LUND UNIVERSITY
School of Economics and Management

Bachelor's Programme in Economy and Society

The Demographic Dilemma: Japan and the future of a post-population growth economy

by

Nguyen Chi Dang Quang
Nguyen.cd.Quang@gmail.com

This thesis investigates the relationship between demographic ageing and economic growth in Japan, updating existing literature with more empirical evidence from recent decades. It conducts its investigations through OLS regressions on macro-level time series data for Japan. The paper finds empirical evidence which suggests that the relationship between demographic ageing and economic growth is not a direct one. Instead, the older populations are less capable of utilising machine capital in their labour, thus lessening the latter's effectiveness in boosting labour productivity. It provides an alternative explanation to Japan's recent economic performance and perhaps highlights the importance of automation in a post-population growth world.

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Abbreviations

Abbreviation	Definition
BOJ	Bank of Japan
FRED	Federal Reserve Bank of Saint Louis
FDI	Foreign Direct Investment
GDP	Gross Domestic Product
NGO	Non-governmental Organisation
OLS	Ordinary Least Squares
PPP	Purchasing Power Parity
TFP	Total Factor Productivity

1 Introduction

Japan presents a peculiar case of economic development that is unique in many ways. As Kuznets (1971) has accurately posited, there are four different types of economies: developing economies, developed economies, Argentina, and Japan. Indeed, Japan's economic development has been unique, it is the forerunner of the Asian economies to have industrialized so rapidly both in the late 19th century and managed to even rapidly rebuild itself again after the conclusion of the Second World War into a prominent economic power in Asia (Gerstel & Goodman, 2020). However, in the aftermath of the Plaza Accord of 1985, which devalued the dollar relative to the Yen (among many other currencies), the Japanese economy entered the deep recessionary period known as the Lost Decades (Hamada & Okada, 2009).

Even though Japan had ostensibly recovered to pre-recession levels of economic outputs by the 2010s, the country has fallen behind in terms of economic growth relative to many other economies, rarely even nearing the traditional 2% annual GDP growth benchmark, but is also dealing with consistently low inflation levels, sometimes even dipping back into deflation despite the best efforts of the Central Bank of Japan (henceforth referred to as the BOJ) and the late Shinzo Abe's "Abenomics."

There have been studies such as those from Muto et al. (2016) which have begun suggesting the rapid ageing of Japan's demographics as another possible explanation for its continued stagnation ever since the initial recession of the 1990s. However, even Muto et al.'s (2016) research only focused on the 1980s-2010s period. Little research has been done into the contemporary era, wherein Japan's population ages and fertility rates drop far below replacement levels.

Despite Japan being among the forerunners of economies facing a rapidly ageing population, having just breached 70% age dependency ratio as of 2018 according to the World Bank (2023b), an ageing population is not a phenomenon unique to Japan. In fact, it is a pattern that is felt throughout much of the OECD economies, having all undergone a demographic transition towards a low death rate, low birth rate stage according to Madsen (2014).

1.1 Research Aim

Therefore, this thesis aims to analyse whether Japan's demographic ageing has impacted Japan's economic performance and, if so, through what mechanisms. Should these mechanisms indeed exist, it will be an important consideration for the policymakers of developed economies to consider as they face the difficult task of managing an ageing workforce with a heightening elderly population which must somehow be financed whilst keeping the economy afloat.

1.2 Research Question

The demographic ageing of Japan's population will undoubtedly pose an intimidating challenge to Japanese public pension and healthcare systems alike, both of which must be funded by a government which already possesses a considerably high level of public debt at over twice the size of its GDP as of 2010 and only continuing to rise over time (Jordà et al. 2020). This outstanding debt restrains Japanese public spending, which could be utilised to boost Japan's GDP. To that extent, the question of whether the productivity of Japanese workers can keep up with the increasing proportion of retirees and shrinking labour force has become one of top policy importance. The very possible reality of worker productivity not growing fast enough to fund the increasing demand of Japan's pay-as-you-go public pension system against an increasingly ageing Japan is a troubling one.

Yet there has been literature, such as those made by Acemoglu and Restrepo (2017) which proposed that the concerns of a shrinking labour force do not necessarily mean the current economic trajectory of Japan is doomed to recession as automation technologies can alleviate this impending crisis of labour shortage. To therefore investigate this possibly, the primary research question of this thesis will be as follow:

To what extent does Japan's ageing population correlate with the country's labour productivity from the time period 1990-2019?

2 Literature Review

2.1 Theoretical Framework of Economic Demography

Throughout recent decades, several economic research have presented contrasting estimations for the strength and even direction of the relationship between an ageing population and growth of economic productivity.

Bloom et al.'s paper (2010) discusses the theoretical implications of an ageing population on economic growth rates (especially in terms of income per capita) before analysing global empirical data and other similar research in the field in order. They argue that there are two primary channels through which population ageing affects economic growth: the shrinking size of the labour force and household savings rate. As the share of elderly people (which shall henceforth refer to people aged over 65, Japan's current retirement age) in a population increase, so too does it imply, ceteris paribus, that the ratio of elderly people relative to the working-age population has increased. This is, in essence, the old-age dependency ratio and implies that as the population ages, the amount of labour capital per person, regardless of age or employment status, will decrease.

Alongside this decrease in the supply of labour, Bloom et al. (2010) also posits that retirees are on average dissavers. That is to say, retirees unsurprisingly withdraw their pension savings (ie: investments) to spend on now that they are retired. On a macro scale, an ageing population would therefore also imply a reduction in private capital investment per capita offered to the economy as well as the proportion of dissavers (retirees) increase relative to savers (workers) in an economy. However, the ageing population taxes not only the private pensions, but the public pension system as well. As the proportion of the elderly population not only increases but also lives longer as life expectancy continues to rise as well, Bloom et al. therefore argues that the public pension systems will come under increasing stress to provide for more pensioners for a longer time as well.

However, Bloom et al. (2010) argues that these effects are not necessarily a given or unavoidable. Instead, the crux of their empirical argument is that the behaviours of age groups change over time in response to changes in the age-structure as well. Mainly, as life expectancy increases, the current working-age population will save more money for their own retirement as

they will expect to enjoy said retirement for longer, in effect increasing the savings rate per working-age individual.

Instead, Tang and Macleod's (2006) research focused on how the age of workers may impact labour productivity. Although their empirical research is on Canadian provinces specifically, some of the intuition of their research may still apply. Their findings suggest that Canadian provinces with an older average age of workers also grew slower economically speaking. They argue that, firstly, older workers' age does not necessarily correlate with having more work experience. Secondly and perhaps most importantly, older workers have a harder time adapting and fully exploiting newer, more productive technologies which would otherwise greatly boost labour productivity.

2.2 The Case of Japan

Muto et al. (2016) focused their analyses more specifically on the effects of Japan's ageing population and its interaction with the Japanese economy between 1980s-2000s, more specifically through the use of counterfactual simulations. Unlike Bloom et al's (2010) more optimistic analysis, which argued proper leverage of government policies ahead of time can mitigate the worst adverse effects ageing might have on the economy, Muto et al.'s research (2016) indicates that the adverse effects on Japan are a given rather than mitigatable, partially due to the fact that Japan is ahead of even most other developed economies in terms of its demographic problem.

Most interestingly, Muto et al.'s (2016) empirical research indicates that population ageing's relation with economic growth isn't purely negative but is rather multi-faceted. Population ageing is in it of itself a combination of primarily two factors: an increase in life expectancy and a decline in fertility rates. Muto et al. (2016) argue that these two factors have opposite effects on economic growth. A decline in the fertility rate will lead to an (eventual) decrease in workers relative to pensioners in the economy, forcing governments to impose higher taxes on a smaller working force to fund the current pension system, and thus reducing disposable income available for consumption. On the other hand, an increase in longevity will encourage households to work more hours and save more for their retirement, as similarly argued by Bloom et al. (2010), thus positively affecting growth in per worker productivity.

However, Muto et al. (2016) concludes that the overall negative effect of a shrinking workforce relative to the elderly population will have more economically contractionary effects than the expansionary effects of encourageing higher workforce participation rate and hours (both statistics for which Japan is already among the highest in the world for, thus limiting how much further this factor can be pushed.)

2.3 Ageing as a driver of automation

On the other hand, Acemoglu and Restrepo (2017) suggest that perhaps population ageing, overall, does not have a strong correlation with productivity growth and may even have a positive relationship, thereby refuting Muto et al.'s (2016) claim. Although the study is more global in scope like Bloom et al. (2010) rather than Japan-centric, Acemoglu and Restrepo (2017) nevertheless argues that a shrinking labour force, driven by the ageing population, will foster endogenous technological change and the adoption thereof. In other words, they argue that the shrinking of the labour force will not impact per capita productivity but may even positively impact *per worker* productivity as employers will substitute the diminishing labour supply with more capital, specifically in the form of robots, automation and artificial intelligence. Therefore, Acemoglu and Restrepo (2017) argue that the concern of "secular stagnation" (p. 174), wherein economies will experience very little real economic growth in the long term, can be mitigated if the conditions are correct to allow for the efficient adoption of automation technologies in the workplace.

However, the cross-country regression analysis performed by Acemoglu and Restrepo (2017) does not establish a causal relationship between ageing and the adoption of more advanced automation and robotics technology and further research in this direction is warranted. Furthermore, due to the global scope of their cross-country analysis, they did not analyse in detail the mechanisms which specifically drive endogenous technological change and if it is driven by ageing, thus concluding that their study is not causal, nor do they state how countries and companies alike will be financing the adoption of these automation technologies. The latter point is especially pertinent in relation to Japan since, as aforementioned, their high debt-to-GDP ratio constrains the government's ability to increase public investment, leaving the private sector as the main driver of investment and adoption of automation.

Prettner (2013) uses endogenous and semi-endogenous population growth models to further investigate these technological effects, to which they come to very similar conclusions as Muto et al.'s (2016) argument: A decrease in fertility rates harms productivity growth and vice versa for a decrease in mortality rates. However, unlike Muto et al. (2016), Prettner concluded that the positive productivity effects of decreased mortality rates can overcome the adverse effects of reduced fertility rates. However, unlike Muto et al.'s empirical research, Prettner's paper focused more on the endogenous growth frameworks and the theoretical underpinnings for how ageing interacts with productivity growth. Therefore Prettner's (2013) framework should be viewed as a possibility for ageing to lead to positive productivity growth whereas Muto et al.'s empirical research shows the limitations of the theoretical research.

2.4 Hypothesis

Based on the literature review done thus far, the increase in life expectancy did not have significant bearing on the rapid growth of Japanese labour productivity during the Japanese Economic Miracle from 1880-1990. However, this thesis will therefore propose the hypothesis that:

> From the Lost Decade of the 1990s onwards, the increase in longevity which promptly causes demographic ageing will have a moderately weak positive correlation regarding Japanese labour productivity.

The reason this thesis proposes that the relationship is positively correlated rather than negative is based on the argumentation made by Acemoglu and Restrepo (2017) primarily, that the shrinkage of the labour force will cause firms to respond by employing more labour-saving technologies (automation or otherwise), which thereby boosts productivity. However, this thesis argues that the relationship will only be weakly positive as the argumentations provided by Tang and Macleod (2006) also holds intuitive sense even if their precise empirical results were not based on the Japanese context.

Overall, this thesis proposes that while labour productivity might have a weakly positive relationship with labour productivity, it is not enough to be a source of economic growth, but rather a means to prevent economic recession and decreases in GDP per capita due to population ageing.

3 Research Design

As indicated by the proposed research question, this thesis focuses on investigating the correlation between population ageing and economic growth and will therefore be primarily quantitative. Hence, this study will focus on the macro-level effects of an ageing population on economic growth by employing a quantitative method, an ordinary least squares (OLS) regression, over a qualitative one to answer the proposed research question.

The paper will begin the study from 1980 as that is the extent to which data on labour productivity is available for and marks the beginning of the Japanese Economic Miracle. However, the thesis will also be analysing whether the relationship between demographic ageing and labour productivity growth has changed from the 1990 as it is the beginning of Japan's (recessionary) lost decades from which Japan still hasn't fully recovered. The thesis will not carry the analysis beyond 2019 as the Covid-19 pandemic and recession created exogenous shocks which will be difficult to control and complicate the scope of the research.

This research will primarily be gathering primary data from the Jordà-Schularick-Taylor Macrohistory Database (2020), henceforth simply the Macrohistory Database, which contains the per-capita GDP levels of several countries including Japan and a plethora of standard macro-economic variables which can be used as control variables for the regression. Supplementing this, data on total factor productivity from the Federal Reserve Economic Data, henceforth, simply referred to as FRED (2020) will also be included. The Long-Term Productivity Database produced by Bergeaud et al. (2023) also includes data on key factors of labour productivity such as capital intensity (how much machine capital is invested per hour of work) and labour productivity (GDP over total hours worked) and will therefore also be incorporated into the analysis.

However, these databases lack demographic indicator variables, therefore, this study will be using the old-age dependency ratio measure taken from OECD data (2024) in addition to raw population and employment data from the Japanese Bureau of Statistics (2023). As all of the

aforementioned databases either came from a trustworthy NGO such as the OECD or from a federal/national level data, such as the FRED and data directly from the Japanese Bureau of Statistics. The Long-Term Productivity Database is itself a project of the Bank of France. All of these databases have also been regularly updated, sometimes correcting for data from previous years as well, thus indicating that the data is relatively accurate.

The regression will therefore collect three types of time series data covering the 1980-2019 time period: a) The Old-Age dependency ratio of Japan as the primary independent variable, b) the labour productivity as the primary dependent variables and lastly c) the net inflow of Foreign Direct Investment (FDI) inflows, which impacts availability of capital.

The thesis will display the regressions in a piece-wise manner to investigate why trends may change when certain variables are included (or omitted) from regressions, which in of itself may elucidate how the inclusion (or lack thereof) of certain variables affects the analysis, which in it of itself is a topic worth discussing.

3.1 Data Transformation

To accomplish the aim of this thesis, some variables will need to be transformed in order to remove the very possible bias of over-estimation and auto-correlation. Several key variables which this thesis will investigate are variables which, by their nature, will mostly increase over time, such as the old age dependency ratio and labour productivity (as measured by the ratio of GDP over total hours worked). That is to say, they are non-stationary variables. As both variables will ostensibly be increasing across the time series, a standard OLS regression will over-estimate the relationship between these two variables by simple virtue of the fact that they are non-stationary and will for most years have the same direction of movement.

To resolve this issue, this thesis will transform all the potentially non-stationary variables to be in terms of year-by-year percentage change instead. Specifically, these variables will be the old age dependency ratio, labour productivity, capital intensity (as measured by machine capital over total hours worked). The total factor productivity and net inflow of FDI will instead be transformed into absolute year-by-year change instead. This is because both variables in their

original form are already in terms of percentage (relative to a base year and relative to the whole GDP of Japan respectively).

By transforming them into absolute change it makes the data more logical to parse. But more importantly, especially for net FDI inflow, absolute change is a better gauge to measure more minute changes. Net FDI inflow into Japan from 1990s onwards, as will be evident in the descriptive table later, is in fact a very small amount relative to the size of its GDP, averaging at barely 0.16% of its GDP. If net FDI inflow was to experience a relative increase of 100% (to double) from the average of 0.16% of its GDP, the new net FDI inflow would still only be 0.32% of the GDP. Not to mention in some years Japan experienced net negative FDI inflow (meaning there were more dis-investments into Japan than investments) before bouncing back again, moving from a slightly negative number to a slightly positive one would, mathematically speaking, be a very large relative change, but tiny absolute change. Therefore, absolute change is perhaps a better measure than relative change in these specific cases.

This thesis will also be creating an entirely new measure: the worker dependency ratio. Rather than a crude measure of the proportion of those aged 65 and higher over those aged 15-64, the worker dependency ratio measures the population of those aged 65 and higher who are explicitly not in the labour force (ie: in retirement) over the population of people in the labour force. Two vital differences exist between the old age dependency ratio and the worker dependency ratio. First, the worker dependency ratio only accounts for those who are actually in the labour force. Those who are not participating in the labour force are not counted, which will provide a more realistic accounting of the proportions of those who are actually working (or looking for work) relative to those who do not. The second difference relates to the first as the classic old age dependency ratio measure presumes all those over the retirement age are, in fact, retired. However, in reality there are a not insignificant number of the Japanese population aged 65 and over which are participating in the labour force which the old age dependency ratio does not account for, but the worker dependency ratio does. This will allow the thesis to incorporate new dimensions which previous studies may have overlooked: the working elderly.

3.2 Limitations

Due to the limitations of the scope and the need to keep a certain degree of simplicity in the study, the issue of endogeneity will become a major limitation in the regression(s) that this study will perform.

As a theoretical example, if this study controls for net FDI inflow, it poses the potential problem that net FDI inflow itself might have a relationship to the old-age dependency ratio. For example, foreign actors deciding which countries to invest in might consider the ageing-population of Japan as a factor against the country in comparison to other countries with a larger proportion of working population or about to experience demographic dividends.

In the above example, net FDI inflow is itself a channel through which the relationship of old-age dependency can potentially shape growth rates in GDP per capita, in other words, a mediator variable. Therefore, by controlling for year-by-year net FDI inflow, the regression would inadvertently be controlling for one of the variables through which the effects of Japan's demographic ageing on the growth rate of per capita productivity would manifest itself. In essence, the regression would be underestimating the strength of the relationship between old-age dependency and the growth rate of per capita GDP in this example.

A limitation of available data also hampers the capability of this thesis. The Japanese Bureau of Statistics (2023) does not unfortunately contain detailed enough information on both the precise population and labour participation rate by age, only by age group increments. Thus, the precise average or median age cannot be fully calculated unless certain assumptions are made. Thus, this thesis will generally be using the old age dependency ratio and later the worker dependency ratio as a proxy for median age. Yet as one can assume, this is not a completely accurate proxy as that is based on the assumption that the age distribution from age group to age group is uniform. It is not the case in reality.

Furthermore, this thesis assumes that in the era of ICT, information is relatively available, widespread and cheap to obtain. Thus, the thesis assumes that in recent decades employers, government officials and individuals alike are both acutely aware and will react accordingly. Thus, the thesis did not employ any time-lagging in its variables as it expects changes to the old age dependency ratio will have relatively immediate noticeable effects on, for example, the labour market and/or labour productivity.

Another more implicit assumption made in this thesis that should be discussed is the issue of wealth distribution. This thesis is assuming, for the sake of simplicity, that changes in GDP per capita would be distributed in such a way that the distribution of wealth would remain relatively the same, both in terms of overall inequality between social classes and age groups, but the reality can be quite different. Although outside this thesis's immediate scope, wealth distribution is still extremely relevant to a demographic ageing society. Acemoglu and Restrepo (2017), for example, points out that although automation does indeed increase labour productivity, it in fact leads to a decrease in the *wages* of workers as automation doesn't simply augment labour productivity, it *replaces* it and effectively reduces the demand for human labour, leading to a reduction in wages. It therefore implies that the fruit of automation isn't equally shared but is disproportionately enriching capital owners rather than labourers.

There is also the matter of household income distribution rather than individuals in a vacuum. While centering the unit of analysis around individuals allows for a more generalized and applicable analysis, especially due to the far wider availability of data, it ignores the important dimension that these individuals are part of families that financially support and care for one another. Children are, in a materialistic sense, a form of investment or even pension fund for the parents themselves once the latter enters retirement. While the old age dependency ratio does represent this concept, it does not represent the changes in household income over time as a result of demographic ageing.

3.3 Implications

This research can update the current literature on economic demography and contribute to the current understanding of the economic landscape of Japan. Japan is far from the only country to be experiencing population ageing. Indeed, it is a near-universal issue in developed economies, from the US and Western Europe to Korea and possibly even China. Therefore, the interplay between demographic ageing and economic growth is of great relevance for present and future policymakers of not just Japan but many developed economies as well as the size of their labour force decrease whilst the proportion of retirees increase.

In fact, Japan being ahead of the curve of many other countries in terms of demographic ageing may mean the insights of this study could be of use to policymakers of other countries to

anticipate and appropriately respond to demographic ageing to pre-emptively tackle the issue before public pension systems as they are currently designed become stressed to its breaking points.

As for implications for Japan itself, the study's outcomes may indicate the future trajectory of Japan's economic performance without drastic change or highlight the increasing necessity of automation and further labour substitution by machine or human capital if current living standards are to be maintained. This topic will also be of vital interest to Japanese policymakers, as the issue of growth in a post-population growth era is a novel challenge for any country.

4 Data & Descriptive statistics

Variable (unit)	Source of Data	Mean	Standard Deviation	Minimum	Maximum	Year of Data availability
Real GDP per capita growth rate in PPP (% per year)	Macrohistory Database	2.61%	6.36%	-49.4%*	17.6%	1871-2019
Old age Dependency Ratio (%)	World Bank Database	24.7%	12.1%	10.4%	49.9%	1970-2019
Growth of old age Dependency Ratio (% per year)	World Bank Database**	3.23%	0.87%	1.67%	1.67%	1970-2019
Worker Dependency Ratio	Japanese Bureau of Statistics	16.4%	8.33%	0.09	0.32	1980-2019
Net inflow of FDI (% of GDP)	World Bank Database	0.16%	0.21%	-0.05%	0.82%	1980-2019
Growth of net inflow of FDI (% per year)	World Bank Database**	0.02%	0.20%	-0.44%	0.70%	1980-2019

Total Factor Productivity Index (2017=100)	FRED	85.9%	15.4%	49.2%	100.1%****	1954-2019
Growth of TFP (% per year)	FRED**	0.36%	1.27%	-3.57%	3.22%	1980-2019
Ratio of Capital Stock over Total Hours Worked (2010 PPP)	Long Term Productivity Database	40.0	54.1	1*****	161	1870-2019
Growth of Capital Stock over Total Hours Worked (% per year)	Long Term Productivity Database**	4.68%	11.7%	-33.3%	100%*****	1871-2019
Labour Productivity (Ratio of GDP over total hours worked in 2010 PPP)	Long Term Productivity Database	11.1	13.5	0.65*****	41.72	1890-2019
Growth of Labour Productivity	Long Term Productivity Database**	3.09%	-6.21%	-49.9%	18.4%	1891-2019

*Outlier due to the year 1945 being included

**Indicates the variable is data transformed from the original data source for the purpose of this thesis

***The data from which the worker dependency ratio is built from is based on time series population by employment status and age group and is thus not included for the sake of brevity. A sample of the original data is provided in Appendix 1

****Not rounded to 3 significant figures to indicate that the max is at exactly 100% (it is not the base year of 2017).

*****Outliers/relatively low numbers are due to data from the 1870-1890 era of Japan being included (when Japan was only beginning to industralise)

Table 1: Descriptive statistics of the variables taken into account between the period 1950-2019.

Table 1 describes the statistics which will be used in this study. Most of the variables gathered from the Macrohistory database go back to approximately the 1860s-1880s to the

present day. However, mid to late 19th century Japan is a host to a variety of statistical outliers seeing as Japan began industrialising in the 1870s with the Meiji Restoration. For similar reasons, data points around the year 1945-1950 are also subject to outliers as it is the immediate year of the nuking of Hiroshima and Nagasaki, Japan's surrender and subsequent post-war rebuilding. On the other hand, most of the variables from the other database have data that mostly only goes back to the 1980s with a couple of exceptions.

To first show the general trends of the data in relations to one another, especially those relevant to this thesis, this study will begin by showcasing the association between the two primary variables of the study: Real GDP per capita and the Old Age Dependency ratio:

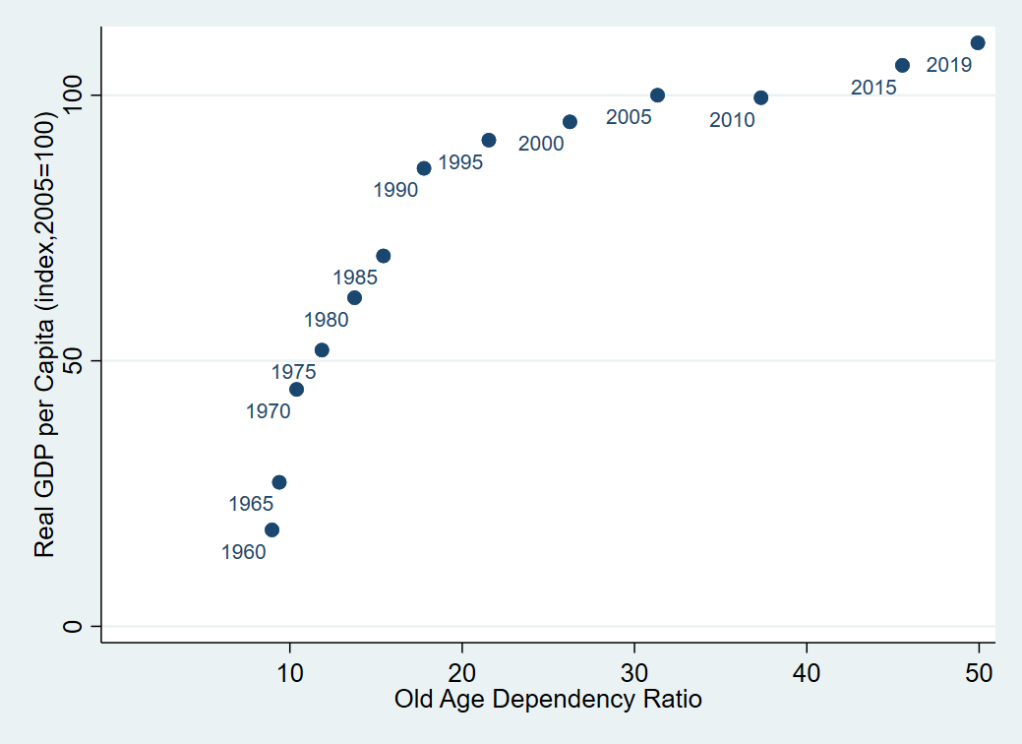

Figure 1: Correlation between Old Age Dependency Ratio and Real GDP per Capita in Japan between 1960-2020

As Figure 1 shows, two distinct trends are displayed, separated precisely by 1990, the year of Japan's asset price bubble crash and the ensuing Lost Decades. Prior to 1990, the slope of the relationship between the old age dependency ratio and real GDP per capita was quite steep. This is partly because Japan has naturally aged over time, such that typically speaking, the old

age dependency ratio will always increase over time. Thus, the initial steep slope between the dependency ratio and GDP per capita could also be attributed to Japan's rapid industrialisation between 1960 and 1990s, especially with regards to the economic boom of the 1980s. However, after 1990 the slope became much flatter. In other words, the real GDP per capita did not increase significantly even as the old age Dependency Ratio increased substantially, at least when compared to the previous time period.

Yet this figure nonetheless demonstrates that Japan has slowed down significantly in its growth of GDP per capita, in part because it had now reached the technological and efficiency frontier of a developed nation but also in part due to the Lost Decades of the 1990s. However, Aoki (2013) argues that the unfavourable shift in demographics itself could have played a role in Japan's stagnation during the Lost Decades. Indeed, Aoki noted that it was precisely in 1990 that the public and government began to notice that Japan's total fertility rate had dropped to only 1.57, a metric which would only further decrease as time passed.

As several of the literature have argued thus far, the possible ameliorator to population ageing's adverse effects on productivity is investing greater capital per worker. To further investigate this relationship, the figure below displays the relationship between capital intensity, measured in terms of capital stock over hours worked and labour productivity, measured in terms of GDP over total hours worked:

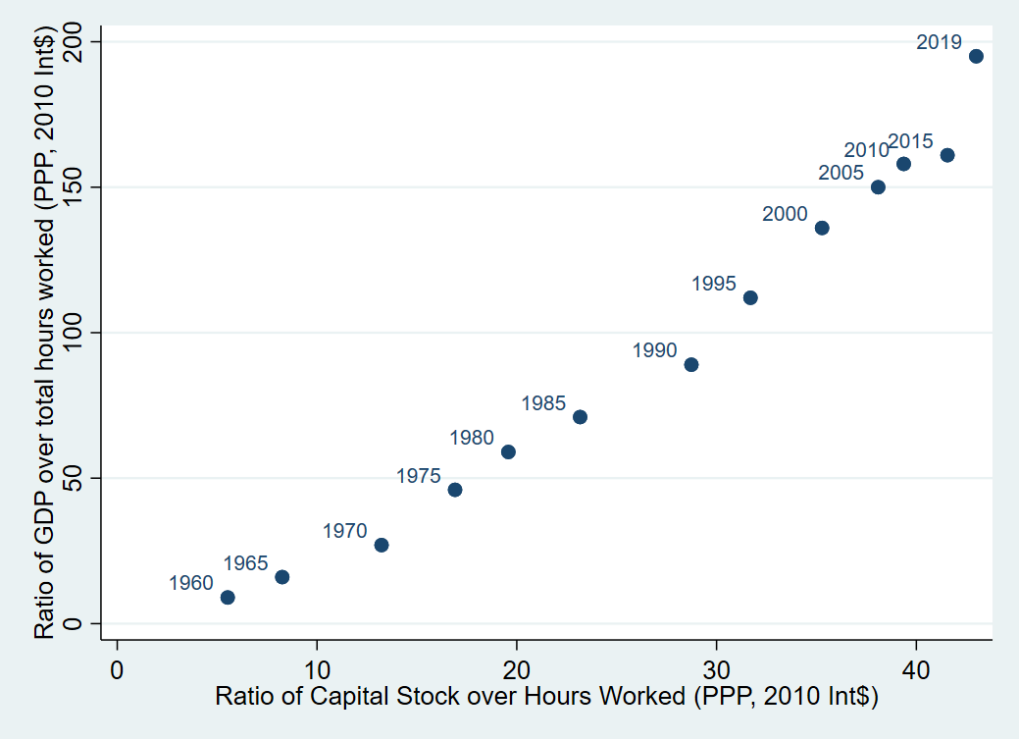

Figure 2: Correlation between capital intensity with regards to labour productivity.

All units in this figure are adjusted to be in terms of 2010 PPP dollars. The relationship between labour productivity and capital intensity appears to be relatively straightforward and linear for the most part across the time period. An additional investment of 10 dollars into capital per hours worker will usually correlate with labour productivity increasing by roughly 40 to 50 international per hour. However, a peculiar phenomenon in this relationship can be seen from roughly 2010 onwards. While in the immediate 2010 to 2012 time period it is perhaps understandable that the measure of labour productivity is moving erratically (as a result of the global financial crisis and the ensuing recovery), the relationship between capital intensity and labour productivity has nevertheless weakened significantly since approximately 2010 even until 2015, wherein additional investment of capital stock per hours worked has not led to nearly similar levels of increasing returns in labour productivity. It could be argued that the decrease in the slope of the relationship could even have been prior to 2010, with the slope having grown flatter from 2005 onwards. Conversely, it appears that between 2015-2019 this relationship has strengthened significantly once again.

However, this figure only encompasses one specific tenet of labour productivity: investment of machine capital. It does not account for a different form of capital that is just as crucial a component to labour productivity: human capital. Indeed, Aoki (2013) has argued that the unfavourable demographic shift towards a shrinking population (and, by extension, a shrinking labour force) has negatively impacted a Japan-specific system employed by many Japanese firms: On-the-job training for lifetime employment. Traditionally, Japanese workers are often hired by a specific firm for the duration of their working age. As such, it is in the firm's interests to train their workers in the specific skills they will need as they will likely stay with the firm until the day they retire. However, the labour shortages driven by Japan's shrinking population has threatened this system and perhaps has given favour to contract workers (in recent days, this is not dissimilar to what is now referred to as the gig economy). However, due to the nature of these contract workers the on-the-job training with expectations of long-term work with the company no longer functions, thus a vital component of human capital formation in Japanese firms is perhaps lost.

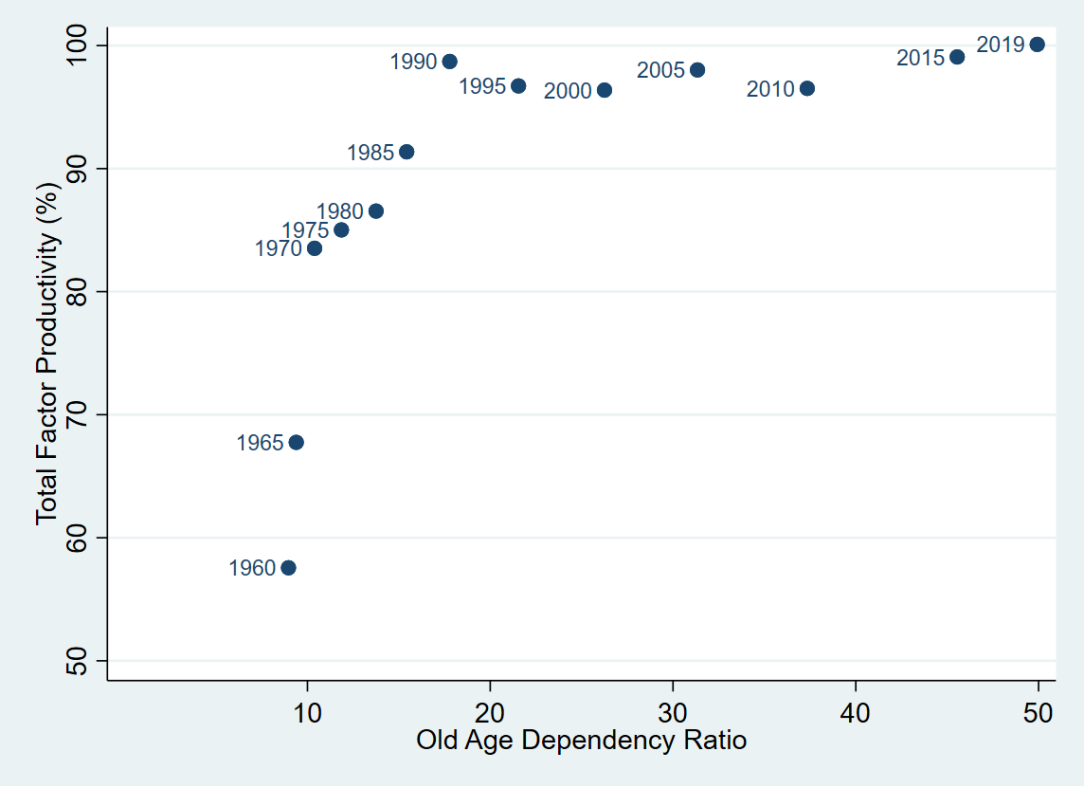

Figure 3: The relationship between Old Age Dependency Ratio and total factor productivity.

This figure instead displays the correlation between old age dependency ratio and total factor productivity (TFP). Unlike capital intensity, which represents the amount of physical capital invested into labour, TFP effectively represents how effectively these capital inputs translate into outputs. In other words, it is a measure of the increase in output per unit increase in inputs, whether it be labour or capital (human or machine). As figure 3 therefore demonstrates, the TFP saw immense growth between 1960 to 1970 and 1980 to 1990. However, from 1990 onwards the relationship fluctuated much more often rather than a clear sign of growth, signaling the end of the Japanese Economic Miracle.

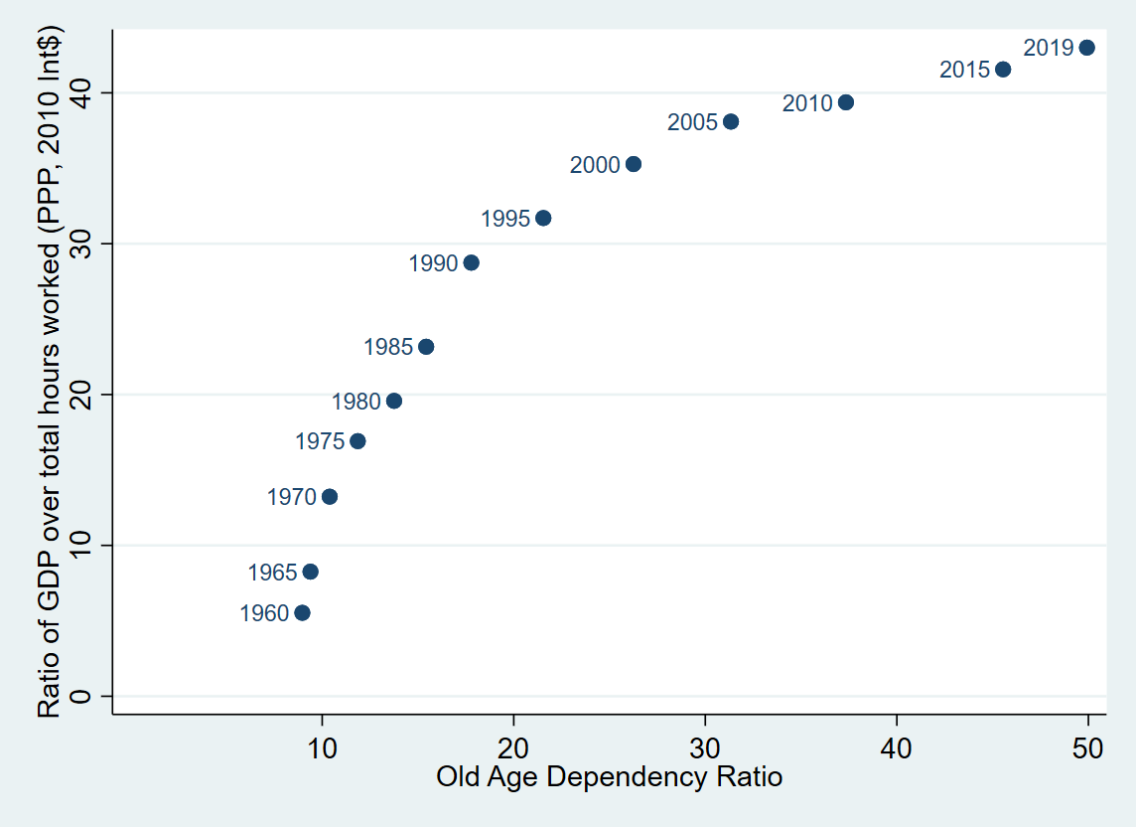

Figure 4: Correlation between the Old Age Dependency Ratio and the Ratio of GDP over total hours worked.

This figure encompasses the aim of the study: to investigate the correlation between Japan's ageing population (in this case using the old age dependency ratio as the unit of measurement) and labour productivity. Unlike what figure 1 suggests, which depicts the GDP per capita over the old age dependency ratio, figure 4 instead seems to indicate that labour

productivity has not stalled in relation to the old age dependency ratio by the 1990s. Indeed, there is still decent productivity growth relative to ageing at this point. Instead, the stagnation only begins around 2005 and onwards, suggesting that perhaps the 1990s financial crisis isn't the only factor at play in explaining Japan's slowdown in economic growth. But even then, the change in the relationship follows a gradual, logarithmic pattern over time. This suggests that the mechanism behind the change in the relationship between labour productivity and population ageing is a gradual process rather than any singular, sudden, watershed event. In order to investigate multivariate relationships, regression analysis will therefore be needed to fully answer this question.

5 Empirical Results

5.1 Analysis

Variable	Coefficient	Standard Error	P-value
Growth rate of Old age Dependency Ratio	0.14	0.15	0.33
Growth rate of capital intensity	0.37	0.04	0.00
Total Factor Productivity	1.11	0.09	0.00
Growth of net FDI inflow	-0.02	0.63	0.98
Constant	0.04	0.57	0.95
Adjusted R^2	0.84		

Table 2: Regression of labour productivity with regards to long term interest rates, public debt to GDP ratio, the old age dependency ratio, the total factor productivity, FDI net inflow, the real effective exchange rate of the Yen and capital intensity from 1990 to 2019

This regression shows a staggering adjusted R^2 value of 0.84 which suggests that almost the entirety of factors affecting the movement in labour productivity is accounted for in this

regression. The growth rate of old age dependency ratio and the net FDI inflow have a p-value above 0.05, therefore these variables have an insignificant effect on labour productivity. Total factor productivity is predictably a significant and very strong predictor of labour productivity. For every percent by which TFP grows each year will result in an a slightly higher than one percent increase in labour productivity in that same year, which is illogical. However, as this regression is linear, it can overlook that the relationships between these variables and economic growth change over time. As figure 3 has previously indicated, 1990 appears to be a major turning point for the Japanese economy when the economic bubble of the 1980s burst. Therefore, this thesis will be conducting two regressions, one pre-1990 and one post-1990.

Variable	Coefficient	Standard Error	P-value
Growth rate of Old Age Dependency ratio	1.05	0.54	0.11
Growth rate of Capital Intensity	0.08	0.24	0.74
Growth rate of TFP	1.48	0.26	0.002
Growth rate of FDI inflow	0.0002	0.0001	0.20
Constant	-1.05	1.02	0.35
Adjusted R^2	0.8888		

Table 3: Regression of labour productivity growth with regards to the growth of the old age dependency ratio, capital intensity, TFP and FDI inflow from 1980 to 1990.

As this regression shows, none of the dependent variables, including the old age dependency ratio, were significant predictors of labour productivity growth except for the growth rate of TFP, where the variable has both a significant and strong effect on the growth of labour productivity. In fact, it could be argued that the regression overstates the effect of TFP growth on labour productivity. With no other variable and the constant (which admitted starts in the negative) in this regression being insignificant, it implies that for every additional percent TFP increases by, it translates to more than 1.4 percentage point increase in labour productivity, which would be nonsensical.

Furthermore, the adjusted R^2 value for the regression is very high at around 0.88, which indicates that the regression could be overfitted. The Variance Inflation Factor (VIF) of this regression can be calculated to test for the possibility of multicollinearity among the variables as a reason for the high adjusted R^2 value. The results show that, the highest VIF was only 2.43 for growth of labour productivity, which indicates that while there could be some limited multicollinearity, it should not be high enough to indicate the abnormal adjusted R^2 value (the full VIF table for the regression is displayed in Appendix 2).

Variable	Coefficient	Standard Error	P-value
Age Dependency ratio	1.00	1.34	0.49
Growth rate of Capital Intensity	0.61	0.55	0.31
Growth rate of FDI inflow	0.0005	0.0002	0.10
Constant	-1.05	2.5	0.57
Adjusted R^2	0.4397		

Table 4: Regression of labour productivity growth with regards to the growth of the old age dependency ratio, capital intensity and FDI inflow from 1980 to 1990.

Indeed, performing the same regression but not including the growth rate of TFP results in an adjusted R^2 value of 0.44, a slightly low if less abnormal value. In combination with the results of the previous VIF test, it indicates that the adjusted R^2 value of the previous regression might not be the result of an overfit but could be accurate to the regression. In other words, in line with the previous regression results, TFP is a major explanatory variable in the growth of labour productivity in the 1980-1990 period (ie, during the Japanese Economic Miracle). Two interpretations can therefore be drawn from the previous regression: either the relationship between TFP and labour productivity is being vastly overestimated or the estimation is correct and none of the other stated variables are relevant to the growth of labour productivity. It should be noted that these two interpretations are not mutually exclusive to the other.

Variable	Coefficient	Standard Error	P-value
Age Dependency ratio	0.38	0.19	0.049*
Growth rate of Capital Intensity	0.27	0.07	0.001
Growth rate of TFP	0.97	0.14	0.000
Growth rate of FDI inflow	0.00003	0.0001	0.78
Constant	-0.73	0.74	0.34
Adjusted R^2	0.63		

*Not rounded to 3 significant figures to show that it is just under the 0.05 significance level.

Table 5: Regression of labour productivity growth with regards to the growth of the old age dependency ratio, capital intensity, TFP and FDI inflow from 1990 until 2019.

This regression suggests that from 1990 onwards, the age dependency ratio's growth has become a relevant factor in the growth of labour productivity, being only just under the 0.05 threshold. Therefore, although the null hypothesis could be rejected for the growth rate of the old age dependency ratio, the relationship should not be automatically seen as significant, and it should be much less correlated. The P-value is not a threshold measure, it is a scale and therefore there is a just under 1 in 20 chance that the relationship between labour productivity growth and growth of old age dependency ratio is insignificant.

Nevertheless, the correlation is also decently strong in its effect - for every additional percent by which old age increases, it corresponds with an additional 0.38 percent increase in labour productivity or vice versa. Although it should be noted that, as indicated by the relatively high P-value, the standard deviation for the growth of the age dependency ratio is quite high, at 0.19 percentage point standard deviation when the coefficient is at 0.38 percentage points. In other words, there is still much uncertainty in the strength of the relationship between the age dependency ratio and labour productivity.

Unlike the 1980-1990 regression, the growth rate of capital intensity has also become significant in its relationship with labour productivity growth with an additional percentage point growth of capital intensity correlating with an additional 0.27 percentage points for capital intensity. TFP growth continues to have a significant relationship with labour productivity,

although the effect is comparatively less strong. However, it is nonetheless quite high and significant compared to the pre-1990 period, with a coefficient of 0.97. FDI inflow, meanwhile, has remained extremely weak and insignificant in its relationship with labour productivity. In other words, it would imply the growth of labour productivity in Japan has had no effect on encouraging foreign investments into Japan or foreign direct investment has had no real effect on stimulating the growth of labour productivity. It should also be noted that the constant of this regression is still insignificant.

However, these previous two regressions by their nature presume all the other included independent variables as constant when measuring any single independent variable's relationship with regards to labour productivity growth. However, if the argument posited by Acemoglu and Restrepo (2017) were correct, it would imply that there might exist a moderation effect between capital intensity and the old age dependency ratio itself in relation to labour productivity. More specifically, employers will substitute labour with more capital as the population ageing progresses. In effect, as the age dependency ratio increases, the effect of capital intensity on labour productivity should also strengthen.

Variable	Coefficient	Standard Error	P-value
Age Dependency ratio	-6.38	2.48	0.06
Growth rate of Capital Intensity	-3.37	1.15	0.04
Moderation effect between Old Age Dependency Ratio and Capital Intensity	1.64	0.54	0.04
Growth rate of TFP	1.33	0.17	0.001
Growth rate of FDI inflow	0.0002	0.00008	0.03
Constant	14.4	5.15	0.049*
Adjusted R^2	0.9652		

*Not rounded to 3 significant figures to show that it is just under the 0.05 threshold.

Table 6: Regression of labour productivity growth with regards to the growth of the old age dependency ratio, capital intensity, TFP, net FDI inflow and the moderation effect between the old age dependency ratio and capital intensity from 1980 to 1990.

This regression once again features a very high adjusted R^2 value of more than 0.96. As with table 3, the high adjusted R^2 value is almost solely caused by the growth rate of the TFP variable. All independent variables with the exception of the age dependency ratio itself are considered significant in this regression (the moderation effect between old age dependency ratio and capital intensity is still significant). It should be noted that while the constant is significant, it is once again at the threshold of rejecting the null hypothesis.

Nevertheless, the regression portrays a drastic difference between labour productivity and capital intensity than what the previous regressions suggested. The direction of the relationship has flipped, whereas the previous regressions suggested a positive relationship between capital intensity and labour productivity, this regression projects a negative relationship, and quite a strong negative relationship too, with an additional percentage point of capital intensity growth leading to more 6 percentage point decrease in labour productivity, which would at first seem illogical.

However, when the moderation effect is accounted for, the results become more logical as the regression suggests that the moderation effect is quite strong. That is, either for every additional percentage point by which the old age dependency ratio grows, the effect of capital intensity on labour productivity grows by an additional 1.64 percentage point or vice versa. In other words, it would seem Acemoglu and Restrepo's argument (2017) that an ageing population will drive increasing reliance on automation as a form of capital to increase labour productivity in order to counteract the effect of a shrinking labour force.

TFP still remains significant and strong in its relationship with labour productivity, only diminishing slightly compared to table 3. FDI net inflow has also become significant in its relationship with labour productivity, but only extremely weakly so. For every additional percentage point by which FDI net inflow grows by, it barely increases labour productivity by 0.0002 percent, or vice versa.

Variable	Coefficient	Standard Error	P-value
Age Dependency ratio	0.08	0.46	0.87
Growth rate of Capital Intensity	4.72	1.42	0.003
Moderation effect between Old Age Dependency Ratio and Capital Intensity	-1.09	0.36	0.006
Growth rate of TFP	1.24	0.29	0.000
Growth rate of FDI inflow	0.0002	0.0002	0.382
Constant	0.10	1.75	0.953
Adjusted R^2	0.4212		

Table 7: Regression of labour productivity growth with regards to the growth of the old age dependency ratio, capital intensity, TFP, FDI inflow and the moderation effect between the old age dependency ratio and capital intensity from 1990 to 2019.

For the post 1990 period, the old age dependency ratio once again becomes insignificant in its relationship with labour productivity. However, capital intensity has become strongly positive in its relationship with labour productivity (with a coefficient of 4.72). In contrast, the

moderation effect has become negative. In other words, the regression now implies that either the old age dependency ratio has a negative effect on capital intensity's effect on labour productivity or vice versa. The reversal of the relationship's direction either refutes Acemoglu and Restrepo's (2017) argument or indicates a poorly fitted model. However, assuming the model is not a poor fit, the regression might not necessarily disprove Acemoglu and Restrepo, but rather might indicate that the relationship between demographic ageing, capital intensity and labour productivity has changed when comparing before and after the lost decade recession.

Recalling figure 2, which indicates a relatively strong relationship between capital intensity and labour productivity can be observed from the 1970-1990 period. From 1990 to 2000, the Lost Decade, the relationship is still noticeable but has become weaker. However, it has been approximately 2015 onwards that the relationship has plateaued noticeably. In fact, despite capital stock having increased by more than 50 dollars per hour worked over these 5 years, an approximate 33% increase in labour intensity, labour productivity has barely increased. To that extent, Acemoglu and Restrepo's (2017) argument would no longer apply to Japan's situation in the recent decade.

However, following Tang and Macleod's (2006) own argumentation which posits that the effect of an older working population would also negatively impact labour productivity, the results of table 7 might in fact portray this effect indirectly. While old age dependency ratio is still insignificant in its impact with labour productivity, the strong negative moderation effect with capital intensity may indicate that either an older working population has more difficulty adopting new technologies (in other words, not benefitting as much from more capital investment as before) as Tang and Macleod (2006) claimed. Alternatively, capital intensity became a method to substitute the labour productivity growth loss from an ageing population in more recent years, thus shifting from stimulating productivity growth to maintaining current productivity levels in the face of an ageing population.

To further investigate the claims made by Tang and Macleod (2006) of older workers being less productive, the following regression will use the old age dependency ratio as a proxy for the average age of workers. Unfortunately, data on employed workers by age groups in Japan are not comprehensive enough to calculate the precise median or average for. To that extent, the thesis will now instead employ the worker dependency ratio measure which this thesis has created to explore the relationship between the growth rate of TFP with worker dependency

ratio. The thesis will therefore now perform regressions with TFP as the dependent variables and the worker dependency ratio as the main independent variable:

Variable	Coefficient	Standard Error	P-value
Worker Dependency ratio	-0.04	0.17	0.83
Labour productivity Growth	0.53	0.11	0.002
Capital Intensity growth	-0.13	0.14	0.41
Constant	0.07	1.73	0.97
Adjusted R^2	0.81		

Table 8: Regression of total factor productivity with regards to the growth of the worker dependency ratio, labour productivity and capital intensity from 1980 to 1990.

For the 1980-1990 period, this regression produces an unsurprisingly very similar result to table 3, but inverting labour productivity growth and TFP growth as the independent and dependent variable respectively. In both cases, Labour productivity growth is the only independent variable with a significant relationship with TFP growth during this time period. Specifically, it suggests that just above half of the growth in Japanese TFP during the 1980-1990 period was driven by growth in labour productivity. The high adjusted R^2 value of this regression is once again almost solely due to the relation between TFP and labour productivity.

Variable	Coefficient	Standard Error	P-value
Worker Dependency ratio	0.09	0.02	0.00
Labour productivity Growth	0.89	0.08	0.00
Capital Intensity Growth	-0.16	0.04	0.001
Constant	-2.77	0.52	0.00
Adjusted R^2	0.82		

Table 9: Regression of total factor productivity with regards to the growth of the worker dependency ratio, labour productivity and capital intensity from 1990 to 2019.

From 1990 onwards, the worker dependency ratio does in fact become significant to the growth of TFP, positively so in fact. However, it is still a somewhat weak correlation with a coefficient of only approximately 0.09. Labour productivity growth is significant and has an even stronger relationship with TFP growth than in the 1980-1990 period with a coefficient of approximately 0.89. Capital intensity growth is also significant in its relation to TFP growth. However, the correlation is either spurious or indirect. Capital intensity growth is only included within the regression to account for the effect of capital endowment on labour productivity. TFP measures the amount of output that can be produced with the same unit of input, whether it be labour or capital. In other words, TFP growth should not be affected to large degrees by the growth of capital intensity. Instead, the regression results for capital intensity here effectively offsets the most likely overestimated relationship between labour productivity growth and TFP, which results from increased capital input rather than true TFP growth.

Variable	Coefficient	Standard Error	P-value
Worker Dependency ratio	0.45	0.65	0.52
Labour productivity Growth	1.71	1.52	0.31
Moderation effect between Worker Dependency Ratio and Labour productivity	-0.11	0.14	0.47
Capital Intensity Growth	-0.13	0.15	0.41
Constant	-5.00	6.72	0.49
Adjusted R^2	0.80		

Table 10: Regression of labour factor productivity with regards to the growth of the worker dependency ratio, labour productivity, capital intensity and the moderation effect between worker dependency ratio and labour productivity from 1980 to 1990.

Evidently, this regression is a poor explanator of TFP growth for the 1980-1990 period. None of the independent variables listed significantly related to labour productivity growth. Puzzlingly, the adjusted R^2 is still very high given none of the variables were significant in its relationship even with the constant itself being insignificant.

Variable	Coefficient	Standard Error	P-value
Worker Dependency ratio	0.06	0.02	0.01
Labour productivity Growth	0.54	0.24	0.04
Moderation effect between Worker Dependency Ratio and Labour Productivity	0.02	0.01	0.16
Capital Intensity Growth	-0.14	0.05	0.006
Constant	-2.25	0.62	0.001
Adjusted R^2	0.83		

Table 11: Regression of total factor productivity with regards to the growth of the worker dependency ratio, labour productivity, capital intensity and the moderation effect between worker dependency ratio and labour productivity from 1990 to 2019.

For the 1990-2019 period, the regression reveals that the worker dependency ratio and labour productivity growth had become significant with regards to TFP growth. However, the moderation effect between worker dependency ratio and labour productivity remains an insignificant predictor of TFP growth.

The existence of a positive relationship between worker dependency ratio and TFP growth therefore challenges Tang and Macleod's (2006) argument that an older working population would struggle in adapting more modern technologies, at least in the case of Japan (Tang and Macleod's study was specific to the context Canada). TFP growth is still outpacing the effects of a shrinking Japanese labour market from demographic ageing. Given that Japan already has relatively high capital intensity (in other words there is high capital input relative to labour input), it is perhaps the growth of capital *productivity*, which is unfortunately absent from the regression due to a lack of data. Perhaps this capital productivity component is the main driving component of TFP growth in recent decades.

Therefore, the regression provides more credence to Acemoglu and Restrepo's (2017) explanation as to why TFP growth might not have a negative relationship with regards to the worker dependency ratio, but in fact a positive relation to it. The "endogenous response of

technology" (Acemoglu & Restrepo, 2017, p.179) to demographic ageing would naturally lead to employers both adopting more and developing better automation. In the absence of capital productivity being represented in the regression, it is therefore possible the regression attributed the positive effect to the growth of worker dependency ratio instead.

5.2 Discussion

To summarize, this study has investigated the relationship between old age dependency ratio (and worker dependency ratio) with regards to labour productivity growth and TFP growth, respectively. Before the Lost Decades, labour productivity growth was driven almost solely by TFP growth rather than growth in capital endowment. However, as the regression does not break the TFP growth down to its constituent parts, it remains unclear to what extent the labour productivity growth is a result of growth in machine capital productivity and which part is human capital development.

From 1990 onwards, however, capital endowment itself has become significant in its relationship with labour productivity but is moderated by the old age dependency ratio, even though the latter does not have a significant relationship itself with labour productivity growth. In other words, it suggests that the correlation between capital intensity and labour productivity weakens as the population ages. This could suggest that Tang and Macleod's (2006) findings are accurate. Older workers would be less proficient in adapting new technology, translating to labour productivity benefiting less from capital endowment as the population ages. Indeed, the results would explain graph 1. As a reminder, the relationship between the old age dependency ratio and GDP per capita changed drastically from pre-1990 to post-1990. Specifically, the relationship became much weaker after 1990, and perhaps even non-existent from 2010 onwards. This could perhaps explain the lack of a significant relationship between old age dependency ratio and labour productivity since 1990 as, simply put, GDP per capita and labour productivity has not kept up with demographic ageing in Japan.

As for TFP growth itself, the relationship is much less clear. There does not appear to be a moderation effect between the worker dependency ratio and labour productivity in this regard, so the results of table 9 will be primarily used for the rest of the discussion. It suggests that an ageing population does not necessarily mean TFP growth is stifled and might even encourage the

research and adoption of more sophisticated technologies, which would counter Tang and Macleod's arguments and lend more credence to that of Acemoglu and Restrepo's (2017).

However, it is important to restate here that as the extent of this study only extends to performing regressions, this study has run does not investigate nor imply causality between any of the correlations studied thus far. Some of these aforementioned relationships identified in this thesis may therefore be merely spurious correlations. By corroborating these empirical results with the evidence and argumentations of existing papers on the subject, it provides more credence to the possibility that the correlation isn't spurious. However, this thesis cannot concretely claim this with only the use of OLS regressions alone.

The implications of these results for Japanese policymakers and the future of the Japanese labour market could be troubling. Figure 1 shows that labour productivity is only increasing fast enough to maintain a relatively slow growth rate of real GDP per capita. On one hand that, assuming the relationship remains somewhat constant, this means Japan will be able to maintain a relatively stable standards of living. On the other hand, the current predicament could in many ways be described as secular stagnation. If the regression result does in fact show a causative relationship between an ageing population and a decrease in marginal return from capital investment, then capital substitution as a tool to compensate for the shrinking and ageing labour force is becoming less and less effective over time due to the very process of demographic ageing itself. To that extent, the secular stagnation caused by demographic ageing could be a critical issue confronting the future of Japanese economic growth as capital endowment struggles to keep up with the loss in labour productivity.

However, this study has also found a positive relationship between the growth rate of TFP and worker dependency ratio, although it is unclear through what mechanism this relationship operates. It could operate through a mechanism in which Acemoglu and Restrepo (2017) argue that ageing and shrinking labour force is met with an endogenous response to further develop labour-saving technologies. Alternatively, it could be operating through the mechanism of work training as Onofri (2004) suggests wherein older workers will be more experienced (more endowed with human capital, in other words) and therefore be more productive.

On the other hand, Tang and Macleod (2006) argue that age does not necessarily coincide with skill nor experience. After all, individuals can switch professions entirely, and experience a

lapse of unemployment in the middle of their working life, et cetera et cetera. All of these possibilities provide a considerable argument against the assumption that age equates to experience. However, given the context of the Japanese labour market wherein lifetime employment at a workplace is considered the norm, the assumption that age roughly equates to more workplace experience or human capital endowment is arguably valid for the Japanese context. Conversely, as Aoki (2013) has posited, demographic ageing poses a threat to this very system of Japanese lifetime employment as the shrinking labour force will mean Japanese firms must either accept employing less individuals over time, a fixture which will be long term due to the aforementioned expectation of lifetime employment, or start to switch to more contract based sources of employment, which Aoki (2013) has find empirical evidence of. All in all, the issue of whether age can serve as a sufficient proxy of human capital in the form of experience is still unclear and will most definitely vary from sector to sector and era to era.

This opens to another important discussion regarding the statistical analysis done thus far in this paper: the question of validity and limitations. As mentioned, this study lacks a direct measure or sufficient proxy of human capital, the closest being the age dependency ratio. The traditional measure of years of schooling is not as effective for Japan due to two reasons. Firstly, Japan was already a relatively developed economy by the 1980s with relatively high standards of living and on average most individuals have finished at least high school and by 2000 on average half of the Japanese population aged 25-34 have achieved tertiary level education (OECD, 2022).

Secondly, human capital does not only comprise education but includes factors such as job training and experience as well. As aforementioned, the Japanese work culture of lifetime employment also means employers are willing to provide their workers extensive on-the-job training. As there is no readily available measure or proxy to represent this factor, it is unfortunately outside the scope of this thesis to gather sufficient data to represent this accurately in the statistical analysis.

Another issue with regressions 8 to 11 is with regards to the worker dependency ratio measure. The thesis has created and used this measure as it was better reflective of the fact that an increasing number of the Japanese population continue to participate in the labour market past the traditional retirement age of 65, however in using the measure, the thesis has implicitly made certain assumptions and simplifications that, upon closer scrutiny, will reveal some flaws that compromises the accuracy of the analysis. First, the measure presumes that working hours

remain constant throughout the age groups of workers, that a 30-year-old individual would work the same approximate number of hours as someone over the age of 65.

Indeed, this would initially seem irrelevant to the context of TFP growth as it is only measuring how efficient a set sum of machine capital and labour hours can produce, working hours is not a factor to consider. However, in the context of the overarching goal of this thesis to analyse the extent to which the Japanese economy can adapt and grow despite the ageing population, this context does matter.

TFP could indeed grow faster, if only marginally it should be noted, due to some mechanism as a response to population ageing or due to having an older, more experienced population. But given that several sources of empirical research (Acemoglu & Restrepo, 2017; Onofri, 2004; Tang & Macleod, 2006) have shown evidence that older people will tend to put in less labour hours than younger workers, it provides the context that perhaps some other factor at play could explain the relationship between TFP growth and demographic ageing. While it is outside the immediate scope of this thesis, there have been tentative research, such as those done by Pencavel (2016), which suggests that lower working hours or shorter work weeks correspond with higher per hour labour productivity as the individuals are more physically and mentally well rested. Along similar lines, due to a limitation of available public data, this study did not contain a measure of working hours, nor does it specifically differentiate between full-time workers or part-time workers. Regardless, the bigger picture is that TFP growth is just one part of the GDP per capita equation, which is itself only one measure of living standards and whether the latter can be maintained in the face of an ageing population.

This research must also re-emphasize the possibility of spurious correlations. Japan has indeed begun to grow much slower economically since the 1990s, even after partially recovering by the turn of the 21st century. Of course, it can very well be that the implications of this paper are correct and population ageing has dampened economic growth due to a loss in the effectiveness of capital intensity to boost labour productivity, thereby slowing down the rate at which Japan can grow economically. However, there are alternative explanations to this phenomenon which does not necessarily involve age, the most straightforward one is that Japan has simply reached the technological frontier of the developed world. They are no longer benefiting from the catch-up economic effect, and thus are simply no longer growing as quickly as before. Yet this theory is not itself without problems. In terms of GDP per capita, Japan has

already largely caught up by the 1970s, the start period of the regressions done within this analysis (World Bank, 2023). In fact, by 1990, Japan was markedly above the OECD average of GDP per capita. It can still perhaps be argued that by the 1970s Japan has neared the technological frontier, but not yet reached the edge. By the 1990s, Japan might have effectively gone from being near the technological frontier (ie: an OECD country) and towards being a technological leader, which might still explain the growth slowdown in a manner not related to demographic ageing.

6 Conclusion

6.1 Research Aims

The initial purpose of this research was to delve into the question of whether Japan can continue to grow economically or, at the least, can sustain the burden of a rapidly ageing population in recent decades. To that extent, the results of the statistical analysis done within this thesis suggest that while Japan has still been economically growing, albeit slowly in recent decades. However, this thesis has also found evidence which could suggest that this growth will continue to slow down over time as the population ages. Therefore, if the assumption is that wealth distribution remains relatively the same over time, Japan might enter a secular stagnation phase where GDP per capita and standards remain stable but relatively unchanging, or at least, it will experience only very slow growth going forward.

6.2 Research Objective

On a more technical side, this paper investigated the relationship between ageing, as represented by the old age dependency ratio and worker dependency ratio with growth in labour productivity and TFP. This thesis began with the hypothesis that there would be a moderately strong relationship between labour productivity and population ageing, or at the very least population ageing caused by increased longevity.

Table 5 investigated this directly and indeed displayed a moderately positive relationship between the old age dependency ratio and growth of labour productivity. However, as has been

discussed, the relationship is borderline insignificant, which therefore seems to indicate that the relationship between demographic ageing and labour productivity is dubious.

Instead, it would seem that the relationship between the old age dependency ratio and labour productivity is not direct but works instead as a moderator variable. Specifically, the old age dependency ratio's impact on labour productivity does not occur directly, but rather through the effectiveness of capital intensity. It suggests that older demographics are less capable of making optimal use out of more (presumably) advanced machine capital. Indeed, this is in line with the arguments made by Tang and Macleod (2006).

This thesis also discovered a weakly positive relationship between TFP and the worker dependency ratio, with no significant moderation effect. This indicates that there is an endogenous response to the threat of a shrinking workforce by spurring further research and development to improve TFP.

6.3 Practical Implications

For Japanese policymakers, the implications of this analysis would be troubling. Given that historically attempts to bolster fertility rates in Japan has had negligible effects, there are little alternatives in the demographic avenue other than further opening the country up to immigration and integration, another topic that Japan has evidently been quite reluctant to approach. The alternative of proceeding along current trajectories holds several pitfalls that policymakers will need to address to avoid potential stagnation or possible wealth inequality arising from these demographic changes. Automation, as it currently stands, offers a promising method of circumventing the issue of a shrinking labour force. With the recent advances of artificial intelligence, the types of jobs which can be automated.

However, without proper laws and redistributive channels, the boons of automation for labour productivity could potentially disproportionately benefit capital owners over labourers and thus could threaten to increase income inequality. Furthermore, employers and policymakers alike will need to consider providing more extensive labour retraining or otherwise take into consideration the very real possibility that older workers in their employment will have more trouble adapting to and making the most use of newer labour-saving technologies. Efforts to bolster labour productivity must be the top priority of Japanese public policymakers and employers alike as the population pyramid increasingly becomes top heavy.

Despite the extensive focus of this research on the Japanese context, demographic ageing is a common phenomenon to practically all OECD economies. Thus, while some contexts may be quite different from country to country, some of the basic intuitions of this study may still prove useful. Considering that Japan is a leader in the realm of demographic ageing, other countries that still have a comparatively younger population should invest effort into training its labour force with the capability to employ and operating automation technologies, perhaps even retraining those who are currently working in fields that is under threat of being made obsolete due to automation.

6.3 Future Research

This thesis also contributes to the existing discipline of economic demography and could prove helpful to future researchers in the field. As previously mentioned, literature on the impacts of demographic ageing in modern Japan (specifically, from the 2000s onwards) has been lax. This thesis therefore updates the research until 2019 and analyzes the issue through a macro-level time series. However, alternative lenses and analysis methods may offer new insights, interpretations, or correlations of demographic ageing, such as cohort level or household level studies of a representative sample.

Furthermore, this study's research primarily centers around regressions. Unfortunately, due to the limited scope of the thesis, it did not perform any causality test, and thus this study could only establish potential relationships between the variables and speculate on the direction of the relationship. Therefore, further research can contribute by investigating the causal link between demographic ageing and economic growth.

As previously mentioned, other developed economies are also undergoing various degrees of demographic ageing, thus the possibility of replication studies with other countries could reveal how different countries and economic dynamics also affect how demographic ageing affects economic growth in different contexts.

Bibliography

Acemoglu, D. & Restrepo, P. (2017). Secular Stagnation? The Effect of Ageing on Economic Growth in the Age of Automation, *American Economic Review*, vol. 107, no. 5, pp.174–179.

Aoki, R. (2013). A Demographic Perspective on Japan's 'Lost Decades', *Population and Development Review*, [e-journal] vol. 38, no. SUPPL.1, pp.103–112, Available Online: https://www.jstor.org/stable/23655289.

Bergeaud, A., Cette, G. & Lecat, R. (2023). Productivity Trends in Advanced Countries between 1890 and 2022, Review of Income and Wealth, [e-journal] vol. 62, no. 3, pp.420–444, Available Online: http://www.longtermproductivity.com/download.html.

Bloom, D. E., Canning, D. & Fink, G. (2010). Implications of Population Ageing for Economic Growth, *Oxford Review of Economic Policy*, vol. 26, no. 4, pp.583–612.

Federal Reserve Bank of Saint Louis. (2020). Federal Reserve Economic Data, Available Online: https://fred.stlouisfed.org/.

Gerstel, D. & Goodman, M. P. (2020). Japan: Industrial Policy and the Economic Miracle, in From Industrial Policy to Innovation Strategy: Lessons from Japan, Europe, and the United States, [e-book], pp.5–9, Available Online: http://www.jstor.org/stable/resrep26046.5.

Hamada, K. & Okada, Y. (2009). Monetary and International Factors behind Japan's Lost Decade, *Journal of the Japanese and International Economies*, vol. 23, no. 2, pp.200–219.

Japanese Bureau of Statistics. (2023). Japan Population Census, Available Online: https://www.e-stat.go.jp/en/stat-search/files?page=1&layout=datalist&toukei=00200532&tstat=000001116777&cycle=0&tclass1=000001116800&tclass2val=0.

Jordà, Ò., Schularick, M. & Taylor, A. M. (2020). Macrofinancial History and the New Business Cycle Facts, NBER Macroeconomics Annual, Vol. 31, Available Online: https://www.macrohistory.net/database/.

Kuznets, S. (1971). Nobel Prize Lecture, Stockholm, 11 December 2014

Madsen, E. (2014). Potential and Pitfalls: The Economic Implications of Population Ageing, *Georgetown Journal of International Affairs*, [e-journal] vol. 15, no. 2, pp.4–9, Available Online: https://www.jstor.org/stable/43773621.

Muto, I., Oda, T. & Sudo, N. (2016). Macroeconomic Impact of Population Ageing in Japan: A Perspective from an Overlapping Generations Model, *IMF Economic Review*, vol. 64, no. 3, pp.408–442.

OECD. (2022). Education at a Glance 2022: OECD Indicators. Available Online: https://www.oecd-ilibrary.org/sites/1e0a77e5-en/index.html?itemId=/content/component/1e0a77e5-en#section-d1e12220 [Accessed 10 May 2024].

OECD. (2024). Old-Age Dependency Ratio, Available Online: https://data.oecd.org/pop/old-age-dependency-ratio.htm [Accessed 10 March 2024].

Onofri, P. (2004). The Economics of an Ageing Population: Macroeconomic Issues, Economic and Social Research Institute, [e-book] ESRI Studies Series on Ageing

Pencavel, J. (2016). Recovery from Work and the Productivity of Working Hours, *Economica*, [e-journal] vol. 83, no. 332, pp.545–563, Available Online: https://www.jstor.org/stable/26746601.

Prettner, K. (2013). Population Ageing and Endogenous Economic Growth, *Journal of Population Economics*, [e-journal] vol. 26, no. 2, pp.811–834, Available Online: https://link.springer.com/article/10.1007/s00148-012-0441-9.

Tang, J. & MacLeod, C. (2006). Labour Force Ageing and Productivity Performance in Canada, *Canadian Journal of Economics*, [e-journal] vol. 39, no. 2, pp.582–603, Available Online: https://www.jstor.org/stable/3696170%0A.

World Bank. (2023a). Foreign direct investment, net (BoP, current US$) - Japan, OECD Members, Available Online: https://data.worldbank.org/indicator/BN.KLT.DINV.CD?locations=JP

World Bank. (2023b). Age dependency ratio (% of working-age population) - Japan-Japan, OECD Members, Available Online: https://data.worldbank.org/indicator/SP.POP.DPND?locations=JP

Appendix

Appendix 1: Sample employment data from the Japanese Bureau of Statistics

Age Group	Population (ten thousand persons)	Labour Force Participation Rate (%)
15-19	621	16.2%
20-24	704	69.3%
25-29	765	85.3%
30-34	916	81.0%
35-39	965	81.0%
40-44	842	84.2%
45-49	780	86.1%
50-54	789	83.7%
55-59	999	77.0%
60-64	894	59.8%
65 and over	2810	20.2%

Sample population data from the Japanese Bureau of Statistics for the year 2008. Note that the labour participation rate for those aged 65 and over is just over 20%. Unfortunately, the database does not contain the precise years for these workers past the age of retirement.

Appendix 2: VIF Sample

Variable	VIF
Capital Intensity Growth	2.43
Old Age Dependency Ratio	2.11
TFP Growth	1.74
Net FDI Inflow Growth	1.44

VIF sample for table 3, none of the variables had an overtly high VIF to the point that significant levels of autocorrelation between the independent variables should be assumed.