDP is declining while the ratio of investment to GDP is increasing for all of the three scenarios. What’s more, the change differences for consumption and investment contribution to GDP in these scenarios are not significantly. This is due to the lack of consumption and investment stimulates strategies in the simulations in one hand. It also indicate that the population aging has little effect for consumption and investment and the change tendency for the contribution of consumption and investment may because of the other demographic transition in the scenarios such as the gender structure changes, the urbanization changes and the human capital structure changes. For the real reasons that can explain the change of consumption and investment pull effect for GDP growth, further decomposing of different types of demographic transition should be simulated to figure out the exact explanation.

However, the pull effect for export to GDP growth is different between base scenarios and other two compared scenarios. The results show that the contributions for export to GDP growth are increasing for all the three scenarios. However, in the base scenario, the growth rate for export contribution is slower than the other two scenarios. For example, export explain 26.57 percent of GDP growth in 2010, while it is 56.84 percent, 70.36 percent and 67.62 percent respectively for the base scenario, the “NODE” scenario and “NOOD” scenario in 2050. This is because of the increase of aging population that cause the reduction of total labor supply, which increase the cost of labor force and made the Chinese manufacturing industry lack of international competitiveness. For the reason that contribution for export in “NODE” scenario is larger than “NOOD”, detailed demographic transition structure needs to be quantified in future researches.

7. Poverty and Inequality Simulation in the Context of Demographic Transition

Both the FGT index and the Gini index are employed to estimate the poverty and inequality evolution. The scenarios with and without population aging are used to compare the impact of the demographic transition so that we can get an idea of the relationship between population aging and income distribution. To study the distributional effect among different households' age groups, we decompose the FGT index and Gini index by eight different household groups which are classified by area and household head's age. In addition, regression-based inequality decomposition with the Shapley value decomposition method is further used to identify the relative contribution of demographic variables on income inequality, including the measure of demographic change. In this section, we briefly describe the FGT index, the Gini index and their decomposition as well as the principle of the regression-based inequality decomposition method first. Then, the results from the updated income from the micro-simulation are introduced to the poverty and inequality index and a general conclusion on the impact of demographic transition to income distribution is summarized finally.

7.1 Specification of the Poverty and Inequality Index

(1) FGT index and its decomposition

There are quite a lot of poverty measurement indices, the most popular of them are Foster-Greer-Thorbecke (FGT) Index, and the Watts Index, Sen-Shorrocks-Thon (SST) Poverty Index. The FGT index which is proposed by Foster, Greer and Thorbecke in 1984 is used in this research. The normalized FGT index is estimated as the function in 5-1.

$$\hat{P}(z;\alpha) = \sum_{i=1}^{n} w_i[(z-y_i)/z]^{\alpha}{}_{+} \Big/ \sum_{i=1}^{n} w_i \qquad (5\text{-}1)$$

Where, w_i denote total population when the sampling weight accounts for; z is the poverty line and represents the household income per capita. The parameter a can be valued at 0, 1 and 2. When a=0, the FGT can measure the poverty incidence or heat-count (abbreviated HC) which is the ratio of poor people to total population. For a=1, the poverty gap (abbreviated PG) can be calculated, that measures the gap between income per capita for poverty and the poverty line. For a=2, the severity of poverty (abbreviated PS) can be calculated, which measures the equilibrium level of the poverty distribution. Both the poverty incident and poverty gap are measured in this paper.

The form of FGT decomposition can be represented as

$$\hat{P}(z;\alpha) = \sum_{g=1}^{G} \hat{\emptyset}(g)\hat{P}(z;\alpha;g) \qquad (5\text{-}2)$$

Where G is the number of population subgroups. This can estimate the FGT index in each of the subgroups and measure the contribution of subgroups to total poverty as well. The relative contribution of each of the subgroups to total poverty can be regarded as

$$\hat{P}(z;\alpha;g) = \hat{\emptyset}(g)\hat{P}(z;\alpha;g)/\hat{P}(z;\alpha) \qquad (5\text{-}3)$$

(2) Gini coefficient and its decomposition

The Gini coefficient can be represented as

$$I = 2\int_0^1 (p - L(p))dp \qquad (5\text{-}4)$$

This definition indicates that the Gini index is equal to the double distance for the Lorenz curve with the perfect equality line. The Gini coefficient is ranged between 0 and 1. The smaller the Gini coefficient is, the more equal for a society. Usually, the 0.4 is taken as the international warning line, which implies that inequality is large in a society if the Gini coefficient over 0.4. The Gini index can be decomposed by population subgroups as follows:

$$I = \sum_{g=1}^{G} \emptyset_g \varphi_g I_g + \bar{I} + R \qquad (5\text{-}5)$$

Where, the $\emptyset_g$ is the population share of group g to total population; φ_g denotes the income share of group g; $\sum_{g=1}^{G} \emptyset_g \varphi_g I_g$ indicates the between-group inequality and $\bar{I}$ is the within-group inequality; R is the residue implied by group income overlap.

In order to identify the relative contribution of demographic characteristics to income inequality, we employ regression-based inequality decomposition with a Shapley value decomposition method at selected time points in this research. The first step of this method is to specify an income generation equation with the household income per capita for dependent variables and the household demographic characteristics for the independent variables (5-6).

$$Y = \hat{\beta}_0 + \hat{\beta}_i X + \hat{\varepsilon} \qquad (5\text{-}6)$$

Where $\hat{\beta}_0$ and $\hat{\varepsilon}$ denote, respectively, the estimated constant and the residual. X is the independent variable, including the household's demographic characteristic, and $\hat{\beta}_i$ is the slope of each variable i. Let $\hat{Y} = \hat{\beta}_0 + \hat{\beta}_i X$ and $\tilde{Y} = \hat{\beta}_i X$, according to Wan (2004), the contribution of the regression residual $\hat{\varepsilon}$ to total income inequality can be indicated as $I_{\hat{\varepsilon}} = I(Y) - I(\hat{Y})$ and the contribution of the constant is calculated as $I_{\hat{\beta}_0} = I(\hat{Y}) - I(\tilde{Y})$. The relative Gini index can be decomposed as

$$I(\tilde{Y}) = [E(y_i)/E(\tilde{Y})] \times C(y_i) \qquad (5\text{-}7)$$

Where, E is the expectation operator and $C(y_i)$ is the concentration index of y_i ranked by $\tilde{Y}$. The Shapley approach is based on the expected marginal contribution of the component.

7.2 Main Results on the Distributive Effects

Both poverty and inequality's effects on evolution in the context of demographic transition are presented in this section with the FGT and the Gini index as well as their decomposition methods mentioned before. Moreover, in order to quantify aging's impact on both poverty and inequality, the scenario of non-population aging across nine different time points is used for comparison with the basic demographic evolution scenario.

(1) The impact of demographic transition on total poverty

The choice of the poverty line is crucial when measuring the poverty. We use both the World Bank's poverty line and China's official poverty standard for comparison. The WB's poverty line is 1.25 dollar per day based on the purchasing-power parity (PPP) in 2005. The China's official poverty line is adjusted every year during the past decades and it is set at 2300 yuan per year in 2011, which is equal to 1.8 dollars per day based on the PPP in 2005. It is worth noting that both of the urban and rural household incomes in different years are divided by a household specific CPI so that we can use the same poverty line both for rural and urban household as well as for different simulated years' comparison.

Both the poverty incidence and poverty gap associated with the two poverty lines is presented in table 4. The poverty incidence and poverty gap is, respectively, 7.24 percent and 3.53 percent with the Chinese poverty line of 2300 yuan per year in 2010. Generally speaking, in the context of basic demographic evolution and economic growth, poverty is greatly reduced by 2020. Take the 2300 yuan poverty line as an example, the poverty incidence reduced from 7.24 percent in 2010 to 4.08 percent in 2015 and further dropped to 2.91 percent in 2020. However, the poverty reduction after 2020 slow to only a 0.01 percent point reduction from 2020 to 2030 and only 0.0055 percent point reduction from 2030 to 2050. This is because poverty is a universally persistent problem. The government has to improve the well-developed social assistance system to address poverty.

Compared with base scenario, poverty is estimated to reduce faster in the two comparable scenarios. For example, the poverty incidence is estimated to decrease to 3.55 percent in 2015 and to further drop to 1.47 percent and 1.09 percent in 2030 and 2050 respectively in the "NODE" scenarios, similar with "NOOD" scenario. This is because of the faster macroeconomic development due to the "demographic dividend" with the relative abundance of the labor force. In other words, the general demographic transition would reduce poverty while population aging itself opposes poverty reduction as it slows economic development.

Table4: FGT with Two Poverty Line in Three Scenarios

scenarios	base scenario				NODE scenario				NOOD scenario			
Poverty line	2300 yuan per year		1.25 dollar per day		2300 yuan per year		1.25 dollar per day		2300 yuan per year		1.25 dollar per day	
year	a=0	a=1	a=0	a=1	a=0	a=1	a=0	a=1	a=0	a=1	a=0	a=1
2010	0.0724	0.0353	0.0565	0.0298	0.0724	0.0353	0.0565	0.0298	0.0724	0.0353	0.0565	0.0298
2015	0.0408	0.0236	0.0346	0.0208	0.0355	0.0212	0.0295	0.0190	0.0366	0.0216	0.0308	0.0193
2020	0.0291	0.0190	0.0251	0.0174	0.0231	0.0164	0.0208	0.0153	0.0238	0.0167	0.0213	0.0156
2025	0.0236	0.0167	0.0211	0.0157	0.0181	0.0144	0.0165	0.0138	0.0186	0.0146	0.0169	0.0140
2030	0.0190	0.0145	0.0173	0.0138	0.0147	0.0127	0.0140	0.0124	0.0154	0.0129	0.0143	0.0125
2035	0.0188	0.0146	0.0170	0.0140	0.0146	0.0129	0.0142	0.0126	0.0153	0.0130	0.0144	0.0127
2040	0.0175	0.0139	0.0160	0.0133	0.0139	0.0123	0.0134	0.0121	0.0144	0.0125	0.0137	0.0122
2045	0.0153	0.0122	0.0141	0.0117	0.0122	0.0108	0.0118	0.0106	0.0127	0.0110	0.0120	0.0107
2050	0.0135	0.0108	0.0125	0.0103	0.0109	0.0096	0.0104	0.0094	0.0113	0.0097	0.0107	0.95

To further understand the distributional impact on the specific household group, we decompose the income distribution index into different population groups by areas and household head' age to estimate the poverty and inequality in each of the different household groups and their contribution. In order to estimate the demographic transition impact, the household groups are classified by household head's age, which can represent the age status for a household. If the household head's age is less than 30, it is classified as a young household, 30-45 is regarded as an adult household, 45-60 is taken to be a senior household and old household if the household head's age is over 60. There are eight segments for household, including: rural-young, rural-adult, rural-senior, rural-old, urban-young, urban-adult, urban-senior, urban-old.

From the results of the FGT poverty index decomposition in table 5, we can draw the main idea that (1) nearly all household specific poverty is declining with the development of economic growth and demographic transition. (2) From the cross-section data, the general poverty for rural areas is much more serious than for urban, and the old group is worse off than the young group. Among them, the rural old household is the group most seriously threatened by poverty. In 2010, for example, the FGT index for rural old households is 19.65 percent while it is only 0.1 percent for urban adult households. The entire FGT index is over 10 percent in the rural household group while the largest poverty incidence is only 1 percent for the urban group. This can be attributed to migrants in rural China where the old populations are left in rural areas while the working-aging populations move to work in urban areas. (3) The relative young household group can escape poverty much easier than can the old household. For example, the rural young and adult household is estimated to experience a reduction in the poverty incidence from 15.94 percent and 13.47 percent in 2010, respectively, to 2.61 percent and 3.43 percent in 2030 while the rural old household's poverty incidence stays above 10 percent in 2030. It's worth noting that, the poverty incidence for the urban old household experiences a tiny increase. (4) After considering the population share, the rural senior contributes the most to the total FGT poverty incidence with a relative contribution of 42.44 percent to the total population poverty incidence in 2010. But with the relative faster reduction of poverty for this group as well as the declining on the rural population due to urbanization and population aging, the contribution on poverty for this group is decreasing and it is estimated to contribute only 30.61 percent in 2030 while the rural old household group become the largest contributor to poverty incidence since 2030. (5) The poverty reduction is slowed down after 2030 may because of the specific household who are hard to out of poverty.

Table5: The FGT index decomposition by household subgroup in the context of demographic transition

		rural-young	Rural-adult	Rural-senior	rural-old	Urban-young	Urban-adult	Urban-senior	Urban-old	total pop.
2010	FGT index	0.1594	0.1347	0.1074	**0.1965**	0.0015	0.0010	0.0008	0.0101	0.0724
	Pop share	0.0144	0.1965	0.2859	0.0613	0.0357	0.2011	0.1663	0.0380	1.0000
	Absolute contrib.	0.0023	0.0265	0.0307	0.0120	0.0001	0.0002	0.0001	0.0004	0.0724
	Relative contrib.	0.0318	0.3657	**0.4244**	0.1664	0.0007	0.0028	0.0018	0.0053	1.0000
2015	FGT index	0.0832	0.0791	0.0578	**0.1370**	0.0008	0.0009	0.0006	0.0110	0.0408
	Pop share	0.0160	0.1793	0.2772	0.0611	0.0390	0.1955	0.1831	0.0478	1.0000
	Absolute contrib.	0.0013	0.0142	0.0160	0.0084	0.0000	0.0002	0.0001	0.0005	0.0408
	Relative contrib.	0.0326	0.3473	**0.3926**	0.2050	0.0007	0.0045	0.0025	0.0129	1.0000
2020	FGT index	0.0501	0.0559	0.0406	**0.1250**	0.0007	0.0011	0.0002	0.0129	0.0291
	Pop share	0.0141	0.1628	0.2625	0.0605	0.0384	0.2040	0.2029	0.0536	1.0000
	Absolute contrib.	0.0007	0.0091	0.0107	0.0076	0.0000	0.0002	0.0000	0.0007	0.0291
	Relative contrib.	0.0243	0.3130	**0.3661**	0.2597	0.0010	0.0081	0.0016	0.0237	1.0000
2025	FGT index	0.0388	0.0425	0.0324	**0.1148**	0.0008	0.0011	0.0002	0.0132	0.0235
	Pop share	0.0130	0.1598	0.2436	0.0624	0.0373	0.2146	0.2068	0.0613	1.0000
	Absolute contrib.	0.0005	0.0068	0.0079	0.0072	0.0000	0.0002	0.0000	0.0008	0.0235
	Relative contrib.	0.0214	0.2882	**0.3356**	0.3043	0.0013	0.0104	0.0021	0.0343	1.0000
2030	FGT index	0.0261	0.0343	0.0278	**0.1068**	0.0008	0.0009	0.0000	0.0125	0.0190
	Pop share	0.0111	0.1430	0.2087	0.0627	0.0381	0.2365	0.2198	0.0785	1.0000
	Absolute contrib.	0.0003	0.0049	0.0058	0.0067	0.0000	0.0002	0.0000	0.0010	0.0190
	Relative contrib.	0.0152	0.2582	0.3061	**0.3533**	0.0016	0.0114	0.0000	0.0515	1.0000
2035	FGT index	0.0256	0.0348	0.0282	**0.1178**	0.0008	0.0007	0.0000	0.0152	0.0188
	Pop share	0.0102	0.1252	0.1920	0.0606	0.0406	0.2413	0.2407	0.0873	1.0000

	Absolute contrib.	0.0003	0.0044	0.0054	0.0071	0.0000	0.0002	0.0000	0.0013	0.0188
	Relative contrib.	0.0139	0.2326	0.2889	**0.3805**	0.0017	0.0094	0.0000	0.0705	1.0000
2040	FGT index	0.0245	0.0345	0.0279	**0.1258**	0.0017	0.0007	0.0000	0.0184	0.0174
	Pop share	0.0092	0.1080	0.1790	0.0523	0.0439	0.2484	0.2688	0.0879	1.0000
	Absolute contrib.	0.0002	0.0037	0.0050	0.0066	0.0001	0.0002	0.0000	0.0016	0.0174
	Relative contrib.	0.0129	0.2138	0.2861	**0.3774**	0.0043	0.0105	0.0000	0.0926	1.0000
2045	FGT index	0.0252	0.0346	0.0274	**0.1212**	0.0017	0.0007	0.0000	0.0158	0.0152
	Pop share	0.0079	0.0928	0.1574	0.0467	0.0457	0.2590	0.2884	0.0987	1.0000
	Absolute contrib.	0.0002	0.0032	0.0043	0.0057	0.0001	0.0002	0.0000	0.0016	0.0152
	Relative contrib.	0.0131	0.2108	0.2830	**0.3711**	0.0050	0.0126	0.0000	0.1021	1.0000
2050	FGT index	0.0261	0.0360	0.0274	**0.1162**	0.0008	0.0007	0.0000	0.0141	0.0135
	Pop share	0.0067	0.0791	0.1288	0.0431	0.0481	0.2771	0.2978	0.1164	1.0000
	Absolute contrib.	0.0002	0.0028	0.0035	0.0050	0.0000	0.0002	0.0000	0.0016	0.0135
	Relative contrib.	0.0130	0.2113	0.2620	**0.3721**	0.0027	0.0151	0.0000	0.1217	1.0000

(2) The impact of demographic transition on inequality

Compared with the poverty, the story is somewhat different for inequality with the demographic. Population aging is estimated to improve equality according to our research in China. From the results in table 6, we can see that all inequality in the three scenarios is reduced in 2015 and then increased for the three scenarios. However, the change rate is different from the base scenario. Compared with the "NODE" and "NOOD" scenarios, inequality is much better in the basic demographic transition scenario. For example, the Gini coefficient increases to 0.4790 in 2020 and further increases to 0.5170 and 0.69 respectively in 2030 and 2050; but it is 0.6223 and 0.6246 in 2030, respectively, in the scenarios of "NODE", "NOOD". These indicate that though population aging has negative effects on economic growth and is not good for poverty reduction accordingly, it may lead to improved equality of distribution. However, in the case of the basic demographic transition, which includes four types of demographic change, inequality still increases. This may be due to other demographic transitions. Further research on different scenarios of various types of demographic change can involve studies to estimate the exact causes of inequality. In the later sub-section, we further decompose inequality by demographic characteristics and try to explain the main reasons for inequality.

Table6: GINI index evolution in the context of three scenarios

Year	BASE	NODE	NOOD
2010	0.4753	0.4753	0.4753
2015	0.4674	0.4550	0.4549
2020	0.4790	0.4842	0.4833
2025	0.4959	0.5445	0.5448
2030	0.5170	0.6223	0.6246
2035	0.5506	0.7204	0.7241
2040	0.5933	0.7837	0.7858
2045	0.6440	0.8090	0.8098
2050	0.6900	0.8123	0.8124

As for the inequality decomposition by household group in the context of demographic transition, we can get the following conclusions from the estimated results in the following figures.

1) The between group inequality explains the majority part of the Gini coefficient. Take Gini coefficient in 2010 as an example, the between group inequality contributes 59.24% to the total population's inequality with an absolute contribution of 0.2816 and it keep around more than half of the contribution to inequality for the whole periods' simulation.

2) The between group inequality keeps a "U" shape tendency during the demographic transition while the inequality within group is increasing with the same background. For example, the absolute contribution of between group inequalities, regarded as a Gini coefficient, decreases from 0.2816 in 2010 to 0.2437 in 2030 and then increase until 0.4829 in 2050. At the same time, the Gini coefficient within group contributes 0.068 to the total Gini coefficient and this keeps increasing and reaches 0.0835 and 0.1149 in 2030 and 2050 respectively.

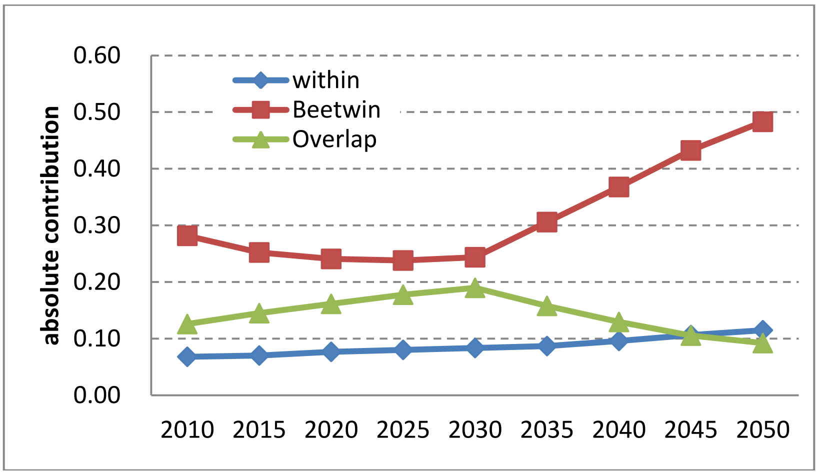

Figure 8: the absolute contribution of within and between groups gini coefficients to total inequality

3) For the Gini coefficient index decomposition by household subgroup without considering the population share and income share, the inequality for rural household groups is much more serious at the beginning, while urban households suffer higher inequality than do rural households with the development of demographic changes(see figure 9). This may due to the urbanization, which is regarded as the increasing of the urban population in the base scenario. Before 2025, the rural old household pose the greatest threat of inequality among the eight household groups, while after 2030, urban young household group become the most inequality group with the highest Gini coefficient among the eight household groups.

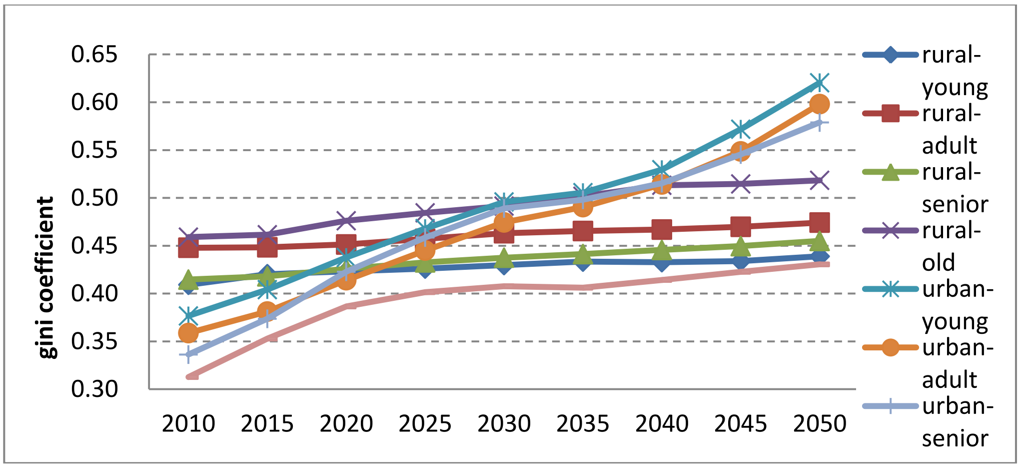

Figure 9: the Gini coefficient index decomposition by household subgroup[4]

4) After considering the income and population share for the different subgroups, the absolute Gini coefficient for urban adult household is the largest in the year of 2010. However, the urban senior group is sharply increasing for its contribution to total inequality during the demographic transition.

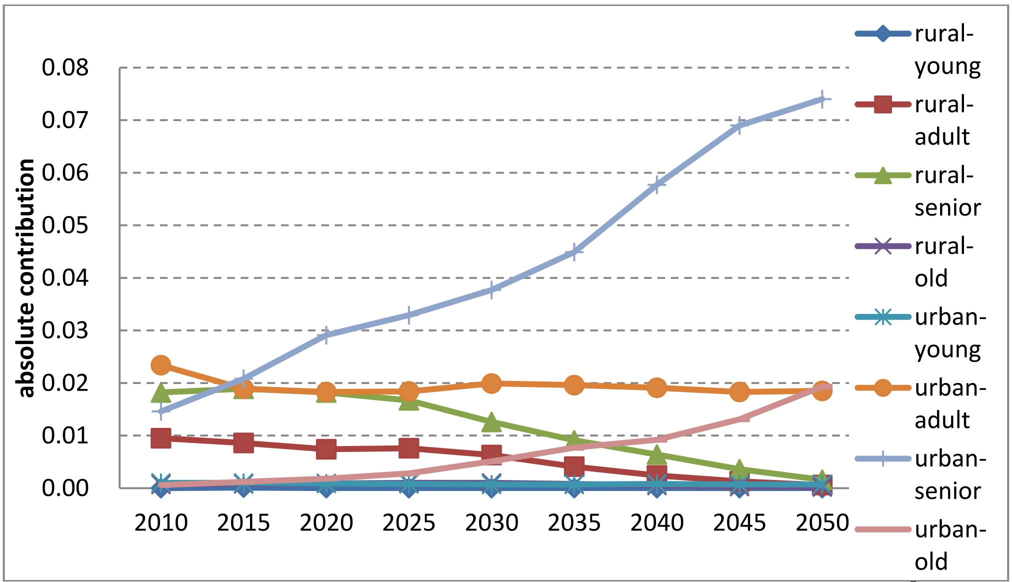

Figure 10: the absolute Gini coefficient index decomposition by household subgroup[5]

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4 Without consider the income share and population share.

5 Without consider the income share and population share.

(3) The contribution of demographic characteristics to inequality and its variation tendency

In this sub-section, we decompose income inequality using the regression based Gini decomposition by sharply value method at 9 different time points to compare the contribution of the demographic characteristic to inequality. The contributions and relative percentage contributions of these demographic variables for each selected year are presented in table 7. The variable of "average age within a household" is regarded as the key demographic variable for measuring the population aging trend. The regression results are not reported in this part because the contribution of inequality to the statistically insignificant determinates is estimated to be zero or to approach zero in the decomposition method described in the previous section.

The results indicate that a significant part of the change in income inequality can be explained by rural-urban areas and the average age within a household. It is worth noting that the "average age" is the most significant variable and the contribution of this variable to inequality is estimated to exhibit a dramatic increase with the progress of demographic transition. For example, the variable of "average age within a household" only contributes 0.0111 with 2.34 percent to total inequality in 2010, and this contribution is estimated to increase to 0.1584 with approximately 30 percent in 2030. The absolute contribution of average age keeps increasing while its relative contribution to inequality holds stable from 2030 to 2050. Meanwhile, about 42.95 percent of total inequality can be attributed to the difference of areas in 2010; the contribution of this variable is decreased to 18.12 percent in 2030, and then it keeps increase again but still less important than average age. This indicates that the inequality between urban and rural is estimated to decline while the inequality between the different age groups will increase which is in line with the results mentioned in the last sub-section. There are other two noticeable contributors to inequality; one is the region variable, which remains stable despite exhibiting a tiny decline before 2030, in terms of its contribution to total inequality. However, the contribution of regions variables to total inequality declined faster after 2030 and its contribution to inequality only 2.07 percent in 2050. The other noticeable variable is "the school year for household head"; it is not very significant before 2030. However, the contribution of this variable turns to be noticeable contribution to inequality after 2030 and its relative contribution is 21.78 percent in the year of 2050, which is over the contribution for urban/rural areas. Other demographic variables, such as the household size, the dependent ratio, the number of unhealthy and females within a household, however, do not contribute a lot to total inequality but for some changes.

Table 7: The contribution of the demographic characteristic with the regression based Gini decomposition by sharply value method

		average age	Areas (rural/urban)	regions	household size(Ln)	dependent ratio	No. of unhealthy	No. of female	Household head educate.	residuals	Total
2010	Absolute Contrib.	0.0111	0.2042	0.0424	0.0448	0.0059	0.0047	-0.0007	0.0196	0.1436	0.4755
	Relative Contrib.	0.0234	**0.4295**	**0.0891**	0.0942	0.0124	0.0099	-0.0015	**0.0411**	0.302	1
2015	Absolute Contrib.	0.055	0.1761	0.0446	-0.0015	0.006	0.001	0.0002	0.0162	0.1697	0.4674
	Relative Contrib.	**0.1177**	**0.3768**	**0.0955**	-0.0031	0.0128	0.0021	0.0005	0.0348	0.3631	1
2020	Absolute Contrib.	0.0928	0.1445	0.0416	-0.004	0	0.0021	0.0018	0.0094	0.1909	0.479
	Relative Contrib.	**0.1938**	**0.3016**	**0.0868**	-0.0083	0	0.0043	0.0037	0.0196	0.3984	1
2025	Absolute Contrib.	0.1244	0.1175	0.0402	-0.0007	0.0007	0.0051	0.0024	0.0037	0.2027	0.4959
	Relative Contrib.	**0.2509**	**0.2369**	**0.081**	-0.0014	0.0014	0.0103	0.0048	0.0074	0.4087	1
2030	Absolute Contrib.	0.1584	0.0937	0.038	0.0042	0.0038	0.0079	0.0025	-0.0001	0.2086	0.517
	Relative Contrib.	**0.3064**	**0.1812**	**0.0736**	0.0082	0.0074	0.0153	0.0047	-0.0003	0.4034	1
2035	Absolute Contrib.	0.1785	0.1155	0.0322	0.0015	0.0073	0.0077	0.0039	0.0117	0.1924	0.5506
	Relative Contrib.	**0.3241**	**0.2098**	**0.0586**	0.0027	0.0132	0.0141	0.0071	0.0212	0.3494	1
2040	Absolute Contrib.	0.19	0.1307	0.0253	-0.0019	0.0086	0.0069	0.0053	0.0498	0.1785	0.5933
	Relative Contrib.	**0.3202**	**0.2204**	0.0426	-0.0031	0.0145	0.0117	0.0089	**0.0839**	0.3009	1
2045	Absolute Contrib.	0.2013	0.1356	0.0193	-0.0012	0.0107	0.0054	0.0067	0.1051	0.1612	0.644
	Relative Contrib.	**0.3126**	**0.2105**	**0.0299**	-0.0018	0.0165	0.0084	0.0104	0.1632	0.2503	1
2050	Absolute Contrib.	0.2062	0.1244	0.0143	0.0152	0.0126	0.004	0.0069	0.1502	0.1561	0.69
	Relative Contrib.	**0.2988**	**0.1803**	0.0207	0.022	0.0183	0.0059	0.01	**0.2178**	0.2262	1

8. Conclusions

Demographic transitions influenced by population aging have been attracting increasing attention throughout China and are emerging as an important issue in most developing countries. However, only a few researches have studied the relationship between income distribution and demographic transition for developing countries as the issue of population aging began to unfold at the beginning of the 21st century for developing countries. From the existing empirical studies on developed countries, the population transitions have been known to generate negative economy-wide effects and the general trend of such researches regarding the relationship between demographic transition and income distribution is inconclusive as there is evidence both supporting a positive and a negative relationship.

China is among the few developing countries that have stepped into the aging population society. The researches on China's demographic transition with income distribution are start to emerging in recent years and the results regarding this relationship are still not clear. The existing studies mainly using the panel data and decomposing the inequality by aging and simulate the contribution of aging on inequality. However, demographic transition is a long process; the economic and social impact by population aging has not yet emerged throughout China. Thus, it would be better to quantify the distributional effects in the context of demographic transition using the linkage between macroeconomic models with micro simulation models. The recent development of macro-micro modeling frameworks which integrate the CGE model with a microeconomic model has proved useful in capturing the effect of macro shocks to micro distribution.

In this paper, we investigated the evolution of poverty and inequality in the context of demographic transition. An integrated recursive dynamic computable general equilibrium (CGE) model with a behavior micro simulation model is used to measure the income changes in light of the shock of demographic changes, which includes the basic scenario such as population aging, gender shifts, urbanization and human capital structure changes that contribute to real economic development. Two comparative scenarios with demographic change simulations other than population aging are adopted for capturing the real impact of population aging. With the two scenarios at hand, both the FGT index and the Gini coefficient are employed to estimate the poverty and inequality changes due to demographic transition. A regression-based inequality decomposition with the Shapley value decomposition method is further used to identify the relative contribution of each demographic variable to income inequality.

We found that a significant portion of the decrease in poverty and an increase in inequality is expected in the context of the multi-demographic transition. However, though population aging has negative effects on economic growth and is not good for poverty reduction accordingly, it may lead to improved equality of distribution. Inequality is negative during population aging as there would be a sharp increase in income inequality with the comparative scenario, which excludes the population aging transition. The process of poverty reduction is much slower with population aging's slowdown of economic growth. These demonstrate that measures for stimulating the second demographic dividend should be carried out, such as through further enhancement of education for human capital accumulation to increase labor productivity, and the adjustment of the industry structure through the institutional arrangement. The reduction of poverty and inequality is an important policy objective for China as well as for other developing countries. The studies on China's case indicate that the old population, especially the rural old population, should be emphasized because both poverty and inequality are more serious amongst these groups than amongst other household groups. This suggests that it is important to target the improvement of the social pension insurance system, especially for China's rural areas where China's social insurance coverage is insufficient. In addition, urbanization, which is measured by urban population share in our scenario, may be able to reduce poverty, but not inequality. Relevant measures to address urbanization, such as ensuring migrant's citizenship, improving the educational system, and enhancing social security and medical security, especially for those households who were in rural areas, may be helpful for reducing the inequality associated with the process of urbanization. Further researches on specific demographic structure changes (such as urbanization, human capital accumulation and gender ratio shifts) with different scenarios can be studied to find the demographic reason for poverty and inequality. Future research subjects should also focus on China's rural population and the related economic and social problems as well.

As for methodological considerations, there are quite a lot of scholars attempting to link CGE models with micro models and it is proving useful in analyzing the distributional impact of exogenous policy shocks. This is an area of great interest as approaches and techniques are still under development. This paper is a layered behavioral methodology in a top-down fashion that links the results from a CGE model to the micro data. However, poverty and inequality changes can in turn induce changes in the macro economy itself and therefore, a trail of a top-down and bottom up linkage would be much better for connecting the macro model with the micro model. This may provide fertile areas of study for future researches.

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