PEER-REVIEWED ARTICLE

# A Graphical Presentation of the Steady-state Economy Model

Theodore P. Lianos[1]

Emeritus Professor, Athens University of Economics and Business, Athens, Greece.

## Abstract

*There are several theories claiming that their policies can save the planet from environmental catastrophe. This paper claims that it is only the Steady-State Economy model on which such reasonably effective expectations can be based. This is so for two reasons. First, the SSE is based on a clearly defined economic model which is presented graphically and briefly analysed. Second, it includes a policy proposal for reducing the size of global population. This is now approaching eight billion people and is expected to exceed nine billion in the next thirty years. The logic of the SSE suggests that stabilising population is not sufficient. The global population should actually be reduced if environmental balance is to be restored.*

**Keywords:** steady-state economy; population; environment

## 1. Introduction

Over the last fifty years, the increasing intensity of environmental problems faced by the global community has led to the development of several important ideas and proposals regarding systemic changes to reverse existing environmental tendencies. Most prominent among them are the Steady-State Economy (Daly,

1 tplianos@aueb.gr

1972, 1996), the Green Growth Economy or Green Economy (OECD, 2011, 2015; UN, 2012), the ideas of Degrowth (Kallis, 2011; Kallis, Kerschner and Martinez-Alier, 2012; Hickel and Kallis, 2020), Ecosocialism (Kovel and Löwy, 1991; Angus et al., 2009; Löwy, 2018), and Ecomodernism (Asafu-Adjaye et al., 2015). These ideas and proposals are sometimes referred to as theories. Strictly speaking, a theory is a statement that can be tested, and in that sense these ideas are not theories. However, we can continue to call them theories as long as we understand that in essence they are simply ideas or proposals. Although these theories share the same objectives – i.e. ecological equilibrium and distributional justice – their analyses and policy suggestions differ widely.

A convenient way for seeing the basic differences between these proposals is provided by the Impact Equation (Ehrlich and Holdren, 1971) commonly presented as

$$I = PAT$$

where I = impact, P = population size, A = affluence defined as consumption per capita and T = technology.

In this equation, technology (embodied and disembodied) can be thought of as a factor that transforms total production into environmental impact, however measured, and therefore it can be seen as representing efficiency in the use of resources.

In terms of the impact equation, the Green Growth and Eco-modernist positions see the solution to environmental problems in technological progress that will reduce the value of T, making possible absolute or relative decoupling, thus enabling economic growth to continue whilst reducing impact.

By contrast, the ideas of Degrowth centre on a reduction of production and consumption per capita (A) suggesting at the same time a non-violent and democratic transition beyond capitalism, without specifying the nature and the institutions of the post-capitalism system. For eco-socialists, environmental problems signify a crisis of the capitalist system itself and suggest that the health of the environment and distributional justice will coincide with the socialist transformation of society. Thus, for eco-socialists, the impact equation says little as it does not discriminate among systems of social organisation, although critics have suggested that it is not clear how the variables of the equation will behave in a socialist society, especially given the failures of environmental policy in the former Soviet Union and other state socialist countries.

Given that environmental problems result from the amount of total production undertaken for human consumption, it is interesting, and at the same time surprising, that these theories totally ignore the size of world population. It is only the steady-state economy (SSE) model that recognises the importance of the per capita consumption (A) and the size of population (P).

The purpose of this paper is to discuss briefly the steady-state economy and to give a graphical exposition in order to make clear that, unlike the other theories mentioned above, it is based on a well-defined basic macroeconomic model.

## 2. The Steady-State Economy

The first descriptions of a steady-state economy are to be found in Plato's *Laws* and in Aristotle's *Politics,* both written in fourth century BC (Plato, 1926; Aristotle, 1932). Both models have the same basic elements, namely land limited in extent and a standard of living which is comfortable but not luxurious. These two elements determine the size of population of the city-state. The Aristotelian model is much more elaborate (Lianos, 2016), but both models are based on the recognition of the scarcity of resources, which at that time was synonymous with limited productive land, and on the idea that the good life of citizens, to the extent that it depends on the availability of material goods, necessitates restrictions on the size of population.

In chapter VI of his *Principles of Political Economy* Mill (1970 [1848]) briefly discusses the steady state, which he calls the stationary state and characterises it as 'a very considerable improvement on our present condition' (1970 [1848]: 113). He defines the optimum population as 'the density of population necessary to enable the mankind to obtain, in the greater degree, all the advantages both of co-operation and of social intercourse' (Mill, 1970 [1848]: 115). Mill was against population increase for two reasons. First, he argued, a strict restraint on population is indispensable for a better distribution of income and, second, independently of the supplies of food and clothing 'it is not good for man to be kept perforce at all times in the presence of his species' which may happen in an overcrowded world (Mill, 1970 [1848]: 115).

Writing in 1930, Keynes (1963 [1930]) made the prediction that stability of population and peace would solve the economic problem – i.e. the problem of satisfying unlimited wants with limited resources.

> I draw the conclusion that, assuming no important wars and no important increase in population, the economic problem may be solved, or be at least within sight of solution, within a 100 years. This means that the economic problem is not – if we look into the future – the permanent problem of the human race (4).

Given that Keynes' optimistic vision was penned nearly a century ago, the present state of affairs is particularly disappointing and sad.

More recently, the idea of a steady-state economy is present in Boulding's spaceship Earth (Boulding, 1966), implied in Ehrlich's Population Bomb (Ehrlich, 1971), and more developed in *The Limits to Growth* (Meadows et al., 1974). However, Herman Daly (1972, 1991, 1996, 2008, 2010, 2019) is perhaps the most significant developer of the concept. A steady-state economy is defined by Daly as:

> an economy with constant population and constant stock of capital, maintained by a low rate of throughput that is within the regenerative and assimilative capacities of the ecosystem. This means low birth equal to low death rates, and low production equal to low depreciation rates … Alternatively, and more operationally, we might define the SSE in terms of a constant flow of throughput at a sustainable (low) level, with population and capital stock free to adjust to whatever size can be maintained by the constant throughput that begins with depletion of low-entropy resources and ends with pollution by high-entropy wastes. (Daly, 2008: 6).

It should be noted that, in the above quotation, Daly actually gives two definitions of the SSE. In the first, population and capital are constant. In the second, it is the flow of throughput which is constant at a sustainable level and population and capital are free to change. The two definitions imply different consequences for the standard of living people can enjoy. If population is kept constant, improvements in productivity will allow higher per capita income whereas the constant flow of throughput may allow a bigger population size with a constant per capita income. However, in both cases, *stability of population and stability of resource consumption are key features.*

O'Neal et al. (2010: 11), expand the content of the SSE to include the following objectives: (a) sustainable scale, i.e. a size that is kept within the capacity of the global ecosystem to provide resources and absorb the wastes created by production and consumption; (b) efficient allocation of resources; (c) fair distribution in the sense of people having equal opportunities and by putting limits to excessive inequality of income; and (d) high quality of life in the sense of giving best global practice for health services, wellbeing, leisure time, economic stability, etc.

It is evident from the above that in the steady-state economy the role of government is important. It can change tax rates, intervene in markets to improve efficiency, impose restrictions on the use of resources when it seems necessary and keep population size constant, among other things. Daly (2017) suggests major changes in the monetary system, the most important of which is to abolish the fractional reserve banking system and establish a 100 per cent reserve requirement, but in my view this is not a required element for the steady-state economy (Lianos, 2018).

## 3. The Long-run Equilibrium in the Basic Model of the SSE

The basic elements of the SSE model are the following:

(1) A well-behaved production function which connects total product with inputs.

(2) Constant capital stock which implies that net investment is zero or that gross investment is equal to depreciation.

(3) Population is constant, which implies that births plus immigration are equal to deaths plus emigration and therefore the supply of labour is constant. Of course, in a worldwide context, migration will not be a factor in the stability of population because emigration from one country will be immigration to other countries.

(4) The quantity of output produced with given capital, labour and technology should not exceed the size that creates dangers for the sustainability of the system. Thus, the availability of resources and the ability of the system to absorb wastes determine maximum output. Sustainability is achieved and maintained if the difference between biocapacity (BC) and ecological footprint (EF) is zero or positive, i.e. BC – EF = 0 or greater.

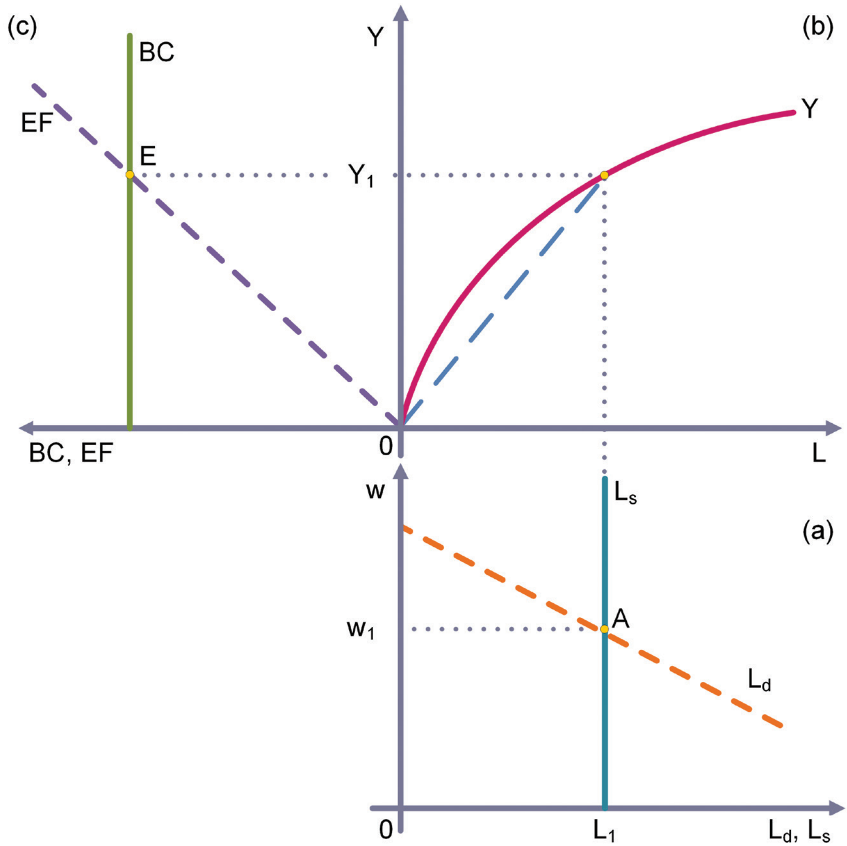
(5) The government has the authority and the ability to follow policies that eliminate discrepancies and coordinate markets so that equilibrium in one market is consistent with equilibrium in other markets. Prices are free to fluctuate for purposes of allocative efficiency.

Long-run equilibrium in a SSE is reached when the level of employment is such that, given the production function and the available technology, total production is at a level where the ecological footprint is equal to biocapacity (or less), as shown in Figure 1. Part (a) shows the labour market with the usual downward sloping demand for labour ($L_d$) and a constant supply of labour ($L_s$) which is a fraction of the constant population. Part (b) shows the production function which connects labour employment with total product (Y). Part (c) shows the ecological footprint (EF) and biocapacity (BC). Biocapacity is drawn as a straight line for simplicity. The ecological footprint is linearly and positively related to total product. Product per capita is shown by the slope of the dotted line in part (b). The functional distribution of income is shown in part (a) where labour's share is the area $0L_1Aw_1$ and capital's share the triangle $wAw_1$.

The equilibrium position shown in Figure 1 is unique because there is only one level of total product which corresponds to equality of EF (ecological footprint) with BC (biocapacity). It may be argued that, with respect to sustainability, any level of total product can be at equilibrium as long as EF is less than BC.

Of course there is nothing in the SSE to guarantee that per capita product would be sufficient for a high standard of living because biocapacity is exogenous and the standard of living depends on the population size. Given that the production function is subject to diminishing returns, a reduction of population (and labour supply) will reduce total output, but will raise per capita product, raise wages, reduce total profits and reduce the ecological footprint. An increase in population will have opposite effects.

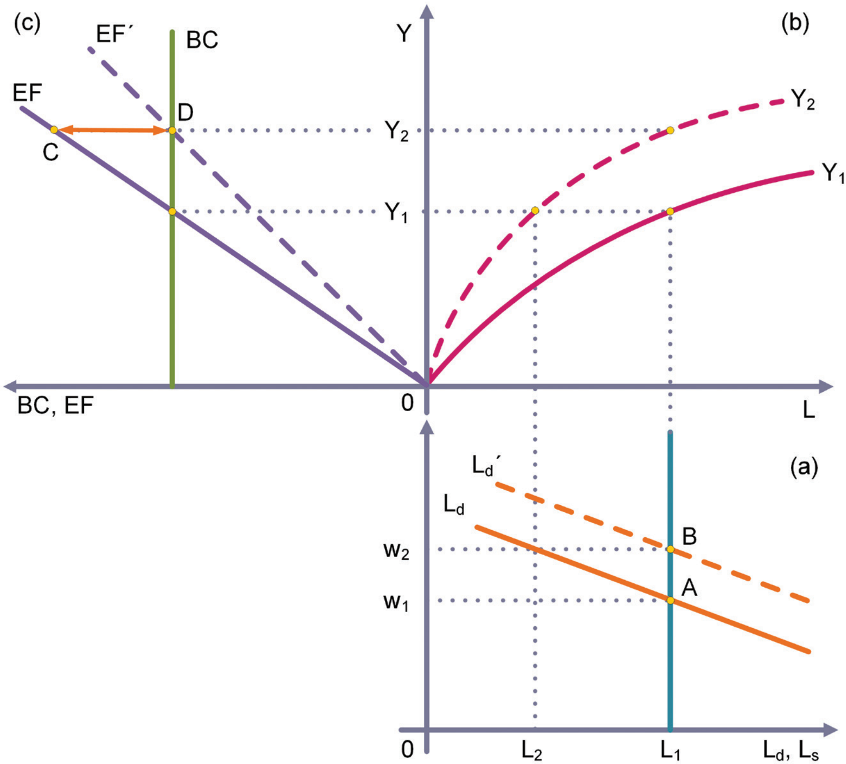
**Figure 1: A steady state economy in long-run equilibrium**




## 4. The Effects of Technological Change

The role of technological change in SSE is important because it raises productivity and per capita product. However, at the same time, it may raise the use of limited resources and the ecological footprint unless new techniques of production allow absolute decoupling so that total product increases while the ecological footprint stays constant or declines. Figure 2 shows the effect of a technological change that increases productivity of labour and shifts the production function to $Y_2$.

**Figure 2: Increase of ecological deficit following an improvement in technology**




With production at level $Y_2$ and with constant population, the ecological footprint becomes greater than biocapacity and an ecological deficit appears as shown by the distance CD in part (c). This deficit can be eliminated by following policies to reduce total production, e.g. by reducing the length of the working day and thus reducing the labour supply at point $L_2$. In this case, what is lost in potentially higher output is gained in leisure time. Also, the ecological deficit may be eliminated if the new technology reduces the waste of production and the line EF rotates to the right and becomes EF'.

## 5. The Size of Population

The main objective of the SSE is a sustainable level of total product – i.e. a constant flow of throughput at a sustainable level. According to Daly, once this level is determined, population and the stock of capital are free to adjust to whatever size can be maintained by the constant throughput (Daly, 2008: 4). This definition leaves the size of population undefined for two reasons. First, there may be more than one way of combining labour and capital to produce the sustainable quantity of output. Second, given that the least cost combination will be chosen, there is no way to guarantee that the resulting per capita product will be enough for an acceptable standard of living. In other words, the sustainable level of output can be produced by many different quantities of labour supplies and thus it is likely for the SSE to coexist with a population size that corresponds to a low standard of living. Incidentally, this is what would happen if degrowth policies are followed.

In the steady-state economy model, the size of population is of central importance in the sense that it affects the equilibrium values of the other variables, with the exception of biocapacity. It is therefore crucial to determine its optimal size. It needs to be remembered that the question of optimal size is different from that of how many people the Earth can support in the sense that it requires the adoption of a criterion on the basis of which optimality is determined. I believe that most people will agree that a high quality of life, however defined, is the relevant criterion. Twenty-four centuries ago Aristotle used the term 'best life' to refer to high quality of life and defined it as follows:

> For the present let us take it as established that the best life, whether separately for an individual or collectively for states, is the life conjoined with virtue furnished with sufficient means for taking part in virtuous action. (1932: 1323b40–1324a2)

More recently, Daily et al. (1994) wrote of a decent life for everyone, by which the authors meant that all should have access to sufficient food, education to whatever level they are capable, best-in-class health care, sanitary living conditions, and – more difficult to define – equal economic opportunities. Cohen (2017) goes further in arguing that:

> The real crux of the population question is the quality of people's lives: the ability of people to participate in what it means to be human; to work, play, and die with dignity; and to have some sense that one's own life has meaning and is connected with other people's lives. (42)

Given that resources are limited, the level of output consistent with a high quality of life cannot be determined independently of the size of population. The existence of an upper limit implies a trade-off between population and living standards. Every country, and by extension the world, can be said to operate under a budget constraint determined by the upper limit of available productive resources. It follows that there is an optimal population size that corresponds to a per capita product which is sufficient for providing the means for a high quality of life.

Thus, it appears that the steady-state economy model requires not just a constant population but a constant population of a given size and this in turn involves social choices regarding the desired standard of living. In terms of Figure 1, the size of population that corresponds to $L_1$ is compatible with a sustainable level of production, but it may not provide sufficient means for a high quality of life for everyone. A reduction of population and a corresponding reduction in the supply of labour will increase per capita income – the straight line in section (b) will rotate to the left – and at the same time will reduce the ecological footprint.

## 6. The Institutional Framework

With respect to the institutional framework within which the SSE can function, the question has been raised of whether the SSE implies a capitalist or a socialist system of social organisation. It is argued by some authors (e.g. Smith, 2010; Binswanger, 2009), that a steady-state economy is not compatible with capitalism because capitalism implies growth since the basic motive behind its functioning is profit. Daly's answer to this question is that the SSE economy 'is something different from capitalism and socialism' (2010). However, I argue that the SSE is compatible with both systems (Lianos, 2021).

## 7. Discussion

Theoretically, in a SSE the size of population must be constant or with small deviations that do not threaten the stability of the environment. However, the

SSE model needs to include not just constant population size but an optimum size consistent with sustainability. At the present time, world production is not sustainable as the ecological footprint exceeds biocapacity by approximately seventy per cent. Therefore, from a policy point of view, supporters of SSE should argue not for *constant* but for *declining* population. When Herman Daly first spoke of the need for keeping population constant, its size was about three billion, less than forty per cent of its present size. At the present time, a policy proposal for constant population is not relevant to the existing state of affairs.

Despite the undeniable detrimental effects of overpopulation and the predicted growth of world population in the next fifty years, it seems unrealistic to expect, at present, a worldwide agreement to undertake effective measures for stabilising and reducing the world population to a level that would be consistent with a sustainable level of world production. Rather, one should expect a deterioration of the economic and ecological state of affairs to be followed by extensive social unrest in many parts of the planet. (Acemoglu et al., 2017)

Although the effects of overpopulation are obvious, it is not likely that population reduction policies will be adopted. Governments, religious leaders and representatives of organised economic interests are pro-natalists for obvious reasons. Also, in many countries, economic conditions and the existing institutional framework favour the social norm of a large family. Even in overpopulated countries, with the exception of China, overpopulation is a taboo subject.

It is sometimes suggested that there is a close theoretical proximity between the SSE and Degrowth and also that the SSE is the end-state of Degrowth. However, the theoretical differences between the two, as well as the expected results of the corresponding suggested policies, are vast. First, Degrowth is mainly a political agenda without clearly defined objectives and without a well-specified economic model, whereas SSE has a well-defined economic model as shown in figures of section 3. For example, the size of population which is a crucial variable in the SSE is almost never mentioned in the Degrowth literature and when it is mentioned (Kallis, Kerschner and Martinez-Alier, 2012), it is left to be decided within the framework of ecofeminism, suggesting that the creation of coming generations is a female responsibility alone. It is implied that female empowerment and rejection of societal and family coercion will be enough to reduce birth rates.

Second, the policy implications are vastly different. Degrowth to sustainable level without population reduction would have catastrophic results. The present level of world production is 1.7 times that compatible with ecological equilibrium (Earth overshoot day was 22 August in 2020). Given that the 2020 world GDP was 84.54 trillion, the sustainable level of world production is approximately 49.7 trillion current US$. Capital depreciation is about fifteen per cent of GDP and therefore the net product would be about 42.4 trillion. With the present size of world population of 7.9 billion, this amount corresponds to 5,367 US$ per capita. Third, Degrowth theorists expect degrowth policies to be associated with a political movement that would lead to social transformation (political transition) that would make the suggested policies possible, which is not implied by SSE.

Obviously, the main policy suggestion that follows for the version of SSE presented here is a decline in population size. This will be followed by a gradual decline in total product to environmentally sustainable levels, but this would not bring poverty and social unrest because population also declines and, thus, per capita product may be constant or more likely increase. The Appendix presents some results from the Japanese economy which in the last ten years has experienced a decline in population size. Also, as mentioned above, a SSE is compatible with capitalism and socialism or any other democratic socio-economic system. It should be self-evident that, given the limited space and resources of the Earth, there is *no* system of social organisation that could offer a respectable level of wellbeing without significant reduction of the world population size. Of course, it is not suggested that population reduction will automatically solve all economic problems of the world, but it is claimed that it will make solutions much easier.

In a recent study, O'Neal et al. (2018) have examined the possibility of a good life for all within planetary boundaries assuming a population of seven billion. They conclude that some basic physical needs (i.e. nutrition, sanitation, access to energy, elimination of extreme poverty) can be satisfied by using resources at a level that does not overstep planetary boundaries but, for more qualitative goals (i.e. life satisfaction, healthy life expectancy, secondary education, democratic quality, social support, and equality), it would be necessary for the provisioning systems that mediate between resource use and social outcomes to become two to six times more efficient. The overall conclusion of this is that 'if people are to lead a good life within planetary boundaries, then the level of resource use associated with meeting basic needs must be dramatically reduced' (O'Neal et al., 2018: 6). Also, Hickel (2018) asks if it is possible to achieve a good life for all within planetary boundaries and his answer is in the affirmative on the condition that the rich countries enter into a period of degrowth and thus resources are freed to be used for growth in the poor countries. The probability that this condition can be met in the present state of affairs in the world is practically zero.

Both these studies refer to the role of population reduction, but they do not make it a central factor. It seems, therefore, that the only common ground between SSE and Degrowth and other theories is that they all claim they can bring environmental equilibrium and save the planet.

## 8. Conclusion

Among the theories claiming that their policies can save the planet from environmental catastrophe, it is only the Steady-State Economy model on which such reasonably effective expectations can be based. This is so for two reasons. First, the SSE is based on a clearly defined economic model. Second, it includes a policy proposal for reducing the size of world population. Given that production and consumption take place for the sole reason of satisfying human needs, it is difficult to understand why some theories totally ignore the number of humans living on Earth.

The SSE needs to be supplemented by a clear definition of the optimum size of population and by a numerical value of that size. The existing estimates give an optimum size of about three billion people (Lianos and Pseiridis, 2015). Even with a large margin of error, the conclusion that the Earth is overpopulated cannot be avoided.

## Appendix

Japan is a major industrial country with a population of 126 million and a GDP of 4.3 trillion in 2020 (in constant 2015 US$). In terms of current US$, Japan's GDP in 2020 was 4.98 trillion. Since 2009 Japan's population has been declining and therefore provides a real-world demonstration of the economic effects that may follow population decline. Table A.1 below presents data on population, Gross Domestic Product (GDP), GDP per capita, and trade balance for the 2010–2020 period.

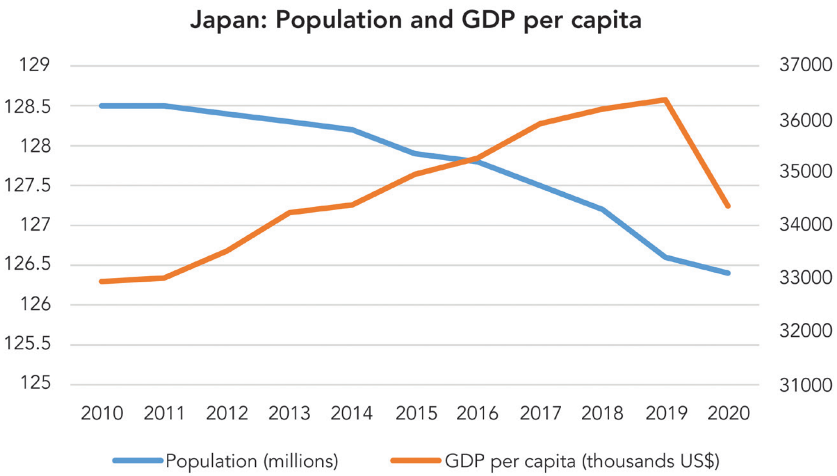
**Population, GDP, GDP per capita and Trade Balance of Japan, 2010–2020 in constant 2015 USD. Sources: United Nations, World population prospects, and World Bank, National Accounts Data**

| Year | Population (millions) | GDP (trillions US$) | GDP per capita (thousands US$) | Trade balance (billions US$) |
|---|---|---|---|---|
| 2010 | 128.5 | 4.219 | 32,942 | 83.25 |
| 2011 | 128.5 | 4.220 | 33,011 | –33.4 |
| 2012 | 128.4 | 4.278 | 33,518 | –95.9 |
| 2013 | 128.3 | 4.364 | 34,240 | –119.4 |
| 2014 | 128.2 | 4.377 | 34,387 | –119.6 |
| 2015 | 127.9 | 4.445 | 34,961 | –18.4 |
| 2016 | 127.8 | 4.478 | 35,265 | 48.8 |
| 2017 | 127.5 | 4.553 | 35,914 | 45.3 |
| 2018 | 127.2 | 4.577 | 36,188 | 11.6 |
| 2019 | 126.6 | 4.591 | 36,362 | 8.7 |
| 2020 | 126.4 | 4.325 | 34,366 | – |

According to these data, in the ten-year period from 2010 to 2020, population has declined from 128.5 million to 126.4 million. In the same period, GDP increased from $4.22 trillion in 2010 to $4.59 trillion in 2019 with a fall to $4.33 trillion in 2020 as a consequence of the Covid pandemic. Thus, as a result of the increase of GDP and the decline of population, per capita GDP has increased. One might assume the growth of GDP to be attributed to an increase of total demand either because of an expansion of exports or a reduction of imports or both. The table shows that the trade balance has been positive and negative and therefore does not seem to have been directly connected with the growth of GDP.

Figure A.1 shows clearly that, during this period, population and GDP move in opposite directions. Population decline has not led the economy to a period of recession. Japan's experience cannot be generalised, but it does provide evidence in support of the SSE model prediction that population decline may result in higher per capita product.

**Figure A1: Population and GDP of Japan, 2010–2020**

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