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To cite this article: M D Ulhaq and A Wahid 2022 *IOP Conf. Ser.: Earth Environ. Sci.* **1039** 012031

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System Dynamics Modeling for Demographic Bonus Projection In Indonesia

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Abstract. Statistics Indonesia has released the result of the 2020 census. The outcome of the 2020 census is principal as it becomes the basic data for the latest projection of Indonesia's population. This research about the population projection using system dynamic is conducted to know the population proportion and demographic bonus. The researchers use system dynamics modeling to project Indonesia's demographic bonus. This modeling is conducted by projecting Indonesia's population based on three age groups: young (0-14 years old), adult (15-39 years old), middle-aged (40-64 years old), and old (65+ years old). The projection using system dynamics modeling shows that in 2025, we have a better result than the previous year. In 2025, it is predicted that the working-age population has the highest percentage, which is 69.38%, and the dependency ratio will be at its lowest percentage, which is 44.13%. Therefore, the peak of demographic bonus is projected to happen in 2025.

1. Introduction

When a demographic transition happens, marked by a significant shift in age structure and a declining birth rate, a country will experience a demographic bonus. Ogawa [1] said that demographic dividend happens due to a shift in society's age structure, in which the working-age population is larger than the non-working. In other words, the population involved in the production is larger than the population involved in consumption. According to the United Nations [2], the demographic bonus creates opportunities for economic growth.

In 2017, in its press conference entitled "Demographic Bonus 2030-2040: Indonesia's Strategy in Manpower and Education", the Ministry of National Development Planning of the Republic of Indonesia stated that Indonesia is predicted to experience a demographic bonus in 2030-2040. It is also projected that the working-age population makes 64% of the total population.

In its report entitled "Social Statistics Analysis on Demographic Bonus and Economic Growth", Statistics Indonesia [4] said that the population projection based on the 2010 Indonesian census predicts the peak of demographic bonus to happen in 2025. In 2025, it is anticipated that the lowest dependency ratio is at 44.2% (or in other words, 100 persons of working age will support 44 persons of non-working age), the old-age dependency ratio is at 33.2%, and the young age dependency ratio will be at 11%.

Statistics Indonesia [5] has published a report on population projection for 2015-2045 based on the 2015 Intercensal Population Surveys. To create the projection, the demographers used two types of assumptions: assumption A based on policies and assumption B based on trends. However, the published data is the result of assumption A. In assumption A, it is predicted that our population will be 294.1 million people in 2030 and will be 318.9 million people in 2045. Meanwhile, in assumption B, the total population in 2030 is 292.5 million, and the number will be increased to 311.6 million in



2045. Based on the same projection, 2020 has the lowest dependency ratio at 45.5%. The result of population projection for 2015-2045 based on age (%) and dependency ratio (%) can be seen in table 1.

Table 1. Parameters of Indonesian Population Projection Results for 2020-2045

Age	2020	2025	2030	2035	2040	2045
0-14	24.5	23.3	22.4	21.7	21.1	20.7
15-64	68.7	68.6	68.0	67.1	66.1	65.2
65+	6.7	8.1	9.6	11.2	12.8	14.1
Dependency ratio	45.5	45.7	47.0	49.0	51.3	53.4

Data source: Statistics Indonesia (2018) (in percentage)

Statistics Indonesia has released the result of the 2020 census. It plays a significant role in the latest population projection because it is the basic data for the projection. This population projection uses system dynamics to know the upcoming population proportion as well as the demographic bonus. The UN [6] said that the countries approaching the demographic dividend period should invest in human capital, improve access to health, enhance education for any age group, and create more productive employment opportunities. Additionally, Djamhari [7] argued that the working-age population is vulnerable to poverty in their old age. It explains why population projection is necessary. In this paper, the researchers use system dynamics modeling to project Indonesia's upcoming demographic bonus. System dynamics modeling has been used in several population projections. Mahdi et al. [8] used it in projecting population in Banda Aceh, Kunte and Damani [9] used it in population projection for India, and Pitoyo et al. [10] used it in population projection for Indonesia. This method gives an alternative for population projection results provided by the UN and Statistics Indonesia, particularly in demographic dividend.

2. Methodology

2.1 Data

This research uses three types of data released by the UN and Statistics Indonesia. The first data is the 2020 Population Census result released by Statistics Indonesia, the second one is the data on births and deaths from the UN, and the last is the data of Indonesia's population based on age group, which is the result of population projection for 2020-2045 conducted by the UN (UN, 2019). The 2020 Population Census result is used as the primary data for projection that uses this method, which includes population based on age group. Meanwhile, the result of population projection functions to compare and verify the projection result that uses system dynamics modeling.

Statistics Indonesia, the United Nations, and System Dynamic, as shown in Table 2. Statistics Indonesia uses only four kinds of assumptions (international migration assumption is ignored) since its projection model aims to know the population of each province as well as the composition of the urban and rural population. The United Nations uses only three kinds of assumption because it explains neither the population of each province in detail nor the segmentation of urban and rural population. On the other hand, System Dynamic model uses two kinds of assumption so that it has a simpler model. The simpler model is expected to make the making assumption process easier without lessening the accuracy of the result.

Tabel 2. The comparison of assumptions used by Statistics Indonesia, the United Nations, and System Dynamic

NO	ASSUMPTION	The Central Bureau of Statistic	The United Nations	System Dynamic
1	Fertility	The Total Fertility Rate (TFR) is projected by using the logistic function, referring to the ideal TFR targeted by the National Population and Family Planning Board, which is 2,1 in 2025	The TFR is projected by using Bayesian Hierarchical Model (BHM)	The model follows the projection of UN TFR for a medium scenario, which then changed into Birth Rate
2	Mortality	The Infant Mortality Rate (IMR) is projected by using the logistic function, in which the early IMR (2010) is 30 and keeps falling	Using Life expectancy (LE) that is projected using BHM, assuming that the increasing life expectancy will reduce the death rate	Using the UN's mortality projection
3	International Migration	This assumption is ignored due to the poor quality of international migration data, the unrecognized pattern and direction of international migration, and the global change that is highly dynamic	There are two scenarios: constant migration (normal) that corresponds to the last data, and zero migration (no migration)	No international migration
4	Per-age group transition	Not mentioned	Not mentioned	The total population per age group (P_Y , P_A , P_{MA} , and P_O) is divided by the duration between age group (t_Y , t_A , and t_{MA})
5	Interprovincial Migration	This assumption is calculated by using the Age-Specific Net Migration Rate (ASNMR) method, based on age and sex	None because the projection only covers national scope	None because the projection only covers national scope

6	Urbanization	This research uses the Urban-Rural Growth Difference (URGD) formula to project urban and rural population. This formula makes urban population projection based on the differences between urban and rural population growth rate	None because it does not discuss urban-rural population	None because it does not discuss urban- rural population
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2.2 Assumed Births

To know the projection of birth rate based on age group, the researchers use the database of birth rate per age group ratio, in which the 2015 birth rate multiplied by total birth rate.

$$\Delta LLPKU_p = \frac{\Delta LLT.LLPKU_{2015}}{LLT_{2015}} \quad (1)$$

Furthermore, the projected birth rate per age group is determined by adding the projected growth rate of the birth rate per age group to the birth rate per age group in 2015.

$$LLPKU_p = LLPKU_{2015} + \Delta LLPKU_p \quad (2)$$

The projection result is shown in Table 3 The birth rate is projected to fall from 59,157 births per 1000 women (2015-2020) to 57,282 births per 1000 women (2020-2025) and 56,032 births per 1000 women (2025-2030).

Table 3. The Projection of Birth Rate (LL) and Total Fertility Rate (TFR)

NO	PERIOD	TFR	LL
1	2015-2020	2,32	62,28
2	2020-2025	2,21	59,16
3	2025-2030	2,12	57,28
4	2030-2035	2,04	56,03

2.3 Assumed Deaths

Death rate (LM) per 1000 women is assumed to be increased despite the IMR is decreased. In 2010, the IMR was 30 and it fell to 25 in 2015. In the next period, the rate is assumed to linearly fall to 16 in 2030, which corresponds to the UN projection. It happens in the 7 scenarios of the UN projection. Meanwhile, for the constant mortality scenario, the IMR is only the 2015 IMR, which is 25 (United Nations, 2015). The system dynamic model uses the death rate shown in Table 4, which calculated based on the nMx value (the death rate per age group). The calculation uses the level 23 Manual IV life table. The death rate of 0-14 years old age group and 15-39 years old age group is obtained by calculating the weighted average of total nMx in those age groups. Meanwhile, the calculation for 40-64 years old and 65+ years old age group uses the highest nMx in those age groups. After that, the total birth rate is grouped based on each age group.

Table 4. The projection of IMR and death rate

NO	PERIOD	IMR	LM (death rate per 1000)
1	2015-2020	21	12,98
2	2020-2025	19	8,01
3	2025-2030	16	9,32
4	2030-2035	14	9,58

2.4 Model

The model used in the population projection, which uses system dynamics method, can be seen in Figure 1. Modeling simulation uses Stella version 9.0.2 software.

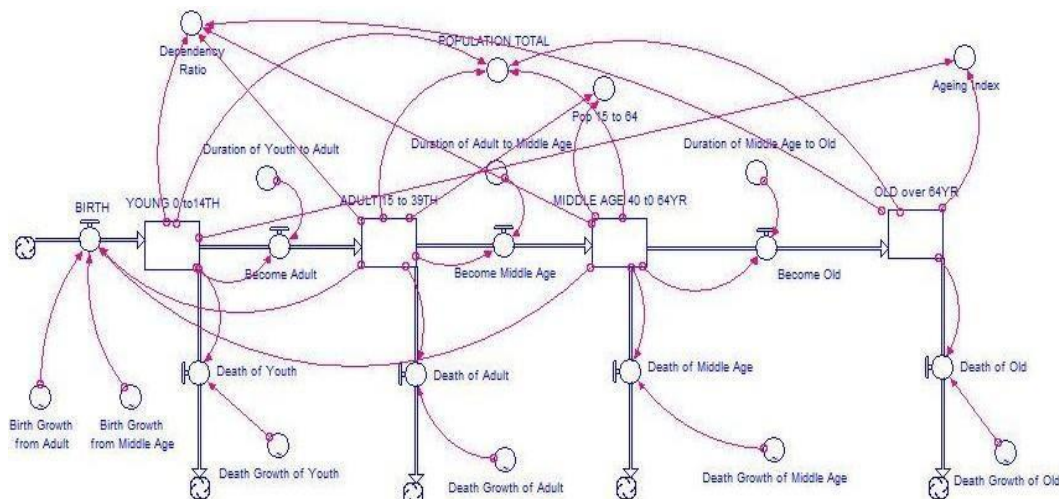


Figure 1. System Dynamics Modeling for population projection

The mathematic equation used in the stock box is a differential equation, such as those appearing in ‘young’ stock box (0-14 years old), ‘adult’ stock box (15-39 years old), ‘middle-aged’ stock box (40-64 years old), and ‘old’ stock box (64+ years old).

$$\frac{dP_Y}{dt} = P_A B_A + P_{MA} B_{MA} - P_Y D_Y - \frac{P_Y}{t_Y} \quad (3)$$

$$\frac{dP_A}{dt} = \frac{P_Y}{t_Y} - P_A D_A - \frac{P_A}{t_A} \quad (4)$$

$$\frac{dP_{MA}}{dt} = \frac{P_A}{t_A} - P_{MA} D_{MA} - \frac{P_{MA}}{t_{MA}} \quad (5)$$

$$\frac{dP_O}{dt} = P_{MA} t_{MA} - P_O D_O \quad (6)$$

P_Y is young population (0-14 years old), P_A is adult population (15-39 years old), P_{MA} is middle-aged adult population (40-64 years old), P_O is old population (65 years old and older), BY is the birth rate of young population, BA is the birth rate of adult population, BMA is the birth rate of middle-aged adult population,

DY is the death rate of young population, DA is the death rate of adult population, DMA is the death rate of middle-aged adult population, DO is the death rate of old population, t_Y is the time that young population takes to be adult population, t_A is the time that adult population takes to be middle-aged adult population, and t_{MA} is the time that middle-aged adult population takes to be old population.

On the other hand, the formula used in the converter dependency ratio circle and aging index circle is as follows:

$$dr = \frac{(P_Y + P_O)}{(P_A + P_{MA})} \quad (7)$$

$$ai = \frac{(P_O)}{(P_Y)} \quad (8)$$

2.5 Calculation

2.5.1. Verification

The result of population projection that uses System Dynamics Modeling needs to be compared with the result of projection by Statistics Indonesia and the United Nations. The comparison is made from 2020 to 2045, at each five-year interval. The comparison aims to know the difference in amount and percentage of the projection result that uses system dynamics modeling.

Comparison formula used in this paper is the same as the formula used in research conducted by Keilman [11]. This formula can calculate the percentage of the difference between the results. The formula can be seen in the following equation:

$$P = \frac{(\text{System Dynamics projection} - \text{the UN or the Central Bureau of Statistics projection}) \times 100}{\text{the UN or the Central Bureau of Statistics projection}} \quad (9)$$

2.5.2. Dependency Ratio

The dependency ratio shows the population aged 0-14 years old and over the age of 65 per 100 persons aged 15-64 years old. The old-age dependency ratio shows the population aged 65+ years old per 100 persons aged 15-64 years old. The young age dependency ratio reveals the number of population aged 0-14 years old per 100 persons aged 15-64 years old.

2.5.3. The Percentage of the Working-Age Population

The percentage of the working-age population means the proportion of the working-age population per population of the projection year.

$$ai = \frac{\text{Population aged 15-64 years}}{\text{Population of the projection year}} \quad (10)$$

3. Result and Discussion

3.1 The result of population projection for 2025-2045

The results of population projections using system dynamics modeling for the years 2025- 2045 as shown in figure 2. The trend of each age group and total population continues to increase, except for the 0-14 years old age group. Population growth trends can provide an overview of the condition of the population structure in the projected year and the projected demographic bonus.

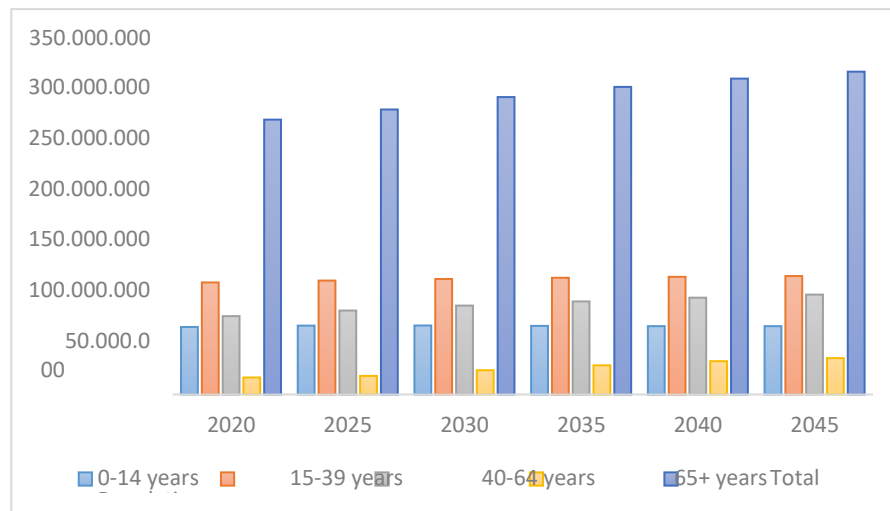


Figure 2. The Result of Population Projection with System Dynamics Modeling

In 2025, it is projected that the total population of Indonesia will reach 280,266,236 people and increase to 317,343,466 people in 2045. The number of people aged 0-14 years has a downward trend. In 2025, it will reach 67,646,995 and decline to 67,157,077 in 2045. The population aged 15-39 years old continues to increase, reaching 111,892,143 in 2025 and rising to 116,398,016 in 2045. The population aged 40-64 years will increase as well, with the population of 82,565,204 in 2025 and rise to 98,092,886 in 2045. Meanwhile, the elderly population continues to increase, reaching 18,161,793 in 2025 and becoming 35,695,485 in 2045. The increase in the elderly population is quite significant (see table 5).

Table 5. The Result of Population Projection for 2025-2045 (System Dynamics Modeling)

Year	0-14 years old	15-39 years old	40-64 years old	65+ years old	Total Population
2020	66,362,732	110,166,411	77,042,345	16,632,429	270,203,917
2025	67,646,995	111,892,143	82,565,304	18,161,793	280,266,236
2030	67,778,201	113,496,918	87,353,988	23,780,483	292,409,592
2035	67,450,178	114,763,569	91,499,873	28,660,689	302,374,310
2040	67,175,071	115,685,349	95,059,429	32,705,292	310,625,142
2045	67,157,077	116,398,016	98,092,886	35,695,485	317,343,466

3.2 Proportion of the working-age population

The results for the projection using system dynamics modeling show that the age composition for the productive age population will reach its highest point in 2025, reaching 69.38 percent. However, in the following projection years, the proportion of the working- age population continues to decline to 67.59% in 2045. The proportion of young people has a downward trend from 24.14 percent in 2025 to 21.16 percent in 2045. Meanwhile, the proportion of the elderly population has an increasing trend from

6.48 percent in 2025 to 11.25 percent in 2045. The momentum for the demographic bonus is in 2025, with a high proportion of the productive age population. This is in line with Ogawa's [12] opinion regarding the demographic dividend. However, we should not ignore the upward trend of the elderly because it is a sign that Indonesia is entering an aging population.

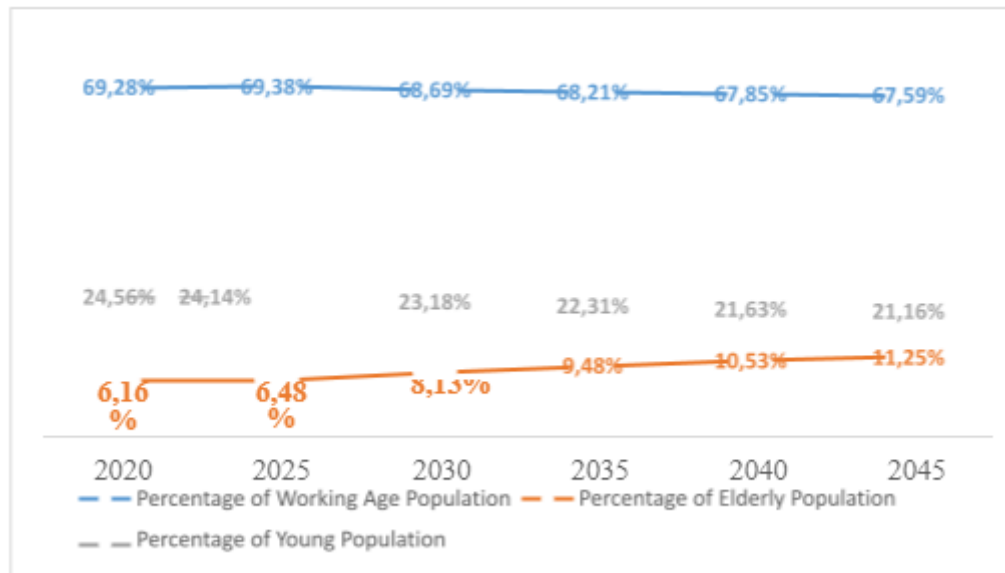


Figure 3. Age Composition

3.3 Dependency ratio

The total dependency ratio aims to measure the economic burden borne by the working-age population (15-64 years) to the non-working-age population (0-14 years and 65+ years). The dependency ratio is used to determine the implications of the results of population projections carried out. The dependency ratio is obtained from the population projection. The results of the calculation of the dependency ratio can be seen in Figure 6.

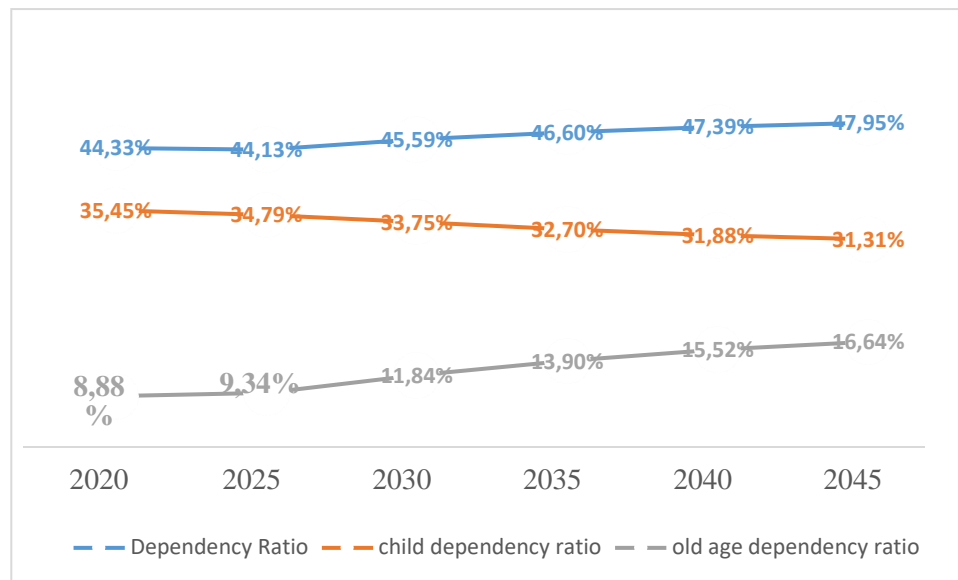


Figure 4. Dependency Ratio

Using system dynamics modeling, the total dependency ratio for 2025 is 44.13 percent, then increases to 46.60 percent in 2035, then rises again to 47.95 percent in 2045. The total dependency ratio in 2025 is the lowest point before finally rising again in the following projected years. The dependency ratio of children has a downward trend from 34.79 percent in 2025 to 32.70 percent in 2035 and 31.31 percent in 2045. Meanwhile, the elderly dependency ratio continues to increase. In 2025, its percentage is 9.34 percent, then rises to 13.90 percent in 2035 and increases to 16.64 percent in 2045. With a high proportion of the productive age population and a low total dependency ratio, 2025 is predicted to be the moment Indonesia is experiencing a demographic bonus. The dependency ratio graph can be seen in Figure 4.

3.4 Comparison with the un projection results

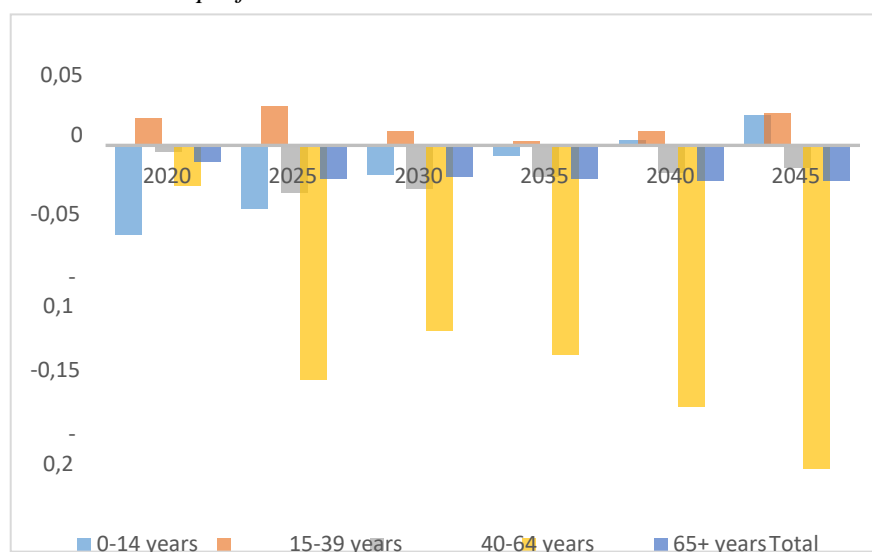


Figure 5. Comparison between the UN and System Dynamics Modeling Projection Result

The comparison of the projection results aims to determine the difference between the results of the UN projection and those using system dynamics modeling. Figure 5 shows that the results of the two projections have differences in each age group and the total population. In the 0-14 years old age group, the projected results of system dynamics modeling until 2035 are lower than the UN. However, for 2040-2045, the projection result using system dynamics modeling is higher than the UN. In the 15-39 years old age group, the result of the system dynamics is higher than the UN. In the age group of 65+ years, the system dynamics modeling projection is much lower than projected by the UN. Meanwhile, the result of the total population projection using system dynamics modeling is lower than the UN.

4. Conclusion

The population projection results using system dynamics modeling show that 2025 is a demographic bonus momentum for Indonesia. In 2025, the proportion of the productive age population reached the highest figure of 69.38 percent and continued to decline in the following years. The total dependency ratio in 2025 was at its lowest point of 44.13 percent but continued to rise in the upcoming years. In addition, we need to be aware that the proportion of the elderly population continues to increase to 11.25 percent and the elderly dependency ratio reaches 16.64 percent in 2045. It is a sign that Indonesia will soon experience population aging.

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