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MACROECONOMICS 1

PROJECT

JAPAN: HOW TO FIGHT SHORTAGE OF PEOPLE IN THE LABOR MARKET

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I. Introduction

The successful transformation of Japan from a war-ravaged country into a developed economy has been a topic of discussion since the 60s. Such tremendous growth was due to a number of factors, among which there is the shift of labor from low to high productivity. Moreover, there is low unemployment and high employment rates in the Japanese labor market, which result in a labor market performance above the OECD¹ average. However, structural changes, such as technological progress or population ageing are factors, which contribute to the transformation of the supply and demand for labor.

The population ageing is an important problem for Japan. According to the 2014 estimations about 38% of the Japanese population was above the age of 60, and 25.9% was above the age of 65. The last figure increased to 29.1% by 2022. According to the 2023 reports almost a third of Japan's population is over 65, 36.23 millions². This issue has a negative impact on Japan's economy. Thus, in 2020, the International Monetary Fund forecast: "the ageing and shrinking population will strain Japan's public finances, as age-related spending – such as on healthcare and pensions – rises while the tax base shrinks"³. Moreover, the birth rate is falling and the population is decreasing due to this problem.

Recent researches have shown that AI⁴, the current technological innovation, can influence the labor market⁵. The net impact of AI on employment is ambiguous. On the one hand, it will displace some human labor and lead to unemployment, while on the other hand, AI can raise labor demand due to the high productivity effect it provides and create new job's opportunities for workers, whose skills are complementary to AI. Thus, Japan's situation with population aging could be improved by the maximization of AI's impact on economic growth with the minimum effect of job displacement.

¹ The Organization for Economic Co-operation and Development

² Wakamatsu-cho, Shinjuku-ku Current Population Estimates / Wakamatsu-cho, Shinjuku-ku [Electronic resource] // Statistics Bureau of Japan : [website]. — URL: <https://www.e-stat.go.jp/en/stat-search/files?page=1&layout=datalist&toukei=00200524&tstat=000000090001&cycle=7&year=20230&month=0&tclass1=000001011679> (date of application: 16.05.2024).

³ Japan: Demographic Shift Opens Door to Reforms / [Electronic resource] // International Monetary Fund : [website]. — URL: (date of application: 16.05.2024).

⁴ Artificial intelligence

⁵ Katarina Milanovic Artificial Intelligence and the Labor Market / Katarina Milanovic [Electronic resource] // Sciences Po : [website]. — URL: <https://www.sciencespo.fr/women-in-business/en/news/article-artificial-intelligence-and-the-labor-market/> (date of application: 16.05.2024).

II. Japan overview

In order to support our future analysis of the article, some recent key macroeconomic indicators of Japan's labor market and its dynamics will be provided below.

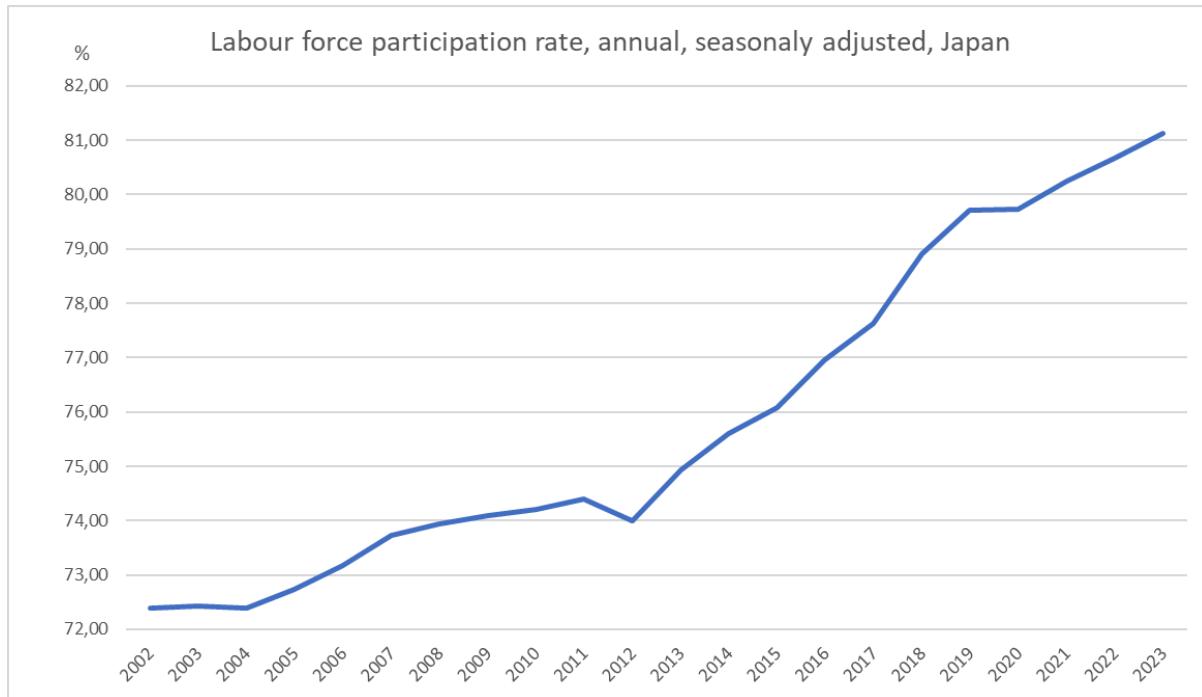


Figure 1.

The labor force participation rate in Japan averaged 63.69% from 1953 until 2024, reaching its highest of 74% in June 1955 and a record low of 58.5% in 2012⁶. It is worth mentioning that the labor force participation rate as a whole has increased (Figure 1) over the past 20 years (from 2002 to 2023). In 2023 it reached the value of 81%⁷.

⁶ Japan Labour Force Participation Rate / [Electronic resource] // CEIC : [website]. — URL: <https://www.ceicdata.com/en/indicator/japan/labour-force-participation-rate#:~:text=Japan%20Labour%20Force%20Participation%20Rate,million%20people%20in%20Dec%202022> (date of application: 19.05.2024).

⁷ Organization for Economic Co-operation and Development Labor Force Participation Rate Total: From 15 to 64 Years for Japan [LRAC64TTJPA156S] / Organization for Economic Co-operation and Development [Electronic resource] // FRED, Federal Reserve Bank of St. Louis : [website]. — URL: <https://fred.stlouisfed.org/series/LRAC64TTJPA156S> (date of application: 27.05.2024).

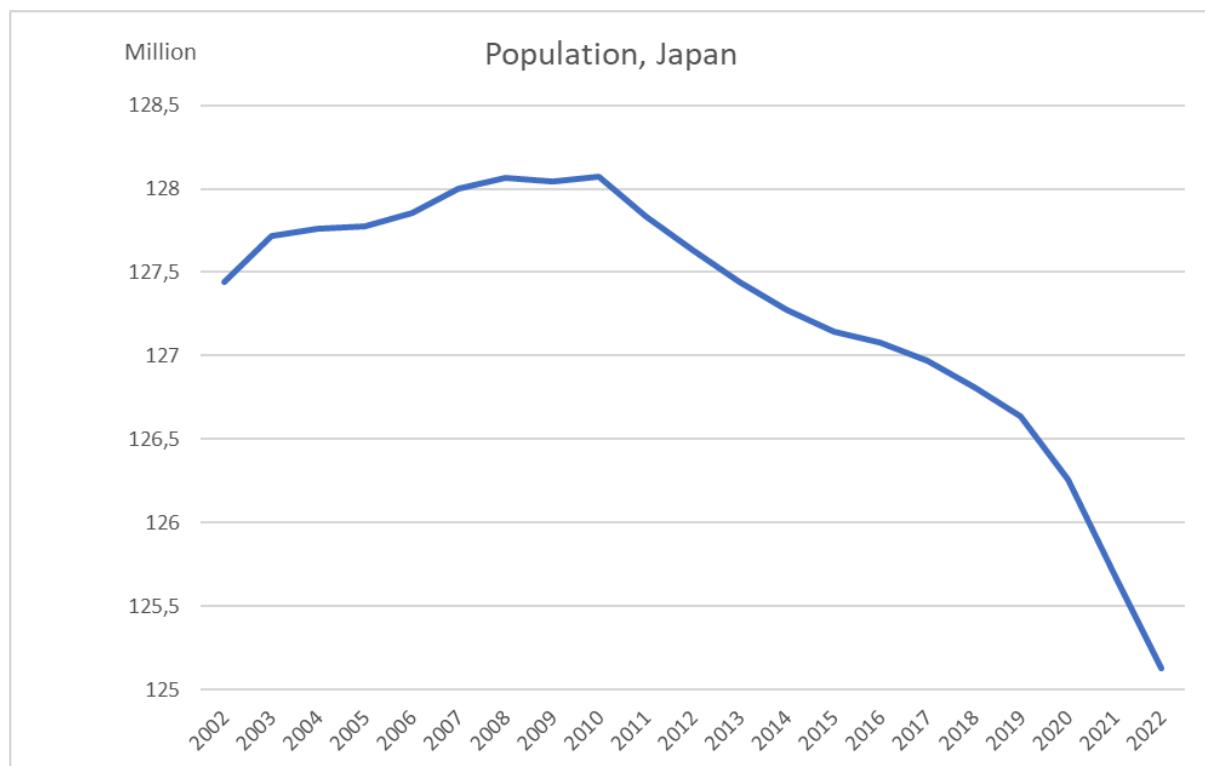


Figure 2.

The total population in Japan was estimated at approximately 125 million people in 2022⁸. It can be seen that the population has dramatically decreased after 2010 (Figure 2). In general, there is a negative trend in population growth.

⁸ Eurostat: Demographic Statistics, United Nations Statistical Division, Population and Vital Statistics Report (various years), U.S. Census Bureau: International Database, Secretariat of the Pacific Community: Statistics and Demography Programme. Population, total - Japan / Eurostat: Demographic Statistics, United Nations Statistical Division, Population and Vital Statistics Report (various years), U.S. Census Bureau: International Database, Secretariat of the Pacific Community: Statistics and Demography Programme. [Electronic resource] // The World Bank : [website]. — URL: <https://data.worldbank.org/indicator/SP.POP.TOTL?locations=JP> (date of application: 25.05.2024).

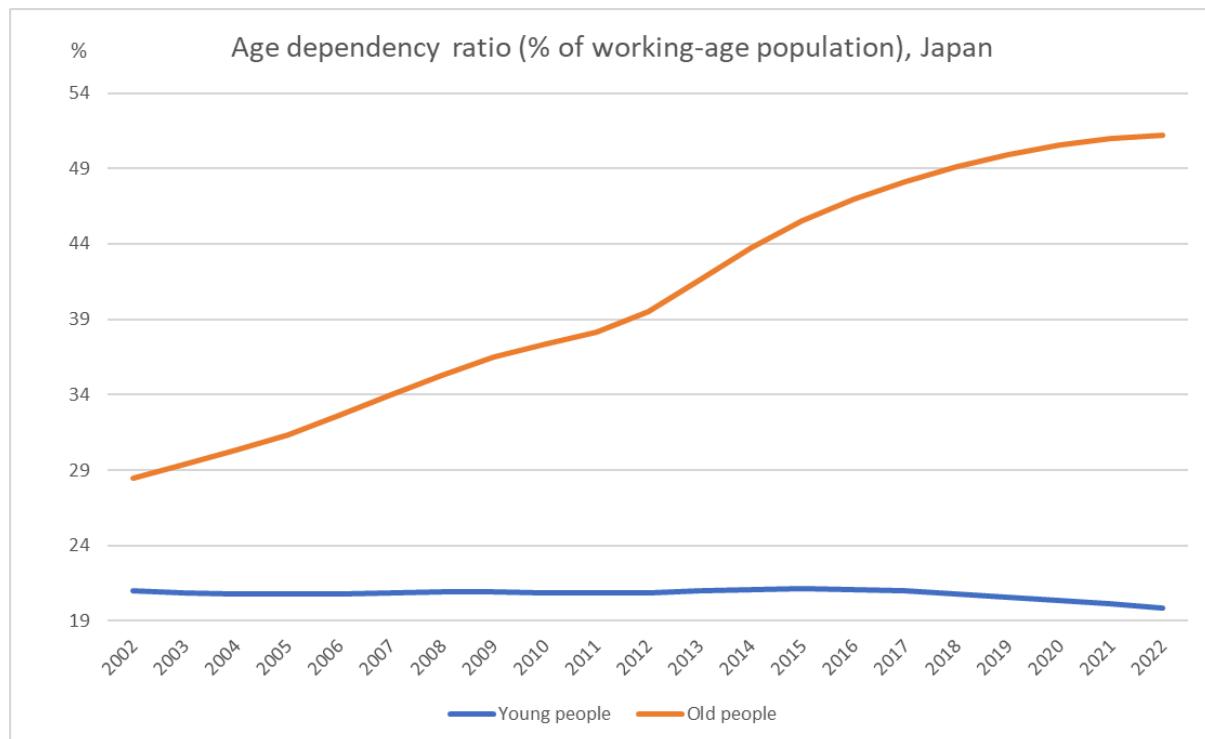


Figure 3.

Age dependency ratio shows how the young population (younger than 15) / old population (older than 64) relates to the working age population (in %). From the graph (Figure 3) it can be seen that the dependency ratio of old people was always much higher than the dependency ratio of the young population. Moreover, it is worth mentioning that over the last 5 years the young dependency ratio has steadily decreased, while the old dependency ratio has dramatically increased, exceeding the value of 50%⁹ (approximately 51,2% in 2022).

⁹ United Nations Population Division's World Population Prospects: 2022 Revision. Age dependency ratio, old (% of working-age population) / United Nations Population Division's World Population Prospects: 2022 Revision. [Electronic resource] // The World Bank : [website]. — URL: <https://data.worldbank.org/indicator/SP.POP.DPND.OL> (date of application: 26.05.2024).

United Nations Population Division's World Population Prospects: 2022 Revision. Age dependency ratio, young (% of working-age population) / United Nations Population Division's World Population Prospects: 2022 Revision. [Electronic resource] // The World Bank : [website]. — URL: <https://data.worldbank.org/indicator/SP.POP.DPND.YG> (date of application: 26.05.2024).

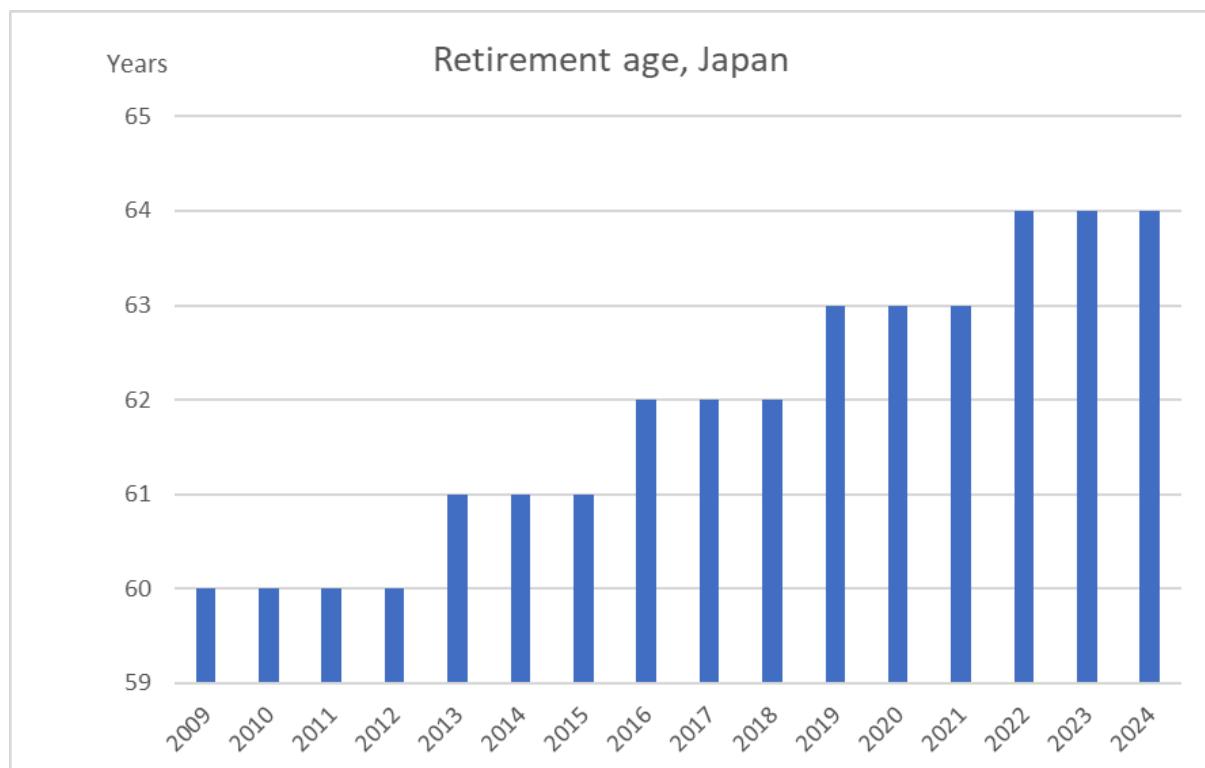


Figure 4.

The retirement age in Japan averaged 61.88 years from 2009 until 2024¹⁰. In 2024 the retirement age remained unchanged at 64 years from 2023. Overall, the retirement age has increased (Figure 4), leading to an increase of the aging population in the labor force.

¹⁰ Wakamatsu-cho, Shinjuku-ku Current Population Estimates / Wakamatsu-cho, Shinjuku-ku [Electronic resource] // Statistics Bureau of Japan : [website]. — URL: <https://www.e-stat.go.jp/en/stat-search/files?page=1&layout=datalist&toukei=00200524&tstat=000000090001&cycle=7&year=20230&month=0&tclass1=000001011679> (date of application: 16.05.2024).

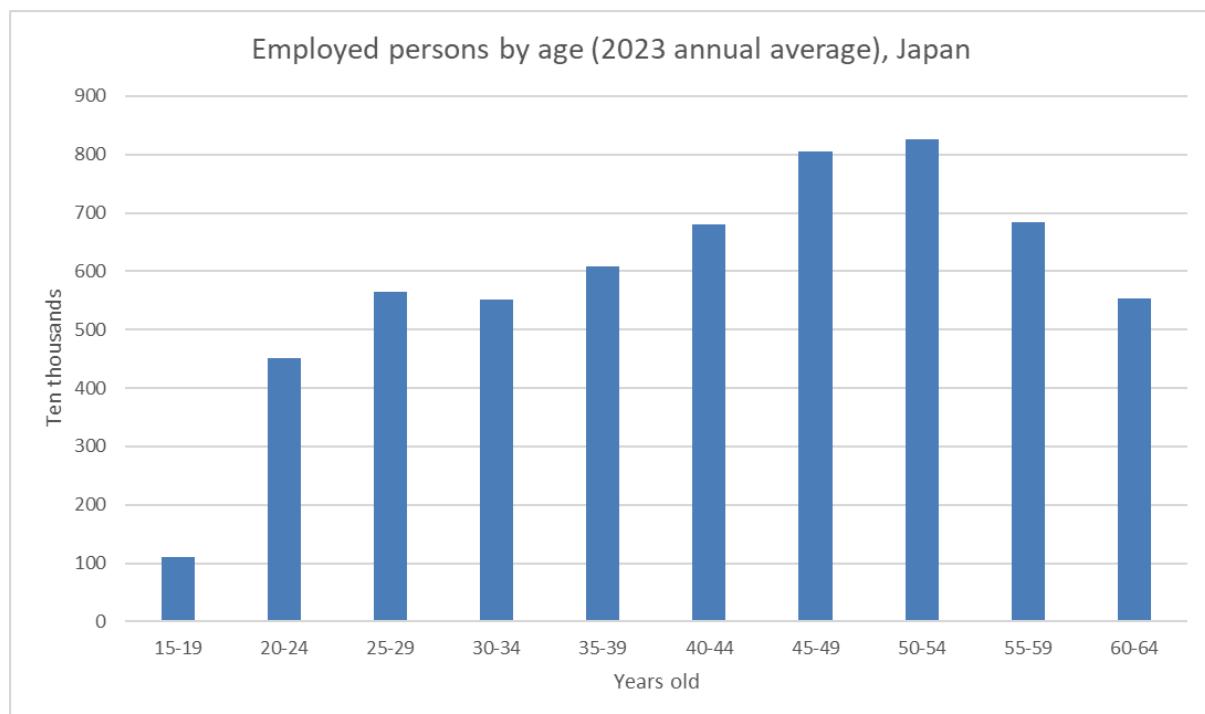


Figure 5.

It can be seen that the highest average number of workers are workers at ages 50-54, and the number of workers from 60 to 64 years is slightly higher than the number of workers 30-34 years old, 554 and 551 ten thousand respectively¹¹. Overall, the number of employed persons increases as the category's age increases, as it can be seen from the graph (Figure 5).

¹¹ Statistics of Japan / [Electronic resource] // e-Stat : [website]. — URL: <https://www.e-stat.go.jp/en/stat-search/files?page=1&layout=datalist&toukei=00200524&tstat=000000090001&cycle=7&year=20230&month=0&tclass1=000001011679&tclass2val=0> (date of application: 16.05.2024).

III. The story. Analysis of article¹²

= G =

THE SITUATION: Japan is facing a tight job market. There are fewer people who are not working but want to work, and this number has dropped a lot in 20 years.

CONSEQUENCES: Because there aren't enough workers, companies are paying more for part-time work. This pay rise is the biggest in years, except for the time during the pandemic.

REASONS: More jobs are available for older folks and women who previously left jobs for family reasons. But now, there aren't enough of these people left to fill all the jobs.

CHANGES: Japan used to have lots of extra workers from the countryside that could work in factories, but not anymore. Now, wages are going up because there aren't enough workers.

NEEDS: Businesses need to find new ways to work because they can't rely on cheap loans and a big workforce anymore. They might struggle if they don't make enough profit.

SOLUTIONS: To deal with the worker shortage, companies could make jobs more productive, move workers around better, and hire more people from other countries.

FUTURE: Experts think Japan will need a lot more workers in the future. Using things like AI could help make work more efficient.

= E =

LABOR MARKET DYNAMICS:

Japan is experiencing a contraction in its labor force participation rate, with a significant reduction in the latent workforce - individuals who are not actively employed or seeking employment but are willing to work. This contraction is quantified by a decrease from 2.97 million to 2.33 million in the potential labor pool over two decades.

¹² Hirofumi Kanaoka Japan is running out of people on sidelines of job market / Hirofumi Kanaoka [Electronic resource] // Nikkei : [website]. — URL: <https://asia.nikkei.com/Spotlight/Work/Japan-is-running-out-of-people-on-sidelines-of-job-market> (date of application: 12.05.2024).

WAGE INFLATION:

The scarcity of labor is exerting upward pressure on wages, evidenced by a 3.8% increase in hourly wages for part-time workers.

DEMOGRAPHIC SHIFTS:

The demographic transition, characterized by a 15% decline in the working-age population and an increase in employment among traditionally non-working demographics (older individuals and women), is reshaping the labor market. The near disappearance of the M-shaped employment curve for women indicates a structural change in workforce participation.

TURNING POINT:

The situation mirrors the Lewis model, where the "Lewis Turning Point" signifies the absorption of surplus labor by the industrial sector, resulting in wage increases. Japan's current difficult situation suggests a new inflection point, driven by the diminishing returns of integrating female and older workers into the labor force.

ECONOMIC POLICY & CORPORATE STRATEGY:

The end of Japan's negative interest rate policy by the Bank of Japan introduces new fiscal pressures, potentially leading to changes in corporate strategies amidst rising labor costs and interest rates. This shift may lead to shutdown of low-profit businesses, which previously thrived under deflationary conditions.

PROJECTION & SOLUTION:

To mitigate the impending labor shortage projected to reach nearly 8 million by 2035, Mitsubishi UFJ Research and Consulting advocates for a 1 percentage point annual increase in labor productivity, which could address approximately 70% of the deficit. This underlines the importance of productivity enhancement as a counterbalance to workforce shortages. The adoption of Artificial Intelligence by the city of Osaka for administrative tasks exemplifies the potential for technology to increase productivity and allow workers to engage in more complex, value-added activities.

= M =

JAPAN LABOR MARKET STRUCTURE IN 2003 & 2023:

«notations»

PNW - population of non-working age

PW - population of working age, 15-64 years old

NLF – not in the labor force, inactive people able to work, but not seeking a job

U – unemployed people, who are not working and are seeking a job

E – employed people, who are currently working

e - employment rate

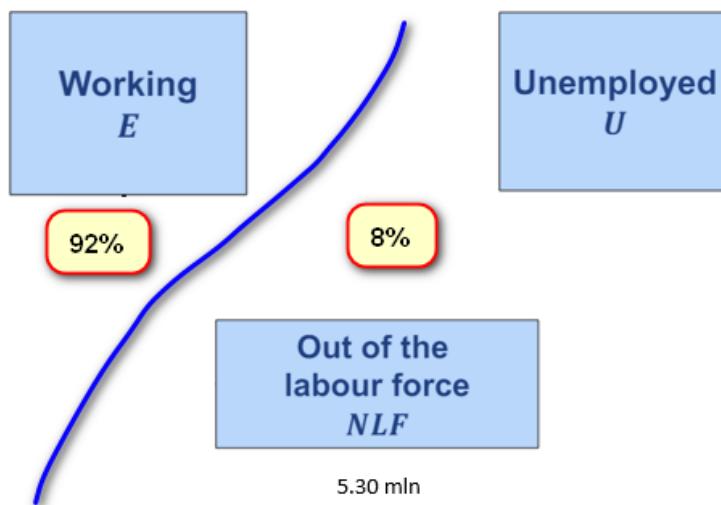


Figure 6.

Figure 6 details on market structure in 2003:

$$NLF_{2003} = NLF_{2023} + 2.97 \text{ mln} = 2.33 \text{ mln} + 2.97 \text{ mln} = 5.30 \text{ mln}$$

$$\text{«potential workers»} = U + NLF$$

$$\frac{U + NLF}{PW} = \frac{U + 5.30 \text{ mln}}{PW} = 8 \% \quad (1)$$

$$e = \frac{E}{PW} = 92 \% \quad (2)$$

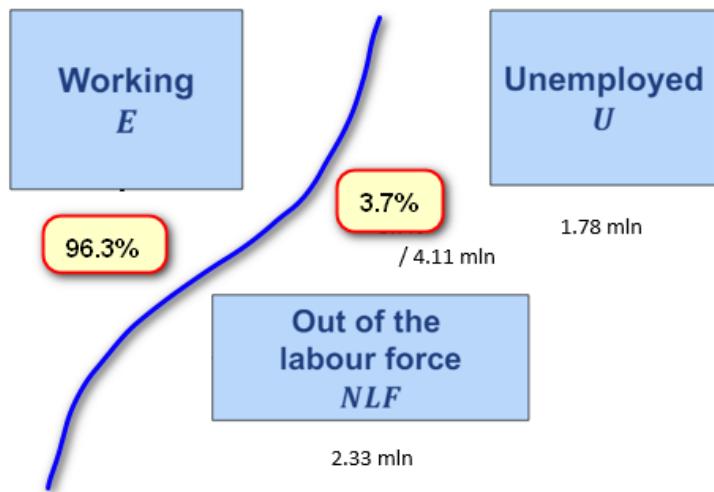


Figure 7.

Figure 7 details on market structure:

$$NLF_{2023} = 2.33 \text{ mln}$$

$$U_{2023} = 1.78 \text{ mln}$$

$$NLF_{2023} + U_{2023} = 2.33 \text{ mln} + 1.78 \text{ mln} = 4.11 \text{ mln}$$

$$\frac{NLF + U}{PW} = \frac{4.11 \text{ mln}}{PW} = 3.7 \% \quad (3)$$

$$e = \frac{E}{PW} = 96.3 \% \quad (4)$$

DYNAMICS & CONSEQUENCES:

Figure 8 comprehensive comparison of labor market structures in 2003 and 2023:

$$(2) \cup (4) : \quad e_{2023} - e_{2003} = 96.3 \% - 92 \% = 4.3 \%$$

The employment has increased by 4.3 % in the last 20 years due to economic recovery and more job opportunities for people past the traditional retirement age and women who had left the labor market to raise children. Statistical evidence can be seen from figure 8¹³.

¹³Ministry of Internal Affairs and Communications [Electronic resource] Statistics of Japan / Labour Force Survey / Historical Data // e-Stat : [website]. — URL:

(1) \cup (3) :

$$\frac{NLF_{2023} + U_{2023}}{PW_{2023}} - \frac{NLF_{2003} + U_{2003}}{PW_{2003}} = 3.7\% - 8\% = -4.3\%$$

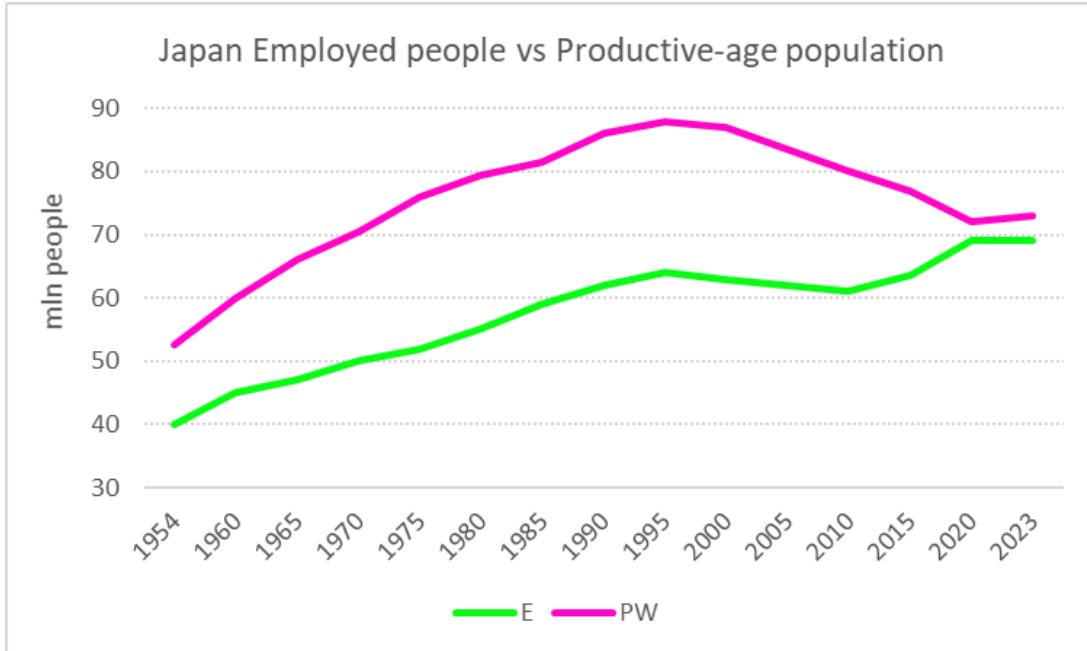


Figure 8.

Employed people \uparrow , PW $-15\% \downarrow \Rightarrow$ shrinking labor pool $\Rightarrow w \uparrow$ (Lewis Turning Point)
(Figure 9)

«notations»

w - hourly wages, wages

wages \uparrow $(W_T / W_{T-1} - 1) \times 100\% = 1\%$	hourly wages \uparrow $(W_T / W_{T-1} - 1) \times 100\% = 3.8\%$
--	---

Figure 9.

<https://www.e-stat.go.jp/en/stat-search/files?page=1&layout=datalist&toukei=00200531&tstat=000000110001&cycle=0&tclass1=000001040276&tclass2=000001011681&tclass3val=0> (date of application: 26.05.2024).

POTENTIAL PROBLEMS & SOLUTIONS:

«notations»

A - technology | N - number of workers in company | C_w - costs of firms on wages

The end of negative interest rate and increasing wages may shake out low-profit businesses, which will damage the economy.

Mitsubishi UFJ Research and Consulting estimates that in 2035 Japan will be nearly 8 million workers short of the level needed for real gross domestic product to match the economy's potential growth rate of 0.5% per year.

Proposed solutions for the problem:

1) Higher labor productivity

$$A \uparrow \Rightarrow N \downarrow \Rightarrow C_w \downarrow = N \downarrow \times w$$

It estimates that an annual increase of 1 % in labor productivity would make up about 70% of the shortfall. Artificial intelligence could help companies work more efficiently.

2) Job mobility

job mobility $\uparrow \Rightarrow$ staff will be able to carry out wider range of tasks \Rightarrow no need to hire a lot of highly specialized staff $\Rightarrow N \downarrow \Rightarrow C_w \downarrow = N \downarrow \times w$

3) Foreign participation in the labor force

foreign participation in the labor force \Rightarrow labor pool $\uparrow \Rightarrow w \downarrow \equiv C_w \downarrow$

IV. Solow model

Assumptions and set-up

The main objective of this work is to argue the author's opinion on ways to tackle the impact of demographic features of Japan on its economy. Specifically, in order to eliminate the effect of declining labor force, he suggests to attract foreign workers, increase labor productivity and implement "artificial intelligence and other tools that could help companies work more efficiently". So, we will first analyze the initial situation of a downturn of share of potential workers, and after that, we will explore and assess the effectiveness of proposed measures. Our goal is to assess long-term effects of the measures on the economy. Thus, here Solow model can be applied. In addition, the author of the article focuses on production abilities of Japan, not its demand side, which supports our decision to apply supply-side theory in the case analysis. First, let us list crucial assumptions that make this theory applicable for the case analysis. Basic Solow model assumptions are the following.

1. Factors of production are substitutes not complements
2. Saving rate s is exogenous
3. Wages adjust so that the supply of labor and the demand for labor adjust perfectly
4. Other assumptions are not mentioned here but are specified later in the model setup.

We will consider neoclassical aggregate production function of 3 independent variables: $Y(t) = F(K(t), L(t), A(t))$. Hereinafter, we will skip time t in the notations. The author wants to emphasize that improvement of technology will make labor more efficient, so, in our turn, we would like to interpret A as effectiveness of labor. Thus, we assume labor-augmenting neoclassical production function: $Y = F(K, AL)$.

Now, let us move to the model setup. Define capital accumulation equation $\Delta K \equiv K_{t+1} - K_t = I_t - \delta K_t$, meaning change in the stock of capital is equal to gross investment at that point of time minus depreciation (assume it is a linear function of

depreciation δK_t). In continuous time model, $\Delta t \rightarrow 0 \Rightarrow \frac{dK}{dt} \equiv I - \delta K$. Let s be the proportion of output Y that is saved. We have $I \equiv S = sY$, so $\dot{K} = sY - \delta K$.

Now we move to the evolution of labor and technology. Assume, growth rate of labor n is

exogenous, and in continuous time $n = \frac{\dot{L}}{L}$. Similarly, assuming evolution of technical

change g is exogenous as well, let us set $g = \frac{\dot{A}}{A}$. Denote $k = \frac{K}{AL}$ capital accumulation per

unit of effective labor, $y = \frac{Y}{AL} = f(k)$ output per unit of effective labor.

$$k = \frac{K}{AL} \Rightarrow [\text{taking logs}] \Rightarrow \ln(k) = \ln(K) - \ln(A) - \ln(L) \Rightarrow$$

$$[\text{taking time derivatives of both sides}] \frac{d \ln(k)}{dt} = \frac{d \ln(K)}{dt} - \frac{d \ln(A)}{dt} - \frac{d \ln(L)}{dt} \Rightarrow$$

$$\frac{\dot{k}}{k} = \frac{\dot{K}}{K} - \frac{\dot{A}}{A} - \frac{\dot{L}}{L} = \frac{\dot{K}}{K} - (g + n) \Rightarrow \frac{\dot{K}}{K} = \frac{\dot{k}}{k} + (g + n) \quad (1)$$

We also have $\dot{K} = sY - \delta K$, so by dividing both sides by K we obtain

$$\frac{\dot{K}}{K} = \frac{sY}{K} - \delta \quad (2)$$

$$(1) = (2) \Rightarrow$$

$$\frac{\dot{k}}{k} + (n + g) = \frac{sY}{K} - \delta \Rightarrow \frac{\dot{k}}{k} + (n + g) = \frac{sY/\textcolor{blue}{AL}}{K/\textcolor{blue}{AL}} - \delta \Rightarrow \frac{\dot{k}}{k} = \frac{sf(k)}{k} - (n + g + \delta)$$

$$[\text{multiply both sides by } k] \Rightarrow \dot{k} = sf(k) - (n + g + \delta)k$$

By definition, in steady state, the state variable (in our model $k=K/AL$) is constant, so the growth rate is zero.

$$\frac{\dot{k}}{k} = 0 \Leftrightarrow \text{there exists a certain level } k^* \text{ such that } sf(k^*) = (n + g + \delta)k^*$$

We ignore trivial solution $k^* = 0$ and consider only $k^* > 0$

Basic model

Status-quo in the basic model

This section aims to discuss the impact of ongoing trends in Japan's demography on its economic situation. Here, we will apply a standard graphical and algebraic analysis in a basic version of the Solow model. Assume, initially Japan's steady state was point (0). As Hirofumi Kanaoka, the author of the news article, mentions: "Japan's labor pool is losing precious depth, with the share of potential workers falling by half over two decades". We can incorporate this effect in the model by falling growth rate of labor n to negative levels. Indeed, this is supported by statistical facts that the birth rate in Japan is falling rapidly while

the population is aging¹⁴. After the change in labor growth rate occurs, the economy moves to the new steady state (1). Let us illustrate this more clearly in Solow diagram (Figure 10).

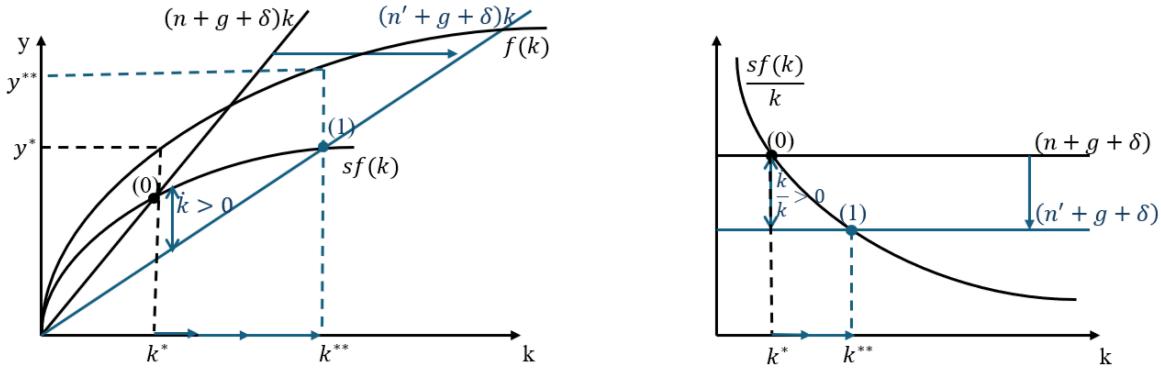


Figure 10.

Solow diagram demonstrates that lower n leads to the situation where the economy reaches new steady state equilibrium with higher levels of capital and output per unit of efficient worker. However, these results are not sufficient to fully evaluate the effects of changing trends in population on the economy, that is why, let us further look at transition paths of some other key macroeconomic variables. While transition dynamics of some variables, such as k and y , are seen from the Solow diagrams, others require some additional algebraic derivation, which we will introduce further in this section.

Interest rate r :

Here, we make an additional assumption that capital market is perfectly competitive, implies that all firms are price takers on capital market and maximize profits according to

$$\pi = F(K, AL) - (r + \delta)K - wL \rightarrow \max$$

$$\text{F.O.C. } MPK = \frac{\partial Y}{\partial K} = r + \delta$$

Thus, capital market clears when the capital is paid its marginal product net of depreciation:

$$r = MPK - \delta$$

$$MPK = \frac{\partial Y}{\partial K} = \frac{\partial [f(K/AL, 1) \times AL]}{\partial K} = f'(k) \frac{\partial (K/AL)}{\partial K} AL = f'(k) \frac{1}{AL} AL = f'(k)$$

On balanced growth path, $\delta = \text{const}$, $k = \text{const}$, $f'(k) = \text{const}$, then $r = \text{const}$.

However, during periods of transition to a balanced growth path, the rate of return may vary.

Assuming $\dot{\delta} = 0$, the growth rate of the rate of return to capital $r = MPK - \delta$ is

¹⁴ Birth rate, crude (per 1,000 people) - Japan / [Electronic resource] // The World Bank : [website]. — URL: <https://data.worldbank.org/indicator/SP.DYN.CBRT.IN?locations=JP> (date of application: 16.05.2024). Life expectancy at birth, total (years) - Japan / [Electronic resource] // The World Bank : [website]. — URL: <https://data.worldbank.org/indicator/SP.DYN.LE00.IN?locations=JP> (date of application: 16.05.2024).

$$\frac{\dot{r}}{r} = \frac{[f'(k)]}{f'(k) - \delta} = \frac{f''(k)\dot{k}}{f'(k) - \delta}$$

As k rises (as in our case), we obtain $f'(k) > 0$, $f''(k) < 0$, $\dot{k} > 0$, thus $\frac{\dot{r}}{r} < 0$.

GDP per capita:

For simplification of mathematical analysis, we take not GDP per capita itself, but its logarithm.

$$y = \frac{Y}{AL} \Rightarrow \frac{Y}{L} = Ay \Rightarrow \ln\left(\frac{Y}{L}\right) = \ln(y) + \ln(A)$$

Since taking logarithm is a monotonic transformation, behavior of $\ln(y)$ is analogous to behavior of y . As for labor productivity A , it can be derived explicitly.

$$g = \frac{\dot{A}}{A}$$

The rate of change of logarithm is constant and $= g$

$$\int d \ln A(t) = \int g dt \Rightarrow \ln(A(t)) = \ln(A(0)) + gt \Rightarrow A(t) = A(0)e^{gt}$$

$$\ln\left(\frac{Y}{L}\right) = \ln(y) + \ln(A_0 e^{gt}) = \ln(y) + \ln(A_0) + gt$$

Growth rate of GDP:

$$y = \frac{Y}{AL} \Rightarrow Y = yAL \Rightarrow \ln(Y) = \ln(y) + \ln(A) + \ln(L)$$

Taking time derivatives of both sides we obtain

$$\frac{\dot{Y}}{Y} = \frac{\dot{y}}{y} + \frac{\dot{A}}{A} + \frac{\dot{L}}{L} = \frac{\dot{y}}{y} + g + n$$

In steady state y is constant, thus $\frac{\dot{y}}{y} = 0$. Thus, in *steady state* $\frac{\dot{Y}}{Y} = g + n$.

Wages w:

Transition path of wages is similar to the transition path of the logarithm of wages. Assuming perfect competition result in the labor market, firms maximize their profits according to

$$\pi = F(K, AL) - (r + \delta)K - wL \rightarrow \max$$

$$\text{F.O.C. } MPL = \frac{\partial Y}{\partial L} = w$$

$$w = MPL = \frac{\partial Y}{\partial L} = \frac{\partial [f(K/AL, 1) \times AL]}{\partial L} = f(k) \frac{\partial (AL)}{L} + f'(k) \frac{\partial (K/AL)}{\partial L} \times AL =$$

$$f(k) \times A - f'(k) \frac{K \times AL}{AL^2} = A [f(k) - kf'(k)]$$

$$\frac{\partial w}{\partial k} = A [f'(k) - f'(k) - kf''(k)] = -Akf''(k) > 0, \text{ so wages increase with } k$$

$$\ln(w) = \ln(A) + \ln(f(k) - kf'(k))$$

Taking time derivatives we obtain

$$\frac{\dot{w}}{w} = \frac{\dot{A}}{A} + \frac{[f(k) - kf'(k)]}{[f(k) - kf'(k)]} = g + \frac{[f'(k)\dot{k} - f'(k)\dot{k} - kf''(k)\dot{k}]}{[f(k) - kf'(k)]} = g - \frac{kf''(k)\dot{k}}{f(k) - kf'(k)}$$

$$\text{In steady state } \dot{k} = 0 \Rightarrow \frac{\dot{w}}{w} = g.$$

With this we can now obtain transition paths (Figure 11) which demonstrate more extensively the impact of decrease in growth rate of labor.

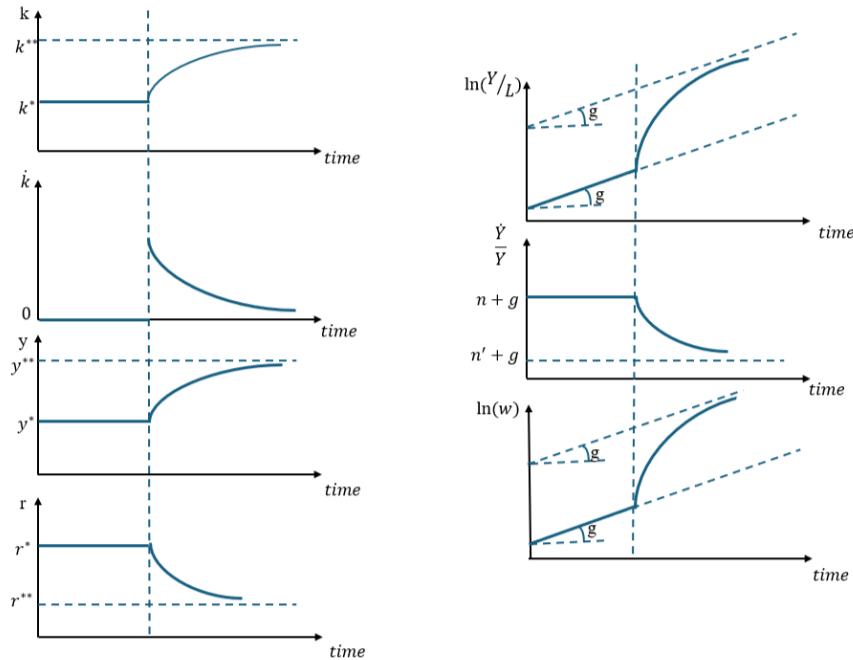


Figure 11.

Some of the interesting results of graphical analysis are the following. User cost of capital $r + \delta$ is expected to fall in the new steady state, while wages are expected to increase, as well as GDP per capita. However, a fall in the growth rate of labor causes lower GDP growth. So, now let us move to the next section, where we discuss policies proposed by the author to fight economic consequences of demographic shifts in Japan. Similarly, for now we look at the standard version of Solow model.

Policy proposition in the basic model

Hirofumi Kanaoka in his article proposes two main measures to fight economic consequences of the decrease in the working-age population. The first one is to stimulate foreign participation in the labor force. We will model it as a *rise in L* which is not accompanied by a rise in *n*. This is indeed the case for Japan, as among economically developed countries of the world Japan is among the group of countries with a relatively closed immigration system. It is aimed at preventing inflow of unskilled labor into the country. The evidence of this is the fact that 98% of population of the country are ethnic Japanese¹⁵. More extensively this issue is discussed further in the QA section while answering the question from team 01_2. So, indeed, the rise in labor force does not affect the growth rate of the number of workers.

As for the next policy, the author suggests to increase labor productivity and implement artificial intelligence to increase efficiency of labor. In our model it will be a *rise in labor productivity growth g*. The motivation for increasing *g* and not *A* is the following. Productivity paradox (Solow paradox) is described as a slowdown in productivity growth in the US in the 1970-1980s despite rapid development of information technology (IT). It is reflected by a famous quote of Robert Solow: “You can see the computer age everywhere but in the productivity statistics”¹⁶. Nevertheless, productivity growth effects need time to be seen in the statistics: “Firms need to rethink their business models, managers need to develop expertise for the digital age, workers need to be retrained to interact with these new technologies, complementary web applications and software need to be designed”¹⁷. Then, productivity boom occurs. So, despite the fact that similar to IT in the XX century, implementation of AI may not be explicit immediately, it definitely has long run effects, and it is the key reason why this proposition in the article is modeled as growth in *g* (*growth parameter*), not *A* (*value parameter*).

Now, in the Solow diagram (Figure 12) we consider that initial steady state (1) is the one that is settled after the demographic changes occurred. After an increase in *L* $k = K/AL$ immediately drops to $k' < k^{**}$. Additionally, after an increase in growth rate of labor productivity *g*, the line $(n + g + \delta)k$ rotates counterclockwise, leading to a new steady state levels of capital and output per efficient unit of labor k^{***} and y^{***} respectively. Here, we

¹⁵ Miguel Barrientos, Claudia Soria Japan Ethnic groups / Miguel Barrientos, Claudia Soria [Electronic resource] // IndexMundi : [website]. — URL: https://www.indexmundi.com/japan/ethnic_groups.html (date of application: 14.05.2024).

¹⁶ ‘We’d better watch out’, New York Times Book Review, 12 July 1987, page 36.

¹⁷ Georgios Petropoulos, Mamta Kapur Artificial intelligence: increasing labour productivity in a responsible way / Georgios Petropoulos, Mamta Kapur // The German Marshall Fund of the United States. — 24 November 2022. — P. 3, 11.

make an assumption that immediate levels of k and y are higher than the ones in the new steady state. This is directly connected with features of the Japanese migration policy described above. It is relatively strict, and to make the model more applicable for the case analysis we assume that inflow of foreign workers is relatively low, which is modeled by making immediate levels of k and y higher than the ones in the new steady state, as already stated above. The new steady state is depicted by point (2) in the Solow diagram.

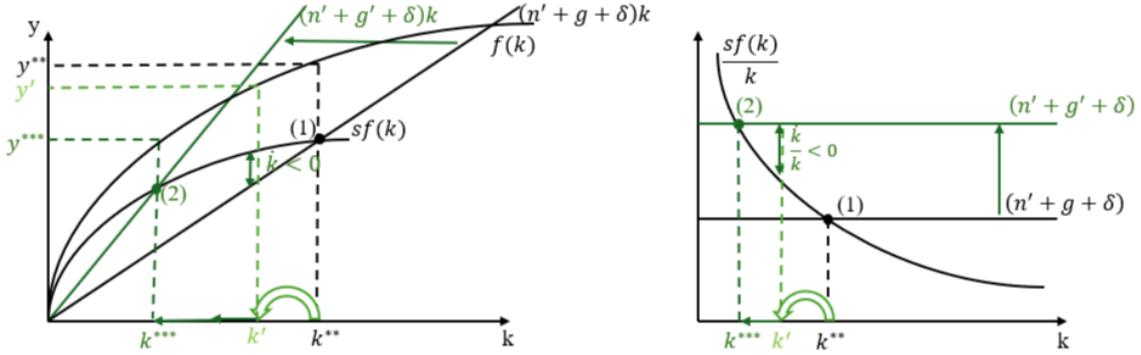


Figure 12.

The transition paths are the following (Figure 13):

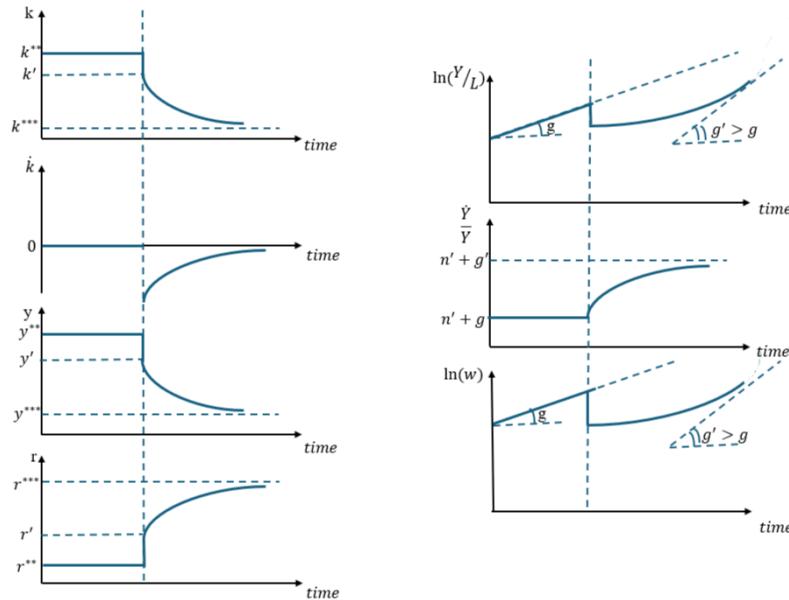


Figure 13.

Similar to the previous section, transition dynamics of k and y are seen from the Solow diagram. Other transition paths are derived from the algebraic formulae also described above. Here, we can see that as a result of proposed policies, capital and output per efficient unit of labor fall, both in SR and LR, while interest rate r increases which may threaten small

businesses in Japan by imposing larger costs for using capital. GDP per capita and wages fall immediately after implementation of proposed policies, but are even higher than in the steady state (1) due to higher growth of labor productivity g . Growth rate of GDP also rises. The answer to the question whether the new steady state level of output growth will exceed the one before demographic changes occurred depends on which absolute value is higher Δn or Δg . If the increase in the growth rate of labor productivity exceeds the absolute value of the decrease in the growth rate of labor, the model predicts that Japan will manage to combat demographic effects on GDP growth rate.

Extended model

The primal aim of this section is to extend the basic version of Solow model by adding the new parameter. In the extended setup we introduce new variable J as employed labor, which occupies some portion of labor force L , meaning $J = \alpha L$, $0 < \alpha < 1$. Thus, α is the proportion of people who are currently employed out of the whole labor force. The author of the article notices “increased labor participation by women and older people” in Japan. So, with the new variable in the setup we are able to incorporate the status-quo demographic situation in Japan as an increase in α . This does not contradict the analysis performed in the basic model section. When we consider the basic Solow model setup variables and the article we are trying to analyze, the most appropriate approach would be to model a decrease in labor growth rate n to illustrate ongoing trends in Japan’s demography. However, in order to make the model more applicable and not over complicated, we extend it by adding new variable α and model demographic shocks as an increase only in this new variable. Let

$k = \frac{K}{AJ} = \frac{K}{A\alpha L}$ be capital per efficient unit of employed labor. When women and elderly start to find new jobs, this contributes to increase in the proportion of people who are currently employed out of the whole labor, i.e. increase in α . This immediately lowers capital per efficient unit of employed labor. We can demonstrate this effect in the Solow diagram (Figure 14) and analyze some transition paths (Figure 15).

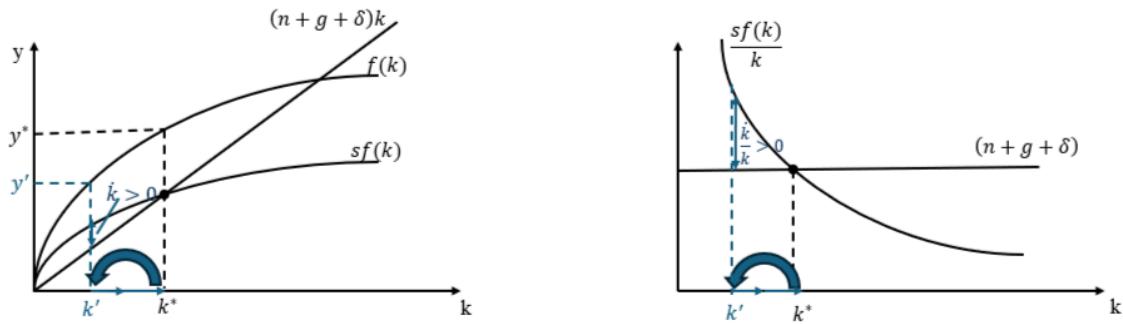


Figure 14.

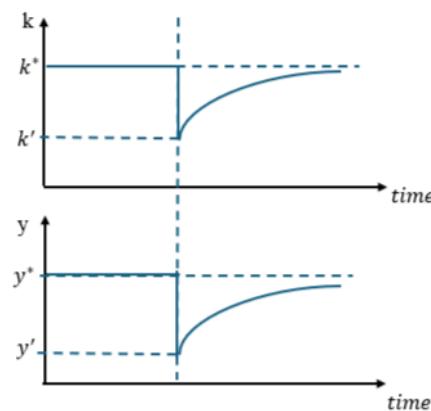


Figure 15.

Capital and output per unit of efficient labor k^\wedge and y^\wedge :

$$k^\wedge = \frac{K}{AL} = k \times \alpha \Rightarrow \ln(k^\wedge) = \ln(k) + \ln(\alpha)$$

$$y^\wedge = \frac{Y}{AL} = y \times \alpha \Rightarrow \ln(y^\wedge) = \ln(y) + \ln(\alpha)$$

Immediately after women and elderly find jobs, we have two simultaneous effects – on one hand α increases, but on the other hand capital (output) per efficient unit of employed labor (k and y) fall, so in SR the total effect is unclear, but in LR, k^\wedge and y^\wedge definitely converge to higher steady states (Figure 16).

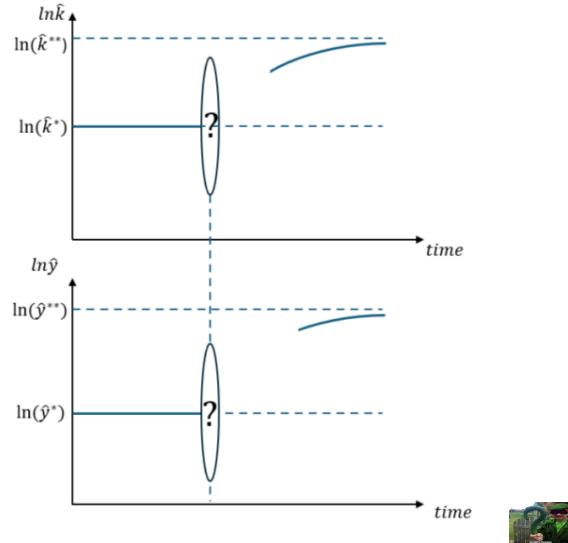


Figure 16.

Capital and output per unit of labor \tilde{k} and \tilde{y} :

$$\tilde{k} = \frac{K}{L} = k \times \alpha \times A \Rightarrow \ln(\tilde{k}) = \ln(k) + \ln(\alpha) + \ln(A) = \ln(k) + \ln(\alpha) + \ln(A_0) + gt$$

$$\tilde{y} = \frac{Y}{L} = y \times \alpha \times A \Rightarrow \ln(\tilde{y}) = \ln(y) + \ln(\alpha) + \ln(A) = \ln(y) + \ln(\alpha) + \ln(A_0) + gt$$

Capital and output per unit of labor \tilde{k} and \tilde{y} grow at rate g in steady state. When α rises, the effect in SR is unclear, similar to transition dynamic of capital and output per unit of efficient labor, but in LR it converges to a higher steady state (due to the fact that in LR both α and y and k increase) with the same growth rate g (Figure 17).

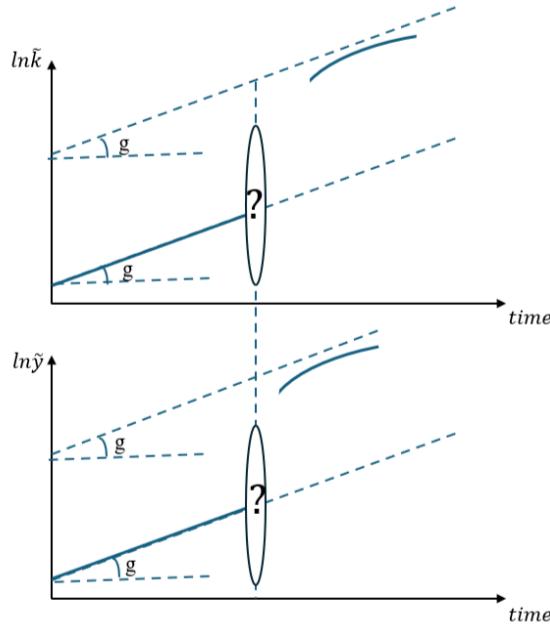


Figure 17.

Growth rate of GDP:

$$Y = y \times A \times \alpha \times L \Rightarrow \ln(Y) = \ln(y) + \ln(A) + \ln(\alpha) + \ln(L)$$

Taking time derivatives of both sides we obtain,

$$\frac{\dot{Y}}{Y} = \frac{\dot{y}}{y} + g + n + \frac{\dot{\alpha}}{\alpha}$$

Though there was one-off increase in α , it does not grow continuously, so

$$\frac{\dot{\alpha}}{\alpha} = 0$$

$$\frac{\dot{Y}}{Y} = \frac{\dot{y}}{y} + g + n$$

The transition path of the growth rate of GDP is depicted in Figure 18.

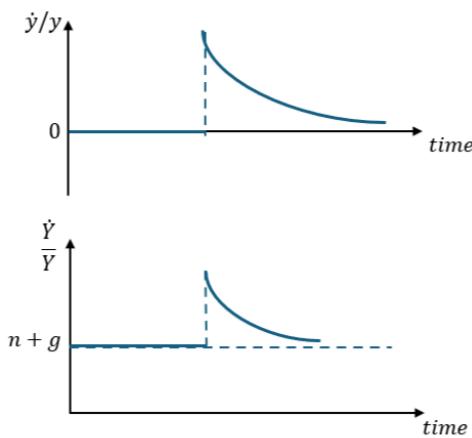


Figure 18.

Transition paths for wages w and interest rate r are similar to the ones described in the basic model.

Once we have reached the steady state after demographic shifts (increase in α), when we incorporate policies proposed by the author (increase L and g), the analysis and the outcome of these measures will be the same as described in the previous section for the basic model.

Modification of the model

Now let us introduce an additional modeling approach to make it more applicable for case analysis. Actually, it is the government that funds R&D projects which are partially aimed at

increasing labor productivity. Particularly, Japanese government invests in three major fields: biotechnology, quantum technology and AI¹⁸. Thus, we will modify Solow model¹⁹ by adding a productive government. Government expenditures are interpreted as those related to implementation of artificial intelligence.

Let output per effective unit of labor have the following form

$$y(\tau) = f(k, m) = k^\alpha m^\beta, \alpha, \beta > 0, \alpha + \beta < 1$$

(in this section notation for time is τ).

For simplification, we assume government runs balanced budget policy and finances its expenditures with proportional tax at rate t . So, more explicitly, the government raises tax rate t to finance its expenditures. We also introduce saving rate s , $0 < s < 1$.

Now we have three economic agents in the model: consumers, firms, and government, whose behavior in continuous time is modeled with the following functions.

Consumption per effective unit of labor: $c = (1 - s)(1 - t)y$

Investment per effective worker: $i = s(1 - t)y$

Government spendings per effective worker: $m = ty$

Having $m = ty$ and $y(\tau) = f(k, m) = k^\alpha m^\beta$, by substituting m into the latter formula we obtain $y = k^\alpha (ty)^\beta$. We can explicitly derive $y = k^{\alpha/(1-\beta)} t^{\beta/(1-\beta)}$.

Recall capital accumulation equation: $\frac{dK}{dt} = \dot{K} = I - \delta K$. But now $I \equiv S = s(1 - t)Y$,

$$\text{so } \dot{K} = s(1 - t)Y - \delta K \Rightarrow \frac{\dot{K}}{K} = s(1 - t)\frac{Y}{K} - \delta.$$

Above we also derived that $\frac{\dot{K}}{K} = \frac{\dot{k}}{k} + (n + g)$, where g is growth rate of labor productivity,

$$\Rightarrow \frac{\dot{k}}{k} = s(1 - t)y/k - (n + g + \delta)$$

Substituting explicitly derived y we have:

$$\frac{\dot{k}}{k} = s(1 - t)k^{\alpha/(1-\beta)-1}t^{\beta/(1-\beta)} - (n + g + \delta)$$

In steady state:

¹⁸ Wakamatsu-cho, Shinjuku-ku Results of the Survey of Research and Development / Wakamatsu-cho, Shinjuku-ku [Electronic resource] // Statistics Bureau, Ministry of Internal Affairs and Communications : [website]. — URL: <https://www.stat.go.jp/english/data/kagaku/1549.html#:~:text=Chart%201%20Growth%20of%20R%26D,billion%20yen%20for%20quantum%20technology> (date of application: 14.05.2024).

¹⁹ George-Marios Angeletos The Solow Growth Model (and a look ahead) // MIT Lecture Notes. P. 31.

$$\dot{k} = 0 \Rightarrow s(1-t)k^{\alpha/(1-\beta)-1}t^{\beta/(1-\beta)} = n + g + \delta$$

$$k^* = \left(\frac{s(1-t)t^{\beta/(1-\beta)}}{n+g+\delta} \right)^{1/(1-\alpha/(1-\beta))}$$

Now the objective is to find optimal tax rate that would maximize output per efficient worker y in the steady state. Given $t = \text{const}$, we need to maximize k^* . Since s, n, g, δ are constants, it would be the same as setting

$$\begin{aligned} \frac{d(1-t)t^{\beta/(1-\beta)}}{dt} &= 0 \\ \frac{\beta}{1-\beta}t^{\beta/(1-\beta)-1} - \left(\frac{\beta}{1-\beta} + 1\right)t^{\beta/(1-\beta)} &= 0 \\ t^* &= \beta \end{aligned}$$

Meaning, output per efficient worker maximizing level of tax rate is equal to output per worker elasticity with respect to government services. We do not specify the positions of the initial tax rate and the increased tax rate relative to the optimal level. However, the model dynamics depend on it. That is why we consider several cases of how relative position of initial tax rate and its change affect some key variables in the modified model.

Production function in intensive form y :

Immediately after an increase in tax rate t , production per unit of efficient labor y rises. It can be seen directly from the formula $\uparrow y = k^{\alpha/(1-\beta)}(t \uparrow)^{\beta/(1-\beta)}$ (power $\beta/(1-\beta) > 0$). However, in LR the outcome may differ (Figure 19).

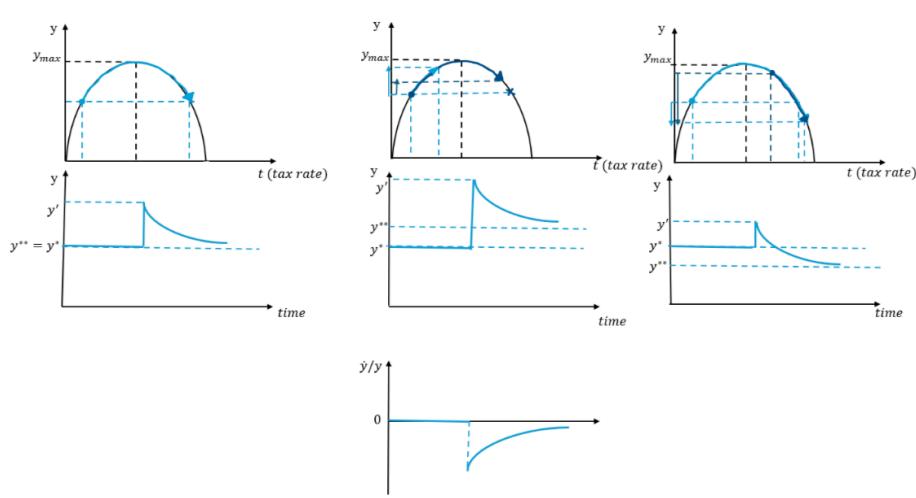


Figure 19.

So, if initially the tax rate was relatively low (below the optimal level), increase in the tax rate will lead to higher output per unit of efficient labor in LR. However, the opposite

situation, when the initial tax rate was already high, increasing it will only make the steady state level of output per unit of efficient labor lower.

Saving function S (saving per unit of efficient labor):

$$S = s(1-t)y$$

Immediate effect on saving function is ambiguous, as while tax rate increases, the component $(1-t)$ falls, while y increases. Afterwards y falls. However, the level of saving per unit of efficient labor in the LR is unclear. But the outcome where output per unit of efficient labor and saving per unit of efficient labor both increase in their new steady states is possible (Figure 20).

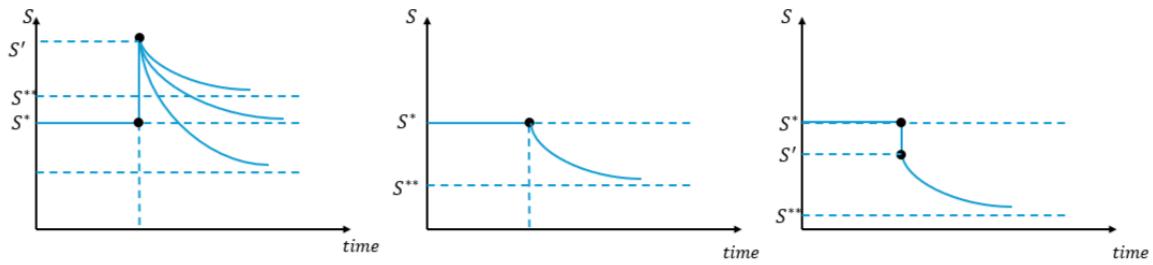


Figure 20.

GDP per capita:

$$\frac{Y}{L} = y \times A \Rightarrow \ln(Y/L) = \ln(y) + \ln(A) = \ln\left(k^{\alpha/(1-\beta)} t^{\beta/(1-\beta)}\right) + \ln(A) = \frac{\alpha}{1-\beta} \ln(k) + \frac{\beta}{1-\beta} \ln(t) + \ln(A_0) + g\tau$$

$\ln(k)$ may behave differently in LR depending on the initial tax rate and the scale of the change, t increases immediately, so there are 3 possible transition paths of GDP per capita (Figure 21).

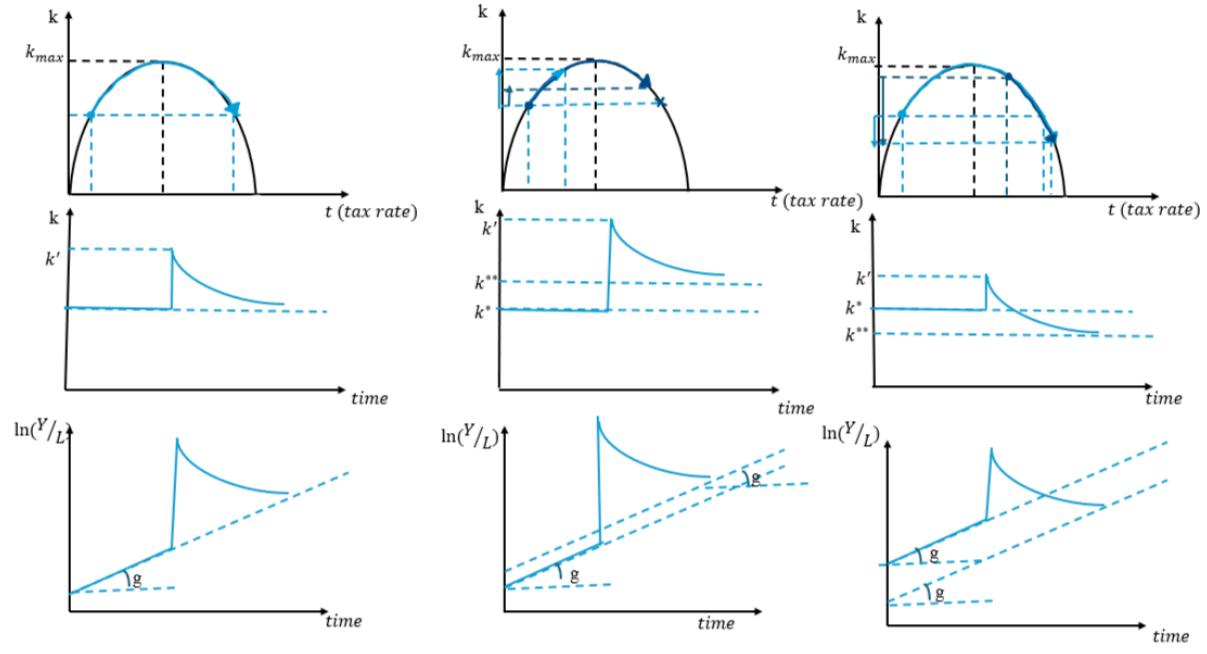


Figure 21.

Growth rates of GDP and GDP per capita:

$$\frac{Y}{L} = y \times A \Rightarrow \ln(Y/L) = \ln(y) + \ln(A) = \ln\left(k^{\alpha/(1-\beta)}t^{\beta/(1-\beta)}\right) + \ln(A) = \frac{\alpha}{1-\beta}\ln(k) + \frac{\beta}{1-\beta}\ln(t) + \ln(A_0) + g\tau$$

Taking time derivatives of both sides we obtain,

$$\frac{(Y/L)}{Y/L} = \frac{\alpha}{1-\beta} \frac{\dot{k}}{k} + \frac{\beta}{1-\beta} \frac{\dot{t}}{t} + g$$

Though there was one-off increase in t , it does not grow continuously, so

$$\frac{\dot{t}}{t} = 0$$

$$\frac{\dot{k}}{k}$$

The transition path of $\frac{\dot{k}}{k}$ is shown in Figure 22.

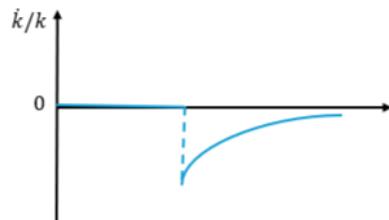


Figure 22.

$$Y = y \times A \times L \Rightarrow \ln(Y) = \ln(y) + \ln(A) + \ln(L) = \ln\left(k^{\alpha/(1-\beta)} t^{\beta/(1-\beta)}\right) + \ln(A) + \ln(L) = \frac{\alpha}{1-\beta} \ln(k) + \frac{\beta}{1-\beta} \ln(t) + \ln(A_0) + g\tau + \ln(L_0) + n\tau$$

Taking time derivatives of both sides we obtain,

$$\frac{(\dot{Y})}{Y} = \frac{\alpha}{1-\beta} \frac{\dot{k}}{k} + \frac{\beta}{1-\beta} \frac{\dot{t}}{t} + g + n$$

The transition paths of $\frac{\dot{Y}}{Y}$ and $\frac{(\dot{Y}/L)}{Y/L}$ are shown in Figure 23 below:

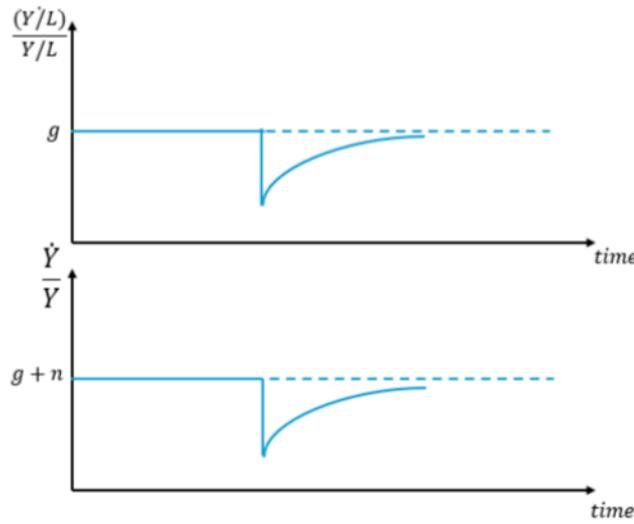


Figure 23.

To close this section, let us reflect on the obtained results.

Based on the initial model, the impact of decrease in growth rate of labor without any intervention will lead to decreased price of capital services for firms, but increase in wages. GDP per capita is expected to rise too, while GDP growth rate is lower. So, investigating into the search for a solution, we test propositions from the analyzed article: to stimulate foreign participation in the labor force ($L \uparrow$) and to increase labor productivity and implement artificial intelligence to increase efficiency of labor ($g \uparrow$). After policy introduction, the costs of capital and labor rise for firms. Similarly, GDP per capita and growth rate of GDP have higher numbers, compared to the steady state in the initial set up.

Now we implement modification of Japanese government intervention with funding research and development projects. And the obtained result is an increase in both: output per unit of efficient labor and saving per unit of efficient labor, if the tax rate is chosen correctly. The same can be said for each of the variables: changes in capital accumulation per unit of efficient labor and the GDP per capita. Though the rate of change of those parameters stays

consistent. But all in all, we can state that a ‘good’ tax rate will make an improvement to Japan’s economy.

Limitations of the model

We used Solow model in our analysis; however, it has some limitations, which must be considered:

- The assumption that Solow model assumes constant returns to scale was applied numerous times in our model. In fact, due to replication of production processes in many industries and statistical averaging effects, Japan's production function may exhibit constant returns to scale.
- Exogenously given technology. That means that technology is given from ‘outside’ of the system. Japan spends almost the greatest share of its GDP on R&D; however, many technologies are imported due to high cost of domestic R&D, lack of natural resources and recent depreciation of yen. That’s why the Solow model with exogenous growth can be applied here. We extend the idea about implementation of endogenous growth models while answering the question from team 08_3.
- Perfect competition. Even though no market is perfectly competitive, Japan has a great variety of firms in all industries and has relatively low barriers to entry and technological imperfections. That all supports the Solow growth model. The only problem here is that the Solow model assumes a closed economy, but Japan’s foreign trade accounts to more than 40% of GDP, however, Japan’s rate is the lowest one in comparison with other countries.
- The modified model does not consider interest rates, and its impact on costs of firms.

Overall, Solow model explains long run growth and steady state in the long run, focusing mainly on levels of technology, savings rate, labor force. Therefore, the choice of Solow growth model was the most reasonable decision from the point of view of the article, which considers the growth rate of the economy in terms of labor force and technology.

V. Conclusion

This paper provides an overview on the effectiveness of policies proposed by the author to combat economic consequences of demographic problems in Japan. Relying on our basic model, we managed to outline that the outcome of negative growth of labor in the Japanese economy is increased GDP per capita, higher wages, but higher interest rates and lower growth rate of output in the new steady state. In order to understand how to fight the negative consequences and bring the growth rate of GDP back to the initial level, we tested the author's propositions on this topic. The received take off contains ambiguous results. It imposes higher costs in terms of payments for capital and labor services, but also higher GDP per capita and higher GDP growth rate. Nevertheless, it is clear that policies can not only offset the negative consequences of labor shortage, but also boost Japan's economy. So, a number of solutions can be highlighted. Let us start with an increase in the number of workers by attracting foreign labor force, for example. Or, speaking economics language, this can be rephrased as enhancing labor market flexibility by promoting the integration of foreign workers into the domestic workforce by, for instance, reforming immigration policies and facilitating the entry of skilled foreign labor to mitigate labor shortages. Then, another proposition is to implement Artificial Intelligence and other tools to help workers perform their jobs more effectively. Using technological innovations will serve as a means to empower the workforce and increase productivity. So, a good solution will be encouraging the introduction of automation and artificial intelligence technologies into production processes, which will give the optimization of operations, reduced costs, and the opportunity for employees to focus on higher value-added tasks.

Finally, in our modified model we propose government intervention by the introduction of a tax for financing R&D expenses. A reasonable increase in tax rate indeed may boost the economy with increased savings and GDP per capita, but long term effects on growth rates of GDP and GDP per capita were not identified. Overall, both basic and modified Solow models predict ambiguous effects (which we already described and summarized above) of policies proposed in the article on Japan's economy.

VI. Discussions QA

Q1 (from team 01_2)

1. According to the Draft (Analysis of proposed policies), it is seen that you assume that inflow of foreign workers is expected (increase in L), however due to some reasons (strict immigration laws) you assume that it will not influence the labour force growth rate – n. However it is primarily relevant in case of the immediate and one-off positive shock of Labor force (one-off mass arrival of the immigrants), whereas the real world data (<https://www.spectator.co.uk/article/is-japan-finally-embracing-immigration/>, <https://www.japantimes.co.jp/commentary/2023/08/06/japan/japan-immigration/>) show that the increase of the foreign labour force is enough sustainable to be considered as permanent, which can be clearly seen on the graph (https://upload.wikimedia.org/wikipedia/commons/3/3d/Foreign_residents_in_Japan.svg). Thereby, in our opinion, it could be reasonable to consider n being significantly influenced by the inflow of foreign workers, especially in the LR, when Japan, all else being equal, will be made by the objective situation to attract foreign workers (this fact is mentioned in articles above). Thus, as for us, the main hypothesis could be based on the assumption that the absolute (measured in people, not %) rate of decrease of the native population is higher than the absolute rate of increase of the immigrant workers.

2. Additionally, just looking for the truth, on the 17th page, there is a statement that the growth rate of Labor productivity must be higher than the growth rate of Labor (absolute value, you mean?) in order for the new steady state level of GDP growth rate to be positive. However if we will consider, just for example, case of 35% rise of Labor productivity and the 30% fall in the Labor, the overall effect will be also negative ($1.35 * 0.7 = 0.945 < 1$). Please, if you will have some time, check this moment

Answer:

1. In order for n to raise immigrants must either stay at Japan for their entire life and assimilate or the flow must increase in the long run. The former assumption is irrelevant: according to the paper “FEATURES OF JAPAN’S MIGRATION POLICY AND THE PROBLEM OF SOCIO-CULTURAL ADAPTATION OF FOREIGN

WORKERS TO MODERN JAPANESE SOCIETY” by Petr E. Podalko²⁰, immigrants face difficulties in social and cultural adaptation. All measures taken are frankly partial. Japan’s lack of historical experience with foreigners makes it difficult to find the right solution. These oscillations are also based on the desire to preserve one’s own identity, the fear of losing the proverbial «code of the nation», so as not to turn into another multicultural conglomerate, with all its inherent problems. Thus, it is hard for foreigners to stay in Japan for their entire life. Regarding the latter assumption, in your articles, it was mentioned that the government struggles in attracting new workers and the trend is negative for years (not even due to pandemic). Even if many Japanese citizens agree that the country needs more immigrants, that doesn’t mean that the growth rate will be seriously changed in a few years.

2. In our model we assumed that the growth rate is always positive, according to the empirical data²¹ (Figure 24).

²⁰ Petr E. Podalko Features of Japan's migration policy and the problem of socio-cultural adaptation of foreign workers to modern Japanese society / Petr E. Podalko // Aoyama Gakuin University Tokyo, Japan. — 2023.

²¹ International Monetary Fund Real GDP growth, Annual percent change / International Monetary Fund [Electronic resource] // IMF : [website]. — URL: https://www.imf.org/external/datamapper/NGDP_RPCH@WEO/JPN?zoom=JPN&highlight=JPN. (date of application: 29.05.2024).

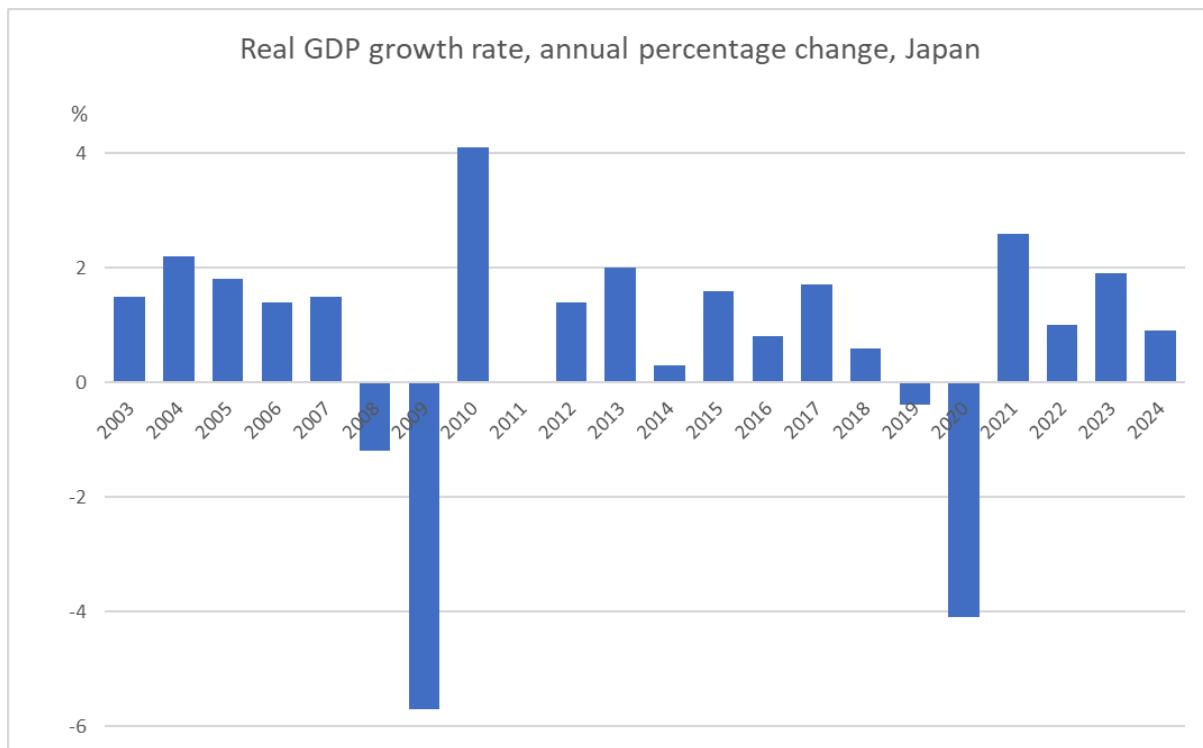


Figure 24.

Q2 (from team 01_3)

In 1954 Franco Modigliani and Richard Brumberg introduced the Life-cycle hypothesis which aimed to explain the intertemporal choice of saving and consumption for economic agents. The theory argues that agents tend to smoothen their consumption by saving while young and consuming while old. This clearly states the relationship between age of aggregated agents and saving rate in the economy. Though, smaller saving rate among elders can be lessened by further introduction of model of “Crossing generations” or “Altruistic connections between generations”, it is crucial to consider saving rate as function of population’s structure as ageing population means lower saving rate and lower steady state. In other words, today’s older population becomes burden for future generations as firstly, there might be not enough saving for maintenance of level of capital. Therefore, our team recommends lessening the assumption of “exogenous saving rate” introduced in your work and consider it as a function of time and population’s structure.

Also, the balanced budget condition assumed in the section 'Modification of the model' doesn't seem to be realistic for Japan. So, this assumption can be lessened as well.

Answer:

1. When we consider “share of potential workers falling”, we model it with falling n which can be supported by falling birth rate and population ageing. Encouraged by LCH, we can also assume that this affects the saving rate in the country (s goes down). It can be supported by data on Japan. In the Solow model, total effect of fall in n and s is ambiguous, because the changes impact in different directions.

Nevertheless, it does not fully cover the proposition of team 01_3. They offer to set $S_t = f(t, X_t)$

S_t – saving rate as a function of time and population structure.

Population structure is itself a complex structure. Relative to our case analysis, we would like to pay attention to the population aging problem, thus making X_t to reflect some population age factor (life expectancy or average age). So, once again, we can build a regression function based on real data (Figure 25). However, on our Solow model we do not have a separate factor such as population age. So, we should either introduce population age parameter to our model and production function or look for parameters on our initial model that are directly affected by population age. The question remains open.²²

²² Japan Gross Savings Rate / [Electronic resource] // CEIC : [website]. — URL: <https://www.ceicdata.com/en/indicator/japan/gross-savings-rate> (date of application: 24.05.2024).
Median Age of Japan / [Electronic resource] // Database Earth : [website]. — URL: <https://database.earth/population/japan/median-age> (date of application: 24.05.2024).

Median age and Gross domestic savings

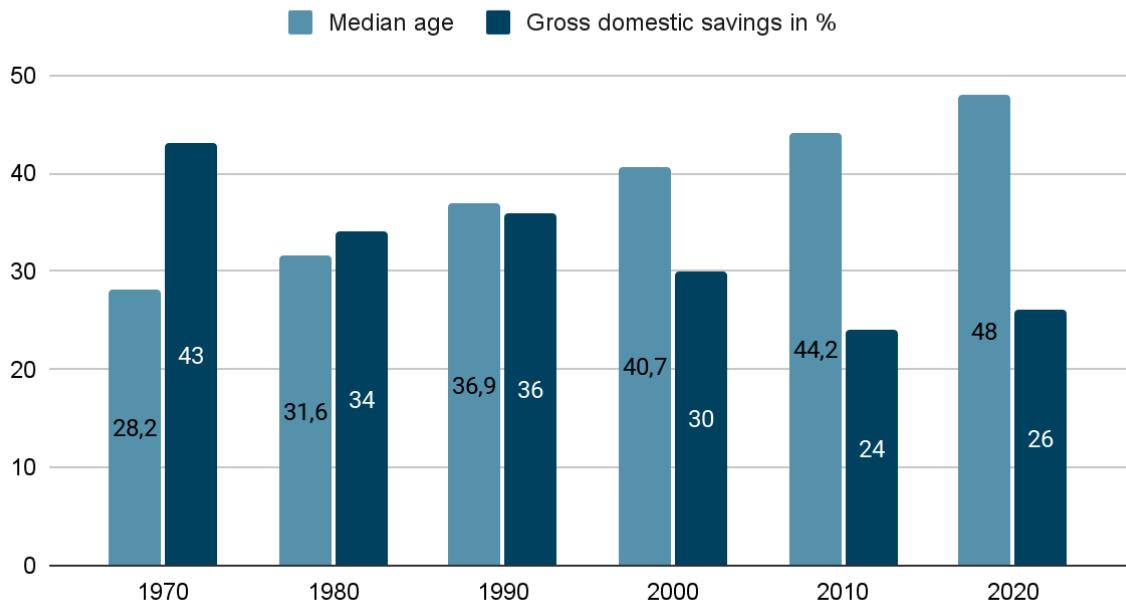


Figure 25.

2. As far as balanced budget assumption is concerned, we understand that this is a decent limitation of our model, but it has to be done in order for our model to be simpler. The limitation is a trade-off between overcomplication and relevancy.

Q3 (from team 08_3)

The Solow Growth model has an assumption about technology being exogenously given. Can your model be adjusted, so as to provide an account for endogenous technological changes? If possible, include that adjusted model into your analysis: this will make it more realistic and perhaps even more accurate.

Answer:

1. For technology to be exogenously given, it requires that innovations freely circulate in the economy between firms; however, it is not true for Japan because of:

- 1) Tight situation in the labor market and increased interest rates by CB of Japan lead to increased pressure on firms in terms of costs, thus, not so much resources left on R&D.
- 2) Charges for use of intellectual property increase²³ (Figure 26).
- 3) Conservative management structure related to the features of the labor market in Japan and the cultural experiences of Japanese people working for many years in the same company hinder the process of technology transfer.

Charges for the use of intellectual property

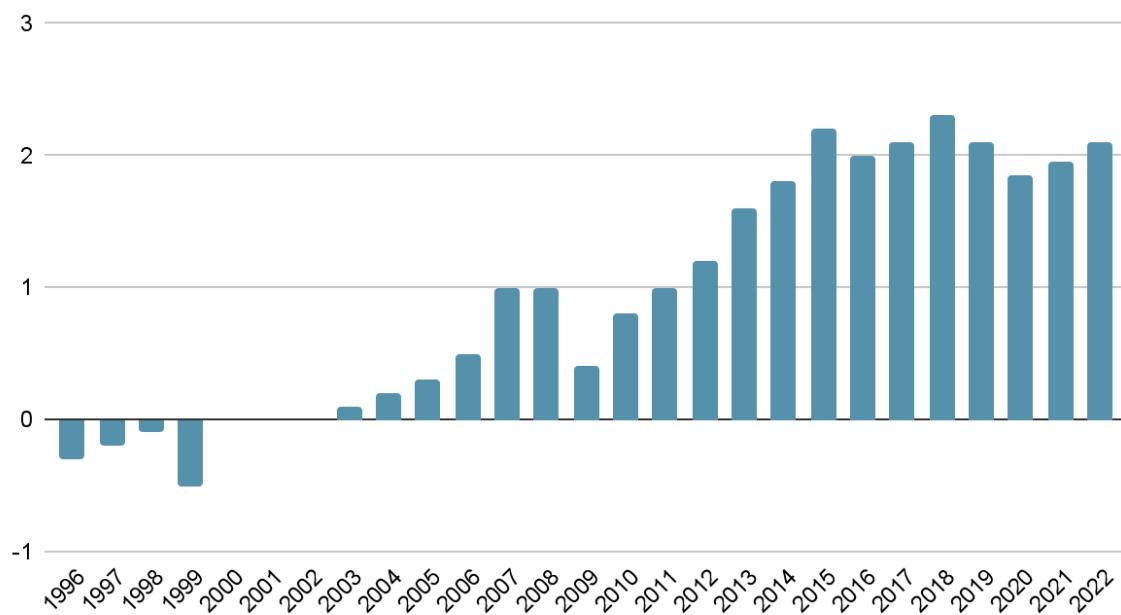


Figure 26.

As a result, endogenous growth models are not applicable for Japan.

²³ Charges for the use of intellectual property - Japan / [Electronic resource] // The World Bank : [website]. — URL: <https://data.worldbank.org/indicator/BX.GSR.ROYL.CD?view=chart&locations=JP> (date of application: 24.05.2024).

VII. Appendix

Original article

Japan is running out of people on sidelines of job market

Businesses face rise in labor costs that will force changes in how they work

Hirofumi Kanaoka, Nikkei staff writer

April 7, 2024 05:40 JST

TOKYO -- Japan's labor pool is losing precious depth, with the share of potential workers falling by half over two decades.

The number of people 15 or older who were not employed or seeking work but still hoped for a job fell to 2.33 million in 2023, down 2.97 million from 20 years earlier, the Ministry of Internal Affairs and Communications' labor force survey shows.

Combined with the 1.78 million unemployed people looking for work, there were 4.11 million potential workers, or 3.7% of the population 15 or older. This is less than half of the 2003 level of 8%.

Hourly wages reflect Japan's labor shortage. When the Japan Institute for Labor Policy and Training compiled data on hourly wages for part-time workers based on monthly labor statistics, it showed a 3.8% increase in the October-December quarter compared with a year earlier.

This is the biggest increase since 2015, excluding the COVID-19 pandemic, and was larger than the 1% wage growth for regular workers.

The decline in the number of people on the sidelines of Japan's labor market owes both to an economic recovery and more job opportunities for people past the traditional retirement age and women who had left the labor market to raise children.

According to the National Institute of Population and Social Security Research, the working-age population from 15 to 64 decreased 15% from its peak in 1995 to 2023, while the number of workers increased by about 4 million over two decades. The M-shaped curve -- a dip in employment among women in their 30s that is associated with marriage and childrearing -- has almost disappeared in Japan.

The country "has nearly reached the limit of being able to offset the decline in workers with women and older people" returning to the labor market, said Munehisa Tamura of the Daiwa Institute of Research.

Nobel Prize-winning economist Arthur Lewis proposed a turning point at which surplus rural labor is fully absorbed into the industrial sector. Upward pressure on wages rises after this point. Economists believe Japan passed the Lewis turning point in the late 1960s. Now, it may be facing a new tipping point in terms of female and older workers.

Companies will be forced to change their strategies. Low borrowing costs -- thanks to rock-bottom interest rates -- and increased labor participation by women and older people had helped Japanese businesses keep expenses down during decades of weak growth. Low-profit businesses were able to survive, but this reinforced deflationary conditions that depressed wages even when the economy picked up.

Now that the Bank of Japan has ended its negative interest rate policy, there will be upward pressure on interest rates. If part-time wages keep rising, low-profit businesses will face a shakeout.

Higher labor productivity, job mobility, and foreign participation in the labor force could help Japanese companies cope. Mitsubishi UFJ Research and Consulting estimates that in 2035 Japan will be nearly 8 million workers short of the level needed for real gross domestic product to match the economy's potential growth rate of 0.5% per year.

It estimates that an annual increase of 1 percentage point in labor productivity would make up about 70% of the shortfall. Productivity must rise about 20% compared with 2021. Artificial intelligence and other tools could help companies work more efficiently, freeing up employees for research and development and other value-creating tasks.

This month, the city of Osaka began allowing about 20,000 municipal workers to use generative AI to help with tasks like translating or preparing meeting minutes.

"We want them to concentrate on more human, fruitful work," a city official said.

References

1. Birth rate, crude (per 1,000 people) - Japan / [Electronic resource] // The World Bank : [website]. — URL: <https://data.worldbank.org/indicator/SP.DYN.CBRT.IN?locations=JP> (date of application: 16.05.2024).

2. Charges for the use of intellectual property - Japan / [Electronic resource] // The World Bank : [website]. — URL:<https://data.worldbank.org/indicator/BX.GSR.ROYL.CD?view=chart&locations=JP> (date of application: 24.05.2024).
3. Eurostat: Demographic Statistics, United Nations Statistical Division, Population and Vital Statistics Report (various years), U.S. Census Bureau: International Database, Secretariat of the Pacific Community: Statistics and Demography Programme. Population, total - Japan / Eurostat: Demographic Statistics, United Nations Statistical Division, Population and Vital Statistics Report (various years), U.S. Census Bureau: International Database, Secretariat of the Pacific Community: Statistics and Demography Programme. [Electronic resource] // The World Bank : [website]. — URL: <https://data.worldbank.org/indicator/SP.POP.TOTL?locations=JP> (date of application: 25.05.2024).
4. GDP growth (annual %) - Japan / [Electronic resource] // The World Bank : [website]. — URL: <https://data.worldbank.org/indicator/ny.gdp.mktp.kd.zg?locations=jp> (date of application: 24.05.2024).
5. George-Marios Angeletos The Solow Growth Model (and a look ahead) // MIT Lecture Notes. P. 31.
6. Georgios Petropoulos, Mamta Kapur Artificial intelligence: increasing labour productivity in a responsible way / Georgios Petropoulos, Mamta Kapur // The German Marshall Fund of the United States. — 24 November 2022. — P. 3, 11.
7. Hirofumi Kanaoka Japan is running out of people on sidelines of job market / Hirofumi Kanaoka [Electronic resource] // Nikkei : [website]. — URL: <https://asia.nikkei.com/Spotlight/Work/Japan-is-running-out-of-people-on-sidelines-of-job-market> (date of application: 12.05.2024).
8. Hirofumi Kanaoka Japan is running out of people on sidelines of job market / Hirofumi Kanaoka [Electronic resource] // Nikkei : [website]. — URL: <https://asia.nikkei.com/Spotlight/Work/Japan-is-running-out-of-people-on-sidelines-of-job-market> (date of application: 12.05.2024).
9. Japan: Demographic Shift Opens Door to Reforms / [Electronic resource] // International Monetary Fund : [website]. — URL: (date of application: 16.05.2024).

10. Japan Gross Savings Rate / [Electronic resource] // CEIC : [website]. — URL: <https://www.ceicdata.com/en/indicator/japan/gross-savings-rate> (date of application: 24.05.2024).
11. Japan Labour Force Participation Rate / [Electronic resource] // CEIC : [website]. — URL: <https://www.ceicdata.com/en/indicator/japan/labour-force-participation-rate#:~:text=Japan%20Labour%20Force%20Participation%20Rate,million%20people%20in%20Dec%202022> (date of application: 19.05.2024).
12. Katarina Milanovic Artificial Intelligence and the Labor Market / Katarina Milanovic [Electronic resource] // Sciences Po : [website]. — URL: <https://www.sciencespo.fr/women-in-business/en/news/article-artificial-intelligence-and-the-labor-market/> (date of application: 16.05.2024).
13. Life expectancy at birth, total (years) - Japan / [Electronic resource] // The World Bank : [website]. — URL: <https://data.worldbank.org/indicator/SP.DYN.LE00.IN?locations=JP> (date of application: 16.05.2024).
14. Median Age of Japan / [Electronic resource] // Database Earth : [website]. — URL: <https://database.earth/population/japan/median-age> (date of application: 24.05.2024).
15. Miguel Barrientos, Claudia Soria Japan Ethnic groups / Miguel Barrientos, Claudia Soria [Electronic resource] // IndexMundi : [website]. — URL: https://www.indexmundi.com/japan/ethnic_groups.html (date of application: 14.05.2024).
16. Organization for Economic Co-operation and Development Labor Force Participation Rate Total: From 15 to 64 Years for Japan [LRAC64TTJPA156S] / Organization for Economic Co-operation and Development [Electronic resource] // FRED, Federal Reserve Bank of St. Louis : [website]. — URL: <https://fred.stlouisfed.org/series/LRAC64TTJPA156S> (date of application: 27.05.2024).
17. Petr E. Podalko Features of Japan's migration policy and the problem of socio-cultural adaptation of foreign workers to modern Japanese society / Petr E. Podalko // Aoyama Gakuin University Tokyo, Japan. — 2023.
18. Statistics of Japan / [Electronic resource] // e-Stat : [website]. — URL: <https://www.e-stat.go.jp/en/stat-search/files?page=1&layout=datalist&toukei=0020052>

4&tstat=000000090001&cycle=7&year=20230&month=0&tclass1=000001011679&tclass2val=0 (date of application: 16.05.2024).

19. United Nations Population Division's World Population Prospects: 2022 Revision. Age dependency ratio, old (% of working-age population) / United Nations Population Division's World Population Prospects: 2022 Revision. [Electronic resource] // The World Bank : [website]. — URL: <https://data.worldbank.org/indicator/SP.POP.DPND.OL> (date of application: 26.05.2024).
20. Wakamatsu-cho, Shinjuku-ku Current Population Estimates / Wakamatsu-cho, Shinjuku-ku [Electronic resoure] // Statistics Bureau of Japan : [website]. — URL: <https://www.e-stat.go.jp/en/stat-search/files?page=1&layout=datalist&toukei=00200524&tstat=000000090001&cycle=7&year=20230&month=0&tclass1=000001011679> (date of application: 16.05.2024).
21. Wakamatsu-cho, Shinjuku-ku Current Population Estimates / Wakamatsu-cho, Shinjuku-ku [Electronic resoure] // Statistics Bureau of Japan : [website]. — URL: <https://www.e-stat.go.jp/en/stat-search/files?page=1&layout=datalist&toukei=00200524&tstat=000000090001&cycle=7&year=20230&month=0&tclass1=000001011679> (date of application: 16.05.2024).
22. Wakamatsu-cho, Shinjuku-ku Results of the Survey of Research and Development / Wakamatsu-cho, Shinjuku-ku [Electronic resource] // Statistics Bureau, Ministry of Internal Affairs and Communications : [website]. — URL: <https://www.stat.go.jp/english/data/kagaku/1549.html#:~:text=Chart%201%20Growth%20of%20R%26D,billion%20yen%20for%20quantum%20technology> (date of application: 14.05.2024).
23. ‘We'd better watch out’, New York Times Book Review, 12 July 1987, page 36.

Acknowledgement

LLM is able to process and analyze vast amounts of data quickly, summarize the basic facts and conceptualize the main ideas. Working on the article included a usage of generative artificial intelligence model Chat GPT 4.0. AI was used for the purpose of enhancement of the analysis of the original article.

The results of the workings provided below consist of 3 sections including a few-shot ‘wise’ prompting strategy details, the answers generated by the model, and the reference.

● FEW-SHOT ‘WISE’ PROMPTING STRATEGY PROCEDURE ●

1) Use the following links for pre-training:

https://edu.hse.ru/pluginfile.php/3327287/mod_resource/content/1/Macro1%20L18%20Capital%20mobility.pdf
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https://edu.hse.ru/pluginfile.php/2310880/mod_resource/content/1/Lecture%202.%20National%20Accounts%20%28part%202%29%20%282022-2023%29.pdf

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https://edu.hse.ru/pluginfile.php/2373573/mod_resource/content/1/Lecture%205.%20Stabilization%20Policies%20in%20the%20Closed%20Economy%20%28part%201%29%20%28the%20last%20updated%20version%29.pdf

https://edu.hse.ru/pluginfile.php/2371898/mod_resource/content/1/Lecture%205.%20Stabilization%20Policies%20in%20the%20Closed%20Economy%20%28part%202%29.pdf

https://edu.hse.ru/pluginfile.php/2384528/mod_resource/content/1/Lecture%206.%20The%20Aggregate%20Demand%20and%20Aggregate%20Supply%20Model%20%28part%201%29.pdf

https://edu.hse.ru/pluginfile.php/2398341/mod_resource/content/1/Lecture%206.%20The%20Aggregate%20Demand%20and%20Aggregate%20Supply%20Model%20%28part%202%29.pdf

https://edu.hse.ru/pluginfile.php/2403567/mod_resource/content/1/Lecture%206.%20The%20Aggregate%20Demand%20and%20Aggregate%20Supply%20Model%20%28part%203%29.pdf

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2) Context for the upcoming question:

- 2nd year BSc economics program;
- intermediate macroeconomics level;
- year final project;
- read a non-academic article

<https://asia.nikkei.com/Spotlight/Work/Japan-is-running-out-of-people-on-sidelines-of-job-market>

3) Now, answer the following question in the context provided above:

【№1】: Briefly summarize the basic facts and conceptualize the main point/idea/argument/problem/issue using general language used by ordinary people in everyday conversations.

【№2】: Briefly summarize the basic facts and conceptualize the main point/idea/argument/problem/issue using economic language, i.e. definitions, concepts, laws and regularities.

Your verbal explanation should be concise.

Ensure that there are NO hallucinations and there is no ambiguity in wording.

● AI ANSWERS ●

-----【№1】-----

Sure, here's a simple breakdown of the article:

1. **Japan's Job Market**: Japan is facing a tight job market. There are fewer people who are not working but want to work, and this number has dropped a lot in 20 years.
2. **Wages Going Up**: Because there aren't enough workers, companies are paying more for part-time work. This pay rise is the biggest in years, except for the time during the pandemic.
3. **Why It's Happening**: More jobs are available for older folks and women who previously left jobs for family reasons. But now, there aren't enough of these people left to fill all the jobs.

4. **Economic Changes**: Japan used to have lots of extra workers from the countryside that could work in factories, but not anymore. Now, wages are going up because there aren't enough workers.
5. **What Companies Need to Do**: Businesses need to find new ways to work because they can't rely on cheap loans and a big workforce anymore. They might struggle if they don't make enough profit.
6. **Possible Solutions**: To deal with the worker shortage, companies could make jobs more productive, move workers around better, and hire more people from other countries.
7. **Looking Ahead**: Experts think Japan will need a lot more workers in the future. Using things like AI could help make work more efficient.

The main point is that Japan's job market is really tight, with not enough people to work the jobs available, which is pushing up wages. Companies need to adapt by becoming more efficient and maybe bringing in workers from outside. Osaka is trying out AI to help city workers do their jobs better, so they can focus on more important stuff.

-----【№2】-----

Certainly! Here's an economic analysis of the situation:

1. **Labor Market Dynamics**: Japan is experiencing a contraction in its labor force participation rate, with a significant reduction in the latent workforce—individuals who are not actively employed or seeking employment but are willing to work. This contraction is quantified by a decrease from 2.97 million to 2.33 million in the potential labor pool over two decades.
2. **Wage Inflation**: The scarcity of labor is exerting upward pressure on wages, evidenced by a 3.8% increase in hourly wages for part-time workers, surpassing the wage growth of regular employees. This phenomenon aligns with the economic principle that scarcity increases value, leading to higher prices—or in this case, wages.
3. **Demographic Shifts**: The demographic transition, characterized by a 15% decline in the working-age population and an increase in employment among traditionally non-working demographics (older individuals and women), is reshaping the labor market. The near disappearance of the M-shaped employment curve for women indicates a structural change in workforce participation.
4. **Economic Theories at Play**: The situation mirrors Arthur Lewis's dual-sector model, where the "Lewis Turning Point" signifies the absorption of surplus labor by the industrial sector, resulting in wage increases. Japan's current predicament suggests a new inflection point, driven by the diminishing returns of integrating female and older workers into the labor force.

5. **Corporate Strategy and Economic Policy**: The cessation of Japan's negative interest rate policy by the Bank of Japan introduces new fiscal pressures, potentially leading to a reevaluation of corporate strategies amidst rising labor costs and interest rates. This shift may necessitate a culling of low-profit businesses, which previously thrived under deflationary conditions.

6. **Solutions and Projections**: To mitigate the impending labor shortage projected to reach nearly 8 million by 2035, Mitsubishi UFJ Research and Consulting advocates for a 1 percentage point annual increase in labor productivity, which could address approximately 70% of the deficit. This underscores the importance of productivity enhancements as a counterbalance to workforce shortages.

7. **Technological Integration**: The adoption of generative AI by the city of Osaka for administrative tasks exemplifies the potential for technology to augment human labor, thereby increasing productivity and allowing workers to engage in more complex, value-added activities.

In essence, Japan's labor market is at a critical juncture, facing a dwindling workforce and rising labor costs. The economic challenge lies in adapting to these demographic and fiscal realities through increased productivity, strategic job mobility, and the integration of foreign labor and technological innovation.

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