ECN 723 Research Project

Japan's Population Decline: An Economic Analysis

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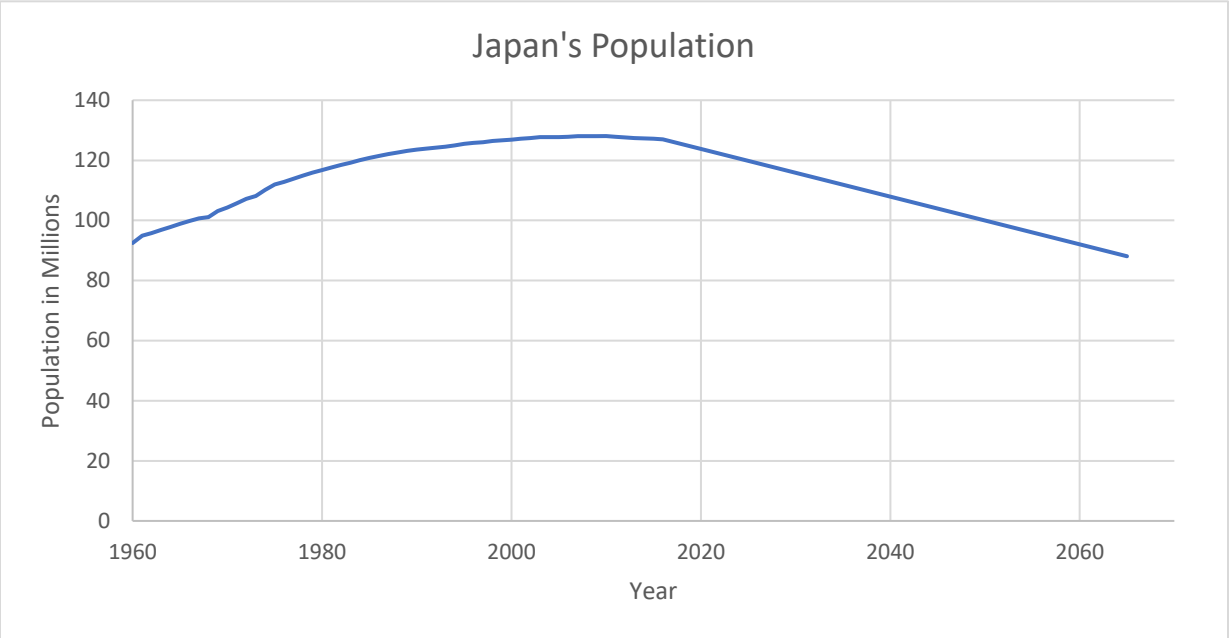
ABSTRACT

This paper studies how a large decline in population may affect the economy of Japan, its two biggest trading partners, and to a lesser extent the rest of the world. Japan's projection of negative population growth is an abnormality when compared to other countries with large economies of the world. The paper finds that even though Japan suffers a large population decline the economic effects may not be as disastrous relative to the current standing of the Japanese economy.

1. Introduction

The purpose of the project will be to discover what the economic effects are on Japan, its crucial trading partners, and the rest of the world with a rapid decline in Japan's population projected for the near future. Japan being the worlds third largest economy based on gross domestic product "GDP ranking by The World Bank (2017)" it will be valuable to analyze the effects of a significant decline in the population of a large player on the economic stage of the world. Japan's population is projected to decline by 30.7% by 2065 (from 127.09 to 88.08 million) "Population Projections for Japan by Tokyo National Institute of Population and Social Security Research (2017)" and population shocks to every other region accordingly. To perform this analysis GTAP will be used, countries, sectors and factors must be set up accordingly for meaningful results to be found. There will be four country groups set up: Japan, USA, China, and the rest of the world (USA and China are separate as they are the largest trading partners of Japan). Sectors will be categorized into seven groups raw primary, labour-intensive manufactured goods, manufacturing goods, transportation(includes utilities and communication), business services, recreational goods, and government expenditure. Finally, five-factor categories will be created land, unskilled labour, skilled labour, capital and natural resources. The paper's subsequent sections are as follows. Section 2 is a review of other papers on the economic impact of the projected population decline in Japan with a variety of findings and conclusions. Section 3 explores the model used to run the experiment and how it has been set up to find meaningful results. Section 4 provides an important preface to the results by presenting statistics found within GTAP relevant to the experiment used for analysis of results. Section 5 provides the results of the various experiments used to

simulate the economic impact of the population decline on Japan's economy. Lastly, section 6 offers a conclusion and final thoughts on the implications of the results found.



2. Literature Review

Japan is currently in a state of severe population decline, and as one of the worlds largest economies, this leaves many economists wondering how or even if at all a population decline will affect Japan's economy. Wong and Furuoka (2005) explore the topic further and investigate the relationship between population and economic growth in East Asian countries. Using the methodology of the Granger causality test, in the countries of Japan, Korea and Thailand they found that a bidirectional Granger causality existed between population and economic growth. This is to say that economic growth affects the population, and population affects economic growth. Subsequently, many future research papers do not question if population declines will affect the economic growth

of Japan, but rather how Japan can hope to resolve the specific issues it will face in the near future due to the current downward trend of population. Horioka et al. (2007) explored the effect that the population decline had on Japan's household savings rate and made predictions for figures Japan may see in the near future regarding household savings rates. Results illustrated that a major determinant of future trends in the household savings rate in Japan can be directly linked to the age structure of the population, mainly based on the life-cycle hypothesis. This paper predicts that Japan will see zero or even negative levels of household savings rates in the years 2010-2024, which was true for 2014. Much like Horioka et al. (2007) Muto et al. (2016) is concerned with the macroeconomic impact of population ageing in Japan with regards to GNP and what can theoretically be done to avoid decreases in GNP. The paper argues that Japan had one of the lowest dependency ratios of all G7 nations in 1990 but had become the highest by 2010 and will remain that way for the foreseeable future. The paper works with these key data in an overlapping generations model finding that GNP growth is adversely affected by the current population trend by the lowering of factor inputs. It is also found that fertility rates have a larger role in the decrease of GNP growth than that of longevity as it decreases workforce size and the ratio of savers in the economy. Muto et al. (2016) prescribe that domestic households should seek out higher return investments abroad which could possibly mitigate the negative effects on GNP that Japan will face in the future. Rather than prescribing domestic households a solution Braun and Joines (2015) lay out what the Japanese government will have to do to avoid a looming fiscal crisis, the model used in this paper was also an overlapping generations model identical to that of Muto et al. (2016). Unlike other papers, this focuses on the effects the population decrease will have even into the next century as the dependency ratio will eventually peak at over 87% and

by 2110 population will drop to 45.9 million from 127.2 million in 2013. The paper finds that to avoid this fiscal crisis the Japanese government will have to reduce government expenditure and raise taxes. It is also found that measures that would be implemented to increase fertility rate may even worsen the fiscal standing of Japan in the immediate to the short run. Mikio (2015) unlike the other papers listed above measures the impact of an ageing population on the economic growth in terms of real GDP per capita in Japan. The paper used a regression method to measure the effects that the dependency ratio and various age groups have on real GDP per capita. Interestingly the paper finds that every age group from 15-75+ except the age group of 70-74 experiences a real GDP per capita growth when those age groups rise in population. This is similar to the results that Muto et al. (2016) found in which longevity does not negatively affect GNP growth but rather a decreasing fertility rate does. Furthermore, it is found that dependency ratios have a higher effect on real GDP growth as dependency ratios rise real GDP per capita growth falls.

3. Model

The model used in this paper to demonstrate the effects of an exogenous population shock to Japan is the Computable General Equilibrium model (CGE) ran through the GTAP software program. The model is designed to quantify how an economy may react to changes in technology, policy or exogenous variables. It must also be noted that the CGE model is static in nature, that is to say, that the model shows the reaction of the effect at only one point in time and each explicit variable cannot be traced through time. The specific experiment in this paper works with the aggregation of four regions, four factors and seven sectors which are expanded upon later in the section. The CGE is

also heavily reliant on many assumptions which may not always apply to the real world. *Figure 1* presents a flow diagram of all the transactions between of agents in the economy presented within the CGE model. This study is concerned first and foremost with the relationship between consumers, producers and the government within Japan, then Japan's connection with specific nations, and lastly the rest of the world.

The model also has the assumption that consumers are all uniform in nature and buy goods in such a way to maximize utility subject to their budget constraint presented below.

$$\sum_{i=1}^{7} pi(1+\tau_i^c)c_i \leq (1-\tau^{inc})(wL+rK)+T$$

The summation is of all seven sectoral goods produced in the hypothetical market represented by *(C_i)* which are multiplied by price *(P_i)* with the appropriate consumer tax applied represented by (τ_i^C). The goods available to the consumer are, *(C_1)* primary sector goods, *(C_2)* machine manufactured goods, *(C_3)* labour-intensive manufactured goods , *(C_4)* utilities, transportation and communication , *(C_5)* business services, *(C_6)* recreations, and *(C_7)* government expenditure. This hypothetically encompasses all of the spending for the consumer which in turn is subject to the constraint of being no greater than the money earned by the consumer after taxes. To further explain the expenditure side of the budget constraint for the consumer, (τ^{inc}) represents income tax placed on the consumers profits which come from (wL) and (rK). Furthermore, (wL) is wages(w) received by consumers for labour hours(L) used by producers, and (rK) is rent (r) received through capital (K) use by producers.

Conversely, producers face the issue of cost minimization as they are concerned with profit, this can be written as below.

$$min_{x_{s,j}} \sum_{i=1}^{7} Pi(1+\tau_i^x)x_{i_j} + wL_j + rK_j$$

subject to

$$y_{dj} = min\left\{z_{int,j}, v_j\right\}$$

where

$$z_{int,j} = min\left\{\frac{x_{1,j}}{a_{1,j}}, \frac{x_{2,j}}{a_{2,j}}, \frac{x_{3,j}}{a_{3,j}}, \frac{x_{4,j}}{a_{4,j}}, \frac{x_{5,j}}{a_{5,j}}, \frac{x_{6,j}}{a_{6,j}}, \frac{x_{7,j}}{a_{7,j}}\right\}$$

$$v_j = F\left(K_j, L_j\right)$$

Equations made using MathType

The final good produced by the firm is represented by (y_{dj}) is produced using an intermediate mix (z_{intj}) and a value added mix (v_j). The intermediate mix for good (j) is produced using intermediate goods (x_i) $i = 1,2,\ldots,7$, with a unit requirement of (a_{ij}). Lastly, the value added mix is a function of (K) capital and (L) labour

The CGE model within the GTAP software program has three separate aggregation categories. The first of the three aggregation categories is a regional aggregation which in this paper was sorted as follows Japan, USA, China, and the rest of the world. USA and China as separate regions as they are the most significant trading partners of Japan and interesting results may be found from the relations of these countries before and after the exogenous shock Japan receives to its population. The next aggregation grouping is of

factors which are land, unskilled labour, skilled labour, and natural resources. The most important of the factor aggregations for the current experiment is that of labour: since the population is shocked it is valuable to categorize labour based on skill since the relative mix changes as population ages. The last aggregation input into GTAP is that of production sectors which are as follows primary, manufacturing, labour intensive manufacturing, utilities and transportation, business services, recreation, and government expenditure. Sectoral aggregations were first split into primary, manufacturing, and service categories with the extra remaining sectors such as labour manufacturing, utilities and transportation (includes communication), and government expenditure split out, this was done because these sectors may bare meaningful results regarding the effects of a population shock on Japan. Conversely, the results of an exogenous population shock on different types of primary sectors may not be very meaningful hence the reason to keep all primary sectors combined.

Three separate experiments are implemented in the model to illustrate the impact of an exogenous population shock to Japan to simulate Japan's projected population in the year of 2065 receiving a static image of the economy and the changes from the present day[1].

The first shock is a population shock[2] (shock to variable POP) on Japan of -30.6% based on the long-term projections of population by the Tokyo National Institute of Population and Social Security Research, Japan's population is expected to decrease from 127.09 to 88.08 million by 2065. To simulate the passing of time until the year of 2065, it is not appropriate to only change population in Japan as it is, of course, changing everywhere.

[1] In this case present day is not Dec 2017 but rather the year GTAP's database was set to which was 2011.

The USA receives a shock of +31.5% based on a UN projected population increase from 312.39 to 410.90 million by 2065 in population, China -8.33% based on a UN projected decrease from 1,348.17 to 1,236.66 million by 2065 , and the rest of the world +65.34%based on a UN projected population increase from 5,225.61 to 8,640.08 million by 2065. Prices in the sectors of government expenditure and recreation in Japan are effectively reduced by introducing a production subsidy (shocking the variable TO). This is done to simulate the fact that by 2065 roughly 42% of the Japanese population will be of the age 60 or over and, therefore, the spending patterns must change leaning towards higher expenditure of consumer income towards recreational and government expenditure goods such as healthcare.

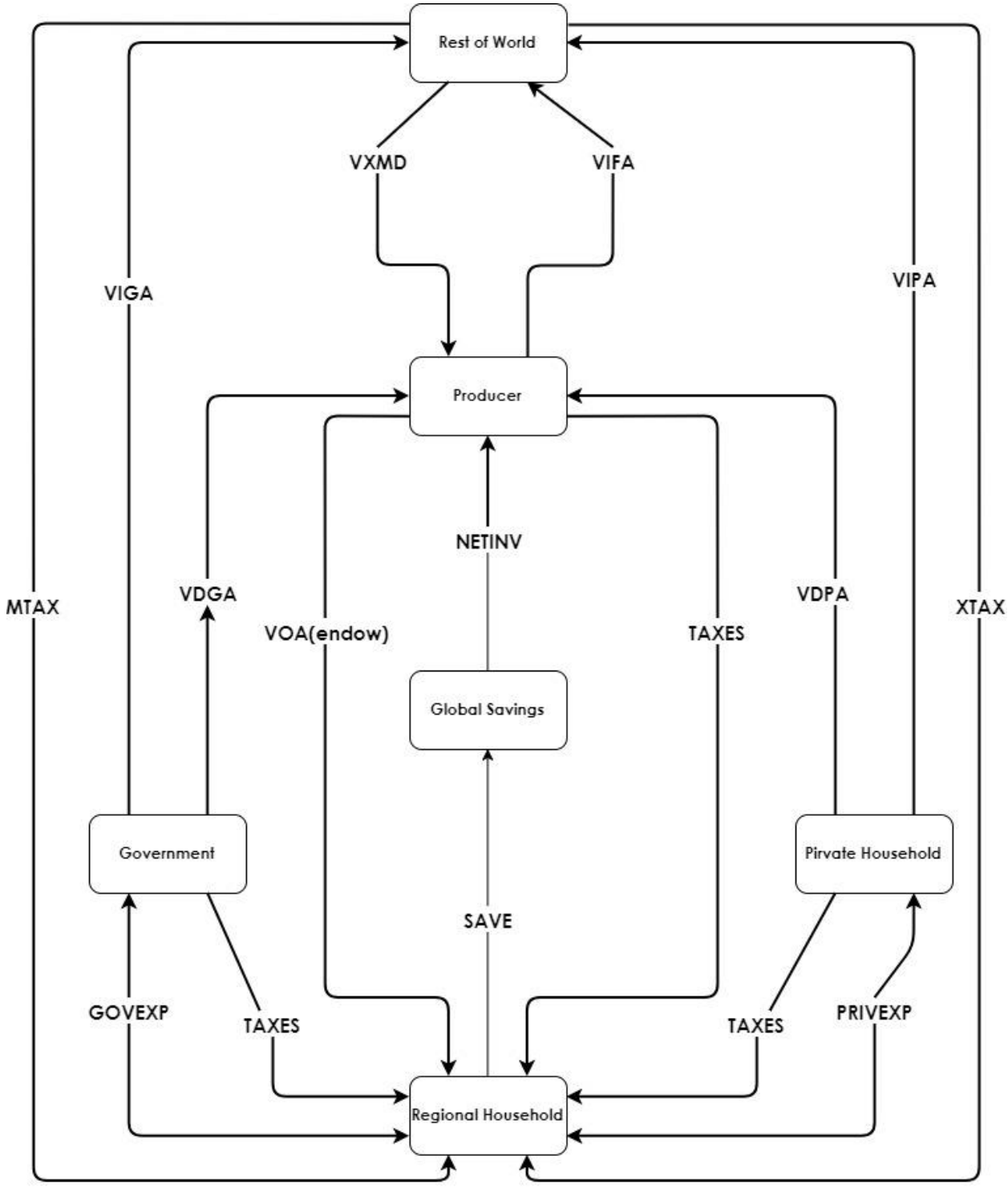
The second experiment adds to the first by also accounting that for the fact that the mix of skilled and unskilled labour changes as populations age. The variable QO is used to shock the endowment of the specific skill level of labour factor. Skilled labour makes up 77.56%[3] of Japan's workforce while 22,44% is unskilled labour. This is used to calculate a shock on each labour skill level from total population decrease, skilled labour experiences an exogenous shock of -23.73% and unskilled labour experiences an exogenous shock of -6.87%., these figures were calculated by multiplying the population decrease on today's endowment of unskilled and skilled labour proportionally.

The third and final experiment is a macro projection exercise. By 2065 capital and technology will change significantly. The variable AOALL and QO is shocked to take into account technological change for all nations. Japan receives a shock of +77.69% which represents the changes to capital and technology, based on long-term

[3] Figures for Japan's workforce skill level was taken from the World Bank.

projections of GDP by the OECD. Furthermore, the USA and China will receive the appropriate projected shock, the rest of the world will receive an increase of 2% each year. With these three shocks combined, it is expected that results become more and more illustrative of the impact that a significant exogenous population shock would have on an economy such as Japan's.

*Figure 1: CGE Circular Flow Diagram (MADE USING THIRD PARTY PROFRAM)*****************



4. Descriptive Statistics

To understand what affects the projected population decrease in Japan will have on the Japanese, Chinese, and American economies[4] it is important to understand the standing of the economies before any exogenous shocks are applied[5]. Firstly, it is valuable to analyze the export patterns of Japan to hypothesize the effects of a significant exogenous population shock. Below illustrated in *table 1* it is easily observable that Japan's exports encompass goods of a manufacturing nature. There appears an important distinction between both manufacturing sectors that must be noted, the labour intensive manufactured goods make up about 62% of all of Japan's exports which alone makes up 8.5% of Japan's GDP for the year of 2011[6]. The fact the majority of exports are heavily reliant on labour may imply a negative effect when the population is shocked. The labour-intensive manufacturing sector in totality accounted for roughly 27.5% of Japan's GDP in 2011.

Table 1: Japanese Export Shares by Sector ($Billions USD)

Sectors	Exports Total	Exports Share in Total	Exports to USA	Exports to China	Exports to Rest of the World
Primary	6.2	1%	0.9	0.7	4.6
LbrManufacturing	542.8	62%	104.1	121.7	317.0
Manufacturing	233.3	27%	23.5	50.7	159.0
UtiliCom	52.1	6%	4.4	5.8	41.9
Business	29.2	3%	6.7	1.0	21.4
Recreation	2.7	0%	0.5	0.3	1.9
GovtExpe	5.3	1%	2.5	0.3	2.5
TOTAL	**871.6**	**100%**	**142.6**	**180.5**	**548.5**

[4] To a lesser extent the effect on the remaining economies of the world as well.
[5] Important to note that all data was created from GTAP using the 2011 data base for all results.
[6] Using the income method calculation of GDP in GTAP, total GDP of Japan is $6,419 billion USD or $6.419 trillion USD .

As mentioned in the previous section labour-intensive manufacturing accounted for about 27.5% of Japan's economy in terms of GDP. Furthermore, It is also valuable to analyze the costs that each sector incurred to understand to what extent is labour a part of the Japanese economy.

Table 2: Japanese Sector Factor Costs ($Billions USD)

Sectors	Land	Unskilled Labour	Skilled Labour	Capital	Natural Resources	Total
Primary	9.4	62.5	20.3	90.5	5.3	187.9
LbrManufacturing	0.0	204.0	108.3	138.1	0.0	450.3
Manufacturing	0.0	117.7	62.5	127.4	0.0	307.6
UtiliCom	0.0	640.1	384.7	600.6	0.0	1625.3
Business	0.0	174.4	311.2	427.2	0.0	912.9
Recreation	0.0	56.7	38.3	661.9	0.0	756.9
GovtExpe	0.0	167.8	668.9	304.3	0.0	1141.0
Total	**9.4**	**1423.2**	**1594.2**	**2349.9**	**5.3**	**5381.9**

Shown above in *table 2* are the factor costs for every sector in Japan. *Table 2* illustrates the vital role that labour plays in the Japanese economy. Labour irrespective of skill level make up more than half of all sector factor costs at %56. It can also be noted that most factor costs for unskilled labour are incurred in the utilities, transportation, and communication sector, these unskilled labourers are a vital part of Japan's economy allowing Japan as an island nation most importantly to trade with the rest of the world as the worlds 5th largest player on the global stage. *Table 3* below provides an alternative view to *table 2* in terms of percentage, it is easier to identify which input factors for each sector play the biggest role relative to cost. With these two graphs it can be seen that the two biggest sectors "UtliCom"[7] and "GovtExpe"[8] are the most reliant on labour in terms of cost. It is fair to say that the two sectors which are very labour intensive may not

[7] Utilities, transportation and communication
[8] Government expenditures such as healthcare, defence, pension, etc.

even see reductions in labour costs even with an increase in technological efficiency because of the nature of the sectors.

Table 3: Japanese Sector Factor Costs (%)

Sectors	Land	Unskilled Labour	Skilled Labour	Capital	Natural Resources	Total
Primary	5%	33%	11%	48%	3%	**100%**
LbrManufacturing	0%	45%	24%	31%	0%	**100%**
Manufacturing	0%	38%	20%	41%	0%	**100%**
UtiliCom	0%	39%	24%	37%	0%	**100%**
Business	0%	19%	34%	47%	0%	**100%**
Recreation	0%	7%	5%	87%	0%	**100%**
GovtExpe	0%	15%	59%	27%	0%	**100%**

Illustrated below in *Table 4* are each sector share in factor employment across all sectors. Interesting results to be found are as described previously that labour irrespective of type make up roughly 56% of all factor costs in the Japanese economy. Furthermore, *table 4* re-emphasizes the importance of the "UtiliCom" and "GovtExpe" sectors, the two sectors account for about 51% of all factor employment costs in the Japanese economy with the 7 sector model presented.

Table 4: Japanese Sector Shares in Factor Employment (%)

Sectors	Land	Unskilled Labour	Skilled Labour	Capital	Natural Resources
Primary	0%	1%	0%	2%	0%
LbrManufacturing	0%	4%	2%	3%	0%
Manufacturing	0%	2%	1%	2%	0%
UtiliCom	0%	12%	7%	11%	0%
Business	0%	3%	6%	8%	0%
Recreation	0%	1%	1%	12%	0%
GovtExpe	0%	3%	12%	6%	0%
Total	**0%**	**26%**	**30%**	**44%**	**0%**

The four tables presented illustrate important findings that need to be taken into account when analyzing results of the model after the exogenous shock is applied. Labour intensive manufacturing made up 27.5% of Japan's total GDP and makes up 62% of all Japanese exports which states the importance of the sector. This is to say that the labour intensive manufacturing sector is a major driver within the Japanese economy, which due to the nature of the sector may be affected to a large extent when a population shock is introduced. The labour force within the labour-intensive manufacturing sector makes up 69% of all factor costs[9] which implies the vital role of the labour force within the sector. Conversely, it can be noticed that the sector of utilities, communication and transportation spends the most of all sectors on labour cost factors. The costs that are incurred encompass a staggering 19% of all factor costs experienced in the Japanese economy. The sector of government expenditure is the second biggest spender on labour across the Japanese economy incurring 15% of all factor costs, of which 12% is skilled labour.[10] The two sectors alone combine to make 34% of all factor costs in the Japanese economy just spent on labour. This is to say when a large exogenous population shock to the economy is applied the two sectors stated would be to a large extent affected as they incur a large amount of the Japanese labour force cost. Labour intensive manufacturing accounts for only 6% of Japan's factor costs in terms of labour but is a large driver of GDP which demonstrates the efficiency of the industry.

[9] Unskilled labour accounts for 45% of all factor costs within the labour intensive manufacturing sector while unsurprisingly skilled labour only makes up 24% of all factor costs.
[10] See *table 4* for sector factor share costs.

Table 5: Japanese Sectors Labour Cost Shares

Sectors	Unskilled Labour	Skilled Labour	Total	Unskilled Labour Share %	Skilled Labour Share %
Primary	62.5	20.3	82.7	76%	24%
LbrManufacturing	204.0	108.3	312.3	65%	35%
Manufacturing	117.7	62.5	180.2	65%	35%
UtiliCom	640.1	384.7	1024.8	62%	38%
Business	174.4	311.2	485.6	36%	64%
Recreation	56.7	38.3	95.0	60%	40%
GovtExpe	167.8	668.9	836.8	20%	80%
Total	**1423.2**	**1594.2**	**3017.4**		

Table 6: Japanese Total Labour Cost Share by Sector

Sectors	Unskilled Labour	Skilled Labour	Total	Unskilled Labour Share %	Skilled Labour Share %
Primary	62.5	20.3	82.7	2%	1%
LbrManufacturing	204.0	108.3	312.3	7%	4%
Manufacturing	117.7	62.5	180.2	4%	2%
UtiliCom	640.1	384.7	1024.8	21%	13%
Business	174.4	311.2	485.6	6%	10%
Recreation	56.7	38.3	95.0	2%	1%
GovtExpe	167.8	668.9	836.8	6%	22%
Total	**1423.2**	**1594.2**	**3017.4**	**47%**	**53%**

Table 5 & *table 6* illustrate further each sectors preference of labour type which is important to take into account when analyzing results of an exogenous population shock. Japan's dependence on labour types based on cost is almost even between skilled and unskilled labourers. *Table 5* presents that 5 of 7 sectors are dependent on unskilled labour but these 5 sectors most dependent on labour make up for than less of half of all labour costs in the economy. This can be taken as the 5 sectors heavily dependent on unskilled labour already have a very high efficiency, more obvious so is labour intensive manufacturing as they account for a large portion of the Japanese economy.

5. Results

The results illustrate the findings after simulating all three experiments. The first experiment encompasses an exogenous shock on population for all regions and a simulation of an ageing population in Japan. The second experiment adds to that of the first by shocking endowment of unskilled and skilled labour proportionally with respect to the population shock implemented. Lastly, the third experiment further adds to the two previous ones by including a shock to technology and capital for all regions. The main objective of this exercise is to illustrate what effect might an exogenous shock of the population have on the Japanese economy, the USA's, that of China's and to a lesser extent the rest of the world.

5.1 Population and Aging Simulation Experiment

The first experiment is the least illustrative in terms of results, of all the shocks but presents a base framework for the shocks to build off of and allow reflection upon differences between each experiments results. *Table 7* presents the change in private household demand for commodities in each respective region. We observe that the most affected sector across all regions is the primary sector, which encompasses food the changes are as follows: -8.94% Japan, +3.93+ USA, -3.71% and ROW +15.08%. The change in private household demand can be attributed to the change in population which each region experiences, in each region where a negative shock on population was implemented a fall in private household demand for primary goods fall and vice-versa. Furthermore, illustrated in *table 7* is the effect that an ageing population has on private household demand change for specific sectors such as recreation (+4.20% in Japan) and government expenditure (+0.49% in Japan), as population ages more money will be

spent on leisure goods by the ageing population and the government experiences an increase in demand for public services. The simulation of age was implemented in GTAP by providing a production subsidy for the amounts visible in table 7 effectively removing taxes. This analysis of the results is also backed up by the life-cycle hypothesis stated in Horioka et al. (2007).

Table 7: Change in Private Household Demand (%)

Sectors	Japan	USA	China	RestofWorld
Primary	-8.94	3.93	-3.71	15.08
LbrManufacturing	-1.11	0.45	-1.7	1.21
Manufacturing	-1	-0.35	-0.88	-1.67
UtiliComm	-0.18	-0.36	0.83	-3.64
Business	-0.1	-0.34	1.49	-4.29
Recreation	4.2	-0.47	1.35	-3.71
GovtExpen	0.49	-0.38	1.31	-3.83

Table 8 and *Table 9* present the changes that each region experience in terms of price for factors and commodities respectively. Price of land in Japan decreases by a significant amount (-12.04%) this can be solely attributed to the fact that land only makes up 0.17% of all factor costs in Japan and is solely used by the primary sector making up just 5% of all of its factor costs. Furthermore, the change in private household demand for primary goods in Japan (-8.94%) affects the primary's sectors demand for factors of input such as land. Furthermore, illustrated in *table 8* is the rising prices of both types of labour (unskilled labour +0.14% skilled labour +0.34%) and capital (+1.24) in Japan, while prices for these three factors fall in the other regions. This can be attributed to the rise or decline in the market's supply of each factor. When the amount of labourers decreases in an economy wages become more competitive rising in nature, and conversely when the supply of labourers increases by a large amount the workforce becomes more competitive overall reducing wages. The increase in the price of capital can be

attributed majorly to the increased demand for recreational goods, the recreational sector has capital making up 87% of all it's factor costs. That is to say as private household demand for recreational goods (+4.20%) rises in the Japanese economy the market price for factor capital (+1.24%) increases because of the increased demand for capital by the recreational sector which makes up for 28.16% of all capital costs demand in the Japanese economy. *Table* 9 illustrates that most countries excluding Japan overall experience a decrease in commodity good prices, which can be related to the falling prices of input factors for manufacturers this means a decrease in market price can be correlated to the changes felt in each respective economies market price of factors. Conversely, prices in primary goods rise in all regions (+0.31% Japan, 1.04% USA, +0.15%, and +2.24%) as food is growing in demand for a rising world population prices rise across all regions.

Table 8: Market Price Change in Factors (%)

Factors	Japan	USA	China	RestofWorld
Land	-12.04	11.47	1.04	18.18
UnSkLabour	0.14	-0.24	-0.22	-0.37
SkLabour	0.34	-0.34	-0.02	-1.24
Capital	1.24	-0.18	-0.23	-0.63

Table 9: Market Price Change in Commodities (%)

Commodities	Japan	USA	China	RestofWorld
Primary	0.31	1.04	0.15	2.24
LbrManufacturing	0.5	-0.11	0	-0.3
Manufacturing	0.79	0.32	0.19	0.24
UtiliComm	0.6	-0.15	-0.03	-0.31
Business	0.58	-0.26	-0.13	-0.67
Recreation	-4.18	-0.13	-0.13	-0.56
GovtExpen	0.04	-0.24	-0.04	-0.72

Table 10 presents the effects of the shock applied on the output of commodity goods by sector and region, it is understandable that industry output of commodities in Japan is decreasing as market prices for vital input factors are increasing in Japan and decreasing in other regions, land is considered non-vital as it only makes up 0.17% of all factor costs in Japan and is only used by the primary sector to make up 5% of their factor costs. There also seems to be a reorganizing of outputs towards primary goods in the other sectors as it is a necessary good and prices around the globe are rising for the commodity providing manufacturers with an opportunity to enter the market. The first shock presents valuable knowledge with the basic knowledge of the effect a basic shock has on Japan's economy in terms of household demand, output and market price changes. Other results such as a change to GDP were not as illustrative of the effect and were not presented, the next two shocks which become more elaborate hold more interesting results.

Table 10: Industry Output of Commodity Change (%)

Commodities	Japan	USA	China	RestofWorld
Primary	-5.38	4.04	0.42	6.02
LbrManufacturing	-2.31	-0.02	-0.68	0.73
Manufacturing	-1.8	-0.14	-0.19	-0.25
UtiliComm	0	-0.12	-0.1	-1.24
Business	-0.27	-0.19	-0.06	-1.08
Recreation	4.13	-0.49	0.8	-3.21
GovtExpen	-0.23	-0.25	0.39	-1.23

5.2 Population, Aging Simulation, and Labour Level Experiment

The second experiment, as stated previously, adds to the first, specifically by providing a shock to skilled and unskilled labour associated with the population shock to indicate that as population changes so do the endowment of each labour source. The tables presented in this section are the same as in the previous experiment to provide a comparison to what the new additional shock changes. Additional tables are added when necessary to better indicate the intuition behind the results. *Table 11* provides an effective example to the extent of the changes experienced between the first and second experiment (see *Table 7)*. *Table 11* further illustrates that private household demand for Japanese sectoral goods has changed to a much greater extent than any other region, this also displays the private households ease to switch pattern of spending. This extreme change between *Table 7* to *Table 11* displays the vital role that labour of both unskilled and skilled nature play on the Japanese economy, as we reduce the endowment of labour across the Japanese economy Japanese sectors most reliant on labour are hardest hit, hence that decreases in private household demand for all these sectors seem similar with the exception of recreation. The recreational sector in Japan, unlike others, only have labour as a whole making up 12% of its total factor costs and only 3% of all labour factor costs in Japan itself.

Table 11: Change in Private Household Demand (%)

Sectors	Japan	USA	China	RestofWorld
Primary	-16.03	4.12	-3.64	15.16
LbrManufacturing	-12.79	0.71	-1.57	1.32
Manufacturing	-12.63	-0.13	-0.76	-1.57
UtiliComm	-11.21	-0.29	0.96	-3.59
Business	-11.45	-0.29	1.62	-4.26
Recreation	-2.99	-0.41	1.47	-3.68
GovtExpen	-13.56	-0.34	1.42	-3.81

Table 12 alternatively provides a view of the change in market price of factors experienced in the second shock. Overall Japan experiences the largest changes in market prices, Japanese land and capital experience the largest deductions in price of all sectors at -25.66% and -9.89% respectively. The drastic reduction in market prices for Japanese land and capital can be attributed to their factor share in Japanese sectors, land only makes up 0.17% of Japanese factor costs and plays a 5% factor cost role only in the primary sector. Capital in the Japanese economy accounts for 44% of all factor costs but comes second to the 56% that labour takes up. Japanese producers will always prioritize labour more so than capital especially as population declines, hence why capital market price decreases more than that of unskilled labour. We also observe that unskilled Japanese labourers experience a decline in wages (-4.46%) while skilled Japanese labourers enjoy an increase in wages (+11.74%). The changes of wage suggest that skilled labour plays a bigger role in the Japanese economy than that of unskilled this can be confirmed by understanding that skilled labour makes up 30% and unskilled labour makes up 26% of all factor costs in the Japanese economy. Furthermore, skilled labour accounts for 53% of all labour costs within the Japanese economy while unskilled labour accounts for 47%, with almost half of that coming from one sector at 21%. The increase in wages of Japanese skilled labourers confirms the vital role skilled labour plays

in the economy as when the population and number of skilled workers drop producers offer a higher competitive wage to attract the skilled workers needed.

Table 12: Market Price Change in Factors (%)

Factors	Japan	USA	China	RestofWorld
Land	-25.66	10.45	1	17.67
UnSkLabour	-4.46	0.32	0.01	-0.08
SkLabour	11.74	0.22	0.29	-0.93
Capital	-9.89	0.36	0.01	-0.34

Table 13 complements *Table 12* as it provides a view of the change in the market price of commodities across all regions. Overall it is observed that Japan experiences the biggest changes in commodity prices, this may be to suggest that the Japan's marketplace prices are adjusting to meet world levels of prices for commodities and find equilibrium as it's economy has slowed, which implies a regional household income and value of GDP decline.

Table 13: Market Price Change in Commodities (%)

Commodities	Japan	USA	China	RestofWorld
Primary	-4.02	1.38	0.31	2.4
LbrManufacturing	-1.84	0.33	0.15	-0.08
Manufacturing	-1.47	0.72	0.36	0.45
UtiliComm	-2.53	0.35	0.17	-0.06
Business	-2.13	0.27	0.09	-0.39
Recreation	-12.06	0.37	0.1	-0.27
GovtExpen	0.85	0.28	0.2	-0.44

Table 14 presents the output changes experienced in industries across all regions. Unsurprisingly the decline of output in all Japanese industries can be for the most part attributed to the population change in the home market and could be partly due to the relocation of producers to economies on the rise, when seeking profit maximization. Furthermore, across other regions it is apparent that there is a significant reallocation of

interest from secondary and tertiary goods to primary commodities which can be attributed to the large increase in population experienced worldwide.

Table 14: Industry Output of Commodity Change (%)

Commodities	Japan	USA	China	RestofWorld
Primary	-9.34	3.5	0.32	5.77
LbrManufacturing	-1.28	-0.57	-1.14	0.25
Manufacturing	-3.51	-0.76	-0.45	-0.61
UtiliComm	-11.93	0.29	0.29	-0.91
Business	-10.25	-0.22	0.06	-0.99
Recreation	-2.94	-0.48	0.87	-3.2
GovtExpen	-13.51	-0.23	0.49	-1.2

Table 15 and *Table 16* provide additional relevant information that complements the results displayed. The results illustrate an economic downturn for the Japanese economy seeing a drop in household income, the value of GDP, industry outputs, and declines in commodity as well as factor prices to stay competitive. Though it may seem that the Japanese economy is affected greatly it is valuable to understand that the Japanese economy is currently the third largest economy and even losing 12.53% of GDP as in this experiment still leaves Japan as a player on the economic stage of the world. It is also worth noting that change in GDP -12.53% in Japan means that GDP per capita in Japan is rising as the Japanese population decrease was greater than the change in GDP at -30.6%.

Table 16: Change in Regional Household Income (%)

Region	Change
Japan	-14.22
USA	0.41
China	0.12
RestofWorld	0.34

Table 15: Change in Value of GDP (%)

Region	Change
Japan	-12.53
USA	0.39
China	0.12
RestofWorld	0.29

5.3 Population, Aging Simulation, Labour, Technological and Capital Experiment

The third and final experiment is the most elaborate of all and takes into account the changing technological inputs and capital of the world. The experiment illustrates the standing of Japan, the USA and China after including a population, ageing simulating, labour, technological, and capital shock (see appendix for a view of all shocks). *Table 17* reports the change in private household demand for sectoral goods by region. *Table 17* illustrates something that was not present in the previous two experiments, the extent to which the USA, and China benefit is much larger as the change in private household demand is increasing for every sector in the two countries. China enjoys the benefits of the technological and capital boost more than the USA, this can also be attributed to China catching up to the USA in term of technological and capital abilities because the country is currently considered less developed than the USA.

Table 17: Change in Private Household Demand (%)

Sectors	Japan	USA	China	RestofWorld
Primary	-14.46	9.08	6.11	17.63
LbrManufacturing	-10.44	6.91	13.84	4.75
Manufacturing	-10.21	6.35	16.92	2
UtiliComm	-9.17	4.48	20.77	-0.26
Business	-9.43	3.78	20.99	-1.22
Recreation	-0.99	4.27	20.02	-0.72
GovtExpen	-11.83	3.61	18.85	-1.07

Table 18 and *Table 19* provide a view into the effects that Japan, the USA, and China experience in terms of change in market price of factors and commodities respectively. *Table 18* illustrates much like the second experiment the decrease in all factors except skilled labour in Japan. This can again be attributed to the vital role that skilled labourers play in the Japanese economy as producers raise wages to fulfil labour needs as there

are not enough labourers. Furthermore, it can be observed that consumer (holders of factors of production) enjoy a boost in the factor prices in the USA and China which overall increases the household income (shown in *Table 21*). *Table 19* illustrates the impact that technology and capital increases in the economy have on the price of commodities. When compared to *Table 13* the falling of prices can be attributed to the rise in technological capabilities and capital. Furthermore, as firms become more efficient industry output for commodities rises (shown in *Table 20*) and prices fall due to the competitive nature of the market this is also supported by *Table 17* which displays the change in private household demand which is increasing in the USA and China.

Table 18: Market Price Changes in Factors (%)

Factors	Japan	USA	China	RestofWorld
Land	-26.3	5.62	-0.78	15.42
UnSkLabour	-7.24	1.63	13.16	-2.03
SkLabour	8.72	1.99	18.37	-2.65
Capital	-12.93	0.71	9.53	-3.19

Table 19: Market Price Change in Commodities (%)

Commodities	Japan	USA	China	RestofWorld
Primary	-8.72	-2.15	-1.96	-2.15
LbrManufacturing	-6.95	-3.08	-5.14	-5.18
Manufacturing	-6.62	-3.2	-4.76	-4.78
UtiliComm	-7.02	-2	-1.36	-4.74
Business	-6.63	-1.26	1.64	-4.64
Recreation	-15.86	-1.89	2.63	-4.43
GovtExpen	-3.44	-1.16	4.74	-4.27

Table 20: Industry Output of Commodity Change (%)

Commodities	Japan	USA	China	RestofWorld
Primary	-7.77	3.23	0.18	7.11
LbrManufacturing	0.62	-1.6	4.53	2.24
Manufacturing	-2.88	-2.44	0.36	0.58
UtiliComm	-11.56	3.61	10.09	0.16
Business	-9.9	0.75	5.29	0.05
Recreation	-0.97	3.73	13.52	-0.52
GovtExpen	-11.97	3.33	13.02	1.21

Table 21, 22 and *23* present the change in regional household income, the value of GDP, and equivalent variation. The change in regional household income is greater in the USA and China than that of the second experiment due to the increased price of factors which benefit the factor holders. Conversely, Japanese factor holders see their household income continue to decline from the initial state. It must also be noted that even though household income changes almost equally in Japan and China, it does not mean that the Chinese regional household is now overall better off. Furthermore, the change in the value of GDP illustrates the continued decline of the Japanese economy as China booms, and the USA experiences an increase but not to the same extent as China. The technological and capital increases presented in the third experiment show that Japan suffers more compared to the results of the second experiment as producers worldwide gain the ability to overtake and replace Japan's vital role in the world's economy. Finally, *Table 23* which presents the changes in equivalent variation welfare measured as in $US trillions illustrates that the EV change in China is the greatest of all regions, while Japan suffers a negative EV change. The majority of the EV change in Japan and China can be directly attributed to the booming economy of China and the world as Japan is continually pushed aside.

Table 22: Change in Regional Household Income (%)

Region	Change
Japan	-16.33
USA	2.63
China	16.25
RestofWorld	-1.25

Table 21: Change in Value of GDP (%)

Region	Change
Japan	-14.99
USA	1.98
China	13.58
RestofWorld	-1.68

Table 23: Change in EV ($US Trillions)

Region	Change
Japan	-0.47
USA	0.63
China	1.21
RestofWorld	1.22

6. Conclusion

The paper explored the economic impact of a significant population decline on the Japanese economy through the GTAP software program and found that results were not as disastrous as many other papers have been warning of. Though no developed country such as Japan should hope to feel the economic impact of a population decline the experiments ran through GTAP presented relatively small changes in EV, GDP and regional household income for an economic giant such as Japan. The results suggest that Japan may lose it's standing as the worlds third largest economy but will no doubt continue to play an important role on the economic stage of the world even through the even of a significant population decline. Lastly, it is important to remember that GTAP is not usually used for such a project and assumptions made in the model may not apply to simulate the period of 2065 in question.

APPENDIX

Regions	First Experiment	Second Experiment	Third Experiment
Japan	Shock POP -30.6%	Shock QO skilled labour endowment -23.73%	Shock QO, AOALL +0.78%
	Target TO 0% for recreation production for 5.38%	Shock QO unskilled labour endowment -6.87%	
	Target TO 0% for gov't expenditure for 0.48%		
USA	Shock POP +31.5%		Shock QO, AOALL +1.69%
China	Shock POP -8.33%		Shock QO, AOALL +4.40%
ROW	Shock POP +65.34%		Shock QO, AOALL +1.08%

Annotated Bibliography

[1] Horioka, Suzuki, and Hatta: "Aging, Savings, and Public Pensions in Japan,", *Asian Economic Policy Review*, vol.2(2), 2007, 303-319.

Objective: Currently Japan is facing a problem of large population decline largely due to the rapid ageing of its population, which leaves many economists discussing the projected economic impact that the country will face in the future. The specific objective that this paper address is the impact of the ageing population on the household savings rate.

Data Set: In 2006 20.6% of the Japanese population was over the age of 65, by 2025 28.7%, and finally 35.7% in 2050 (Japanese government projections). OECD used as a source for household saving rates.

Methodology: The methodology that this paper uses is analyzing the age structure of the past, and the trends over time of Japan's household savings rate to make predictions mainly based on the life-cycle hypothesis.

Findings: The paper concludes that a major determinant of future trends in household saving rates in Japan can be explained by the age structure of the population. The paper predicts that the household savings rate of Japan will continue to decline and drop to the rate of zero and possibly negative.

Comments: The paper applies a very simple concept like the lifecycle hypothesis to make predictions of the household saving rate based on the current age structure. It was predicted in this paper that zero or negative levels of household saving rates will be seen by 2010-2024 and the prediction came true.

Role: This paper will be taken into consideration when analyzing results of the project, the lifecycle hypothesis theory would be incorporated into the analysis.

[2] Muto, Takemasa, and Nao: "Macroeconomic Impact of Population Aging in Japan: A perspective from an Overlapping Generations Model,", *IMF Economic Review*, vol.64(3), 2016, 408-442.

Objective: The objective of this paper is to explore the impacts of a high dependency ratio on a G7 country like Japan because other developed nations may be facing this problem as well. Japan is used because of its very illustrative example of increased longevity and decrease in fertility rates. Japan's dependency ratio (17%) in 1990 was among the lowest of the G7 nations, then in 2010 (35%) the dependency ratio raised to the highest in the group, it is predicted to continue to climb holding the highest dependency ratio of the G7 in 2030 (53%).

Data Set: Dependency ratios, fertility rates, elderly survival rates. All data gathered from United Nations.

Methodology: The overlapping generations model was used and calibrated to Japan.

Findings: The paper finds that Japan's GNP growth is adversely affected by the current population trend by lowering factor inputs. Furthermore, the paper finds that the decline in fertility rates plays a larger role in the decrease of GNP than that of longevity because it reduces workforce size and the ratio of savers within the economy. Domestic households could possibly mitigate the effects on GNP if they could invest savings into higher returns abroad.

Comments: The findings found in this paper were very interesting, and presented the story that the negative effects on GNP could in some way be avoided if domestic households could invest in higher returns abroad.

Role: With the new knowledge of learning that GNP decreases could be avoided with higher return investments abroad it will shape the discussion around the results found and could possibly lead to a testing of domestic household investments.

[3] Braun, Joines: "The Implications of a Graying Japan for Government Policy,", *Journal of Economic Dynamics and Control*, vol.57, 2015, 1-23.

Objective: Currently Japan faces a crisis of an ageing population that will not slow down in the years to come. This paired with the current fiscal standing of Japan will lead to a fiscal crisis that needs to be avoided by taking a course of action to alleviate fiscal pressure. The impact of Japan's population decline will be illustrated over a couple of centuries rather than decades, by 2110 the population will decrease to 45.9 million from 127.2 million in 2013. It is also projected that the dependency ratio will peak at 87% +. Most other papers on this topic do not go past current mid-century and do not address long-term problems that Japan will face.

Data Set: Parameters come from an updated version of NIPA data from Hayashi and Prescott (2002). Quantitative data obtained from National Institute of Population and Social Security Research of Japan (IPSS).

Methodology: Overlapping generations economy model used to find solutions to the predicted fiscal crisis through dynamic simulations.

Findings: The paper finds that to avoid the current fiscal crisis Japan will have to reduce government expenditure and raise taxes. Measures that would be implemented to increase fertility rate may even worsen the fiscal standing in the intermediate to short run.

Comments: This paper uses the same methodology as Muto, Takemasa, and Nao (2016) but addresses a different aspect of the negative impacts of population decline, with this paper included it illustrates the optimal steps or programs the Japanese government undertake to avoid future crisis'.

Role: This paper presents a solution to the current fiscal crisis that other papers didn't address with the addition of concern for the coming century, this may lead to testing of consumer taxation rate and government expenditure in the project.

[4] Mikiko: "Population Ageing and Economic Growth in Japan,", *The International Journal of Sociology and Social Policy*, vol.35(11), 2015, 841-863.

Objective: The objective of the paper is to find out how population ageing impacts economic growth in terms of real GDP per capita in Japan. The paper answers two questions presented, how population age groups and the dependency ratio effect economic change in Japan. It also makes predictions on economic growth for Japan's future.

Data Set: Japan country data used for years 1975 through to 2011.

Methodology: Regression, the dependent variable was changed in real GDP per capita, and independent variable were population composition by age group and dependency ratio, with control variables, included such as fertility rate and population

density. The economic growth equation was also used which is a branch of the Bloom and Wlliamson (1998) model.

Findings: The study finds that every age group from 15 to 75+ excluding 70-74 experiences a GDP per capita growth when the population of those age groups rise. Secondly, it found that as dependency ratios rise GDP per capita growth falls.

Comments: Even though the methodology used was very different from other papers, it furthered the idea that as age rises GDP per capita growth does not fall until the age group of 70-74. It is not until these individuals are gone that GDP per capita growth is affected negatively.

Role: This paper will be used to analyze results of the simulations that will be conducted in terms of GDP per capita growth before and after an exogenous shock.

[5] Wong, and Furuoka: "The relationship between Population and Economic Growth in Asian Economies,", *ASEAN Economics Bulletin*, vol.22(3), 2005, 314-330.

Objective: The study delves deeper into the relationship between population and economic growth. The results of Johansen (1988) and Gregory and Hansen (1996) cointegration methods come to the finding that generally there is no long-run relationship between population and growth of the economy. The study finds that there is still bi-directional Granger causality for Japan, Thailand, and Korea in terms of population and economic growth.

Data Set: The source for economic and population growth data was Heston, Summers, and Aten (2002)

Methodology: Running DF(1978)-PP(1988) unit root test, Johansen (1988) likelihood ratio test statistics, Gregory and Hansen (1996) cointegration test statistics, and finally running a Granger causality test.

Findings: The Granger causality tests produced the most interesting results, in that it seemed population and economic growth in Japan, Korea, and Thailand has a bidirectional Granger causality. But for the countries, China, Singapore, and Philippines economic growth Granger cause population but not the other way around.

Comments: The findings in this paper were interesting in illustrating that the relationship between population and economic growth is a very messy relation and differs greatly from country to country.

Role: This will play an integral part in the project when running the exogenous population shock on Japan, it will decide which type of way the shock is running. If the findings of this paper are accurate in the project there should be an obvious decline in economic growth for Japan.

Reference information

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https://data.worldbank.org/data-catalog/GDP-ranking-table GDP Ranking; "The World Bank Group[US] (2017)"