The Future Demographics of China's Population

Executive Summary

In the 21st century China has emerged as a superpower and a major rival to the United States. Further, China currently has the largest reported population in the world. However, India is projected to surpass the behemoth and China's population is projected to decline by over 300 million people by 2070 according to the UN's population projections (UN WPP). A key driver of China's projected population decline is low birth rates. These low birth rates are a product of the infamous one-child policy which has left its mark on Chinese culture (Silver & Huang, 2022). This issue is further complicated by the potential that China's reported birth rates may be lower than reported (Fuxian, 2022). If true, China's population decline will likely be more severe than anticipated and its population will age faster than currently projected.

In this paper, China's population was projected based on mortality and fertility assumptions using published mortality tables and historical data. Below, Table1.1 presents the results from the Baseline Projections for 2022, 2050 and 2070. The table includes the UN projections for comparison. Overall, the Baseline projections are slightly higher than those projected by the UN. This is driven by two factors. The Baseline assumptions use lower mortality rates (in general) and the Baseline assumptions use higher fertility rates when compared to the UN projections. The fertility assumptions used are favorable (more births projected) relative to the UN projection. This paper's purpose is more towards scrutinizing the reported Chinese mortality as opposed to birth rates which is why a conservative (higher births) view was taken on fertility assumptions. For more scrutiny towards China's birth rates, I encourage readers to study Yi Fuxian's work. Fuxian is a demographer who was one of the first to contend that China may be overstating the number of children being born (Fuxian, 2022).

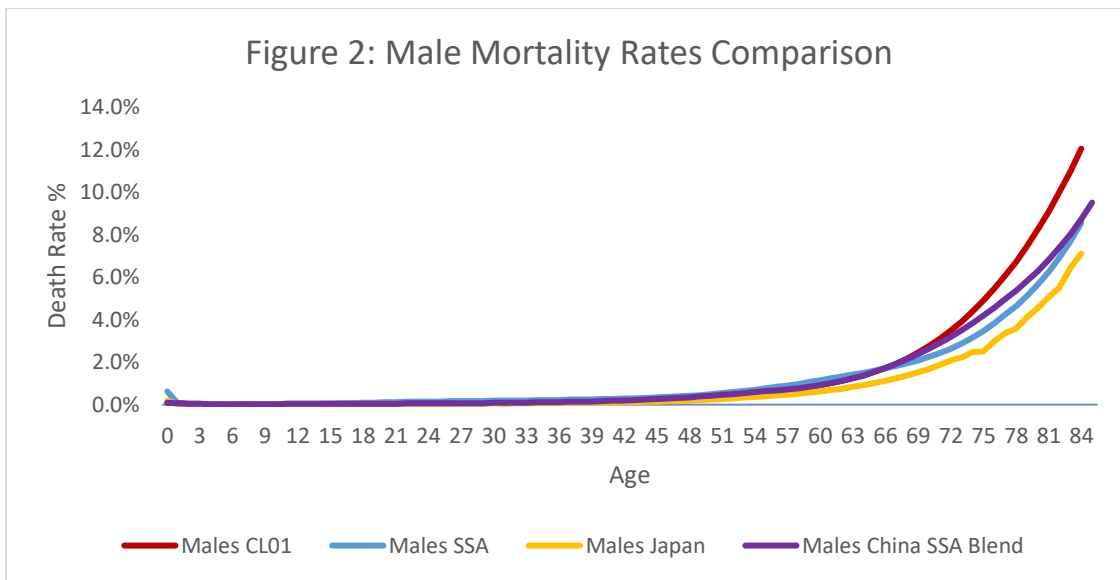| Table 1.1: Baseline China Population Projections			
Year	Baseline Projected Population	UN Projected Population	Delta %
2022	1430	1426	0.29%
2050	1341	1317	1.86%
2070	1126	1091	3.20%

To develop mortality projections, three sources for mortality were considered; the 2013 Insurance Society of China mortality tables ("CL Tables"), the 2019 Social Security Administration ("SSA") Mortality tables (used for US Social Security) and the most recent Japanese Population Mortality tables published by its National Institute of Population and Social Security Research. Table 1.2 below illustrates how the period life expectancy of these three tables compares to the reported Chinese life expectancy as of 2022.

| Table 1.2: Male Life Expectancy Comparison		
As of 12/31/2022		
Mortality Table	Male Life Expectancy	Female Life Expectancy
UN	75.46	81.16
CL	75.92	81.21
SSA	75.73	80.78
Japan	80.98	87.08
China - SSA Blend	77.04	82.30

The CL Tables tie to the UN life expectancy closely. However, these tables appear to have fairly high mortality at old ages when compared to US old-age mortality. As such, a third table was developed that blends old age mortality from the CL tables to that in the SSA tables at old ages. This blended table was used as an alternative sensitivity. Below, Figure 2 complements Table 1.2 as it shows the mortality rates for various mortality tables. The Chinese mortality rates (red line) are higher than Japan and the US at older ages. If China is able to improve its old age mortality by reducing cardiovascular disease, access to healthcare or improve through other means, it could bring its old-age mortality in line with other developed countries. While beneficial for its elderly population it could accelerate China's aging population which would put strain on China's public pensions and healthcare system.

Figure 2: Male Mortality Rates Comparison

Sources: Chinese CL Tables: http://www.isc-org.cn/jgzc/5237.jhtml, US SSA Mortality Tables: https://www.ssa.gov/oact/STATS/table4c6.html, Japanese Mortality Tables: https://www.ipss.go.jp/p-toukei/JMD/00/index-en.html

Below Figure 6 summarizes the projected Retiree Proportion for the Baseline scenario, the UN projections and the US according to the Congressional Budget Office ("CBO"). The Retiree

Proportion was calculated as the percent of the population that was 65 years old or older. This metric is meant to evaluate how old China's population will be in the future. In general, a high proportion of older people will strain a country's social safety net as older people have higher healthcare costs and collect pension benefits after they stop working. China currently has a lower proportion than the US but that changes in the next 10-15 years and China is projected to far surpass the US at the end of the projection. By 2050, it is projected that about 30% of its population will be above 65. China has bleaker picture than the US because of China's lower birth rates and limited immigration which suppresses the amount of younger people entering the population. The Baseline projection is lower than the UN because the Baseline has higher birth rates assumed. Overall, the Baseline scenarios aligns well with the UN population projections.

Figure 6: Retiree Proportion - Baseline vs. UN Projections
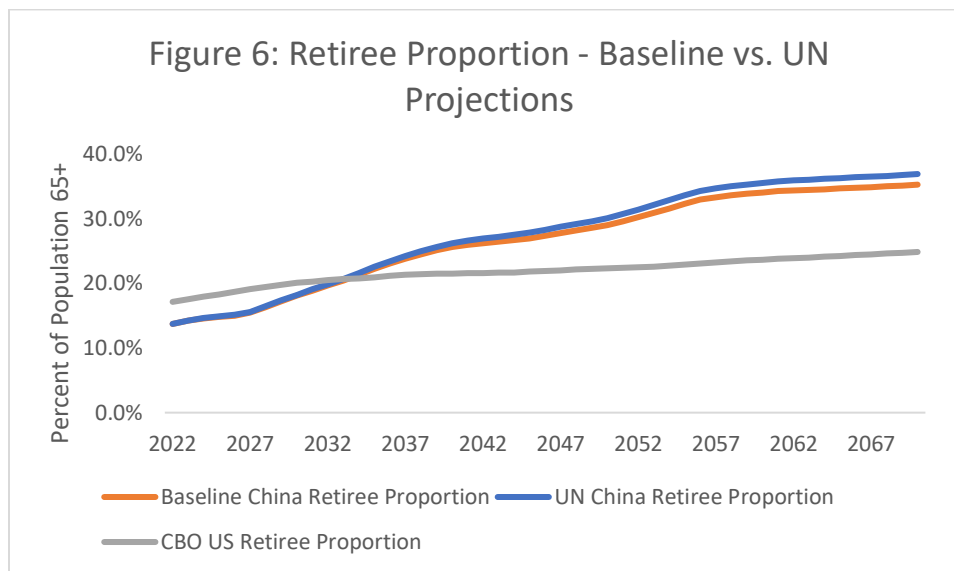
Sources: UN Chinese Projections: https://population.un.org/wpp/, US CBO Projections: www.cbo.gov/publication/57975

I will conclude this summary with why this analysis matters. As mentioned earlier, China is a superpower with significant global influence. If its population collapses it could result in economic consequences. It seems unlikely that China's population will collapse due to mortality but rather its low birth rates could be its Achilles heel. China has poor old age mortality rates relative to the US and the US is by no means the gold standard for elderly mortality. However, a reasonable interpretation is that there is more room for China to improve on the elderly mortality front. In turn, China's aging population could become more severe if its old-age mortality improves. A severely old population could lead to decline as older people do not contribute to the economy relative to younger age populations. This is not to say that old people are bad and young people are good, but rather to point out the balance between young and old population must be reasonable in order for a country to provide a solid safety net to its older population after they finish working. Fertility rates on the other hand represent a significant area of variability for the future Chinese population. If China's fertility rates were in fact overreported as Yi Fuxian assets, then its population could be quite lower. Fuxian estimates that China is overreporting its population by over 100 million (Fuxian, 2022). This means fewer young people can be relied on

to replace the elderly population in the future. In addition, it has the compounding effect of reducing the number of child bearing age women as this underreporting allegedly has taken place since the 1990s. If Fuxian is correct, fertility will be key driver to explain China's population decline and adverse spike in its Retiree Proportion.

Background

As of 2022, China has the largest reported population in the world with a population estimate standing at over 1.4 billion people (UN WPP). India follows closely at just under 1.4 billion people and the United States comes in at a distant third with a population of over 330 million (UN WPP). However, China's population dominance may come crashing down as the UN's projection estimates that its population will shrink to 1.1 billion by 2070. In contrast India's population is projected to rise to over 1.6 billion people by 2070. The UN develops world population and country level population projections each year. Considerable attention will be devoted to analyzing these projections throughout this analysis.

Fundamentally, population change is driven by three factors; deaths, births and net immigration which all point unfavorably to China's projected population growth (or better phrased, population shrink). China has an aging population and therefore could experience higher deaths because mortality generally increases with age. China has experienced low fertility rates partially thanks to its one-child policy being engrained in its baby-having-culture. Fertility rates continued to drop despite China amending the policy to be a two-child policy in 2016 and subsequently a three-child policy in 2021 (Silver & Huang, 2022). Below Figure 1, summarizes the adjusted birth rate over time (calculated as the number of new borns divided by women aged 24 to 35 with this group meant to proxy the number of child bearing age women). As Figure 3 illustrates, the birth rate has declined from a relative peak in 2017. Covid-19 and the strict lockdowns imposed by the Chinese government could have fueled this recent downward trend. In addition, China has a skewed sex ratio at birth. The amount male Chinese babies being born has exceeded females by over 10% since 2002 (UN WPP). This trend is highlighted in Figure 1 below. However, it should be noted that this skew has been easing since 2009. The skewed sex ratio partially explains the reduction in birth rates because there are less women who are able to give birth. In addition, the one-child policy may be a contributing factor as female babies are commonly aborted in China (Silver & Huang, 2022). Lastly, net immigration is not in China's favor as more people emigrate out of China than those who immigrate in. However, net immigration appears to be less impactful than the prior two factors as it is projected to decrease the population by only 300 thousand people per year.

Figure 1: Chinese Adjusted Birth and Male to Female Birth Ratio
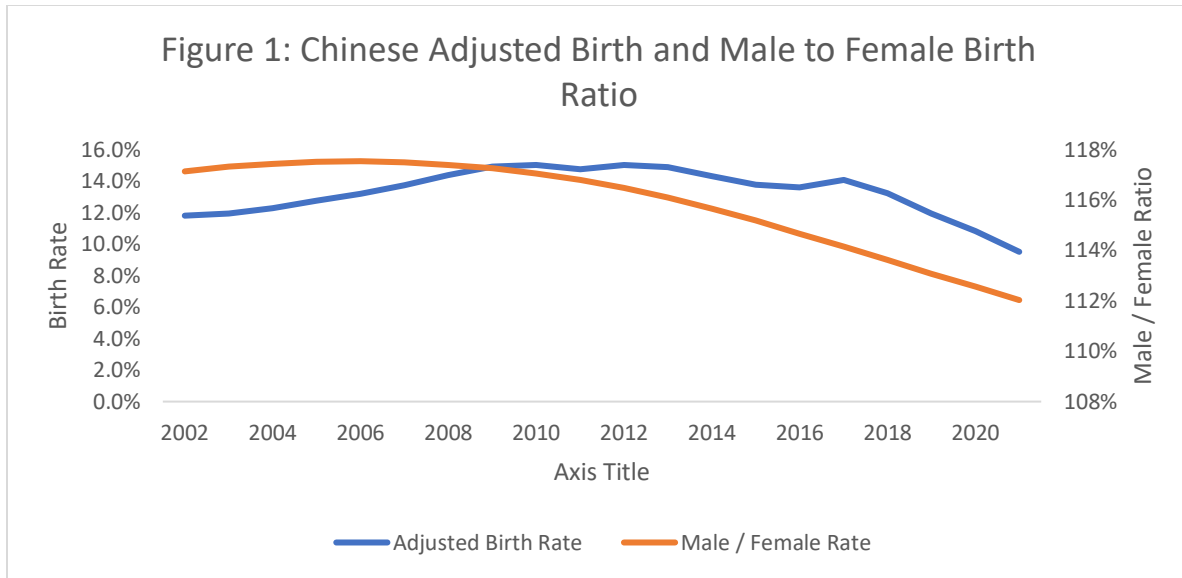
Source: United Nations. (n.d.) (UN WPP). World population prospects. Department of Economic and Social Affairs Population Division. Retrieved February 23, 2023, from https://population.un.org/wpp/

The purpose of this paper is not just to analyze UN projections or historical population data, but rather to develop Chinese population projections based on available data. In this paper, a ground-up population projection was developed and is referred to as "Baseline". This "Baseline" projection was compared to the UN's medium variant (the UN's "Baseline" projection) for reasonableness as well as to analyze differences in methodologies. This analysis' Baseline projections were designed to be conservative or favorable to China's population to prove that China's population is projected to decline even under moderately favorable circumstances. In addition, sensitivities on mortality and fertility assumptions were run to illustrate the range of potential future scenarios for the Chinese population. Building ground-up population projections is not simple task. Further, the reliability of such projections is uncertain because of the integrity of the data inputs used. China has been accused providing fraudulent population data by Yi Fuxian (Person & Lee, 2022). Based on leaked population data released by an anonymous hacker, that may represent the true Chinese population distribution, Fuxian believes that China overstated its births since 1990 which has inflated its younger age population (Fuxian, 2022). The leaked data was a sample of China's aggregate population and proportion of people born after 1990 in this data was lower than reported.
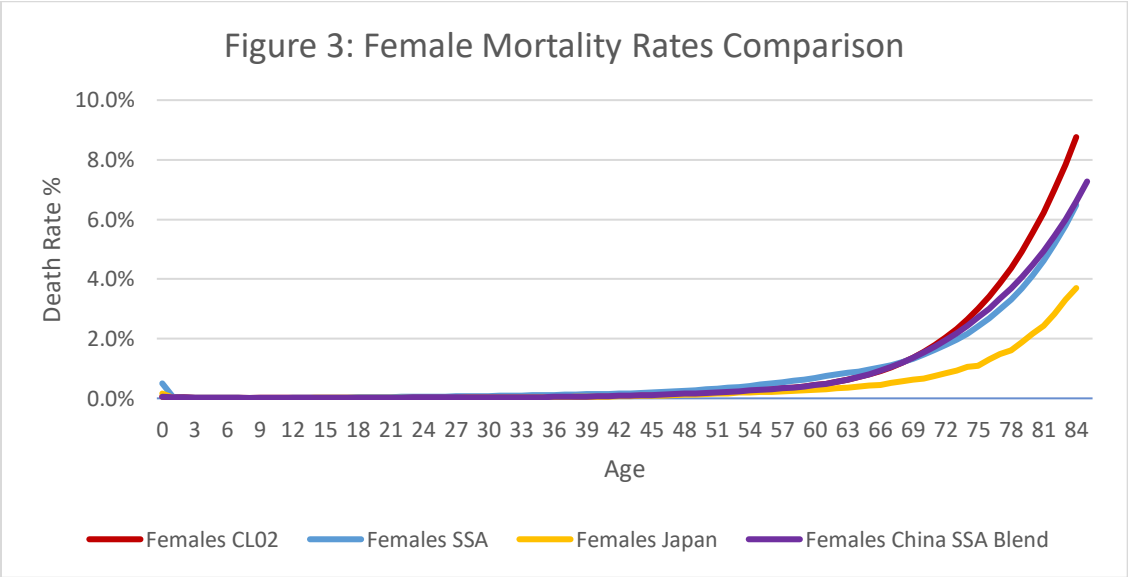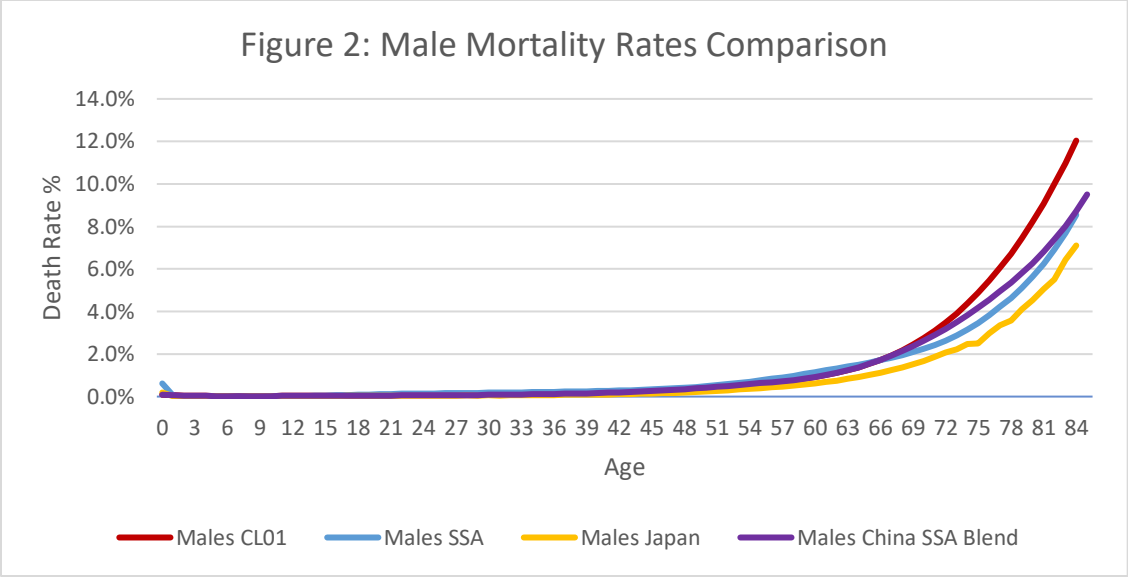
Methods

Assumptions used to predict population generally fall into three categories mortality, fertility and immigration. Mortality represents the amount of people leaving the population due to death while births represent the amount of new people entering the population. Immigration represents a population transfer between countries. Because immigration's small impact to China's

population, no immigration was assumed in this projection. The projection began for years after 2021 which was the last date that the UN published actual population estimates. Below Table 3.1, summarizes the assumptions supporting the Baseline projections.

Table 3.1: Baseline Assumptions	
Assumption Category	**Assumption**
Mortality	
Mortality Table	China
Male Mortality Improvement	1.15%
Female Mortality Improvement	1.15%
Fertility	
Women Childbearing Age	Ages 24 to 35
Birth Rate (% of Childbearing Age Women)	11.9%
Fertility Rate Structure	Static
Male to Women Skew	106.4%
Other	
Immigration	N/A

Mortality tables are typically structured to vary by age and sex. Mortality tables can also vary by risk class (e.g. smokers have higher mortality than non-smokers) and duration (relevant for insurance applications). In general mortality increases with age and mortality rates are generally higher for males compared to their female counterparts. The Insurance Society of China's mortality tables ("CL tables") were used for the Baseline scenario. However, it was determined that these tables have high old-age mortality rates as seen by the red lines in Figures 2 and 3 below. The China SSA blended tables are an alternative table (purple line) which was used in the sensitivity analysis. This table sets mortality rates equal to the CL tables for all ages younger than 65. It then blends rates to the US Social Security Administration mortality tables ("SSA tables") (blue line) over 20 years starting with age 65. Japan's mortality is world class and was used for demonstration purposes as the yellow line below is much lower than all other mortality curves. In addition, mortality rates were assumed to improve by 1.15% each year for both males and females throughout the projection. The 1.15% was determined based on SSA mortality improvement and calibration to UN projected future life expectancy. The SSA mortality improvement and implied UN mortality improvement appears to be in 1.1-1.2% range. It was assumed that mortality rate improvement would start in 2021, for all years because the initial life expectancy of the CL Tables are in line with the current reported Chinese life expectancy. The choice to ignore historical mortality improvement was applied to all tables. While this may not be the most accurate approach, it should not materially impact the results.

Figure 2: Male Mortality Rates Comparison

Figure 3: Female Mortality Rates Comparison

Sources: Chinese CL Tables: http://www.isc-org.cn/jgzc/5237.jhtml, US SSA Mortality Tables: https://www.ssa.gov/oact/STATS/table4c6.html, Japanese Tables: https://www.ipss.go.jp/p-toukei/JMD/00/index-en.html

Fertility assumptions are used to project the number of new children that enter the population each year. Birth rates each year were modeled as a percent of women of childbearing age. Childbearing ages were set to be between ages 24 and 35. In the real world, women can bear children outside of this age interval. Further, a more vigorous modeling technique would be to develop birth rate assumptions for each age. However, this approach was not taken as it complicates the analysis. Based on historical birth rate data from UN population estimates, it was assumed that birth rates would be about 12%, equivalent to China's five-year average from 2017-2021. This represents an increase in birth rates from the two recent low years (2020 and 2021) likely driven by Covid. These rates are still well below the average birth rate in the last 20 years. In addition, it would have been more rigorous to model a birth rate trend where birth rates

start at low 2021 rates and then trend upwards to an ultimate rate. This approach was ignored to avoid complicating the analysis. By projecting constant ultimate fertility rates throughout the projections (called "Static" in Table 3.1 above), there is inherent conservatism (higher birth rates at the start of the projection) baked into the projections. Lastly, it was assumed that sex ratio skew would be 106.4% over the projection period which means that there would be 6.4% more male born than female borns. This assumption was set to align with the UN ultimate assumptions and represents a reduction from current skew levels (112%) as seen in Figure 1 in the Background section.

In general, the population projection is summarized in the formulas below. Conceptually the population in a given year is equal to the prior year population plus births in that year less deaths in that year (ignoring net immigration). For more detail, see attached excel with detailed calculations.

$$Population(t) = \sum_{j=0}^{120} \sum_{s=1}^{2} Population(t, j, s)$$

$$Population(t, j, s) = if\ j > 0, Population(t-1, j-1, s) * \left(1 - q_{j-1}^{s}(t-1)\right),$$

$$else \sum_{j=24}^{35} \sum_{s=1}^{1} Population(t, j, s) * f(s, t)$$

Where; 1) $Population(t, j, s)$ is the projected population in year t for age j and sex s. (Women set to s = 1)

2) $q_j^s(t)$ is the population mortality rate for a person aged j and sex s in year t (adjusting for improvement).

3) $f(s, t)$ represents the number of babies of sex s born per women of childbearing age, note that this rate is kept constant through for all t and childbearing age was assumed to be ages 24 to 35.

In addition to the Baseline projections, various sensitivities were run in order to project the impact different assumption changes have on population totals, Retiree Proportions and births. The Retiree Proportion was calculated as the projected amount of the population over 65 years of age divided by the total projected population. Below Table 3.2 summarizes the sensitivities run.

Table 3.2: Sensitivity Descriptions	
Sensitivity	**Description**
Mortality Table	
CL-SSA Blended Tables	Blend Insurance Society of China's 2013 CL01 and CL02 Mortality Tables for Men and Women at older ages to the US SSA tables.
Japan	Use Japan's 2021 Social Security Mortality Tables
SSA	Use US' Social Security Administration 2019 Mortality Tables
Mortality Improvement	
.5% Mortality Improvement	Assume 0.5% Mortality Improvement throughout the projection
2% Mortality Improvement	Assume 2% Mortality Improvement throughout the projection
Birth Rates	
High Birth Rates	Assume average birth rates rebound to 10-year average levels from 2009-2018
Low Birth Rates Persist	Assume average birth rates seen in the 2020 and 2021 persist indefinitely
Equal Males and Females	Assume average birth rates same as Baseline but Females births are the same as male births

Below is additional commentary related to the sensitivities.

- Mortality Table
  - Japan is an optimistic scenario where China benefits from Japan's life expectancy. This scenario was chosen as a way to stress China's Retiree Proportion.
- Birth Rates
  - High Birth Rates is an optimistic scenario where birth rates were set equal to 14.3%, the average from 2009 and 2018. Further it is assumed that the male to female skew would reduce to 104% compared 106.4% in Baseline.
  - Low Birth Rates Persist is an adverse scenario where birth rates were set equal to 10.2% the average from 2020 and 2021 and assume no correction in the male to female skew (of approximately 112%).
  - Equal Males and Females estimates the impact that could occur if China's newborns were of equal proportion male to female.

Analysis

In this section the results will be conveyed in two parts. The first subsection will be devoted to analyzing the Baseline population projection results when compared to the UN projections. The second subsection will then present the sensitivity analysis results.

Baseline

Below Figure 4 summarizes the Baseline Chinese population projections in comparison to the projections developed by the UN. The UN projections is represented by the blue line and the Baseline projections by the orange line. The Baseline is slightly higher than the UN projection. Baseline projections have slightly lower deaths than UN projections and higher assumed births. The births differential appears to be the bigger driver.

Figure 4: Baseline Chinese Population Projections
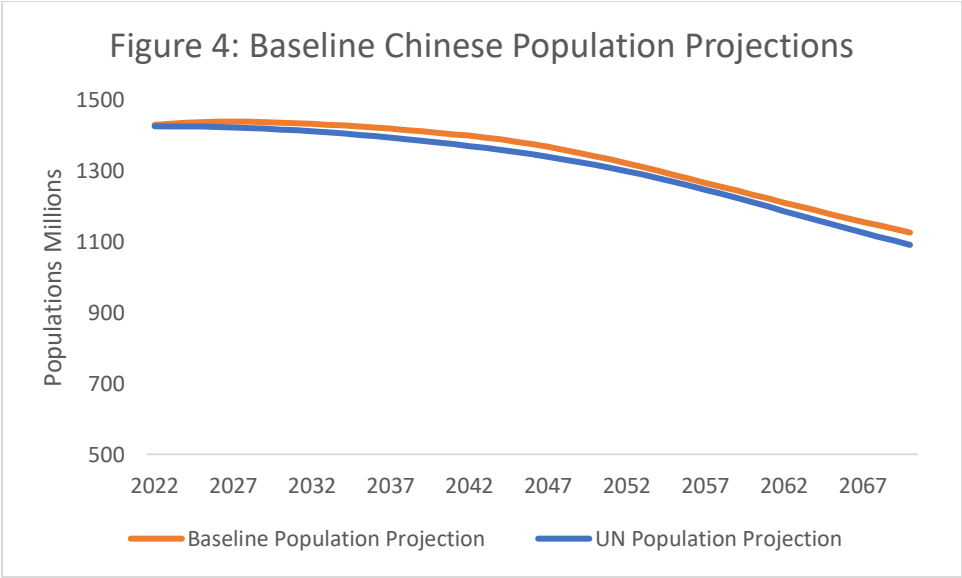
In addition, to projecting total population, the population demographics were also summarized in the next two figures below. Figure 5 splits the population into three categories, children (ages 0-19), working age population (ages 20-64) and retirees (ages 65+). In Baseline, the proportion of retirees increases from roughly 13.5% of the population in 2022 to 35.2% by 2070. This will put a strain on China's pensions and healthcare systems. Further, the amount, of children in the population continues to decline from 23% of the population to 14% of the population. This is likely driven by people aging out of the childbearing age and China's low fertility rates. Further based on Yi Fuxian's findings the future birth rates could be lower than what is projected. Fuxian asserts that China's birth reported rates are too high despite reported birth rates are already being concerningly low.

Figure 5: Baseline China Population Profile Projections
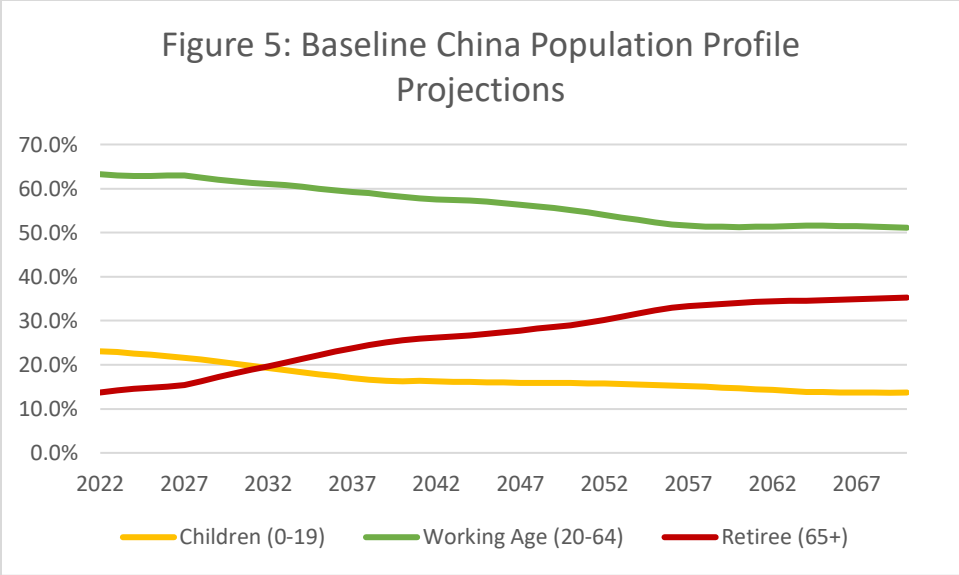
These population demographics were subsequently compared to the UN projections in Figure 6 below. The Baseline projection underestimates the Retiree Proportion when compared to the UN. This appears to be driven by differences in birth rates from the UN projections. Since Baseline projections assume higher births, the denominator used to calculate the Retiree Proportion is higher. In addition, Figure 6 also adds the projected US Retiree Proportion. This proportion was sourced from the Congressional Budget Office ("CBO") 2022 US population projections. As seen below, the US currently has an older population than China but this changes after 2033 and continues throughout the projection. This could be a point of optimism if you are on the US side of the US-China rivalry. However, it should be noted that this reversal is roughly 10 years away. In addition, the fact that China may struggle with an aging population does negate the fact that the financial strength of US social safety nets is in question. For example, the US Social Security system's depletion date is still projected to become insolvent by 2035 (SSBT, 2022) despite China's aging population.


Figure 6: Retiree Proportion - Baseline vs. UN Projections
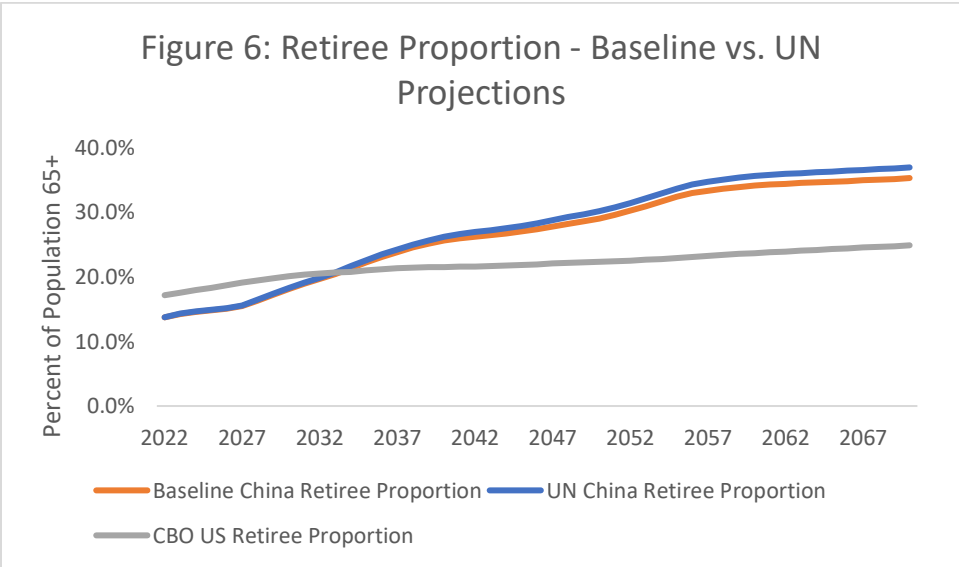
Sources: UN Chinese Projections: https://population.un.org/wpp/, US CBO Projections: www.cbo.gov/publication/57975
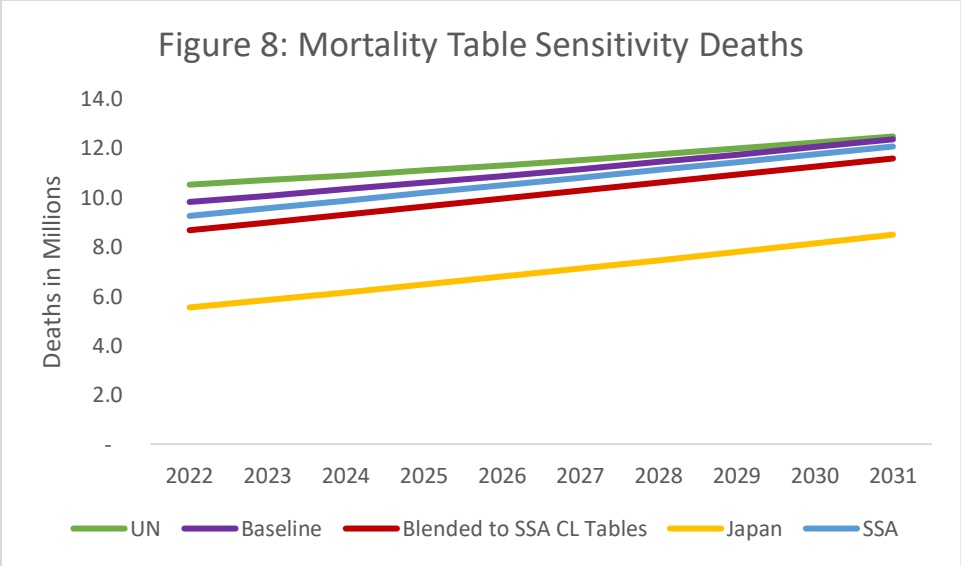
Sensitivities

Now we will shift our attention to the sensitivity results and their implications to China's population. We will start with the mortality sensitivities and then pivot to the Fertility sensitivities. Below, Table 4.1, summarizes the results of the Mortality Table sensitivity population projections at two key years, 2050 and 2070. Two interesting conclusions can be drawn. First, China must achieve Japanese level mortality to avoid population decline by 2050 (however, it will still decline by 2070 with Japanese mortality). As discussed previously, Japan is among the best countries in terms of life expectancy. Based on the fact that China's reported life expectancy is similar to the US, it seems unlikely that it could achieve this feat in near future. However, since China's old age mortality is high one could argue that it has "room for improvement" which would increase the Retiree Proportion and subsequently strain China's safety net. No one should be against improving elderly mortality. However, like many things, improving elderly mortality comes with tradeoffs which appear significantly punitive to China based on its current demographics.

Table 4.1: Mortality Table Sensitivity Population Projections				
		2050 Delta		2070 Delta
Year	2050	UN	2070	UN
UN	1317		1091	
Baseline	1341	1.9%	1126	3.2%
Blended to SSA CL Tables	1365	3.7%	1162	6.5%
Japan	1444	9.7%	1258	15.3%
SSA	1353	2.7%	1148	5.3%

Figure 7 summarizes the Retiree Proportion for the various sensitivities. Japanese mortality leads to a higher Retiree Proportion while all other tables appear to have similar proportions compared to the UN projections.

Figure 7: Mortality Table Sensitivity Retiree Proportion
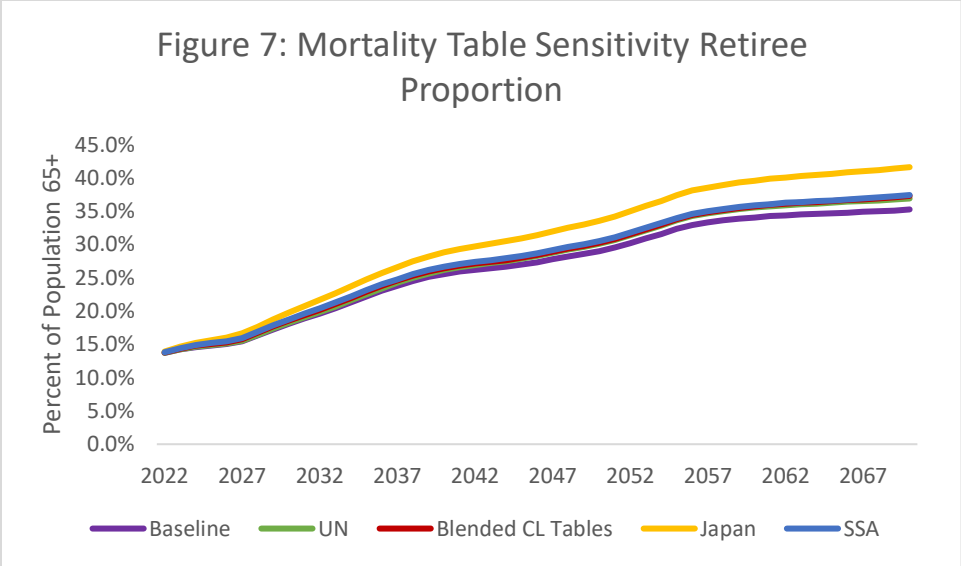
The UN death projections for China are around 10-11 million people per year in the near term (10 years) as can be seen by Figure 7 below. This is slightly higher than projected by Baseline. SSA tables and Blended to SSA CL tables result in lower future mortality as well. This is because both of these tables have lower mortality than the pure CL tables. The reason why the blended tables is lower than both CL tables and the SSA tables is because blended CL tables have lower young-age mortality than the US SSA tables and lower old-age mortality than the CL tables. This dynamic is because the US has high young-age mortality and China appears to have high old-age mortality. US mortality is high at these ages because of poor mortality experienced in the 21st century thanks in large part to opioids and other deaths of despair (Case and Deaton, 2020).

Figure 8: Mortality Table Sensitivity Deaths

Below Table 4.2, presents the mortality improvement sensitivities. The 0.5% mortality improvement sensitivity decreases the Baseline 2070 population by roughly 60 million and the 2% improvement scenario increases the 2070 population by 80 million. Mortality improvement is particularly sensitive in the long run due to its compounding nature.

Table 4.2: Mortality Improvement Sensitivity Population Projections				
		2050 Delta		2070 Delta
Year	2050	UN	2070	UN
UN	1317		1091	
Baseline	1341	1.9%	1126	3.2%
.5% Mortality Improvement	1315	-0.2%	1068	-2.1%
2% Mortality Improvement	1375	4.4%	1206	10.5%

Now it becomes time to analyze the fertility sensitivities. Table 4.3 below summarizes the results for two key years, 2050 and 2070. The Low Birth Rates Persist scenario is of particular interest as these birth rates are more in line with those reported by China in the two recent years. This sensitivity leads to just under a 100 million reduction in population compared to the Baseline 2070 projections. Interesting, the High Birth Rates leads to roughly a 140 million person increase in 2070 compared to the Baseline projections. These birth rates are based on peak birth rates reported by China from 2009 to 2018. However, these birth rates may be fraudulent as discussed by Yi Fuxian's (Fuxian, 2022).

Table 4.3: Fertility Sensitivity Population Projections				
		2050 Delta		2070 Delta
Year	2050	UN	2070	UN
UN	1317		1091	
Baseline	1341	1.9%	1126	3.2%
High Birth Rates	1410	7.1%	1264	15.8%
Low Birth Rates Persist	1293	-1.8%	1034	-5.2%
Equal Males and Females	1342	1.9%	1131	3.7%

Figure 9 below compares the projected births under various scenarios. The Low Birth Rates persist scenario is most in line with the UN projection. However, this scenario assumes that low birth rates experienced in 2020 and 2021 continue indefinitely. The Baseline assumes a rebound because these low birth rates may have been driven by Covid and the Chinese government could add incentives because of its interest in preventing population collapse. In addition, the Baseline and the UN projections begin to converge at the end of the 10-years as shown in the figure below. The Equal Males and Females sensitivity was excluded as the aggregate birth rate was set to the same as Baseline (although the future population projections will diverge). This sensitivity appears to have limited impact compared to Baseline as seen in Table 4.3 above. This scenario may be limited by the interplay between birth rates and the skewed sex ratio which may have not fully been captured in the modeling.

Figure 9: Fertility Sensitivity Births
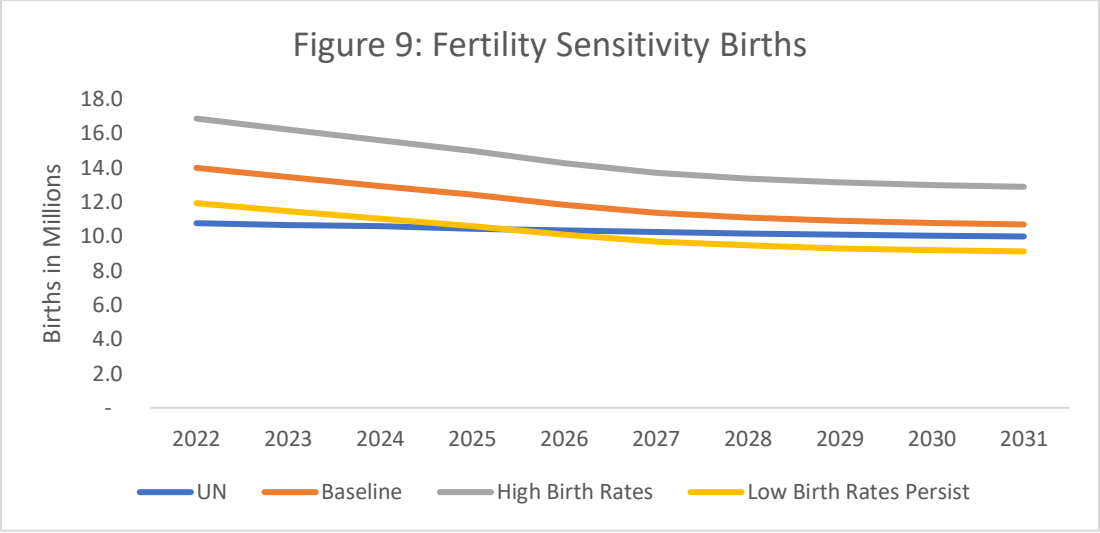
Conclusion

China's future population has significant political and economic implications. As alluded to earlier, it is an emerging super power that appears poised to challenge the US. However, its future population paints a less optimistic picture. For the first part it has a rapidly aging population. This could lead to economic stagnation and strain as its working age population begins to retire. In addition it is projected its population will decline. The Baseline projections project that China's population will decline over the next 50 years despite the Baseline's conservative (relative to the UN) projections. Further, it appears China has fairly high mortality which leads to elderly Chinese dying at higher rates than other countries. If the older age mortality were to improve to align with other peer nations, it could realize an even older future population. The second component of China's poor population outlook is its low birth rates. Chinese fertility rates are low in the aftermath of China's one-child policy and have declined in recent years. Further, it is possible that China's younger population is overstated and its birth rates are even lower than reported. This has worrying implications for China as it indicates that its future population decline and its future Retiree Proportion will both be more severe. Overall, to correct for the low birth rates experienced over the last 30 years, China may need to open its borders to immigration or find a way to get its citizens to have more children.

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