POPULATION AND THE ENVIRONMENT: DISCUSSIONS ON THE IMPLICATIONS OF A LARGE POPULATION[1]

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[1] This is an ongoing research where a specific analytical framework is developed and required data is collected for empirical analysis for future work on Singapore. This paper focuses on the theoretical and intuitive discussions of the implications of an increased population.
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Abstract

In view of the expressed public policy on increasing Singapore's population size, we asked the question as to how an increased population would affect the green environment in Singapore. Implications for both the natural and physical resources, benefits and costs of an increasing population size, and energy usage are analysed. We also report the empirical results and findings from a study on ASEAN and South Asian countries that links environmental impact with a high population, and contrast this with countries in the OECD. The latter in particular is relevant to Singapore in that Singapore is more economically comparable to the OECD countries. Specifically, the findings for the former countries (in ASEAN and South Asia) shows that an increasing population raises carbon dioxide emissions although a larger working-age population does not have a statistically significant impact on carbon dioxide emissions. In the OECD countries, it seems that the older age group (60 to 74 years of age) is the most carbon intensive. It is clear that a high population size will create policy challenges. Without concrete policy responses, these trends will impact the consumption and depletion of resources, accumulation of waste, and congestion. We also explore the Impact, Population, Affluence and Technology (IPAT), and how this would have a bearing on Singapore. Initial findings suggest that technological progress that might reduce pollution per capita may not offer a solution if accompanied by a proportionate increase in population size.

Introduction

There are two broadly defined aspects regarding the implications of a large population on the environment — intuitive arguments and empirical analysis. The former explores and compares the potential benefits and costs of an increasing population. The latter examines empirically the relationship between population and the environment or the possible implications of population on the environment by statistical analyses. One method of the empirical analysis is to examine how population affects carbon dioxide emissions. Another is the relationship between population and the economy, that is, how population growth rate influences the amount of capital investment needed to ensure sustainable development in which constant consumption or well-being over time is guaranteed. This is an extension of the Hartwick Rule in which all the resource rent (i.e., Hotelling rent) is required to be invested in physical capital formulation. The Hartwick Rule assumes constant population growth rate and no technological progress under the economic growth model such as Solow-Hartwick model. By doing away with these assumptions (that is, constant population growth and no technological progress), a new investment rule (or a hybrid Hartwick Rule) is derived. With positive technological and population growth, the hybrid Hartwick Rule suggests that there is surplus in the Hotelling Rent and it can be invested in enhancing environmental quality.

The rest of this paper consists three sections. The first section presents the benefits and costs of a growing population in an economy. The second discusses the possible implications of an increasing population on the quality of physical infrastructure. In the third section, we explore how population could have impacted carbon dioxide emissions in a few Southeast and South Asian countries. The possible impact of total population and working-age population is quantified by the framework of the impact as a function of population, affluence and technology. It also presents how an ageing population has affected carbon emissions in OECD countries. Apart from making statistical inferences between population and the environment, this paper will suggest how population — as a consumer as well as an input factor for production — can contribute to economic growth and hence help the environment. The final part of this paper presents a few thoughts on going forward and outlines key questions.

Intuitive Arguments — Benefits and Costs of Population

How an increasing population brings benefits to an economy can be summarised as a three-stage process. First, a higher population brings more labour force. In turn, more labour force constitutes higher production capacity. Finally, higher production capacity brings higher income and growth. The benefits are further accrued via the following two channels. First, a higher income can pay for past environmental degradation. Second, a higher income demands a higher quality of life, and hence a better environment. The scenario discussed is true when real income increases. If a higher income is attained due to inflation and environmental goods are income elastic, the converse is true.

The ways in which increasing population incurs costs to an economy are diverse but there are five broadly defined key areas — congestion, waste, consumption per capita, spending on public goods and an economy's resilience to natural calamities such as flooding. First, the costs related to congestion include costs in utilising resources; for instance, recreation and open spaces and high density housing will lead to negative externalities such as noise, congestion, traffic congestion and emissions, and hence pollution.

Second, the costs relating to waste are more waste generation, higher subsidies needed for recycling, land pressure for landfills, aesthetics of land and scenic views affected by landfills, and incinerators. There are also location issues in economic infrastructures and facilities, such as the Not In My Back Yard (NIMBY) syndrome.

Third, the increase in consumption per capita as income levels rise will result in higher demands for energy, which in turn will increase costs of production for business, making Singapore less competitive. This exerts an upward pressure on prices and translates to increase costs of living, making Singapore less attractive to both businesses and migrants.

Fourth, as the population increases, a rise in spending on public goods under conditions of limited land size and hence diminishing returns on public investment may increase society's tax burden as well as affect priorities in allocation of public budget in favour of non-environment goods. This degree of increase depends on the present income levels and economic status.

Fifth, there are costs related to Singapore's resilience to natural calamities such as flooding. Decreased co-ordination and higher collateral damage due to a higher population density would increase the cost of calamities.

Implications of Increasing Populations on Physical Infrastructure

Another aspect of the implications of an increasing population is how the quality of physical infrastructure is affected by ever-increasing population size. Increasing population requires more education facilities to be built to accommodate the rising demand for education from a young population.

In addition, the more people there are, the higher the demand for transportation as people commute to work or for leisure. Increased transportation demands will not only accelerate the need for more infrastructures but also cause more congestion in the transportation network.

Increasing population coupled with an ageing population means that not only more people in the population pyramid but also one that is heavy on the top. More senior people require more elderly facilities as well as resources.
When more people chase limited opportunities, resources and facilities, the level of competition in the society becomes intense. This may cause more crimes, which in turn requires more prisons to incarcerate more criminals.

Energy is essential to an economy. When population increases, the economy would require more energy. To meet the increase in demand for energy more energy supply facilities is needed. The first law of thermodynamics states that energy can neither be created nor destroyed. This implies the amount of energy is balanced throughout the consumption process in the form of useful energy and the waste. With all other things being equal, increased population will use more energy and will, in turn, require more facilities such as waste incineration or disposal facility to handle the waste generated in the society.

Along with energy, water is another fundamental resource to sustain life in a society. The level of water consumption will increase when population increases. This requires more water supply facilities to be built.

People do not just work for living but also seek leisure. Increasing population may seek more leisure when they become richer. This in turn necessitates more recreation facilities to be supplied.

Large population constitutes more electorate and more people to be governed to get a consensus to run a city or a town. This will likewise require more government facilities to reflect and meet people’s needs and desire.

All these factors will increase the demand for land-use and drive up land prices, leading to a decrease in green cover which is not considered productive as they do not fall under commercial or public use even though this green cover serves important ecological purposes such as reducing absorption of ground heat during the day, lowering the surrounding temperature and the retention of ground water preventing floods.

Population and Carbon Dioxide Emissions

Apart from the intuitive arguments on how increasing population taxes the environment, the possible relationship between population and the environment, whether it is positive, negative or neutral, has been extensively studied. One typical analytical framework is IPAT where the possible impact (I) is dependent on three factors – population (P), affluence (A) and technology (T). The impact is typically expressed as carbon dioxide emissions, affluence usually enters the equation as per capita GDP, and technology is expressed as the amount of carbon dioxide emitted per GDP. There are many varieties of this functional form. This study introduces two research results — one from the analysis of the impact of population on CO_2 emissions in a few ASEAN and South Asian countries, and another from a study on the impact of population in OECD countries.

The ASEAN and South Asian countries study is based on a Stochastic Impacts by Regression on Population, Affluence, and Technology (STIRPAT) model (Saluja and Chang 2007). The STIRPAT model examined by setting up a relationship between impacts and drivers such as assuming impact is a function of three drivers such as Population, Affluence and Technology.

For the population driver, two sets of populations are considered in the analysis. One set considers the total population while the other takes into consideration only working-age population from age 15 to 64 years. The hypothesis employed for this analysis is that the higher the percentage of the working-age population, the more energy the economy will consume. For the technology driver, energy intensity is employed. The hypothesis is that the higher the energy intensity, the lower the technology. For the affluence driver, a measure of GDP per capita is used.

The total population model tested how carbon dioxide emissions were influenced by total population, GDP per capita and energy intensity. Its functional form is as follows:

$$LnCo2ems_{it} = \phi + \beta_1 LnPop_{it} + \beta_2 LnGDPpc_{it} + \beta_3 LnEI_{it} + u_{it} ,$$

where u_{it} is the error term and *ø* and *β* are the parameters of explanatory variables.

The working-age population model tested the possible impact of the population in the 15–64 age group for carbon dioxide emissions. The regression equation is as follows:

$$LnCo2ems_{it} = \delta + \eta_1 LnPop1564_{it} + \eta_2 LnGDPpc_{it} + \eta_3 LnEI_{it} + \lambda_{it} ,$$

where λ_{it} is the error term and δ and η are the parameters of explanatory variables.

The results show that GDP per capita appears to have statistically significant impact on carbon dioxide emissions across the countries studied while total population appears to have mixed impact. Total population has statistically significant impact in countries like India, the Philippines and Thailand but not in Pakistan or Indonesia. This can be explained by high population growth rates that are associated with increased demand for energy or unplanned urbanisation that causes more transportation fuels being used and greater rural urban migration in those three countries.

Unlike total population in which overall population appear to exert a significant impact on carbon dioxide emissions, working-age population shows totally different results. Working-age population appears to have an insignificant impact on carbon dioxide emissions in the countries studied. This result does not mean emission levels in these countries are not affected by patterns of consumption associated with the age-composition of population. The percentage of the population aged 15–64 and staying in urban areas and their income levels could provide a better explanation. Unlike developed countries, intensive rural-urban migration in developing countries plays an important role in determining the demographic influence on the environment.

Table 1 Impact of Total Population on Carbon Dioxide Emissions

Country	Constant	Population	GDP per capita	Energy Intensity
India	-0.71	4.29**	0.44**	0.12
Pakistan	-0.67	-2.50	0.79**	0.02
Philippines	-0.52	1.27*	1.50***	1.14***
Thailand	-0.85	5.97**	1.33**	0.52*
Indonesia	-0.45	1.25	1.55***	0.20

Notes: *** denotes significance at the 1% level, ** significance at the 5% level and * significance at the 10% level

Table 2 Impact of Working-age Population (15–64) on Carbon Dioxide Emissions

Country	Constant	Population	GDP per capita	Energy Intensity
India	-0.60	2.21	0.46	0.21
Pakistan	-0.84	2.72	0.87**	-0.01
Philippines	-0.52	2.46	1.48***	1.14***
Thailand	-0.86	6.37	1.20**	0.52
Indonesia	-0.39	-3.25	1.75***	0.24
China	-0.43	1.17	1.55***	1.47***

Notes: *** denotes significance at the 1% level, ** significance at the 5% level and * significance at the 10% level

A study examining the relationships between aging population and carbon emissions in OECD countries explores whether different age groups have different impact on carbon emissions, and which age group is the most carbon-intensive one (Menz and Welsh 2012). Carbon emissions per capita is expressed as a function of various variables such as GDP, population, age composition, cohort composition, urbanisation rate, and share of coal in electricity generation. Age composition is further grouped by less than 15, 15–29, 30–44, 45–59, 60–74, and 75 and above. Cohort composition is further grouped by those born in 1920 and earlier, 1921–40, 1941–1960, and after 1960. Key results are that the age group 45–59 has a significant negative impact on carbon dioxide emissions; people aged 60–74 were the most carbon-intensive age group; and people born after 1960 are relatively emission-intensive.

Table 3 Results: Basic Specifications

	No Age Effects	Age Effects	Age (30 – 59
CO_2(1-)	0.64***	0.68***	0.65***
Population	0.68***	0.68***	0.78***
Per capita Income	0.30***	0.34***	0.36***
Urbanization	0.33***	0.30***	0.31***
Coal share	0.002***	0.002***	0.002***
Age < 15		-	-
15 – 29		0.26	-
30 – 44		-1.10	-1.17**
45 – 59		-1.44*	-1.77***
60 – 74		-0.88	-
Age > 75		-0.10	-

Source: Menz and Welsch, 2012, Table 3, p 846.
Notes:* denotes statistical significance at p<0.10 level; ** at p<0.05 level; and *** at p<0.01 level. Figures in red indicate age cohort effects that are statistically significant.

Table 4 Year of Birth Effects

	Cohort Effects	Age and Cohorts	Age/Key Cohorts
CO_2(1-)	0.70***	0.68***	0.68***
Population	0.57***	0.77***	0.75***
Per capita Income	0.31***	0.32***	0.34***
Urbanization	0.27***	0.28**	0.27***
Coal share	0.002***	0.001***	0.001***
Age < 15	-	-	-
15 – 29	-	1.53**	0.72
30 – 44	-	1.37	-
45 – 59	-	1.89	-
60 – 74	-	3.00*	1.80*
Age > 75	-	3.94*	-
Born 1920 and before	-2.18***	-5.06***	-3.31***
1921 – 1940	-0.32	-1.07	-
1941 – 1960	-1.52***	-2.71***	-2.14***
After 1960	-	-	-

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Source: Menz and Welsch, 2012, Table 4, p 847.
Notes:* denotes statistical significance at p<0.10 level; ** at p<0.05 level; and *** at p<0.01 level. Figures in red indicate age cohort effects that are statistically significant

Apart from verifying how population affects carbon dioxide emissions, how population helps to improve environment can be explored with a framework of sustainable development. Along with capital stock, population has a key role in production in an economy. Assuming a representative consumer derives his or her utility from consumption, it is posed that constant consumption over time is considered at least weakly sustainable as it could give a non-decreasing level of consumption or utility. This proposition is called the Hartwick-Solow Rule and is derived in the economy where no population growth and technological improvement are assumed. With positive population growth and technological progress, the amount of savings required for the constant consumption over time could be less than the amount of savings needed under the case of no population growth and technological progress. The surplus can be invested in ecological services and it can enhance environmental quality.

Going Forward and Key Questions

Going forward, there are a few key questions. First, identifying the optimum population size for Singapore is the most urgent question. For this, there are two suggested methods: cost-benefit analyses and economic analyses of population dynamics where population is considered or treated as a driver for economic growth and well-being and at the same time a liability for the environment. Second, how to achieve the optimum population size is another research question. Two broadly defined ways are suggested: Total Fertility Rate (TFR) and migration.

Thoughts on optimum population using demographic or population projections (under various scenarios) do not determine optimum population. A conceptual definition of optimum population is Marginal Cost (MC) = Marginal Benefit (MB) of population size. This is dependent on a number of factors affecting costs and benefits of increasing population size. There is no one magic number and where one sees a study purporting to be an optimum population, it is most likely to have derived that number from one single criterion, for example, the largest per capita output.

Whatever the population size, it will affect our quality of life. A larger population requires more space and hence increases the degree of congestion and externalities. Enjoyment of available environmental resources is negatively affected. Competition for jobs, income and employment is intensified. Innovative capacity can be larger. Speed of decision-making and implementation of policies may be relatively slowed. The speed of decision-making differs across different political systems. Share of burden in providing financial support for health, education, social safety net, etc., will be affected. Therefore, more research and study is required.

Getting empirical data is essential to even begin to talk about various population sizes or population growth. It is the costs and benefits of increased population growth that is crucial to determining the optimum population size.

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