Demographic bonus and the impact of migration: The case of Shanghai

Xizhe Peng, Professor and Dean,
School of Social Development and Public Policy, Fudan University
and
Yuan Cheng, Associate Professor,
School of Social Development and Public Policy, Fudan University

Working Paper Series Vol. 2005-12
September 2005

The International Centre for the Study of East Asian Development, Kitakyushu

Demographic bonus and the impact of migration: The case of Shanghai[1]

Xizhe Peng[2] and Yuan Cheng

Abstract

This paper analyzes the preconditions for harvesting the demographic bonus as well as the corresponding situations in urban and rural China. It introduces an overlapping generation model to illustrate the effects of decline in fertility rate and immigration on the demographic windows. Based on the case of Shanghai, it is argued that internal migration is the bridge to match the conditions of harvesting demographic bonus in both sending and receiving areas, and therefore could prolong the time span of harvesting demographic bonus in the urban areas while provide opportunities for the poor rural areas to be able to harvest demographic bonus, and result in a win-win situation.

Keywords: Demographic bonus; Migration

[1] This paper was completed while Xizhe Peng was a visiting scholar at the International Centre for the Study of East Asian Development (ICSEAD) during summer of 2005. He gratefully acknowledges the ICSEAD support.
[2] Corresponding author, School of Social Development and Public Policy, Fudan University, Shanghai, China.
E-mail address: xzpeng@fudan.edu.cn

1. Introduction

It is evident that, there is a population effect on economic growth. Since 1970, developing countries with lower fertility and slower population growth have seen higher productivity, more savings and more productive investment. They have registered faster economic growth (UNFPA, 2002). The so-called “demographic bonus”, in the form of a large group of working-age people supporting relatively fewer older and younger dependents (low dependency ratio) that creates a one-time opportunity for growth (window of economic opportunity), may have accounted for as much as a third of the East Asian economic miracle (The Economist, March 15th 2003).

Many mechanisms contribute to this effect: Mortality declines first, followed by fertility; Lower fertility increases women's participation in the labour force and helps improve family health and nutrition; smaller family sizes reduce dependency ratios within families and increase incentives to acquire income beyond the basic necessities of life; working-age population increases relative to younger and older dependents. On the whole, the lower dependent ratio helps to speed up the economic and social development. (Leete and Alam, 1999; Bernstein, 2002; McNicoll, 2003)

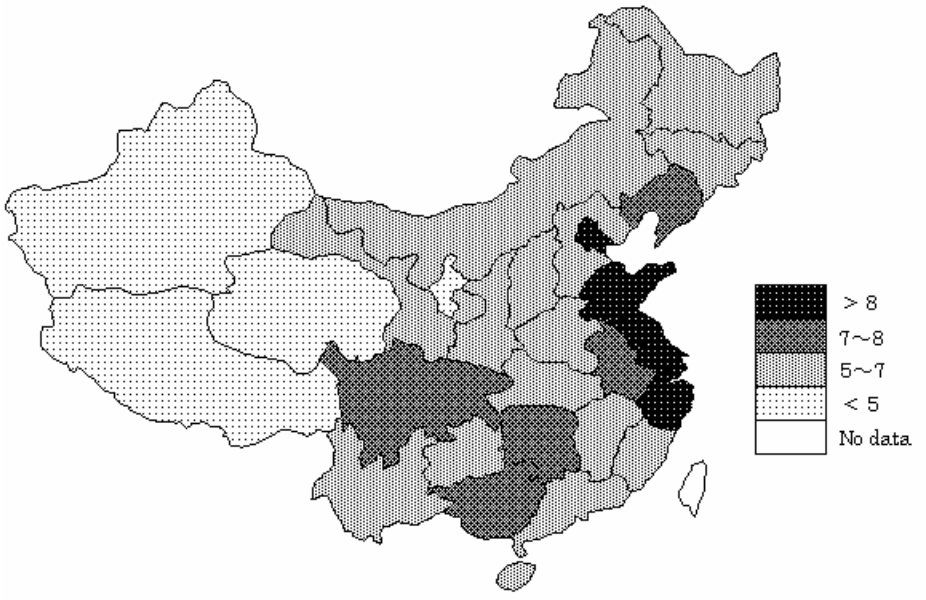
A demographic window opens as the numbers of younger children decrease, and closes as the proportion of older people starts its rapid growth. The opportunity can be realized if countries have made the appropriate investments, not only in family planning, but also in health and education generally, and in employment opportunities for the new and enabled workforce.

China experienced very rapid fertility decline over the last three decades. Its total fertility rate declined from 5.8 in 1970 down to 2.8 in 1979, and dropped further to below replacement level in the 1990s. Although there are disagreements about the data accuracy, it is commonly accepted that China’s current total fertility rate stands around 1.8. By the early 21 century, China’s demographic pattern has characterized by low mortality, low fertility and low growth. Meanwhile, the age structure of the population also experienced rapid change. China entered aged society for the first time in 2000 with its elderly population aged 65 and older exceeding 7 per cent of the total population. In 2004, the shares of three population groups, young (Aged 0-14), working age (15-64) and the elderly (65 years and older) are 21.5%, 70.92% and 7.58% respectively.

Today as we consider China as a whole，the labour force, both in absolute numbers and in percentage terms, continually increases due to the high fertility two decades ago, and the following fertility decline results in a favourable dependency ratio. So, logically China could have more investment and more saving, and then Gross Domestic Product (GDP) surges with ease. In other words, China is harvesting the demographic bonus. (Cai, 2004)

There are regional differences in the path of fertility decline. In general, Eastern China and urban areas are the forerunner of China's fertility transition, while the vast western provinces are lagged behind the national trend. Consequently, the ageing process has already accelerated in some eastern regions and big city centres (Figure 1), and may lead to in the near future in ballooning fiscal burden, weak consumption and poor market innovation. Therefore, there is regional variation in terms of timing of demographic windows of opportunities. (Yu, 1990; Joseph and Phillips, 1999)

Figure 1: Regional Variations in Population Ageing, 2000



Note: The legend means the proportion of the elderly above 65 years to the whole population. (%)
Source: National Bureau of Statistics of China, *China Statistical Yearbook 2001* (Beijing: China Statistics Press), p. 95.

Except for the favourable age structure, there are a few other pre-conditions for harvesting the demographic bonus. The most important are the favourable Employment situation and favourable investment strategy. In other words, if the abundant labour force could not be fully employed, the potential demographic bonus could easily be transferred into a big burden of unemployment that will result in a great challenge rather than window of

opportunities.

However, these favourable conditions may not exist simultaneously for a region. Therefore, the opening of demographic window of opportunities is not only determined by the past demographic pattern but also a combination of demographic and socio-economic factors. This is clearly manifested by the case of China.

In China's rural area particularly in the western part of China, the later fertility transition and relatively higher fertility level result in a relatively younger population age structure and lower dependent ratio as well. However, as China's past economic development since the 1980s has been concentrated in the eastern regions and highly urban oriented, rural development has been much slower and consequently lack of economic opportunities. They have the favourable age structure, but lack of employment opportunities and investments. These situations indicate that the general preconditions for harvesting of the demographic bonus are not met in China's rural and western regions. On the other hand, in China's big cities like Shanghai, earlier and sharp fertility decline in the past has caused rapid ageing process and increased dependent ratios. Shortage of young labour force has already been one of the major constraints of further economic development. This also indicates that the demographic window is approach to close.

In this paper, our analysis, based on the case of Shanghai, focuses on the impact of migration on age structure of urban population that is one of the conditions for the demographic bonus. A theoretic explanation on demographic bonus is presented in Appendix. It is argued that while there are differential regional patterns of demographic dynamics and consequent conditions of demographic bonus, internal migration is the bridge to match the conditions of harvesting demographic bonus in both sending and receiving areas, and therefore could prolong the time span of harvesting demographic bonus in the urban areas while provide opportunities for the poor rural areas to be able to harvest demographic bonus, and result in a win-win situation.

2. Shanghai's demographic pattern

Shanghai is the largest city in China, with a total population of 16.74 million living within its boundary of 6340 square Km in 2000[1]. Shanghai is also one of the most developed

[1] This is a published figure from Shanghai's Fifth Population Census, refers to those who stay in Shanghai for more than half a year at the time of the census, 1 November 2000.

metropolitan areas in China. It produces 5.16% of China's National GDP, with a local per capita GDP of US$ 4,500 in 2001[1]. Shanghai's demographic pattern is the most advanced one in China, and very much close to what prevailing in many developed countries. The major driving force of Shanghai's demographic transition is its rapid fertility decline. While China's nation-wide sharp fertility decline occurred in the 1970s, it is the later 1960s that witnessed the rapid fertility change in Shanghai, more or less 10 years ahead of many other Chinese provinces. Since the middle 1970s, its fertility level has been kept below the replacement level, and the one-child norm of family formation had become prevalent before the official implementation of one-child policy in the 1980s. At present, Shanghai's total fertility rate is as low as 0.8, while the life expectancies at birth for women and men are 81.5 and 77.6 years respectively. Since 1993, Shanghai experienced a negative nature growth rate of the native urban residents.

Corresponding to salient fertility and mortality decline, Shanghai population has been rapidly ageing and becomes very first metropolis with an aged population in China. People aged 60 and over were 1.89 million in 1990, and rose to 2.41 million in 2000, and the proportion of aged population increased from 14.2% to 18.1% during the same time period[2]. The increase rate of old people was 5.6 times that of the total population. It is quite noteworthy that it took Shanghai only about 20 years to increase the proportion of people aged 60 and over among total population from 9% to 18%, while the similar transition lasted 140 years in France and 85 years in Sweden. Under this situation, the support ratio, defined as the proportion of working age population to the whole population, decreases sharply.

Table 1: Dependency ratios in Shanghai in selected years

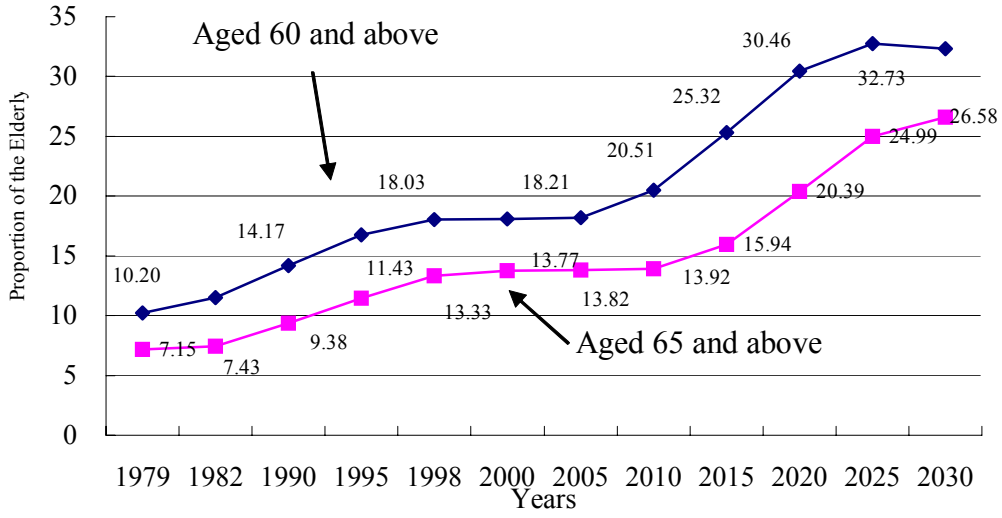
	1953	1964	1982	1990	2000	2002
Young ratio (<15)	52.16	81.98	25.82	26.96	16.76	13.83
Ageing ratio (60+)	5.81	11.79	16.37	20.96	26.14	26.37
Total Dependency ratio	57.97	93.77	42.19	47.92	42.89	40.20

It is projected that the accelerated ageing process will continue and reach its peak in 2030 with an average annual rate of increase being 2.5% during this 30-year period (figure 2).

[1] Only those who hold Shanghai's permanent registration status are counted in this calculation. In China's statistics, at least two terms are commonly used regarding population. One is the population of registered permanent residents (Hukou), the other is current residents including all population living in the place for more than half a year regardless of their registration status. Precaution should be made to interpret those population figures.

[2] These figures refer to native population (local people with Shanghai's household registration status) only.

Figure 2: Ageing Process in Shanghai, 1979-2030
（Native population excluding migrats)



Apart from ageing, another consequence of past population dynamics in Shanghai is the shortage of young labour force. The 1980s is the golden period for Shanghai with abundant supply of young labour force as the bay boomers of the 1950s and early 1960s entered the labour market. However, since the later 1980s, earlier and profound fertility decline in the past decades has led to slower growth of new entrants to the urban-born labour force and the ageing of working population. But the demand for young labour has risen sharply during the same period attributing mainly to Shanghai's rapid development. In addition, the economic restructure has made more than one million of Shanghai's urban labour force, most in their 40s and 50s, suffering from unemployment or become redundant, which leads to the decline of labour fore participation rate.

The negative impact of rapid population aging on economic growth has been well documented. The worsening support ratio has resulted in great challenge to Shanghai's pension system. It is reported that Shanghai's urban pension system has already in annual deficits since 2002, and the gap may further enlarge if no rescue measures are taken. Therefore, the demographic window in Shanghai had opened since the later 1960s due to the rapid fertility decline, and it has been approaching rapidly to close in the coming years. Fortunately, the migration from rural area makes the demographic window in Shanghai remaining open and provides the precondition to harvest the demographic bonus.

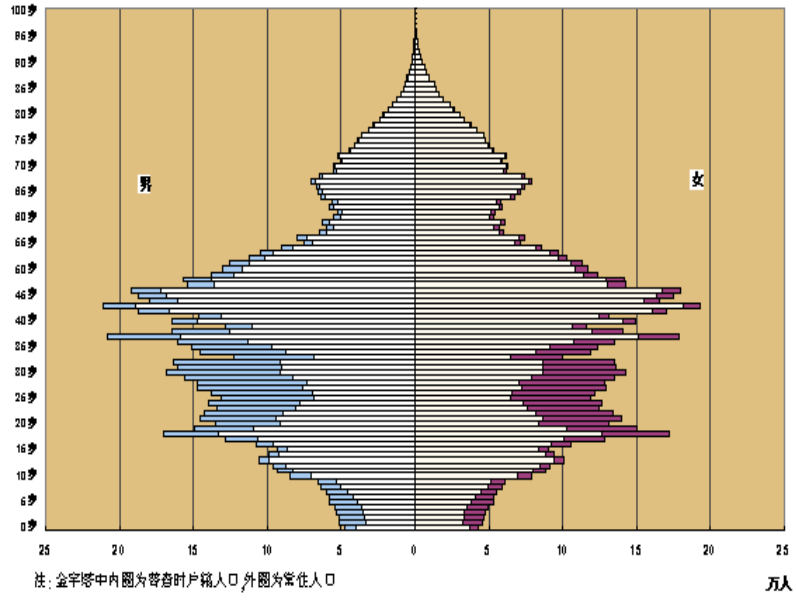
3. The migration factor

On the whole, China's urban employment has grown faster than rural employment since

1978 and this trend will remain in the near future. In a dual economy the migrants from rural areas are the major labour supply for the growing urban economy. Since the early 1980s, China's strict household registration system has been gradually relaxed as one of the results of the transition from a planned economy to a market economy. It is estimated that more than 140 million peasants moved to cities seeking for their fortune. Consequently, an array of demographic and economic factors has worked together to create a large population movement.

At the demanding side, Shanghai needs migrants, specially those young and well-educated ones, to slow down Shanghai's aging process and provide more productive labour force for its sustained development. Shanghai is a city that attracts millions of migrants from everywhere in the world over the last decade. The population census in 2000 showed that Shanghai had a floating population of 3.8711 millions. More recently, the seventh sample survey estimates the floating population to be 4.9879 million at the end of 2003. The gap between long-term residents and registered permanent residents is widening. Majority of the migrants are young people coming from the countryside of neighbouring provinces and are engaging in various manual jobs that the urban workers are not willing to take. In addition, the amount of skilled and educated young migrants, particularly young university graduates, has also increased continuously.

Figure 3: Age pyramid of Shanghai population in 2000

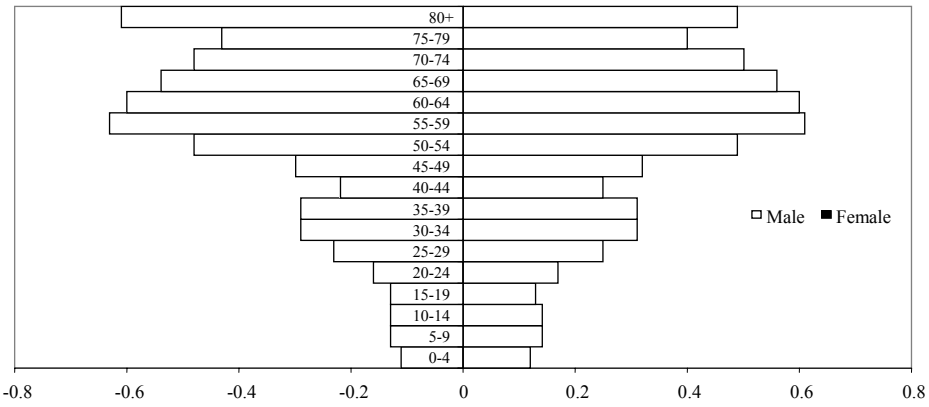


Source: Shanghai's 2000 Population census
Note: Inside pyramid refers to native local population, while the outside refers to migrants.

It can be seen from the Figure 3 that Shanghai's population age structure is characterised by fluctuations, which is the result of China's past political, socio-economic and demographic dynamics. It is also clear that the effect of migration significantly exceeds any other demography component in the process of shaping Shanghai's population Pyramid as the majority of migrants are young adults at their 20s-30s. The flow of young migrants has already greatly restructured Shanghai's actual population age distribution.

The following figure presents a simple projection of Shanghai's population age structure by assuming no migration will occur for the next 40 years. Other assumptions are the total fertility rate remains at the level of 0.9, no migration is allowed, sex ratio at birth is 107, and mortality keeps constant. This is of course an unrealistic extreme case for Shanghai's population development, but it shows us the importance of migration. (figure 4)

Figure 4: 2040 Shanghai Population Structure without Migration after 2000

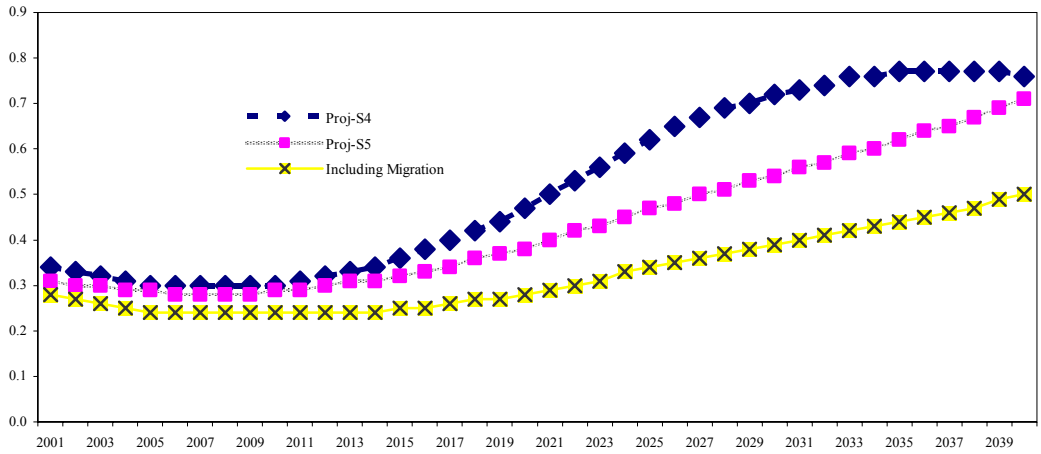


Projections are made to examine the impact of migration on Shanghai's future dependency ratio. Three population projections have been made based on the initial population of 1990 and 2000 respectively, and different future assumptions on demographic variables including net migration. While the projections labelled as Proj-s4 and Proj-s5[1] refer to projections without considering migration, the third projection includes migration into its model simulation[2].

[1] 'Proj-s4' represents the projection of the dependence ratio under the consumption that there was no migration from the fourth national census which was in 1990; 'Proj-s5' represents the projection of the dependence ratio under the consumption that there was no migration from the fifth national census which was in 2000; 'Including Migration' represents the projection of the dependence ratio under the consumption that the future immigration pattern in Shanghai always keep constant.

2 We do not present the details of all procedures and variables of those projections. Simply speaking, a multiple decrement life-table was used to estimate the probability of surviving, and net migration is estimated

Figure 5: Projection of the Dependence Ratio in Shanghai adding Migration



These projections indicate that migration will lay more impact on Shanghai's future ageing process. Furthermore, the effects of migration on Shanghai's future demographic trends may vary according to different intensities of net migration that could be seen from table 1.

Table 2: Projected Dependency Ratio (PDR[1]) based on different migration scenario

Year	2000	2005	2010	2015	2020	2025	2030	2035	2040
PDR of extreme higher migration (median times 1.5)	0.29	0.24	0.23	0.23	0.25	0.29	0.33	0.38	0.43
PDR of mild higher migration (median times 1.1)	0.29	0.24	0.23	0.24	0.27	0.33	0.38	0.43	0.49
PDR of median migration	0.29	0.24	0.24	0.25	0.28	0.34	0.39	0.44	0.5
PDR of mild lower migration (median times 0.9)	0.3	0.25	0.24	0.25	0.29	0.35	0.4	0.45	0.51
PDR of extreme lower migration (median times 0.5)	0.32	0.27	0.26	0.29	0.34	0.41	0.47	0.51	0.55

It looks likely that there is no large difference in PDR based on different migration scenario in the mid-term. But the longer-term impact is salient. So, according to our estimation, with strong immigration, the ageing process of Shanghai population would be greatly delayed.

It shows that, in the short term, the demographic window could remain open by the

by using the time-series forecasting model pioneer by Box and Jenkins (1984), and Lipro 4.0 developed by Evert van Imhoff and Nico Keilman is used to simulate the model.

[1] PDR=(Age group 0-14 + Age group 65 and above) / Age group 15-64

support of immigration, however, in the long term, neither the extreme higher migration scenario nor the extreme lower migration scenario could keep the window open. Considering the general trend of population growth in China and the unbalanced economic development throughout the country, Shanghai will still be under substantial pressure of immigration in the years to come.

4. A simple pension model illustrating the extending of demographic bonus

Selective migration is viewed as one of the efficient measures to cope with the structural shortage of the labour supply and the worsening ageing process. It will also greatly reduce the pressure on the city's pension system. In a highly popular paper named 'Replacement Migration: Is it a Solution to Declining and Ageing Populations?' published by United Nations in 2000, migration has been thoroughly discussed as a potential policy tool for extending the demographic bonus (United Nations, 2000). To make our point more convincing, a simple pension model is employed.

Assuming a highly simplified Shanghai pension scheme in which all long-term migrants are asked to participate in the pension scheme compulsorily[1]. We also assume that Shanghai pension scheme is a perfect Pay-as-you-Go system with no administration cost, and there is no distortion in leisure-labour allocation when those migrants join the urban pension scheme. The other necessary parameters are following: people over exact age 60 are paid a pension equal to 80% of their previous salary that is 15,000 RMB in 2000 with average increase rate of 10% from 2001 to 2025, 5% from 2026 to 2050, and the same for all individuals and at all ages between 20 and 60. The contribution rate would keep constant in the next 50 years that is about 25%.

The total payments by the fund each year will be $P_{60}^{\infty} * SALARY_{year} * 0.8$; the total receipts by the fund each year will be $P_{20}^{60} * SALARY_{year} * 0.25$. The model is only an example that permits pencil-and-paper excise to show the migration effects on the pension system.

5. Conclusion and discussion

The analysis above confirms the conclusion we proposed that the migration in the short run could alleviate Shanghai's pension system pressure, which here is the proxy of

[1] At present, China's pension system is urban focused and usually only covers the urban local residents. Migrant workers are in general not participating to the urban system.

demographic bonus, imposed by sharp ageing, which here represents demographic window impending close.

At least the current system could guarantee the remaining life of already retired people (now they are at least 60 years old and their expected life are about 85), which here could be understood as that the demographic bonus could last for 1~2 decades.

As we expected, the intensity of migration has significant effect on the performance of pension account which here means migration could serve as a nice policy tool extending the lifecycle of demographic bonus, the higher volume of migration the longer the pension system can sustain and the longer term of demographic bonus. With the longer term of demographic bonus, government has more opportunities, time and experience, to formulate public policy achieving demographic bonus.

As we discussed before, the favourable age structure cannot guarantee the harvest of the demographic bonus. At least some other factors are working together as the preconditions for the realization of the demographic bonus such as favourable employment situation and wise investment strategy. However, these preconditions may not occur simultaneously for a region. For instance, in China's rural and poor inland regions, the population age structure is young with very low dependent ratio, but lack of economic opportunities. As a result, it is difficult to harvest demographic bonus. On the other hand, in China's big cities like Shanghai, ageing process has accelerated and aged dependency ratio rose rapidly over the last few years, and will go up even more rapidly in the near future. Although there are a few years to go, demographic window is approaching to close.

Internal migration can be a win-win strategy for both urban area and rural area and is the bridge to match the conditions of harvesting demographic bonus in both areas. In the rural area, even though exporting & losing young able labour force, is highly benefited due to decrease of unemployment pressure and receipt of remittance that has become a very important economic resource for the rural areas. In other words, the migration makes the use of rural surplus labour in production possible no matter how low of their marginal production is. On the other hand, migration helps urban area solve the problem of young labour shortage, and maintain development strength. We demonstrate that urban economy and urban pension system will take advantage of continued supply of young labour force from the rural area. On the whole, both sending and receiving areas benefit from the

migration, as cities prolong the length of demographic window, while rural areas could harvest demographic dividend.

Our study shows the significance of rural-urban migration on harvest demographic bonus. It is worth noting however that under the constraint of population limit, the strong population inflow in theory is not sustainable, meanwhile the migration population itself also would age, and thus in the long run migration could not stop the aging process and the inevitable fate of Pay-as-you-go pension system.

Table 3: The Impact of Migration on the Performance of Shanghai's Pension System

Unit: million RMB

	Scenario A: With Median Migration				Scenario B: Without Migration			
Year	Receipt	Payment	Balance	Accumulate Balance	Receipt	Payment	Balance	Accumulate balance
2000	41250	29453	11798	11798	30788	29453	1335	1335
2002	53089	36255	16834	42772	37707	36100	1606	4476
2004	68300	44615	23685	86433	46119	44055	2064	8557
2006	87294	55791	31503	145548	56070	54436	1634	12232
2008	110609	71060	39549	220846	67603	68600	-997	12039
2010	138895	92927	45968	309699	80341	88628	-8287	-280
2012	172300	124847	47453	404292	93329	117244	-23915	-38917
2014	212470	167527	44943	496333	106947	154454	-47507	-120601
2016	261569	225556	36013	573701	121135	205051	-83916	-268366
2018	320877	304114	16763	617796	135731	270796	-135064	-510977
2020	394568	404861	-10293	611540	151873	353396	-201522	-879280
2022	475901	528283	-52383	533515	170641	447328	-276688	-1393460
2024	558110	678154	-120044	330667	193547	553826	-360279	-2070184
2026	623287	829684	-206397	-40039	211175	646921	-435746	-2912882
2028	661305	961102	-299798	-591493	221532	711632	-490099	-3866338
2030	701086	1107219	-406132	-1347576	234905	768706	-533801	-4910791
2032	740932	1273191	-532259	-2345586	250979	826117	-575137	-6039668
2034	780320	1461556	-681236	-3631076	267880	880791	-612910	-7246387
2036	817218	1656257	-839038	-5226180	284914	923818	-638903	-8509389
2038	853482	1875516	-1022033	-7175902	302626	966412	-663785	-9824322
2040	885216	2116578	-1231362	-9533493	315907	1016647	-700740	-11205465

	Scenario C: With Extreme High Migration				Scenario D: With Extreme Low Migration			
Year	Receipt	Payment	Balance	Accumulate balance	Receipt	Payment	Balance	Accumulate balance
2000	42563	27720	14843	14843	35400	27720	7680	7680
2002	56265	34122	22143	55235	44694	33977	10718	27448
2004	73626	41990	31636	113563	56276	41639	14637	54713
2006	96063	52296	43766	194750	70619	51659	18960	90596
2008	123873	66880	56993	301990	87780	65594	22186	133565
2010	158251	87461	70790	436533	107965	84971	22994	179584
2012	199839	117879	81960	595185	130872	113360	17512	218152
2014	250777	158584	92194	774635	157216	150837	6380	237607
2016	314124	214493	99631	970509	188164	201260	-13096	222569

2018	392808	290228	102580	1174419	224343	268210	-43868	151256
2020	491444	388311	103133	1379886	268427	353597	-85170	2511
2022	616015	509907	106108	1590227	322965	454227	-131262	-235981
2024	729865	659538	70327	1751955	376383	573254	-196872	-594701
2026	821663	813643	8020	1802881	418937	685317	-266379	-1097061
2028	878604	955741	-77137	1694836	444476	775128	-330652	-1725956
2030	935473	1115101	-179627	1391546	471885	867854	-395969	-2482741
2032	993055	1304407	-311352	840513	500815	969615	-468800	-3381791
2034	1048200	1528873	-480672	-32871	530088	1081102	-551014	-4442933
2036	1100048	1767860	-667812	-1267864	558015	1191915	-633900	-5665855
2038	1149213	2047131	-897918	-2945934	585333	1314087	-728754	-7074068
2040	1191832	2356972	-1165140	-5139965	608164	1448781	-840617	-8699345

References

Alun EJ, Phillips DR (1999): "Ageing in rural China: Impacts of increasing diversity in family and community resources", Journal of Cross-Cultural Gerontology, Volume 14, Number 2, June 1999

Bernstein S (2002): "Twenty five years of the one child family policy in China", Asia-Pacific Population Journal, December

Birdsall N, Kelley AC, Sinding SW (2001): *Population Matters: Demographic Change,Economic Growth, and Poverty in the Developing World* (New York, Oxford University Press)

Cai F (2004): "Population transition, demographic bonus and sustainable economic development in China". *Population Study* (人口研究), Isuue 6.

Dai X (1998) "The Pudong New Area Social Development Report"(浦东社会发展报告). *Shanghai Renming Publisher*.

Economist (March, 13, 2003): "Adverse demographics demand longer working lives and Swedish-style pension reforms"

Friedman B, James E., Kane C, Queisser M. (1996): "How Can China Provide Income Security for Its Rapidly Ageing Population?" *World Bank policy research working paper 1674.*

Gujarati D (1995): *Basic Econometrics*. McGRAW-HILL International Editions Press. The third edition.

Hamid F (2002): "Population Ageing and Its Macroeconomic Implications: A Framework for Analysis". *IMF Working Paper WP/02/16*

Hollander D (2000) "Large Immigration Flows Could Help Offset Declines in Developed Populations". Family Planning Perspectives, Volume 32, Issue3, P14-148

Leete R, Alam I (1999). ''Asia's demographic miracle: 50 years of unprecedented change'',*Asia-Pacific Population Journal*, 14(4):9-20

McNicoll G (2003): “Population and Development: An Instroductory View”, No. 174, Policy Research Division Working Paper, Population Council, New York

Liang H (1990): “Shanghai Population Projection”(上海人口规划). Policy Research Report present to Shanghai Municipal Government.

Liang H (1995): “The Research for Shanghai Population Ageing”（上海人口老龄化综合研究）. Policy Research Report present to Shanghai Municipal Government.

Ministry of Agriculture of P.R.C (2002): “The Effects of Migration and Remittances on the Economic Development of Sending Communities in China” *funded by the Ford Foundation*.

Peng X (1993): “Recent Trends in China’s Population and Their Implications”. *Mimeo* London School of Economics.

State Statistic Bureau of China (2001): *China Statistic Yearbook 2000*. Beijing

State Statistic Bureau of China. (1996 and 1997): *China labor Statistic Yearbook 1995 and 1996*. Beijing

United Nations (2000): “ Replacement Migrations: Is it a Solution to Declining and Ageing Populations?”

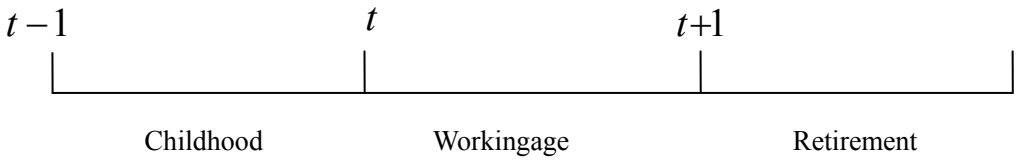
UNFPA (2002). State of World Population 2002: People, Poverty and Possibilities, New York

Wang H, Zuo X (1999): “Inside China’s cities: Institutional Barriers and Opportunities for Urban Migrants”. *The American Economic Review*, Volume 89, Issue 2, P276-280.

Yu T (1990), ‘‘Transition of China's Population: Regional Differentials and Implications for Development Policy’’, *Asia-Pacific Population Journal*

Appendix

Where the demographic bonus comes from?



In our model, we divide the life course into three periods. When individual, in his/her childhood, depends on their parent or borrows money to consume. When entering into the labour force, he/she produces and returns the loan and the correspondent interests. When retiring, he/she uses the saving to live.

L_t refers to individuals born in period t and the population grows at rate n: $\dot{L}(t) = nL(t)$

We use the time point t as the base to show the present value of each variable. We assume the utility take the form of constant-relative-risk-aversion and the coefficient of relative risk aversion for this utility function is independent of consumption.

The production function has constant returns to scale in its two arguments, the capital (K) and the effective labour (AL)[1]. By this property, we work with the intensive form instead of the original form. The assumption of constant returns allows us to work with the production function in intensive form.

$$F\left(\frac{K}{AL},1\right) = \frac{1}{AL}F(K,AL) \qquad 1)$$

K / AL is the amount of capital per unit of effective labour, and $F(K, AL)/AL$ is Y / AL the output per unit of effective labour.

Define $k = K / AL, y = Y / AL, f(k) = F(K,1)$, we get:

$$y = f(k) \qquad 2)$$

The output per unit of effective labour is a function of the capital per unit of effective labour. In the following analysis, we always employ the intensive form as the working horse.

At each point in time the firms employ the stocks of labour and capital, pay them their marginal products, and sell the resulting output. Because the production function has constant returns and the economy is competitive, firms earn zero profits. Furthermore, the knowledge grows at a constant rate g: $\dot{A}(t) = gA(t)$

[1] We choose the Y=F (K, AL) which is also called labour-augmenting or Harrod -neutral, the most commonly used production specification.

The marginal product of capital, $\partial F(K, AL)/\partial K$, is $f'(k)$, where $f(.)$ is the intensive form of the production function. Because markets are competitive, capital earns its marginal product. And because there is no depreciation, the real rate of return on capital equals its earnings per unit time. The real interest rate at time t is

$$r(t) = f'(k(t)) \tag{3}$$

The marginal product of labour is $\partial F(K, AL)/\partial L$, which equals $A\partial F(K, AL)/\partial AL$. In terms of $f(.)$, this is $A\left(f(k) - kf'(k)\right)$. The wage per unit of effective labour is therefore[1]

$$w(t) = f(k(t)) - k(t) f'(k(t)) \tag{4}$$

The household utility is:

$$U_t = \frac{C_{1,t-1}^{1-\theta}}{1-\theta}.(1+\rho) + \frac{C_{2,t}^{1-\theta}}{1-\theta} + \frac{1}{1+\rho}.\frac{C_{3,t+1}^{1-\theta}}{1-\theta} \qquad \theta > 0, \rho > -1 \tag{5}$$

ρ is the discount rate.

The budget is: $C_{3,t+1} = (1+r_{t+1}).\left(A_t w_t - (1+r_t)C_{1,t-1} - C_{2,t}\right)$

Maximize the household utility with the constraint of the budget, we get the differential equation for the capital k[2]:

$$k_{t+1} = \frac{1}{(1+n)(1+g)} s(f'(k_t))\left[f(k_t) - k_t f'(k_t)\right] \tag{6}$$

To analyze the impacts of changes of fertility on the equilibrium capital (k^*), then on the production (y), and finally to the development of the economics, we assume the utility takes the form of logarithmic utility and Cobb-Douglas production[3] and the evolution of k is:

$$k_{t+1} = \frac{1}{(1+n)(1+g)} \frac{(1+\rho)^2 + 1}{(1+\rho)^2 + 2}.(1-\alpha)k_t^{\alpha} \tag{7}$$

We could get the equilibrium capital k^* by

---

[1] The real wage is $W(t) = A(t)\left[f(k(t)) - k(t) f'(k(t))\right]$

[2] The detailed derivation is in the Appendix.

[3] The Cobb-Douglas production function takes the form of $F(K, AL) = K^{\alpha}(AL)^{1-\alpha}$, $0 < \alpha < 1$, $then, f(k) = k^{\alpha}$, $f'(k) = \alpha k^{\alpha-1}$. Under the conditions, $\theta = 1$, $s(r_t) = \frac{(1+\rho)^2 + 1}{(1+\rho)^2 + 2}$

$$k^* = \left[\frac{(1-\alpha)\left((1+\rho)^2+1\right)}{(1+n)(1+g)\left((1+\rho)^2+2\right)} \right]^{\frac{1}{1-\alpha}} \quad 8)$$

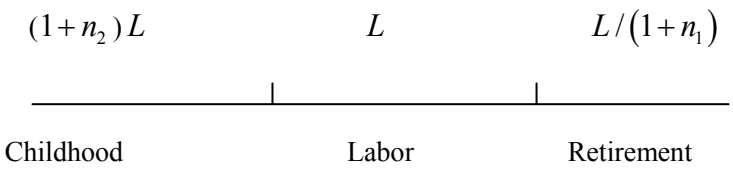
Since $y = k^{\alpha}$, then the equilibrium output y*

$$y^* = \left[\frac{(1-\alpha)\left((1+\rho)^2+1\right)}{(1+n)(1+g)\left((1+\rho)^2+2\right)} \right]^{\frac{\alpha}{1-\alpha}} \quad 9)$$

Since the demographic bonus refers to the income per capita, we would use the concept of $\frac{Y}{N}$ to analyze where the demographic bonus comes from. Because $\frac{Y}{N} = \left(\frac{Y}{AL}\right).\left(\frac{AL}{N}\right) = y^*.\left(\frac{AL}{N}\right)$, we could start the analysis from both the elements of y^* and AL/N. N is the total population in the childhood, labour force and retirement, for example, in Case 1, $N = (1+n_2)L + L + L/(1+n_1)$. We consider two kinds of population phenomena – declining fertility rate and immigrating.

Suppose there is a demographic shock in the period t, like fertility declining or immigration, due to some reasons. Period t could be any time in the time horizon. Then we analyze the demographic impacts on the bonus for the period t and $t+1$. All the results for period $t+1$ are compared with the results for period t.

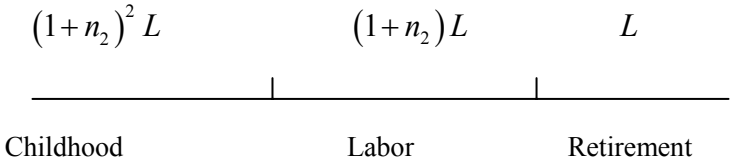
Case 1 **Decline in** ***fertility rate at the period*** t



Declining fertility rate means that $n_2 < n_1$ and a decreased value of n in the formula of y^* in (9). Therefore, $\frac{AL}{N}_{new} = \frac{1}{2+n_2+1/(1+n_1)} > \frac{AL}{N}_{old} = \frac{1}{2+n_1+1/(1+n_1)}$ and $y^*_{new} > y^*_{old}$ Then $Y/N \uparrow$**, which shows that the demographic window could open with a decline in fertility rate** (less children and increase production).

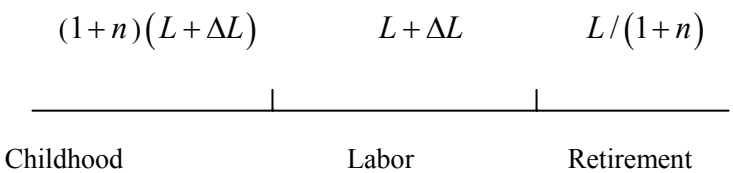
Case 2 No space for fertility rate to decline at the period $t+1$

It is impossible for the fertility rate to decline without limit. For example, in Shanghai, the fertility rate is already below the replacement rate. When the fertility rate keeps at a lower and constant level, we would get



Compared to the Case 1, y^*_{new} at $t+1$ is the same with that at t. Therefore $\frac{AL}{N}_{new,t+1} = \frac{1}{2+n_2+1/(1+n_2)} < \frac{AL}{N}_{new,t} = \frac{1}{2+n_2+1/(1+n_1)}$, where $\frac{AL}{N}_{new,t}$ refers to $\frac{AL}{N}_{new}$ in case 1. Then $Y/N \downarrow$**, which shows that the demographic window could close when there is no space for the fertility rate to decline** (more children and less production). Whether the fertility rate is below the replacement rate does not matter in this case, we only concern the impacts of fertility rate's changing, rather than the level.

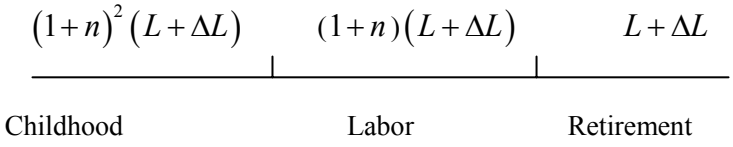
Case 3 Immigration at the period t



Immigration means $\Delta L > 0$. Assuming that the immigrants have the same fertility pattern then the residents, there is no change in n, then in y^*. Therefore $\frac{AL}{N}_{new} = \frac{1}{2+n+1/(1+n)\left(1+\frac{\Delta L}{L}\right)} > \frac{AL}{N}_{old} = \frac{1}{2+n+1/(1+n)}$. Then $Y/N \uparrow$**, which shows that the demographic window could open with immigration** (more working age adult and children, and more productivity).

Case 4 When Immigration meets its limit at the period $t+1$

Every city has its own population carrying capacity. Although immigration is helpful to harvest the demographic bonus, it will meet its limit sooner or later. When the immigrating meets its limit, we get



Compared to the Case 3, y^*_{new} at $t+1$ is the same with that in t. Therefore $\frac{AL}{N}_{new,t+1} = \frac{1}{2+n+\frac{1}{(1+n)}} < \frac{AL}{N}_{new,t} = \frac{1}{2+n+1/(1+n)\left(1+\frac{\Delta L}{L}\right)}$, where $\frac{AL}{N}_{new,t}$ refers to $\frac{AL}{N}_{new}$ in case 3. Then $Y/N \downarrow$**, which shows that the demographic window could close when immigration meets its limit** (more elderly and less production). Additionally, we notice that $\frac{AL}{N}_{new,t+1} = \frac{1}{2+n+\frac{1}{(1+n)}} = \frac{AL}{N}_{old}$ and the income per capita will return to the level before immigration.

To maximize household utility, we set up the Lagrangian:

$$L = \frac{C_{t-1}^{1-\theta}}{1-\theta}.(1+\rho) + \frac{C_{2t}^{1-\theta}}{1-\theta} + \frac{1}{1+\rho}.\frac{C_{3t+1}^{1-\theta}}{1-\theta} + \lambda.\left[A_t w_t - (1+r_t)C_{t-1} - C_{2t} - \frac{C_{3t+1}}{1+r_{t+1}}\right]$$

First order derivatives:

$$\frac{\partial L}{\partial C_{1t-1}} = (1+\rho)C_{1t-1}^{-\theta} - \lambda(1+r_t) = 0 \Rightarrow C_{1t-1} = \frac{(1+\rho)^{\frac{1}{\theta}}}{(1+r_t)^{\frac{1}{\theta}}}.C_{2t}$$

$$\frac{\partial L}{\partial C_{2t}} = C_{2t}^{-\theta} - \lambda = 0 \Rightarrow \lambda = C_{2t}^{-\theta}$$

$$\frac{\partial L}{\partial C_{3t+1}} = \frac{1}{1+\rho} C_{3t+1}^{-\theta} - \frac{\lambda}{1+r_{t+1}} = 0 \Rightarrow C_{3t+1} = \frac{\left(1+r_{t+1}\right)^{\frac{1}{\theta}}}{\left(1+\rho_t\right)^{\frac{1}{\theta}}}.C_{2t}$$

Insert the above results into the budget constrains, get:

$$\left(1+r_t\right).\frac{\left(1+\rho\right)^{\frac{1}{\theta}}}{\left(1+r_t\right)^{\frac{1}{\theta}}}.C_{2t} + C_{2t} + \frac{1}{1+r_{t+1}}.\frac{\left(1+r_{t+1}\right)^{\frac{1}{\theta}}}{\left(1+\rho\right)^{\frac{1}{\theta}}}.C_{2t} = A_t.w_t$$

$$\Rightarrow \left[\frac{\left(1+\rho\right)^{\frac{2}{\theta}}}{\left(1+r_t\right)^{\frac{1-\theta}{\theta}}.\left(1+\rho\right)^{\frac{1}{\theta}}} + \frac{\left(1+r_t\right)^{\frac{1-\theta}{\theta}}.\left(1+\rho\right)^{\frac{1}{\theta}}}{\left(1+r_t\right)^{\frac{1-\theta}{\theta}}.\left(1+\rho\right)^{\frac{1}{\theta}}} + \frac{\left(1+r_{t+1}\right)^{\frac{1-\theta}{\theta}}.\left(1+r_t\right)^{\frac{1-\theta}{\theta}}}{\left(1+r_t\right)^{\frac{1-\theta}{\theta}}.\left(1+\rho\right)^{\frac{1}{\theta}}}\right].C_{2t} = A_t w_t$$

$$\Rightarrow C_{2t} = \frac{\left(1+r_t\right)^{\frac{1-\theta}{\theta}}.\left(1+\rho\right)^{\frac{1}{\theta}}}{\left(1+\rho\right)^{\frac{2}{\theta}} + \left(1+r_t\right)^{\frac{1-\theta}{\theta}}.\left(1+\rho\right)^{\frac{1}{\theta}} + \left(1+r_{t+1}\right)^{\frac{1-\theta}{\theta}}.\left(1+r_t\right)^{\frac{1-\theta}{\theta}}}.A_t w_t$$

$$\Rightarrow C_{2t} = \left(1-s\left(r_t\right)\right).A_t w_t$$

Where

$$s\left(r_t\right) = \frac{\left(1+\rho\right)^{\frac{2}{\theta}} + \left(1+r_{t+1}\right)^{\frac{1-\theta}{\theta}}.\left(1+r_t\right)^{\frac{1-\theta}{\theta}}}{\left(1+\rho\right)^{\frac{2}{\theta}} + \left(1+r_t\right)^{\frac{1-\theta}{\theta}}.\left(1+\rho\right)^{\frac{1}{\theta}} + \left(1+r_{t+1}\right)^{\frac{1-\theta}{\theta}}.\left(1+r_t\right)^{\frac{1-\theta}{\theta}}}$$

The capital stock in period $t+1$ is the amount saved by the labour force in period t.

$$K_{t+1} = s\left(r_t\right) L_t A_t w_t$$

Dividing both sides by $L_{t+1}A_{t+1}$, get:

$$k_{t+1} = \frac{1}{\left(1+n\right)\left(1+g\right)} s\left(r_t\right) w_t$$

$$\Rightarrow \quad k_{t+1} = \frac{1}{\left(1+n\right)\left(1+g\right)} s\left(f'\left(k_t\right)\right)\left[f\left(k_t\right) - k_t f'\left(k_t\right)\right]$$