The sustainability of ageing: a macro panel data analysis on the effects of ageing on environmental impact in OECD countries.

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Abstract

The environment is currently under great pressure. There are several anthropogenic causes labeled as the driving forces behind environmental degradation. One of these drivers that is only briefly touched upon in current literature is population ageing, which is a rapidly increasing phenomenon across the world. In the current literature the debate is often on the influence of ageing on CO2 emissions or energy consumption, whereas literature on a broad spectrum of environmental impact is often lacking. Besides that, the processes of ageing and environmental degradation are happening over time, therefore it is necessary to study the relationship over time. By taking a large time period (T=48) and a large sample of OECD countries (N=28), this study adds to the existing literature as often a small T or a small N is used in similar studies. This study aims to understand the influences of population ageing on environmental impact. However, population ageing is often a process that is closely related to other demographic and economic development factors, such as population growth, economic growth and urbanization. In order to fully understand the impact population ageing has on the environment, the possible influence of the other factors should be considered as well. This study uses a longitudinal panel approach, using a fixed-effects models. The data derives from both the Global Footprint Network and the World Bank. The models analyze the within-country effects of population ageing, population growth, economic growth and urbanization on environmental impact, measured through the Ecological Footprint. The results show that when also taking into account population growth, economic growth and urbanization that population ageing decreases the Ecological Footprint over time, during the time period of 1970 to 2017 for the 28 OECD countries in the sample. This means that in this study population ageing is beneficial to the environment as it decreases resource consumption and pollution on country level.

Keywords: Ecological Footprint, population ageing, urbanization, economic development, Environmental Kuznets Curve, demographic transition model.

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List of abbreviations

EF	Ecological Footprint
EKC	Environmental Kuznets Curve
EMT	Ecological Modernization Theory
IPAT	Impact, Population, Affluence and Technology
OECD	Organization for Economic Co-operation and Development
STIRPAT	Stochastic Impacts by Regression on Population, Affluence and Technology

1. Introduction

All human life depends on nature (Wackernagel et al., 1999), a bold statement but nonetheless carries great implications for the world population. Sustainability is key in maintaining a livable Earth for all, the Earth provides all life on Earth with resources to survive and to be sustainable means to stay within the limits of these resources (Wackernagel et al., 1999; p. 375). In the current global society, humans consume more than the Earth is capable of providing. A term associated with this is the Earth Overshoot Day. This day is defined as the day that humanity demands more from the Earth's ecological resources than that the Earth is capable of regenerating in a year (Earth Overshoot Day, 2020a). This can be measured for either the world population as a whole or per country. Last year the global Earth Overshoot Day was on July 29th, 2019 (Earth Overshoot Day, 2020b). Estimates for this year, per country, show great differences, per example, the Netherlands and Germany are expected to have used their ecological resources by May 3rd, 2020, the United States of America even reached their Earth Overshoot Day by March 4th, 2020. On the other side of the spectrum countries such as Nicaragua and Iraq are expected to reach their Earth Overshoot Day in December of 2020 (Earth Overshoot Day, 2020c). The question then arises, what causes these differences in consumption of the Earth's resources between countries? And what needs to be done to reduce the environmental impact of (over)consumption? To understand what influences resource consumption and the associated environmental impact, it is important to study the demographic and economic structures of human populations who are responsible for the overconsumption of the Earth's resources.

Part of the resource consumption is used for food. Currently enough food is produced to feed the world population, however, due to unequal distribution of the available food, hunger has not yet been eliminated (UN News, 2019). With a growing world population comes also more pressure on food production, from 2010 to 2050 the demand for food is projected to increase with 50% (World Resources Institute, 2019). Raising the food production brings about several challenges. The agricultural land needed to sustain the world population of food cannot be further extended, as this would lead to more pressure on ecosystems, biodiversity and forests (World Resource Institute, 2019). At the same time the amount of greenhouse gasses produced in the food production should also be taken into account, in order to stop global warming. This is directly linked to a very pressing societal problem, the debate about climate change and the human involvement in this matter.

The relationship humans have with the earth and its resources is rather complex. First of all humans consume more than is needed to survive, humans go past acting by instinct and beyond consuming solely to survive. Besides this humans have also brought an economic aspect into the equation. Natural resources are valued economically, creating natural capital. Trade and the ability to eliminate competing species give humans an advantage in the use of resources (Rees & Wackernagel, 1996). The way human populations live and consume has a great impact on the environment. In several studies an attempt is made to define the anthropogenic drivers of environmental impact and to understand the dynamic relationship between the drivers and the environment (among others: Dietz et al., 2007; Rosa et al., 2004; Charfeddine & Mrabet, 2017).

Understanding human population development is essential in coping with the Earth's limited resources. Humans are the drivers of environmental impact, by overusing the Earth's biocapacity. In the research by Dietz et al. (2007) the relationship between different drivers and their impact are studied, where population size and affluence are shown to be the main drivers with the most impact. However, population ageing, urbanization, well-being and education are also important factors to be considered when studying the impact on the environment (Dietz et al., 2007; Rosa et al., 2004). Population development, urbanization and economic development are not separated processes but are closely connected, so one cannot be studied without understanding of the other two processes. To study environmental impact the Ecological Footprint can be considered as it is a measure of human impact, which in turn is impacted by demographic and economic development.

A study of both the Ecological Footprint and demographic and economic variables within and between countries can provide insights into the relationship between them and the dynamic relationship (Duro & Teixidó-Figueras, 2013; Teixidó-Figueras & Duro, 2015). Besides the cross-sectional comparison, the factor time should also be considered. Environmental degradation changes rapidly over time, making it an urgent matter to study and provide sustainable policies for (Sustainable Development Goals, 2016). Besides change in environmental impact over time, demographic change over time influence size and age structure of the human population. This understanding is relevant in studying what influences human population consumption of resources. Population ageing is a demographic change that is projected to increase rapidly in the upcoming decades (United Nations, 2020). It is expected that in 2050 one in six people is aged 65 or over, which is a steep increase. From 9% of the world population being 65 or over in 2019 to 16% in 2050 (United Nations, 2020). Both environmental impact as well as population development are rapidly changing, it is therefore important to understand the impact of the relationship over time. In order to create a sustainable future for all generations to come, it is important to understand which adjustments need to be made to slow down environmental impact.

1.1 Academic and societal relevance

The study on the effects of human's on the Earth's resources and the environment has been under debate for a few centuries in academics. In the 18th and 19th century Malthus contributed to the debate, stating that population growth is an exponential process, whereas resources to support the population only grow arithmetically (Gould, 2015). Population growth, from a Malthusian perspective, is seen as the major problem in development. As populations grow faster than the resources needed to sustain the population, this will eventually lead to poverty and despair, it would be a downward spiral with growing levels of consumption (Gould, 2015). Measures to reduce population growth would be the solution according to Malthusian thinking. This way of thinking was counteracted by Ester Boserup, who argued that an increase in population size could stimulate an increase in agricultural production and technology (Gould, 2015). This would lead to a positive spiral of population growth and development. The approaches of Malthus and Boserup to population development and resource consumption and production are mainly focused on the aspects of population size and population growth. The arguments are lacking the perspective of age structure in a population. Different age groups have different consumption patterns, which should be considered when trying to understand the implications of human life on the environment.

In the empirical literature the relationship between environmental impact and demographic and economic development is studied. The Ecological Footprint is often used as the tool to measure human impact on the environment (amongst others: Rosa et al., 2004; Dietz et al., 2007). The complex relationship between economic development, industrialization and demographic development becomes apparent, for example in Rosa et al. (2004) where industrialization is marked as a driver for economic development with simultaneous population developments. With growing populations comes more pressure on the Earth's resources, which is in turn enhanced by industrialization. Food demand is increased by population growth, resulting in an industrialized extensive use of agriculture. This in turn leads to more pressure on the environment by means of land use and emissions related to industrialization. So, growing populations often simultaneously cause more pressure on ecosystems. As humans are part of these ecosystems eventually people's well-being can be damaged due to environmental degradation in their surroundings (Bremner et al., 2010). Urbanization is an effect of population growth and according to some researchers urbanization is seen as a change in consumption patterns and thus a change in use of resources (Dietz et al., 2007; Rees & Wackernagel, 1996). At the same time a change in population structure also has its effect on consumption patterns, as different age groups have different lifestyles (Erlandsen & Nymoen, 2008; van Vuuren & Bouwman, 2005). It is therefore important to thoroughly structure the different processes as mentioned in the literature. The interrelatedness of these processes should be highlighted in order to understand how these processes are of influence on the environment and thus the Ecological Footprint. Based on empirical literature, an important underlying factor that influences these processes is age structure (Zagheni, 2011; Erlandsen & Nymoen, 2008; Magnani & Tubb, 2007). Several studies show the differences in consumption behavior, driven by age structure, due to changes in lifestyle, needs and income among different age groups (Erlandsen & Nymoen, 2008; Pillemer et al., 2011; Zagheni, 2011; York, 2007).

The interest in care for the environment is increasing, especially among younger age groups as it is often stated that children and young adults are the once having to bare the consequences of climate change and environmental impact. Therefore children and young adults are often looked at to help solve issues related to environmental impact and climate change (UNICEF, 2019). However, as ageing is also a rising issue in almost all countries around the world (United Nations, 2020), it is important to consider how elderly can play a role in solving environmental issues. As the older people (65 and over), might be an important factor in the solution for environmental impact (Pillemer et al., 2011). As older people have a different and less damaging impact on the environment, due to changed needs, lifestyle and income (Erlandsen & Nymoen, 2008; Pillemer et al., 2011; Zagheni, 2011; York, 2007; Wright & Lund, 2000), an increase in the share of older people might even be of benefit to the environment.

In order to properly make assumptions about the role of older people on the environment, both environmental impact as well as population developments should be carefully studied, taking into account other influencing factors such as economic growth and population growth. With focus on consumption patterns (Erlandsen & Nymoen, 2008; Caird & Roy, 2006), as well as energy consumption (York, 2007) and Carbon Dioxide emissions and pollution (Zagheni, 2011; Magnani & Tubb, 2007; Hassan & Salim, 2015; Fan et al., 2006) population ageing has gained some attention. However, population ageing in relation to environmental impact in a broader sense, such as the Ecological Footprint as impact measure, could benefit from further studies. Environmental impact and population ageing are both processes that change over time and differently across countries. Therefore, studying the concepts both spatially and over time is of importance. Some studies are limited by the number of countries (<15 countries) (among others: Teixidó-Figueras & Duro, 2015, York, 2007) or the length of the time series (<30 years) (among others: Fan et al., 2006; York, 2007; Hassan & Salim, 2015). This study will contribute by including a broad environmental impact measurement tool, the Ecological Footprint, a larger sample of countries, 28 countries, and a long time series (48 years).

1.2 Objective of the research and research questions

This thesis will aim to make a contribution to the existing literature by using a large sample of countries and a long time series, to study the relationship of environmental impact and population ageing. The concept of the Ecological Footprint will be used to measure environmental impact of consumption and resource usage, which will be more thoroughly discussed in further chapters. The countries that will be studied consist of most OECD member countries. OECD countries have a variety of geographic locations across the world and together aim to create policies that cross borders to work on global issues. The thesis will be centered around the follow research question:

To what extent does the increase of population aged 65 and over, over the past decades influence environmental impact across countries?

In order to answer the main research question sub-questions are formulated:

1. *How are population development, economic development and technological development related and how do they influence environmental impact separately and together?*

2. *What is the effect of age on consumption of goods and resources and the pollution corresponding to lifestyle and consumption behavior?*

The sub-questions are meant to support in answering the main research question. The study of existing literature and combining this with theory will set the basis for the analysis attempting to answer the main research question. The analysis will study patterns of Ecological Footprints per country over time in relation to demographic and economic characteristics. Data used for the analysis derives from the Global

Footprint Network for the Ecological Footprint and the World Bank for the demographic and economic characteristics of the countries.

1.3 Structure of the thesis

In the next chapter the current literature is reviewed, in which the different anthropogenic drivers will be set apart and current studies on population ageing and consumption will be discussed. Followed by a theoretical framework to support the literature. Both literature and theory will be combined in a conceptual framework. The conceptual framework will be supported with hypotheses that will be tested in the analysis of this study. In the third chapter of this thesis the used data and methodology will be thoroughly discussed, which will then be followed by chapter four on the analysis and the results. In the final chapter of this thesis the main research question will be answered and the thesis will be concluded. Further research will be discussed, as well as possible policy implications resulting from the findings.

2. Theoretical framework

Different studies seek to find out how different anthropogenic drivers influence environmental impact. Population ageing is a factor that is considered in a few studies, often related to only one specific measurement of environmental impact, such as CO2 emissions and energy consumption. However, to fully understand the impact population ageing might have on the environment, it is important to understand the dynamics of other drivers over time as well and the dynamics of the relationship between the drivers. It is then possible to use this information to examine the research question of the present study. Empirical research, both cross sectional as well as longitudinal studies, have studied the anthropogenic drivers both across countries and over time. A theoretical approach can help to identify the mechanisms over time to set the results and findings of studies into perspective. Empirical findings of development of populations in size and age structure can be supported and further understood by studying the demographic transition model. For economic development empirical findings can be further understood by studying the Environmental Kuznets Curve and Ecological Modernization Theory. Linking both the existing literature and theory together, this will lead up to a conceptual model for the present study supported by hypotheses that will be tested in the analysis.

2.1 Literature review

From different fields of study attempts have been to grasp the impact humans have on the Earth. From sociology, to ecology, demography and economics (York, 2007). All different perspectives to understand how humans' social, political, cultural and economic constructs influence the carrying capacity. It becomes apparent that humans are part of the Earth's ecosystem just as other species, however, humans do have a certain dominance over other species making their influence on the ecosystem larger (York, 2007; Rees & Wackernagel, 1996). The pressure that is applied to the ecosystems currently has reached a point that it threatens the welfare of future generations (Teixidó-Figueras & Duro, 2015). Understanding the main factors of environmental pressure is key in moving towards sustainability of societies.

2.1.1 Population growth and ageing

The field of study that the relationship between population development and the environmental impact is in can be best describes as environmental demography: "*The relationship between population and the environment"* (York, 2007; p.857). In the article by York (2007) a good review of existing literature and the history of environmental demography is presented: the relationship between population issues and their fundamental pressure on the Earth's ecosystem and resources. The question is shortly discussed how many people the Earth is capable of supporting. Cohen (1995) tries to answer this question and concludes that there are many different factors and conditions in which humans live that influence their pressure on the Earth resources. However, a very important factor to note is population growth and the biophysical restrictions of the Earth on the human species should be considered accordingly (Cohen, 1995).

Population size and growth is often related to carbon dioxide emissions or other measures of pollution (York, 2007; Jorgenson & Clark, 2010), but it is often assumed that population growth puts pressure on all kinds of environmental impacts (Rosa et al., 2004; Bremner et al., 2010). When populations grow, so do consumption patterns and an increase in the demand for resources is visible (van Vuuren & Bouwman, 2005). However, the relationship between population size and environmental degradation is not linear and more complex (Harte, 2007). It cannot be said that when a population grows, consumption behavior grows linear with the population. Consumption behavior depends on different factors, such as economic development, development of technology and spatial distribution within a nation. Within a society different groups of people have different consumption behaviors, shaped by age, economic situation, and cultural and political beliefs. However, studies show that when population size is associated with carbon dioxide emissions there is a positive association between the two variables, regardless of different groups within the population (Jorgenson & Clark, 2010).

Population growth has received considerable attention in previous studies, however, when considering population development besides growth age structure should also be accounted for (York, 2007). Population ageing is a demographic process with a combination of both higher life expectancy rates and lower fertility rates, creating a population with a relatively high number of older people (York, 2007; Bloom et al., 2010). An ageing population has effects on different aspects of the society, such as health care, but also economic development (Bloom et al., 2010). An ageing population has not only a growing number of old people, the proportion of elderly people in the society is also growing (Bloom et al., 2010), creating a shift in the age profile or age structure of a country. With a growing portion of older people in a society, comes also a change in the labor force. The proportion of working age people often gets relatively smaller, when the proportion of elderly people grows, thus changing the dependency ratio's (Bloom et al., 2010; Erlandsen & Nymoen, 2008; Hassan & Salim, 2015). The dependency ratio is therefore a variable often used to look at population ageing (Erlandsen & Nymoen, 2008).

The ageing of a population is considered to have effects on the macroeconomic structure of a country, which will be more thoroughly discussed in section 2.1.2, but also influences consumption behavior and lifestyle (Erlandsen & Nymoen, 2008; Pillemer et al., 2011; Zagheni, 2011; York, 2007). Different age groups perform different behaviors in terms of consumption, based on their needs, preferences, lifestyle and income. When linking this to environmental impact, this means that different age groups have different kinds of impact on the environment. In a study by Rosebloom (2001) the usage of cars among elderly was researched, in which was showed that older people are using the car more frequently and that public transport is less used compared to for example younger age groups. When looking at energy consumption research has found that when the proportion of people older than 65 grows the energy consumption tends to increase, on a country level (York, 2007). Smaller household sizes and consumption of energy intensive goods, such as cars, by older populations is likely the reason for this (York, 2007; p.859). However, research also shows contradictions in statements on transport of older age people. McDonald et al. (2006) implies that older age people make less use of private transport such as privately owned cars. In an elaborate study by Zagheni (2011) the relationship between CO2 emissions and age structure in the US was tested. It concluded that per capita CO2 emissions rise until the individual reaches the age of 60 and then per capita CO2 emissions tend to decline. Over time this leads to a small but noticeable effect in CO2 emissions. This research is supported by the findings of Hassan & Salim (2015), who performed a panel data analysis concluding that with the rise in older age people the per capita CO2 emissions decrease.

Studies on the consumption patterns of age groups are relevant not only because energy consumption and CO2 emissions have their impact on the environment, but also because consumption of goods means usage of resources needed to produce these goods and thus use of the carrying capacity of the Earth's resources. The consumption level of elderly is often lower and consumption patterns often involve mainly basic needs and less reckless consumption of goods which are considered short-term satisfaction or luxury (Hassan & Salim, 2015; McDonald et al., 2006). Based on a life cycle model, which proposes that there is a cycle to consumption patterns that is linked to an individual's life cycle, consumption tends to drop as the share of elderly people in a population increases (Erlandsen & Nymoen, 2008). Whereas consumption patterns might seem to decline when a person reached their 60's, some researchers suggest that elderly people do consume more energy for example for the use of heating or air conditioning during extreme weather in order to maintain a good health (Magnani & Tubb, 2007). In all statements on consumption in relation to age, economics also play an important role. As consumption is influenced by a person's economy on a micro level, on a macro level consumption patterns also influence the national economy (Zagheni, 2011; Erlandsen & Nymoen, 2008).

Besides changes in consumption and lifestyle of ageing populations, another relevant strand of literature focusses on attitudes toward environmental change and impact among different age groups (Wright & Lund, 2000; Dietz et al., 1998). Younger age groups and elderly are more likely to share similar concern for environmental problems (Keller, 1996). This concern partly stems from the concern for future generations and the intergenerational sharing of natural resources (Wright and Lund, 200). When it comes to protecting or taking care of the environment elderly people are more likely to do this through individual actions, whereas younger age groups are more likely to do this collectively in groups (Wright & Lund, 2000). For elderly environmental volunteering may have great social benefits and spending time with others in nature might also provide health benefits for elderly (Pillemer et al., 2011). However, the share of older people in a population might indirectly affect the spending on environmental protection by the government (Magnani & Tubb, 2007).

2.1.2 Economics development and urbanization

Besides the study of population development such as growth and ageing, environmental degradation or impact is often also studied in relation to economic development (amongst others: Bagliani et al., 2008; Galli et al., 2012; Duro & Teixidó-Figueras, 2013; Caviglia-Harris et al., 2009). Many countries across the world, even low income countries, have experienced economic growth (Galli et al., 2012). Studies show that economic growth often leads to an increase in CO2 emissions, up until a certain point. After a certain income is reached a decrease in CO2 emissions is often noticeable (Hassen & Salim, 2015). Overall it is argued that countries with low income levels have higher environmental degradation and when development reaches later stages the need for environmental care and concern arises (Bagliani et al., 2008). Highly developed countries have higher levels of technology and abundant resources available due to the ability to trade and ship them from all over the world. A theory well linked to this line of arguing is the Environmental Kuznets Curve, which will be more thoroughly elaborated on in chapter 2.2. Industrialization plays an important role in economic development and growth. Countries with mainly producing industries often also have large environmental impacts in the shape of CO2 emissions and usage of natural resources and land area. High income countries often do less production within their own borders and become more service-based economies (Jorgenson & Rice, 2005; Bagliani et al., 2008). However, this does not imply that consumption rates have gone down in service-based economies, it can simply mean a displacement of material production to another country (Dietz et al., 2007). Therefore the environmental impact that exists in manufacturing countries cannot solely be put on the population of these countries. Trade is a very crucial factor in this sense as it creates the possibility to consume goods that are produced outside of a population’s biogeographical location. The level of consumption is highly influenced by its position in the international trading system (Jorgenson & Rice, 2005). In high income countries consumption is often very high, for which the low income and manufacturing countries pay the price, as the effects climate change and environmental degradation of the high consumption patterns occur in the low income and more vulnerable countries (Stephenson et al., 2013; Bremner et al., 2010).

The relationship between population growth and environmental degradation is not straight forward and uniform across the world. When dividing the world into low, middle and high income countries a linear relationship between environmental degradation and population growth is not always found (Galli et al., 2012). An explanatory factor for environmental degradation can then be found in economic development. When it comes to economic development it is often found that consumption rises with economic growth (Dietz et al., 2007). For high income countries Galli et al. (2012) found a rise in average per capita footprint, but only a small increase in population size. The rise in footprint, or consumption, can be explained by growth of national economies and lifestyle improvements (Galli et al., 2012). For middle income countries over time only a small increase in average per capita footprint was found, with a doubling of population over this time. Low income countries showed a reduction in per capita footprint with a very high increase in population size (295%) (Galli et al., 2012). Even though population growth is thus not always the explanation for an increase or decrease in environmental degradation, population aging, however, is still a very important factor to consider. Age and economics are connected through the influence of consumption patterns. The age structure of a country therefore also affects macroeconomics (Erlandsen & Nymoen, 2006).

Population development and economic development often lead to a change in rural and urban living. Industrialization and economic development are the drivers of urbanization (Uttara et al., 2012). Urbanization often has negative effects on the environment, especially in low income or developing countries (Uttura et al., 2012; Capps et al., 2016). The grow of cities often go within a very rapid speed, consequence of this is water and air pollution together with unsustainable land use (Capps et al., 2016). A case study of the United Arab Emirates showed a relationship between urbanization and CO2 emissions, where urbanization leads to an increase in CO2 emissions (Shahbaz et al., 2014). Besides CO2 emissions there is also a difference in consumption patterns between rural and urban populations. Urban populations often show a change in lifestyle and consumption patterns (Dietz el al., 2007). When looking at food consumption for example, differences between rural and urban populations occur. Especially in developing countries, people in rural areas produce a part of their food consumption themselves, whereas in cities this is not possible and they live fully of food imported from outside the city region (Regmi & Dyck, 2001).

Besides food consumption, the consumption of energy and the use of transport are very big contributors that make a difference in environmental impact of urban and rural areas. In a study on environmental impacts of households in the UK by Caird & Roy (2006) it was concluded that rural households and small households had significantly larger per capita footprints than urban and suburban households. The age of household composition was also accounted for as a factor that made a difference in the household footprint. In OECD countries the factors that influence the household footprint are growth in demand for personal transport and electricity, smaller household size and the growth of consumption of goods and services (Caird & Roy, 2006; p. 408). In developed countries urbanization can also be more environmentally friendly, as people in cities have more access to environmentally friendly products and goods, due to the high concentration of people, the prices of such goods become lower (Charfeddine & Mrabet, 2017). The high concentration of people can also lead to more technological innovations, resulting in greener technologies (Charfeddine & Mrabet, 2017).

2.2 Theoretical discussion of population and economic development

In order to place the current literature further in context a theoretical framework is provided. Theories on both population development, such as the demographic transition model, and economic development, such as the Environmental Kuznets Curve, are of importance to further understand the dynamics around the development of environmental impact analysis.

2.2.1 Demographic Transition Model and population development

Important basis to understanding population development is the demographic transition model. In the paper by Stephenson et al. (2013; p.1665) the fundamental principle is well explained: "*The fundamental processes of demographic transition¬which causes a population to move from high mortality and high fertility to low mortality and low fertility¬are associated with a sustained decline in mortality leading to population growth and a decline in fertility leading to population ageing and urbanization*.". This perspective has several consequences for consumption of resources due to the demographic composition of populations in different demographic transition stages, as was shown in different empirical studies. By moving from the high mortality and high fertility stage, the population starts a growth process started by a decline in mortality. This population growth puts a strain on resource consumption, as a growing population simply needs more resources to sustain. When fertility also starts to drop, the population growth does not immediately stop, but gradually slows down. Life expectancy increase, together with fertility decline this leads to a shift in mean age of the population. Besides change in age structure and population size, simultaneously changes in economic development, industrialization and urbanization take place. This also has its impact on resource consumption, as industrialization creates a greater demand for resources by means of an increased production level, economic development increases the purchasing power of the, possibly growing, population and urbanization leads to pressure on ecosystems and environments of the surrounding urban area. An important consideration in the perspective of demographic transition is that the changes in population structure as part of the different stages of a demographic transition, also come with changes in human behavior which influences environmental impact and consumption.

The demographic transition model theory can be integrated or related to other population development theories. One important theorist was Malthus, whose ideas can be related to the second stage of the demographic transition model. In Malthus development theory it is argued that population growth leads to environmental degradation, where population grows exponentially and food production only grows linear leading to environmental degradation and unsustainable population growth (Boserup, 1996; Gould, 2015). In later work technology, which presents the basis for industrialization, was added to the Neo-Malthusian thought. However, technology also only lead to negative effects as sustainable technology was not possible in this theory (Boserup, 1996). Malthus touched upon high levels of fertility by means of one of the assumptions made by Malthus "God gave humans an unchanging force of sexual passion" (Seidl & Tisdell, 1999) leading to exponential population growth.

The Malthusian way of thinking argues that the carrying capacity of the Earth would never meet the population growth that mankind enforced on themselves in the first stages of the demographic transition model, leading to food insecurity and poverty (Seidl & Tisdell, 1999). Basic population biology assumes that logistic population growth happens in all species and is eventually slowed down by the carrying capacity, the limit of the resources (Seidl & Tisdell, 1999). So in this simplified assumption Malthus fear of running out of food for the size of the world population would be unnecessary as population growth would slow down when the carrying capacity of the Earth has been reached. However, human populations have an advantage compared to other species, as they have the ability to eliminate other species from the food chain and the ability to increase technological innovations to produce more food (Rees & Wackernagel, 1996). In a Neo-Malthusian perspective modern technology is considered. However, technology is not seen as a positive development, but rather as a development that increases environmental pressure. Due to modern technology humans are capable of producing goods, such as cars, that are polluting and thus harmful for the environment. Industrialization also leads to urbanization, rural to urban migration, which is considered harmful for the environment by Neo-Malthusians as fast growing cities are considered very polluting (Boserup, 1996).

In Malthus theory on the downward spiral that population growth has on resource consumption, population ageing does not play a role. However, in the Demographic Transition Model population age structure is of importance. The decrease in mortality is a consequence of an increase in health care, eventually leading to higher life expectancy, resulting in larger share of older aged people. An increase in life expectancy and a decrease in fertility lead to a shift in composition of age groups, where the older age group is increasing and the younger age groups are decreasing in size. Older aged people in turn are expected to have lower consumption rates. Based on the demographic transition model theory, eventually all countries are expected to reach the fourth stage: high life expectancy, low fertility and mortality, shifting to an ageing population. The development of populations in both size and age structure has its consequences on the consumption of resources by the population based on the literature review provided earlier. The changes in age and size as proposed by the demographic transition model also have its influence on economic development. The number of people in a population and the distribution across age groups has its effect on productivity by influencing the size of the labor force, but also in consumption behavior in different stages of demographic and economic development.

2.2.2 Environmental Kuznets Curve and Ecological Modernization Theory

Different economic theories can be applied to study the impact of human populations on the environment. The Environmental Kuznets Curve, hereafter EKC, is a well-studied theory by different researchers (among others Caviglia-Harris et al., 2009; Rosa et al., 2004; Bagliani et al., 2008; Dietz et al., 2007). The EKC hypothesis focusses on the relationship between economic growth and environmental degradation, more specifically the relationship between per capita income and environmental quality (Caviglia-Harris et al., 2009). In short, economic growth eventually leads to an improvement in environmental quality (Magnani & Tubb, 2007). In early stages of economic development and industrialization, environmental degradation grows faster than per capita income. This has to do with the need for high production in order to have economic development (Dinda, 2004). Both per capita income and environmental degradation rise in later stages, up until a certain threshold, where per capita income grows faster and environmental degradation lowers (Dinda, 2004). When illustrated in a graph this leads to an inverted U-shape of environmental degradation, see figure 1 (Dinda, 2004; Caviglia-Harris et al., 2009).

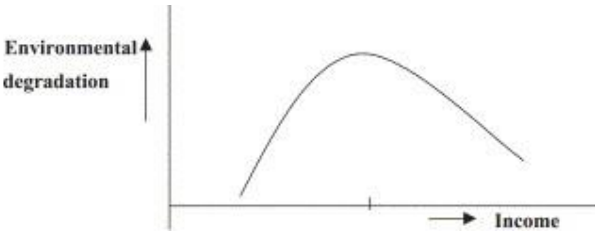

Figure 1. Environmental Kuznets Curve (Dinda, 2004).

The development of per capita income in relation to environmental degradation as hypothesized by the EKC looks very appealing. The explanation of the drop in environmental degradation after reaching a certain point in per capita income lies in the willingness and need for greener production, enlarged interest and care for the environment and the development of more sustainable technology in high income countries (Dinda, 2004; Bagliani et al., 2008). However, there is also criticism and doubts about the validity of the EKC hypothesis. When approaching the EKC hypothesis from a consumption-based perspective it is argued that when income rises and so does the need for greener production within a country, production is often moved to other countries, keeping the consumption patterns in check (Bagliani et al., 2008). This displacement of production and environmental pressure to other countries is known as the Ekins' pollution-haven hypothesis (Bagliani et al., 2008).

Studies on the relationship between a pollutant, or a part of environmental degradation, and income validate the existence of the EKC hypothesis. For example the study by Hassam & Salim (2015) shows a decrease in CO_2 emissions after a certain income per capita has been reached. However, other studies on CO_2 emissions and income show that it varies greatly between low, middle and high income countries whether or not there is an inverted U-shape visible (Fan et al., 2006). When studying the EKC hypothesis with a broader environmental degradation indicator, such as the Ecological Footprint, empirical evidence for the existence of an EKC relationship between economic development and the Ecological Footprint is not necessarily found (Caviglia-Harris et al., 2009). This can be explained by the earlier mentioned displacement of production. The Ecological Footprint takes into account the use of natural resources for consumption, unrelated to where on Earth the resources originate from or are produced into goods.

Another theory that is briefly touched up on some studies regarding the relationship between populations and environmental degradation (Rosa et al., 2004) is the Ecological Modernization Theory, hereafter EMT. The EMT was originally developed by Jospeh Huber, it is a sociological theory developed to better understand the interaction of technology and the environment (Fischer & Freudenberg, 2001; Spaarengaren & Mol, 1992). Technological innovations are seen as the solution to the environmental problems, so taking industrialization even further by developing technology that will restore the environmental problems (Fischer & Freudenberg, 2001). The focus of the theory is not on the amount of consumption or production, but rather on how goods are produced. How goods are produced is the problem function in EMT, this line of thinking is argued by researchers who take into account consumption as part of the problem (such as Carolan, 2010). So rather than just blaming the way of producing, it should also be considered how much is produced for consumption. This is in turn linked to population age structure, as consumption behavior varies across age groups. How much is produced for consumption is affected by how much is demanded by the population given its demographic characteristics. The EMT could therefore benefit from taking consumption into consideration and thereby also the underlying factors that influence macro consumption levels.

The perspective of the EMT relies on a positive relationship between economic growth and environmental quality, meaning that when economies grow the environmental quality increases (Fischer & Freudenberg, 2001). Critics who are fully opposing the theory are calling the EMT perspective impossible 'sustainable capitalism' (O'Connor, 1994), where on the other side of the spectrum researchers praise the EMT for providing perspective on economic growth being a very positive and sustainable future (O'Neill, 1998). The discussion on the validity of the theory has a broad spectrum of criticism and praises, which is thoroughly discussed in Fischer & Freudenberg (2001). Based on empirical studies it cannot be proven fully right or wrong, in some cases or countries there is an increase in environmental quality with economic growth due to technological innovations and in other cases or countries this relationship has not been established (Fischer & Freudenberg, 2001).

Coming back to the argument of (over)consumption, Carolan (2010) makes a compelling argument. In his research he states that when production becomes more ecologically sound or environmentally friendly this does not limit the increase in consumption. Being able to produce greener and perhaps even more efficient, might eventually even lead to more production and consumption of certain goods. There are two solid examples to support this argument, the first one being in the production of cars. Cars are become increasingly cleaner and technology is able to limit the amount of CO2 emissions of cars. The use of cars, however, is only increasing especially in countries such as China and India where the number of cars is rising. So even though cars are become more environmentally friendly, the increase in the use of cars grows faster, outweighing the positive effect of the greener production (Carolan, 2010). The second argument is that of agricultural food production. Despite a rise in more environmentally friendly production methods of food, the increase in overconsumption of food rises faster. The number of resources on Earth are still limited so endless production, no matter how green or environmentally friendly the technology for production is, to meet the growing demand for food is not possible (Carolan, 2010). Linking this back to the assumptions on population growth as stated by Malthus, there is a similarity in the way of thinking about population growth and the finiteness of the carrying capacity of the Earth, despite technological innovations.

2.3 Conceptual model

Both the empirical as well as the theoretical literature show the complexity of the relationships between determinants of environmental pressure and which determinants are the main drivers of environmental degradation. Development of population structure is the key and most essential driver and will lead to development of economics and urbanization, however not in all theory or empirical studies this receives enough attention. As stated by Erlandsen & Nymoen (2008; p.507): "*A demographic change of some magnitude is an example of a structural change, which can potentially overturn existing macroeconomic relationships and cause forecast failure*.", implying that the importance of studying demographics should not be overlooked, failure to properly research demographic change will in turn lead to misunderstanding of the other types of development.

Based on the existing literature it shows that the relationship between humans and the environment is complex and consists of more than only population size. The anthropogenic drivers can be summarized in the categories population, affluence and technology (Rosa et al., 2004; Dietz et al., 2007; Harte, 2007; Wei, 2011; Teixidó-Figueras & Duro; 2015; Fan et al., 2006). In this affluence is the per capita consumption or production and technology is the impact per unit of consumption or production (York et al., 2003). In order to study the relationships between the three, researchers have debated and developed a model called IPAT (Ehrlich & Holdren, 1971; York et al., 2003). The IPAT model consists of environmental impact (I), Population (P), Affluence (A) and Technology (T), so I=PAT and is meant to capture the complex relationship of the anthropogenic drivers on the environment (Teixidó-Figueras & Duro, 2015). The model assumes that each of the three factors have a proportional effect on the environment. However, critiques say that the IPAT model itself cannot test the proportional assumption as technology is derived from dividing environmental impact by the other two drivers (Wei, 2011; p71). The IPAT model cannot be used for hypotheses testing, as it is based on assumptions on the relationship between the drivers and the environmental impact (Rose et al., 2004).

To overcome the issues of the IPAT model York et al. (2003) developed the equation into a stochastic regression model called STIRPAT. STIRPAT stands for Stochastic Impacts by Regression on Population, Affluence and Technology (Teixidó-Figueras & Duro, 2015). The stochastic model does not assume proportionality but it is based on parameters to be estimated and an error term (Rosa et al., 2004; Teixidó-Figueras & Duro, 2015; Wei, 2011). The difficulty with technology that caused problems in the IPAT model is fixed in the STIRPAT model by including T in the error term since technology, or impact of per unit consumption or production, is hard to directly measure through an indicator (Rosa et al., 2004).

With the STIRPAT model as background a model for the present study is created. The conceptual model, presented in Figure 2, shows the relationship between population (demographic development) and affluence (economic development) and environmental impact. In the studies on demographic development it often centers around population growth as the main driver of environmental pressure (among others: York, 2007; Jorgenson & Clark, 2010; van Vuuren & Bouwman, 2005). The theoretical perspective of Malthus and Neo-Malthusians affirm this relationship based on the limits of the carrying capacity of the Earth. However, it is not solely the size of a population that matters, the age structure of the population is also of importance when studying environmental degradation, due to the different consumption patterns of different age groups. This is a topic that has been briefly touched upon in existing literature, mainly in relation to CO2 emissions and energy consumption (Zagheni, 2011; York, 2007; Hassan & Salim, 2015). As ageing is a phenomena of recent time and near future, due to increase in life expectancy in many countries, as well as low birth rates (York, 2007; United Nations, 2020), it is an important factor to study over a period of time. Based on empirical studies countries with a relatively higher share of elderly, also tend to have an increase in energy consumption (York, 2007). However, for CO2 emissions it seems that a decrease is visible, when the share of elderly in a population grows (Zagheni, 2011). It has become apparent from both the theoretical as well as the empirical approaches, that demographic changes often lead to changes in behavior. Therefore a change in age structure will most likely lead to a change in consumption pattern. Based on the earlier mentioned literature and theories it can be stated that even though elderly have a higher need for energy intensive goods and live in smaller household sizes, their overall consumption is often lower and consumption serves mainly basic needs. The CO2 emissions also tend to decrease when the share of elderly grows. This leads to the first hypothesis that will be tested in this study:

H_1: Ageing of a population decreases the Ecological Footprint on country level.

The component of age in economic theory is not explicitly mentioned, however, it definitely is of importance as age does influence macroeconomic structures within a nation (Erlandsen & Nymoen, 2015). Due to ageing there is a shift in the population available for the labor force compared to the children and older people. However, this only indirectly influences the consumption behavior of a population. This study will aim to fill the gap considering age in relation to broader environmental impact. In order to do this, age cannot be studied on its own. Other concepts such as economic growth, population size and urbanization should be considered too. Existing literature does not necessarily agree on the effect of the different drivers of environmental impact, due to differences in study results. The type of environmental impact, such as energy consumption, CO2 emissions or the Ecological Footprint as a whole, also alters the outcome of different studies. Therefore in the present study assumptions are made taken into account the different perspectives and outcomes as discussed in the past research, bearing in mind that the outcomes of this study might differ due to the sample of countries and the tool, Ecological Footprint, used to measure environmental impact. This leads to the following hypotheses:

H_2: Population growth increases the Ecological Footprint on country level.
H_3: Economic growth increases the Ecological Footprint on country level.
H_4: Urbanization decreases the Ecological Footprint on country level.

For economic growth, due to the outplacement of production this does not lower the Ecological Footprint, but technology should not be forgotten. Economic growth can also lead to a rise in greener technology and therefore ways of production. However, the greener production of goods, often does not outweigh the (over)consumption that many developed countries deal with, based on critiques of the EMT (Carolan, 2010).

For urbanization, in developed countries it is often seen that due to the accumulations of people living closely together it is cheaper to buy greener produced goods. Urban areas often also have a higher concentration of public transport, in rural areas this is often less making households more prone to use privately owned cars.

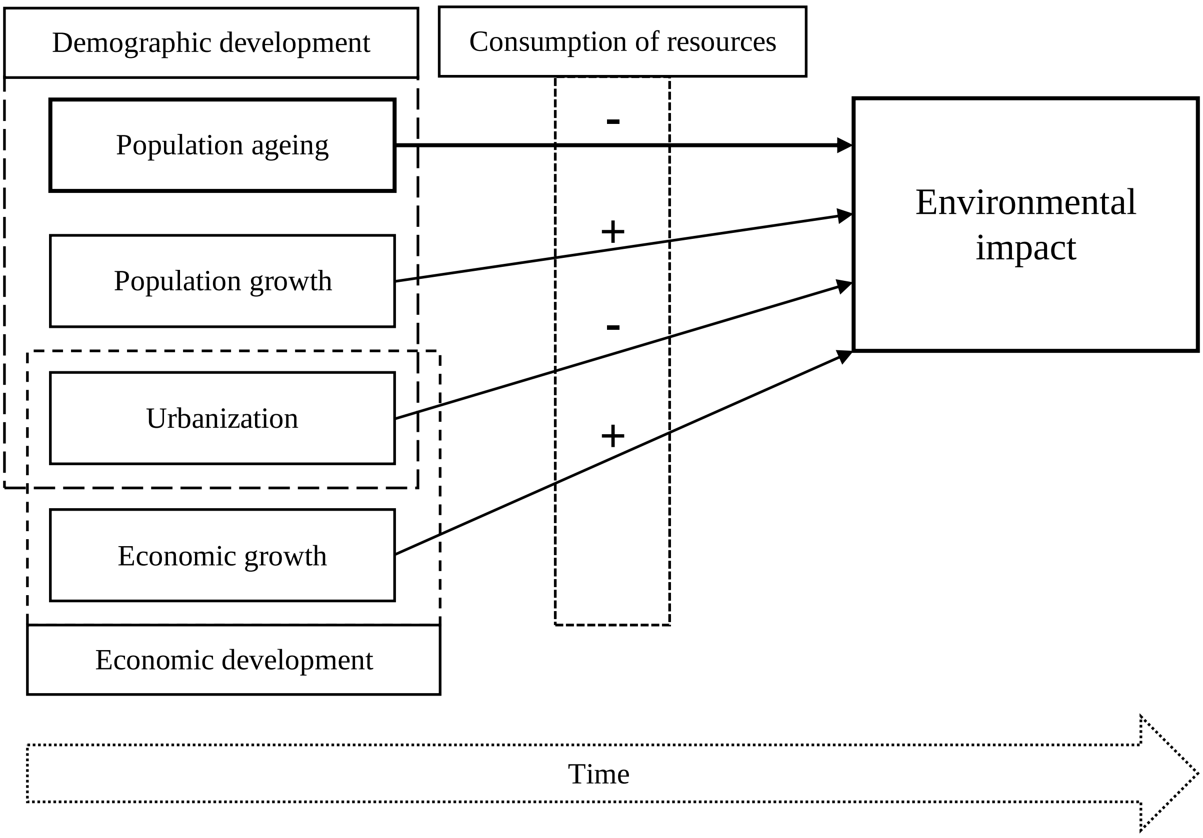

Figure 2. Conceptual model. Source own illustration based on chapter 2.

3. Data and methodology

3.1 Dataset

For this present study the relationship between environmental impact and demographic and economic development of countries will be further explored. It is therefore a macro level study. In order to do so data from two data sources is used, the data on environmental impact is collected from the Global Footprint Network and the data on all other characteristics of nations is from the World Bank. Both date sources provide data on macro, country, level.

The data used from the Global Footprint Network is the Ecological Footprint specified by country and year. The Global Footprint Network creates Footprint accounts for all countries from 1961 onwards (Global Footprint Network, n.d.). Based on internationally available data sources Ecological Footprints and Biocapacity is calculated for all countries. The data collected by the Global Footprint Network is thoroughly assessed, as not all countries have data available or the data sources are not reliable. If data sources are not reliable, in some cases minor improvements can be made to estimate missing values or to fix minor data errors (Global Footprint Network, n.d.). For other countries where data is not available it is not possible to generate the Ecological Footprint or Biocapacity statistics. In cases like this, such as Iceland, data will be missing.

The other used data source is the World Bank open data. The World Bank provides a databank giving access to many different databases. The database used for this study is the World Development Indicators. This database consists of many different development indicators, which are compiled from different internationally recognized data sources (The World Bank, 2020). The World Development Indicators is an often-used database for macro analysis (among others: Bagliani et al., 2008; Hassan & Salim, 2015). Most of the World Bank data derives from statistical offices of countries and the quality relies therefore on the quality of these offices (The World Bank, n.d.). It provides indicators both on economic development as well as on demographic development of all countries, based on the most recent and accurate data sources, on regional, national and global level (The World Bank, 2020).

3.2 Sampling selection

The countries that are analyzed in the present study are OECD member states. OECD countries are spread around the world, therefore creating a geographic heterogenous sample of countries. However, it should be noted that there are no African countries among the OECD members and they will, therefore not be studied in this study. Secondly, most OECD members are economically very well developed and are among the leading countries when it comes to population ageing. Lastly, another important reason to study OECD countries is the motivation or ideology behind the existence of the OECD. The working together of member states to create policies to improve societies and population well-being is a main goal of the OECD. By working together they can set an international standard in policy making, which is vital in creating policies tackling environmental issues, climate change and (over)consumption are crossing country borders. As is stated by the OECD "*Together with governments, policy makers and citizens, we work on establishing evidence-based international standards and finding solutions to a range of social, economic and environmental challenges*." (OECD, n.d.). The sample of this study consist of 28 OECD countries. In total there are 37 OECD members (appendix A), unfortunately for Iceland there are no footprint accounts available, so therefore Iceland is excluded from the study. For eight other countries the data was not available for the years before 1992, therefore they were excluded from the sample. This will be further elaborated on in section 3.3.

The Footprint accounts are calculated from 1961 to 2017, where the range of the availability of indicators from the World Bank reaches from 1960 to 2019. However, for a number of countries, GDP is only recorded from 1970 onwards. In order to use the largest time series, data from 1970 to 2017 are used for this study.

3.3 Data quality and missing values

After thorough assessment by the Global Footprint Network, all countries are assigned a data quality score, based on the reliability of the date over time. The OECD members states all have a data quality score of 3A, meaning that the data used for the footprint accounts of all years is reliable, or a score of 2A, meaning that there might be unreliable data measurements in components needed to calculate the footprint accounts over time, however, this does not significantly affect the overall footprint accounts over time (Global Footprint Network, n.d.). The quality and reliability of the data from the World Bank depends on the quality of the statistical offices in all countries. However, issues in data quality often lies mostly in developing countries, for which the World Bank has set up programs to help invest in good statistical infrastructures (The World Bank, 2020).

Another important note on the data quality for this study is the issue of missing cases. For eight countries the data on the Ecological Footprint and GDP is only available from the year 1992 onwards. These eight countries are Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Slovenia and Slovak Republic. This can be explained by the change in country formations after the dissolution of the Sovjet Union. This will have an effect on the analysis as it will result in an unbalanced panel dataset. The use of panel data for studying dynamics over time is susceptible to attrition, meaning participants leaving the study early (Frees, 2004). In this analysis the opposite of attrition is presented: participants, or in this case countries, entering the study later due to the unavailability of data from earlier periods than 1992. This results in an unbalanced panel dataset, not all countries are equally observed over the time span of 1970 to 2017. To avoid bias in the analysis it is decided to leave out the previously six mentioned countries. The length of the time series is prioritized over the number of countries as participants in the study. The remainder of the sample is still 28 countries, providing enough cases to properly analyse the data.

3.4 Ethical considerations

The use of the databases of the Global Footprint Network and the World Bank is both on macro level. Due to the absence of micro level data, there are no ethical considerations considering anonymity of participants.

3.5 Operationalization of the concepts

3.5.1 Dependent variable: Ecological Footprint

Environmental impact is a broad concept. In different studies it is measured through pollution, such as CO2 emissions (Zagheni, 2011; Hassan & Salim, 2015; Magnani & Tubb, 2007; Fan et al., 2006) or energy consumption (York, 2007; Mazur, 1994; York, 2003). A broader concept to measure environmental impact through consumption of resources is the Ecological Footprint (Jorgenson & Rice, 2005; Charfeddine & Mrabet, 2017; Dietz et al., 2007; Rosa et al., 2004). The Ecological Footprint (hereafter EF) is an indicator of the amount of productive land, both land and sea area, needed to sustain a population. This productive land does not have to be located near the specified population, this could be anywhere on Earth. The EF can be calculated for any population, from individuals to household and from a city to a country level (Caird & Roy, 2006). The EF is the sum of six components, different types of bioproductive land: cropland, grazing land, forest area, fishing grounds, built-up land and energy land (Bagliani et al., 2008). The EF is expressed in global hectares of productive land or sea. This makes it a good comparison tool, as all impact is converted in to a single metric, namely productive land (Rosa et al., 2004). The six components of EF are all aspects of the biocapacity provided by the Earth. The EF of a country can be compared to its biocapacity, meaning whether the country has the productive land and sea to provide for the consumption of its inhabitants (Caird & Roy, 2006). For most densely populated industrialized countries this means that the EF concedes the amount of productive land the country has available, resulting in an unsustainable way of living (Caird & Roy, 2006). This is expressed in ecological deficit (surplus), meaning that the consumption of resources is greater than what the Earth is able to regenerate (Bagliani et al., 2008). However, the EF does consider trade and technology by measuring import and export of products, so the productive land does not have to be in proximity to the population. This does mean that globally the EF should not concede the biocapacity of the Earth, in order to remain within sustainable limits. When speaking of the EF, this mostly relates directly to human consumption. Thus, it could be stated that EF is a consumption-based approach (Bagliani et al., 2008). Given this, EF can be expressed in the following formula (Larson et al., 2013; p.10):

$EF_{consumption} = EF_{production} + EF_{imports} – EF_{exports}$

The formula shows the calculation of the EF of consumption for a specific year, often for a specific country. Environmental impact is the dependent variable of the present study. The concept of EF is used as the measurement of environmental impact through human consumption, influenced by the independent variables. In the dataset the variable EF is collected through the Global Footprint Network, which is calculated as shown in Figure 3. It is expressed as the global hectares need per person to sustain the EF consumption. The measures of the EF are per year and per country. Therefore, it is a suitable measure to use for a longitudinal study.

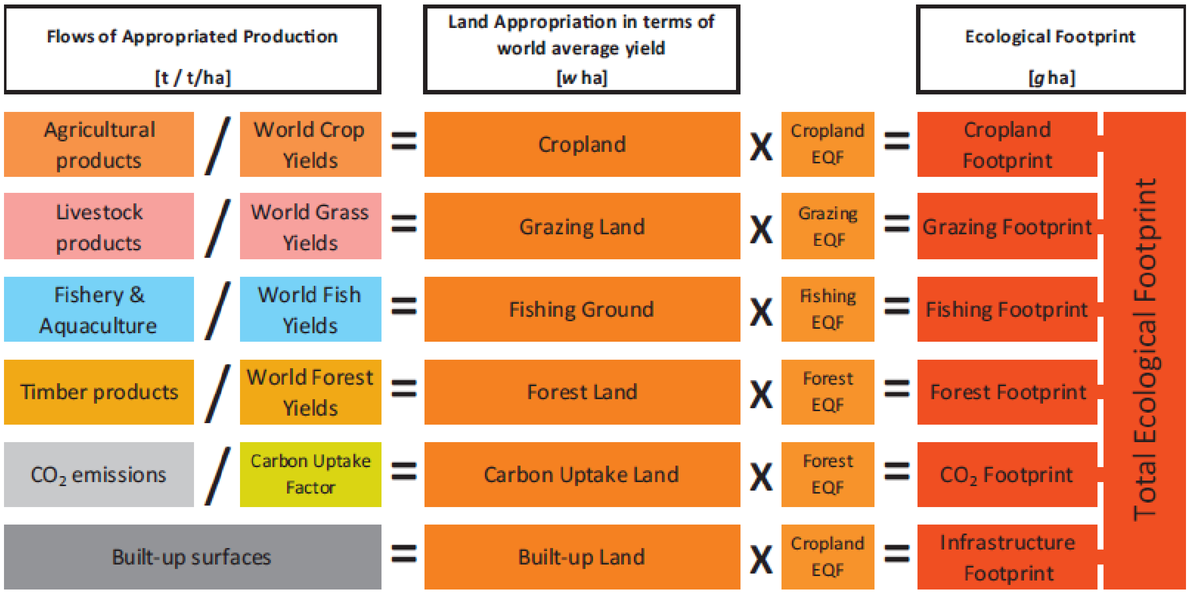

Figure 3. Calculation of the EF by the Global Footprint Network (Lin et al., 2019).

3.5.2 Independent variables

Population ageing

The main independent variable to answer the research question on the effect of population ageing on environmental impact is the share of people aged 65 years and older in a population. The research by Hassan & Salim (2015) studies the effects of population ageing and income growth on CO2 emissions in OECD countries over time. This study is taken as an example in the use of independent variables population ageing and economic growth. For population ageing the data is collected from the World Development Indicators from the World Bank and it consists of the number of people in the population that are aged 65 and over. Due to the study of the variable over time and change in the size of this population group can be seen, either an increase or a decrease in a given country.

In the descriptive analysis it is of interest to study the pattern of population ageing for the different countries over time, separate of the possible relationship to the environmental impact. Therefore, for the descriptive analysis it is necessary to have an ageing variable that is comparable between all countries.

As absolute numbers could differ greatly due to different population sizes of countries, the share of population aged 65 and over in percentages of the total population is used.

Population growth
The independent variable population growth used in this study is the annual population growth rate in percentages. It is calculated as the exponential rate of growth of midyear population from year t-1 to t, expressed as a percentage. According to the World Bank database, population is defined as all inhabitants regardless of legal status.

Economic growth
To measure economic growth GDP is used from the World Bank. The World Development Indicators provide GDP per capita in constant 2010 US dollars. This makes the use of GPD per capita comparable among different countries. As suggested by the EKC hypothesis, the GDP per capita is used in a quadratic form due to the non-linearity of the hypothesized relationship. In order to make the numbers more comprehensible in the analysis, the GDP per capita is expressed in thousands of US dollars. For the descriptive statistics the full GDP per capita in US dollars is used.

Urbanization
The last independent variable used in this study is urbanization. There are two ways of using urbanization, first being the absolute numbers of the population living in urban areas. The second way is the share of the total population that lives in urban areas. The definition of urban area differs per country, the World Bank follows the definitions as set by the national statistical offices, so there may be discrepancies among the definitions. For the descriptive statistics of this study comparability between countries is of importance. Therefore, the share of population living in urban areas in percentages of the total population is used.

3.6 Methodology

The analysis of this research will be a macro panel analysis. With 28 countries as participants, over a time series from 1970 to 2017. As population ageing, but also environmental impact, are dynamic processes over time, it is important to study the subjects, in this case countries, also over time to understand the dynamic aspect of the problem (Frees, 2004). Panel data is appropriate as it allows for the study of countries over time, as it is both cross-sectional and time-series analysis at the same time. The use of a macro panel data analysis gives the analysis both a time and a spatial approach (Yaffee, 2003).

The analysis is started with a descriptive analysis to explore the current patterns of ageing among the countries and the development of the EF over time. The other independent variables are also first explored using descriptive statistics. All variables are continuous variables, which are presented in both tables and graphs in the first section of chapter 4.

For the second section of chapter 4 the macro panel data analysis is performed. The dependent variable Ecological Footprint is hypothesized to be influenced by the number of people in a population aged 65 and over, as well as the population growth rate, the GDP per capita and the number of people living in urban areas. The analysis is done with a fixed panel, as the countries remain the same over all different time observation points. Regular regression analysis considers heterogeneity between the observations or cases. In macro panel data one study object, in this study country, is observed over several moments in time. In this case heterogeneity should be interpreted that there might be similarities between the observations of one country, but differences between the observations between countries (Frees, 2004). There are different approaches towards panel data and the over time effects in the different countries. Using panel data it is possible to study either within-country effects or between- country effects. In this study the focus is on the within-country effects, rather than between-country effects. As the research question aims to know to what extent ageing influences a country's EF, which is an within-country process unrelated to other countries. The appropriate model to suit this research is therefore the fixed-effects model. The other option is the random-effects model, which includes the between-country effects or group-level effect, which is therefore not of interest in this study. Another important aspect of choosing the fixed-effects model is the way the model deals with time invariant variables. The model controls for unobserved heterogeneity, as it controls for time invariant differences between the countries caused by for example culture. According to a similar study where panel data is used to study effects of demographic trends on energy consumption in 14 countries (York, 2007), the fixed-effects model is used. This is justified by Greene (2000), where it is stated that the fixed-effects approach is most appropriate for inter-country comparisons. This is supported by Greene (2000) as random-effects models are not suitable for inter-country comparison (Greene, 2000). The Hausman test can be used to test for statistical differences between the two types models, random and fixed-effects. The results of the Hausman test showed no statistically significant difference between the two models (P=0.15), however, due to the main research question of this research the fixed-effects model is used.

This study makes use of nested models. Model 1 consists of just the effect of population ageing on the Ecological Footprint. Which is formulated as follows:

$$\text{Ecological Footprint}_{c,t} = \beta_0 + \beta_1 \text{ share of population 65 and over}_{c,t} + (\alpha_c + \varepsilon_{c,t})$$

Where $(\alpha_c + \varepsilon_{c,t})$ constitutes the error term, or unexplained variance, α_c is based on fixed country specific effects and $\varepsilon_{c,t}$ is the within variation. In model 2 the effect of population growth is added to the previous model.

$$\text{Ecological Footprint}_{c,t} = \beta_0 + \beta_1 \text{ share of population 65 and over}_{c,t} + \beta_2 \text{ population growth}_{c,t} + (\alpha_c + \varepsilon_{c,t})$$

Afterwards model 3 the effect of economic growth is added to the model. As is hypothesized by the EKC, economic growth is both added in simple function as well as in quadratic function. The latter is added based on the study by Bagliani et al. (2008; p.653): *"a quadratic function with a positive quadratic term would imply that at high levels of GDP there is a positive feedback between income and environmental pressure"*.

$$\text{Ecological Footprint}_{c,t} = \beta_0 + \beta_1 \text{ share of population 65 and over}_{c,t} + \beta_2 \text{ population growth}_{c,t} + \beta_3 \text{ GDP per capita}_{c,t} + \beta_4 \text{ GDP per capita}^2_{c,t} + (\alpha_c + \varepsilon_{c,t})$$

Lastly in model 4 urbanization is added, creating a model with all independent variables.

$$\text{Ecological Footprint}_{c,t} = \beta_0 + \beta_1 \text{ share of population 65 and over}_{c,t} + \beta_2 \text{ population growth}_{c,t} + \beta_3 \text{ GDP per capita}_{c,t} + \beta_4 \text{ GDP per capita}^2_{c,t} + \beta_5 \text{ share of urban population}_{,t} + (\alpha_c + \varepsilon_{c,t})$$

The order of the addition of the independent variables is based on the research question of this study, followed up by the appearance of the anthropogenic drivers in the literature. Meaning that population growth is studied and mentioned more often in the literature than economic growth and urbanization. Economic growth is in turn mentioned more often than urbanization.

4. Analysis and Results

4.1 Descriptive results

The sample consist of 28 countries (=n), with observations for 48 years for all countries (=t), this results in a total sample of N=1344. Table 1 shows the summary statistics of the sample as a whole, for all countries over 48 years. It shows that there is only one missing value, for population growth (N=1343). Table 1 provides an overview of the range of the variables that are included in the analysis, for all countries and all years. For the Ecological Footprint it shows that it ranges from 1,4 gha per person to 17,77 gha per person, which is a rather large range. To set this number in perspective, on average in 2019 the world had 1,6 gha per person available, before the biocapacity of the Earth is exceeded (Global Footprint Network, 2020).

Table 1. Summary statistics overall data (source: all tables and graphs in chapter 4 are based on own analysis, unless specified otherwise).

Variable	Mean	Std. Dev.	Min	Max	Observations
Ecological Footprint (gha per person)	5,837067	2,530318	1,40357	17,7778	N = 1344
Share of population 65 and over (%)	12,65586	4,378732	3,011159	27,10948	N = 1344
Population growth (%)	0,856963	0,725144	-1,853715	6,017009	N = 1343
GDP per capita (constant 2010$)	32169,56	19413,32	1.793	111968,3	N = 1344
Share of population in urban areas (%)	75,35211	11,18294	38,234	97,961	N = 1344

However, to get a better understanding of panel data, it is important to explore the patterns of the different variables over time and across countries. Figure 4 shows the development of the EF over time and the development of population ageing over time across the 28 countries of the sample. It shows an overall increase in population ageing for all countries. At the same time the pattern of the Ecological Footprint is not increasing a lot. For some countries, such as the Republic of Korea, the United Kingdom and Finland, there is a very slight decrease in the EF over time. However, for most countries it shows a unstable pattern of EF development, with some small peaks either up or down. The question then rises, if the peaks up or down can be explained by ageing, or any of the other explanatory variables. This will be further discussed in the macro panel analysis.

The other three variables also show different patterns over time. Starting off with the growth rate (See Appendix B, Figure 1). Most countries in the sample have a positive growth rate, meaning a growth higher than 0, indicating that there is population growth over time. However, some countries show a decrease in this growth rate, for example Colombia and Mexico have positive but declining growth rate. This means that the population does grow, but the speed at which the population grows is slowing down. Some countries such as Portugal and Israel show very high peaks in growth rates, which might be explained by country specific events, which are not visible in the used data. Only one country in the sample shows a steadily increasing growth rate over time, which is Luxembourg. In general it can be stated that most countries show a positive growth rate, of which most fluctuate between 0 and 2%.

For the GDP per capita (Appendix B, Figure 2) it shows that all countries in the sample have experienced growth over the 48 years that are studied. For some countries like Luxembourg, Norway and Ireland, the increase in GDP per capita rises relatively steep, compared to countries such as Chile, Colombia and Turkey. The general trend however, is that for all countries there is economic growth visible over time. Most countries' GDP per capita increases between 10.000 and around 50.000 US dollars. A few countries are worth mentioning, Luxembourg shows an increase in GDP per capita from just under 50.000 US dollars at the beginning of the time period to over 100.000 US dollars at the end of the study period. Norway shows a similar increase, however, it ends just under 100.000 US dollars. Switzerland has the highest GDP per capita at the start of the time period, just above 50.000 US dollars and increases until 75 to 80.000 US dollars. On the other side of the spectrum there are Turkey, Mexico and Colombia, who only show a very small increase of GDP per capita over the time period, and increase to a GDP per capita of around 10 to 15.000 US dollars. So it can be stated that the GDP per capita differs quite substantially between the different countries within the sample.

The share of population living in urban areas (Appendix B, Figure 3) show the degree of urbanization differs greatly and also the speed at which urbanization is happening. With Belgium being the most urbanized country in the sample, but the share of population living in urban areas is only increasing slightly. On the other side of the spectrum, countries such as Portugal and Turkey, started at a very low urban population share, but have both experienced a rather steep increase in urbanization. With the Republic of Korea, Portugal and Turkey being the exceptions, all countries have over 60% of the population living in urban areas. All countries show an increase in urban population, except for Austria. Austria has dropped from just over 60% to a little under 60%.

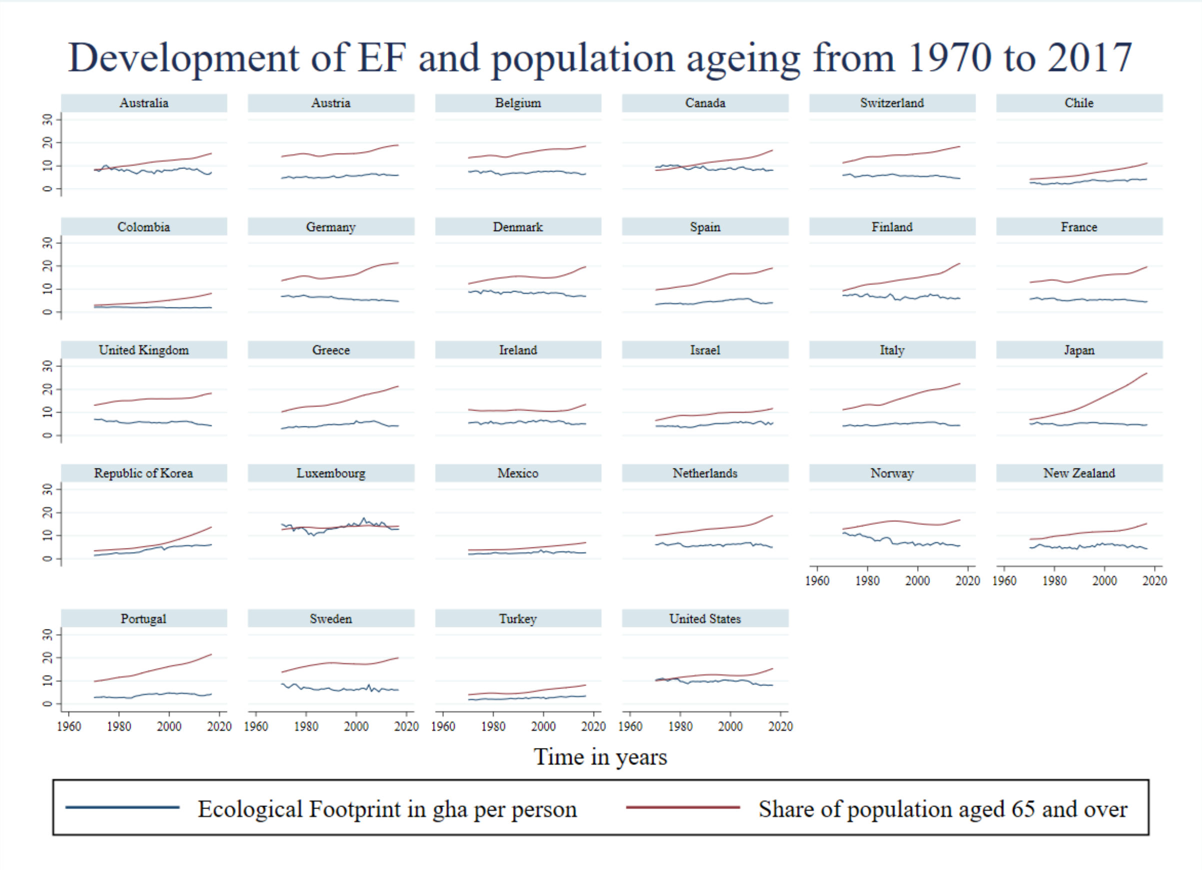

Figure 4. The development of the EF and population ageing from 1970 to 2017 for all 28 countries in the sample.

4.2 Macro panel analysis

In this part of the study the hypotheses mentioned in chapter 2 are tested. The main focus is on the relationship between environmental impact, measured through the Ecological Footprint, and population ageing. This is the first model and the first section of the analysis. For the second section of the analysis the other anthropogenic drivers that might be of influence on the development of the Ecological Footprint, which are population growth, economic growth and urbanization, are tested together with population ageing. By making using of nested models, implying that the first model is nested in the second model and the second model is nested in the third model etcetera, variables are added to the equation. The analysis is performed by the use of STATA. As has been stated before, the analysis aims to research the relationship between environmental impact and population ageing over time. This requires panel data analysis. In order to run the analysis the dataset is declared to be panel data in STATA. The countries are set as the id-variable, which are 28 panels, the time is in years and consist of 48 years from 1970 to 2017. The used type of panel regression is a fixed effects model, based on the explanation provided in chapter 3.

4.2.1 Ecological Footprint and population ageing, model 1

In model 1 the first hypothesis of the study is tested: "H_1: Ageing of a population decreases the Ecological Footprint on country level". In Table 2 the results from the fixed effects regression model is presented. The coefficient of the share of population aged 65 and over indicates a positive relationship between population ageing and the Ecological Footprint, which is significant at a confidence level of 95% ($\beta = 0{,}0188$, $p<0{,}05$). The coefficient of population ageing is relatively small. This means that a 1% increase in the share of population aged 65 and over, increases the Ecological Footprint with 0,0188 gha per person.

Table 2. Regression results of fixed effects model 1.

Variables	(1) Model 1
Share of the population 65 and over (%)	0,0188**
	(0,00950)
Constant	5,599***
	(0,122)
Observations	1.344
Number of countries	28
R-squared	0,003

a) Standard errors in parentheses
b) *** p<0,01, ** p<0,05, * p<0,1

In Model 1 all 28 countries are included, and a total of 1,344 observations are used for the estimation. This means that there are no missing values in the data used for this model. The R-squared of the model is 0,003, which is not particularly high, however, this can be explained due to the fact that only one explanatory variable is considered in this model.

4.2.2 Other explanatory variables, models 2, 3 and 4

In Table 3, the models 2, to 4 are presented alongside model 1. The other three hypotheses of this research are tested. H_2 is tested by use of model 2, H_3 is tested by use of model 3 and H_4 is tested by use of model 4.

Table 3. Regression results of fixed effects models 1 to 4.

Variables	(1) Model 1	(2) Model 2	(3) Model 3	(4) Model 4
Share of population aged 65 and over (%)	0,0188** (0,00950)	0,0139 (0,00986)	-0,00272 (0,0149)	-0,0334** (0,0152)
Population growth (%)		-0,0955* (0,0514)	-0,0180 (0,0551)	0,125** (0,0576)
GDP per capita, in thousands (constant 2010 US$)			0,0304*** (0,00840)	0,0186** (0,00840)
GDP per capita^2, in thousands (constant 2010 US$)			-0,000325*** (0,000069)	-0,000291*** (0,000068)
Share of population living in urban areas (%)				0,0429*** (0,00595)
Constant	5.599*** (0,122)	5.744*** (0,145)	5.367*** (0,161)	2.730*** (0,398)
Observations	1.344	1.343	1.343	1.343
Number of countries	28	28	28	28
R-squared	0,003	0,006	0,025	0,063

a) Standard errors in parentheses
b) *** p<0,01, ** p<0,05, * p<0,1

Model 2 shows the addition of population growth to the first model, with solely population ageing. The coefficient for population ageing has increased slightly, but is also not significant at any of the three levels. The coefficient for population growth is a negative number, significant at a 90% confidence level (p<0,10), meaning one unit increase in population growth rate, decreases the Ecological Footprint with 0,0995, keeping everything else constant. The model fit, the R-squared, has increased slightly from 0,003 to 0,006 meaning that this model is a better fit than the first model.

Model 3 adds economic growth measured through GDP per capita (in thousands) to the model. Two types of GDP per capita were added, due to the expected curve-linear relationship of economic growth on environmental impact. Regular GDP per capita was added, alongside GDP per capita^2. For the regular GDP per capita a thousand dollar increase in GDP per capita has an effect of 0,0304 increase in the Ecological Footprint in gha per person. The GDP per capita is significant at the 99% confidence level. The GDP per capita^2 is also significant at the same level as the regular GDP per capita, however, the coefficient for GDP per capita^2 is negative (β = -0,000325). Together with the positive coefficient for GDP per capita, this provides evidence for a curve-linear relationship of GDP per capita and the Ecological Footprint. The explanatory variables population growth and population ageing have also both changed. For population growth the coefficient has become smaller but the sign has not changed (β = -0,0180, not significant). Population ageing has changed sign, meaning that an increase in the share of population aged 65 and over has a decreasing effect (β = -0,00272) on the Ecological Footprint. However, the coefficient for population ageing is not significant. The R-squared shows an increase in model fit compared to the fit of models 1 and 2.

Model 4 is the final model of the analysis, the share of urban population is added to the model. Starting at the top of the model, the variable share of population aged 65 and over shows a negative relationship with the Ecological Footprint. This means that with a 1% increase in share of population aged 65 and over the Ecological Footprint decreases with 0,0334 gha per person. The coefficient shows a significance relationship between the population ageing and the Ecological Footprint, keeping everything else constant. For population growth a positive significant relationship is estimated (β = 0,125, $p<0,05$), implying that when population growth rate increases, so does the Ecological Footprint. The variables for GDP per capita and GDP per capita^2 still show a curve-linear relationship, as GDP per capita has a positive sign and GDP per capita^2 has a negative sign. Lastly, the variable share of population living in urban areas is added. This variable shows to have a positive significant ($p<0,01$) effect on the Ecological Footprint. A 1% increase in the share of population living in urban areas shows to increase the Ecological Footprint with 0,0429 gha per person, keeping all else constant.

Model 4 is the model where all variables are tested for their impact on the Ecological Footprint. As has been stated in earlier chapters, there are different drivers of environmental impact and the drivers are interconnected. As, for example, demographic changes influence economic development. Based on this notion, model 4 fits best the theoretical approach to what drives environmental impact.

4.2.3 Fit of the model

In order to test for within-country effects, the fixed-effects model is used for this analysis. A statistical test performed to check between statistically significant differences between the fixed-effects model and the random-effects model is the Hausman test (See Appendix B, table 1). The Hausman test did not support a statistically significant difference between the fixed or random-effects model, therefore the choice of model was supported based on content of the research question, which aims to study within-country effects.

In order to test if the fixed effects model is a good fit, the F-test is used to determine this. When the F-test is significant it determines whether there is a significant fixed-effect in the model or the goodness-of-fit has significantly increased. Based on the regression the F-test is performed (Appendix B, Table 2), the F-test showed to be significant ($P<0,01$). Based on the increase of the R-squared statistic in models 1 to 4 it shows that it has an increasingly better fit, with model 4 having the best fit out of all the performed regression analysis.

Another check that is performed is to check for heteroskedasticity. Among panel data autocorrelation and heteroskedasticity is a common problem, as the difference over time and between countries can be great. By means of the Woolridge test for autocorrelation in panel data, the possibility of autocorrelation is tested (see Appendix B, Table 3). Based on these results it can be concluded that there is autocorrelation within the panel data sample. As autocorrelation is often associated with heteroskedasticity, this is tested for as well. The test for heteroskedasticity in the fixed-effects model showed that there is indeed heteroskedasticity for model 4 (Appendix B, Table 4). Heteroskedasticity can bias the standard error in the model. By regressing a robust fixed-effects regression model, the robust standard errors are estimated. As is shown in Table 4, this does not affect the size or sign of the coefficient, but it does alter the significance of the coefficients. There are not enough panels over time to obtain significant results, therefore it is decided to leave out the robust standard error estimations in this analysis. The result is that the standard errors of the used model 4 might be biased and estimated on the smaller side. This can influence the confidence intervals of the coefficients, but should not bias the coefficients itself.

Table 4. Regression results of fixed effects model 4 with robust standard errors.

Variables	(4) Model 4
Share of population aged 65 and over (%)	-0,0334 (0,0365)
Population growth (%)	0,125 (0,110)
GDP per capita, in thousands (constant 2010 US$)	0,0186 (0,0367)
GDP per capita^2, in thousands (constant 2010 US$)	-0,00291 (0,000461)
Share of population living in urban areas (%)	0,0429* (0,0234)
Constant	2,730 (1,669)
Observations	1.343
Number of countries	28
R-squared	0,063

To conclude the analysis section, there are four different models tested in a nested models approach. The last model, model 4, is the most helpful in answering the research question as it provides all different drivers that are studied in this research. Model 4 shows all coefficients to be significant and therefore able to provide answers to the research question based on the hypotheses. The model has been checked for its fit and the fixed-effects model is perceived to be the best model to answer the main research question of this study, however, autocorrelation and heteroskedasticity should be noted.

5. Conclusion and discussion

5.1 Conclusion

This research aims to study the effects of ageing societies on environmental impact, for 28 countries over a period from 1970 to 2017. Taking a time span of 48 years together with the size of the sample for population ageing and environmental impact, provides a study which adds to the current literature as this has not yet been performed. The main question of this study is: *To what extent does the increase of population aged 65 and over, over the past decades influence environmental impact across countries?* It is hypothesized that ageing of a population decreases the Ecological Footprint on country level. Based on the results from the analysis it can be concluded that this is true. The increase in the share of population aged 65 and over decreases the Ecological Footprint, in the sample of 28 OECD countries over 48 years.

As is argued throughout this study, there are more factors both influencing and driving environmental impact. Therefore, besides studying population ageing it is important to consider the other drivers of environmental impact. Based on a thorough literature and theory study of chapter 2, the main factors that are considered are population growth, economic growth and urbanization. In this research these variables can be considered as both explanatory variables for environmental impact, as well as control variables as they control for other drivers while testing the relationship between population ageing and the Ecological Footprint. The main results of the other drivers are as follows: For population growth it was hypothesized that population growth increases the Ecological Footprint. Based on the results of this study, this hypothesis can be accepted. Economic growth increases the Ecological Footprint, based on the results a curve-linear relationship is estimated. This means that initially economic growth leads to an increase of the Ecological Footprint and as GDP per capita increases enough it turns around leading to a decrease of the Ecological Footprint. For urbanization based on the literature it was expected that an increase in the share of population living in urban areas would decrease the Ecological Footprint (among others: Dietz et al., 2007; Shahbaz et al., 2014). This hypothesis was tested to be false, urbanization increases the Ecological Footprint. For all above mentioned results it is implied that the effects occur in a model where all variables are considered. In the next paragraphs the conclusions will be discussed more in depth.

Population growth is often considered as putting great pressure on environments and resource consumption. However, according to the current literature, the relationship between environmental impact and population growth on its own is not solely linear, but should be considered together with environmental growth (Harte, 2007). In the present study the full model with all main drivers of environmental impact, population growth puts a linear significant negative pressure on environmental impact. This means that for the 28 countries studied, overtime there is a trend that when the population growth rate increases so does the Ecological Footprint. According to Malthusian theory, population growth would outgrow the food production. Food production is not measured in this study, but increases in the population growth rate does increase the Ecological Footprint of consumption. As was stated in the descriptive statistics, on average there is 1,6 gha per person available. The lowest measured EF in the sample was 2,7 gha per person. This means that an increase in the EF leads to an unsustainable use of the Earth's resources. Therefore, an increase due to population growth, or any other variable, leads to overuse of the carrying capacity of the Earth. An important note is that population growth is measured through the growth rate. This means that changes in growth rate show a significant relationship with the Ecological Footprint. The growth rate can be either a positive or a negative number, this means that an increase in population growth rate can be either a larger positive rate or a smaller negative rate. It does not provide details on absolute growth. Based on the descriptive statistics it becomes clear that most countries have a positive growth rate, with an average of 0,85%. Thus, for most cases it can be interpreted that an increase in an already positive growth rate leads to an increase of the Ecological Footprint. Based on the demographic transition model theory eventually all countries reach the fourth stage of demographic development. In this last stage of the theory, population growth is relatively low, due to the low fertility levels and the high life expectancy. Based on this it could be suggested that the influence of population growth environmental impact should decrease as countries go through the different transition stages. However, as was seen in the descriptive statistics, the population growth rate is generally higher then 0%, meaning that there still is population growth. Therefore, even in the latest stages of demographic development, population growth still plays a role in resource consumption and associated environmental impact.

Model 4 of the analysis tests both the linear relationships with the Ecological Footprint as well as a curve-linear relationship for GDP per capita and the Ecological Footprint. The significance of both a positive coefficient for GDP per capita as well as a negative coefficient for quadratic GDP per capita supports the Environmental Kuznets Curve hypothesis of a inverted U shape relationship in this sample of countries for the 48 years of study. In other words, this means that with economic growth at a certain point the consumption of resources, as the Ecological Footprint depicts, goes down where economic development keeps increasing. There could be different reasons for this phenomena. The first one being that when economies grow, the inhabitants of countries often become wealthier in terms of money and are therefore capable of buying greener goods. The focus of production also shifts towards more environmentally friendly production, simply as the population can afford this greener consumption which is often more expensive. The other reason for an inverted U shape relationship between economic growth and environmental impact can be that high income countries often show outplacement of production. The production of goods and therefore the consumption of resources, is taking place in different countries and therefore, high income countries do not carry the burden of the consumption and pollution associated with production. However, the Ecological Footprint does account for this in terms including import and export in the calculation of the Ecological Footprint.

For urbanization based on the literature it was hypothesized that when urbanization increases, the Ecological Footprint would decrease. This hypothesis was based on the arguments that urbanization leads to a decline in prices for greener goods (Charfeddine & Mrabet, 2017), as more people live closely together and studies show that rural households have a higher Ecological Footprint than urban households (Caird & Roy, 2006). Due to the accumulation of people in one place, there is more knowledge and manpower to create greener production. However, for the present sample of countries, over time these arguments do not uphold. The increase in urbanization leads to a significant increase in the Ecological Footprint, thus putting more pressure on the environment. This can be related back to the critiques on the EMT. In the EMT it is argued that economic growth leads to greener and better production. As was argued in the literature, urban areas would be the place where greener production fastens and would be more widely available then in urban areas. However, the critiques of the EMT argued that greener production does not outweigh the increased consumption or (over)consumption of goods and resources. This theoretical reasoning can be used as an explanation for the positive relationship between increase in urban populations and the EF.

Keeping all above mentioned findings in mind, statements can be made about population ageing. Based on research on CO_2 emissions and population ageing studies have shown that ageing has a declining effect on CO_2 emissions (Zagheni, 2011; Hassan & Salim, 2015; Magnani & Tubb, 2007). Micro level studies have shown that elderly tend to consume less goods and services, as elderly often consume solely what is needed to sustain their lives (Hassan & Salim, 2015; McDonald et al., 2006). On the macro level of this present study, it can be confirmed that elderly have a negative effect on environmental impact. In other words, as the share of elderly in the population increase, the Ecological Footprint significantly decreases. This statement, however, is only true for the analysis where all the other drivers of environmental impact are considered as well. This means that population ageing should thus be considered in the broader context of the society and the economic development of a country. When considering the demographic transition model, different stages in the transition have different population sizes and age structures. This is relevant when considering resource consumption. As this study shows, ageing has a significant effect on environmental impact. Therefore, different stages in the demographic transition model all might have different effects on the environment based on the age structures that the populations consist of.

Given the outcome of this study, it can thus be concluded that ageing might be beneficial to reducing environmental impact. However, as is also shown by this study, different drivers influence environmental impact and thus the development of population ageing might eventually influence other demographic changes or influence economic development, which in turn can have its impact on environmental degradation. In other words, population ageing does, for example, also influence the dependency ratios which can influence macroeconomic structure. Thus, in the time span of 1970 to 2017 for the 28 OECD countries population ageing decreases the Ecological Footprint, given all other variables are included in the analysis.

5.2 Discussion

This study adds to the current literature, by taking a broad measure of environmental impact, the Ecological Footprint, and studying relationships for a relatively large panel (28 countries) over a relatively long time series (48 years), which fills a gap in the existing literature. The main finding of this study is that population ageing decreases the Ecological Footprint. This is in line with studies on CO2 emissions and energy consumption in relation to ageing (Zagheni, 2011; Hassan & Salim, 2015; York, 2007). Older aged populations have a decreasing effect on the CO2 emissions of a country. This same line of thought can be applied to the present study, where older aged populations have a decreasing effect on the Ecological Footprint. Ageing is a rising issue in many (OECD) countries (United Nations, 2020). Together with ageing, the world is currently also facing climate change. Therefore, it is of great importance to investigate how the two phenomena, ageing and environmental impact, are related.

As with all analysis, the analysis of the present study suffers from some limitations. Environmental impact is a complex concept to study, given that there are many different ways of measuring environmental impact. In this study the choice was made to take a broad measure of consumption of resources, the Ecological Footprint. In other studies CO2 emissions have been used, or single measures of consumption such as energy consumption. By taking a broader concept of environmental impact, such as the Ecological Footprint, it is not possible to distinguish on which parts of the Ecological Footprint are most influenced by age. On the other side, when only taking a small measure of environmental impact, such as CO2 emissions, information is lost on other effects that ageing might have on environmental impact. Therefore, both types of studies are important and complementary to one another. This study also adds to the current literature by using a broad measure of environmental impact, together with the sample size and time series.

Besides different measures of environmental impact, it is also important that environmental impact does not stop at country borders. Therefore, country comparison studies are very important as processes of environmental degradation cross borders, but also happen around the world. In this study no distinction is made between different types of countries, in terms of economic or demographic development. However, the study by Fan et al. (2006) reported differences between low, middle and high income countries in terms of economic and demographic development and environmental impact. For future country comparison studies it can be argued to distinguish between stages of development to investigate differences between population age structure and the Ecological Footprint. Even though country comparison is extremely helpful in understanding global processes of environmental impact, the main limitation of this study is the use of macro-level data. In order to fully understand the within-country dynamics of environmental impact by different age groups, it is best to use micro-level data. By use of this age-consumption profiles can be made for different countries, like the study by Zagheni (2011). A more detailed and thorough understanding of consumption of resources by elderly can be studied by use of micro-level data. However, despite this limitation, a country comparison study is still important, as it provides generalized statements on country-level effects.

In this study different variables to measure different drivers of environmental impact are considered. However, as has been stated more often in this thesis, the impact on the environment by human populations is complex. To further understand the influence age structure on environmental impact different age groups can be used. In the current literature the study of older aged people and environmental impact in the broad sense could benefit from more attention. This thesis aimed to make a contribution to this. For future research it is recommended to study more age groups, but also look at different categories of older aged people, meaning splitting population aged 65 and over into categories such as 65-75, 75-85 and 85+. As life expectancies are also increasing, people are getting older, there might also be differences in environmental impact within the age group 65 and over. Another aspect of population ageing that has been briefly touched upon in this study is the attitudes towards environmental care and protection among different age groups, but especially older aged people. Gaining more insights on attitudes towards the environment, on a qualitative level, might help in understanding changes in consumption behavior and thus in consumption of resources.

By taking population ageing in relation to environmental impact, attempts can be made to reduce environmental impact. It is a step in dissecting how demographic changes influence the environment. Based on this study it can be stated that population ageing reduces environmental impact. These insights can help policy makers in taking action against environmental degradation and to build a more sustainable future for all generations to come.

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Appendix A: OECD countries

List of OECD member states (OECD, 2020).

Australia	
Austria	
Belgium	
Canada	
Chile	
Colombia	
Czech Republic	Excluded from the sample
Denmark	
Estonia	Excluded from the sample
Finland	
France	
Germany	
Greece	
Hungary	Excluded from the sample
Iceland	Excluded from the sample
Ireland	
Israel	
Italy	
Japan	
Korea	
Latvia	Excluded from the sample
Lithuania	Excluded from the sample
Luxembourg	
Mexico	
Netherlands	
New Zealand	
Norway	
Poland	Excluded from the sample
Portugal	
Slovak Republic	Excluded from the sample
Slovenia	Excluded from the sample
Spain	
Sweden	
Switzerland	
Turkey	
United Kingdom	
United States	

Appendix B: Statistical output

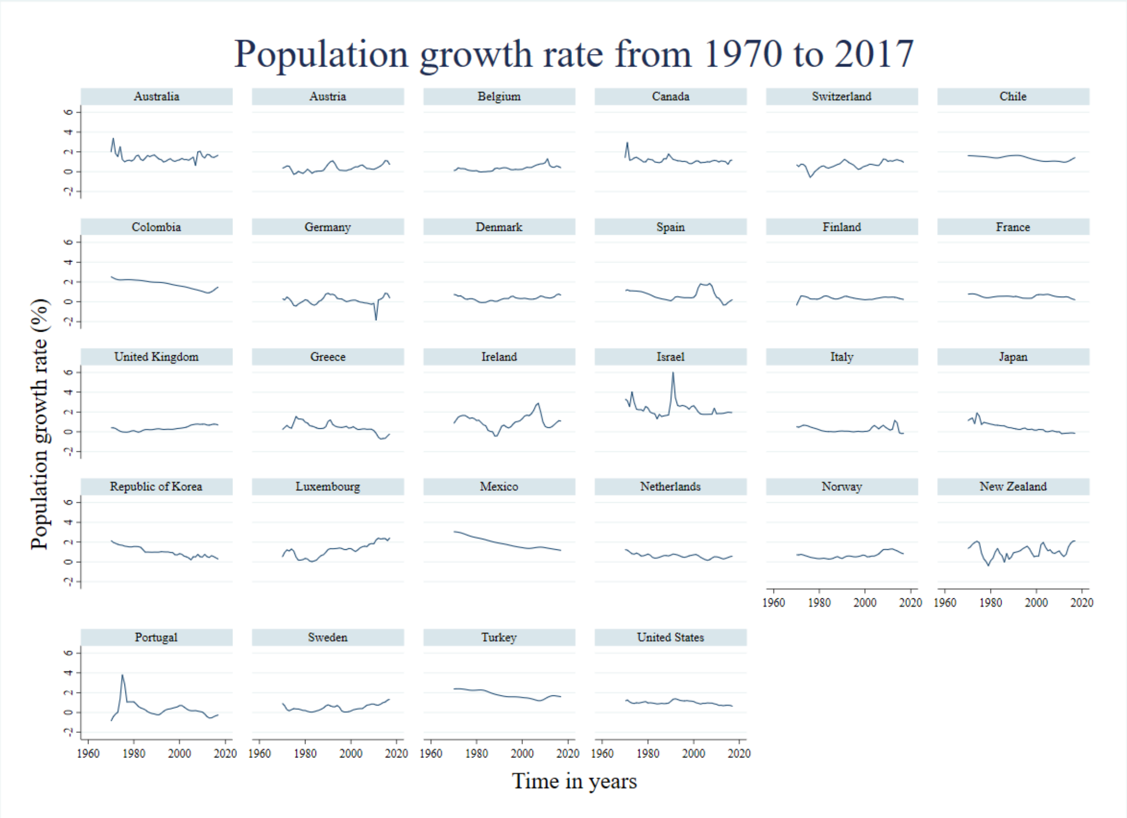

Figure 1. The development of population growth from 1970 to 2017 for all 28 countries in the sample.

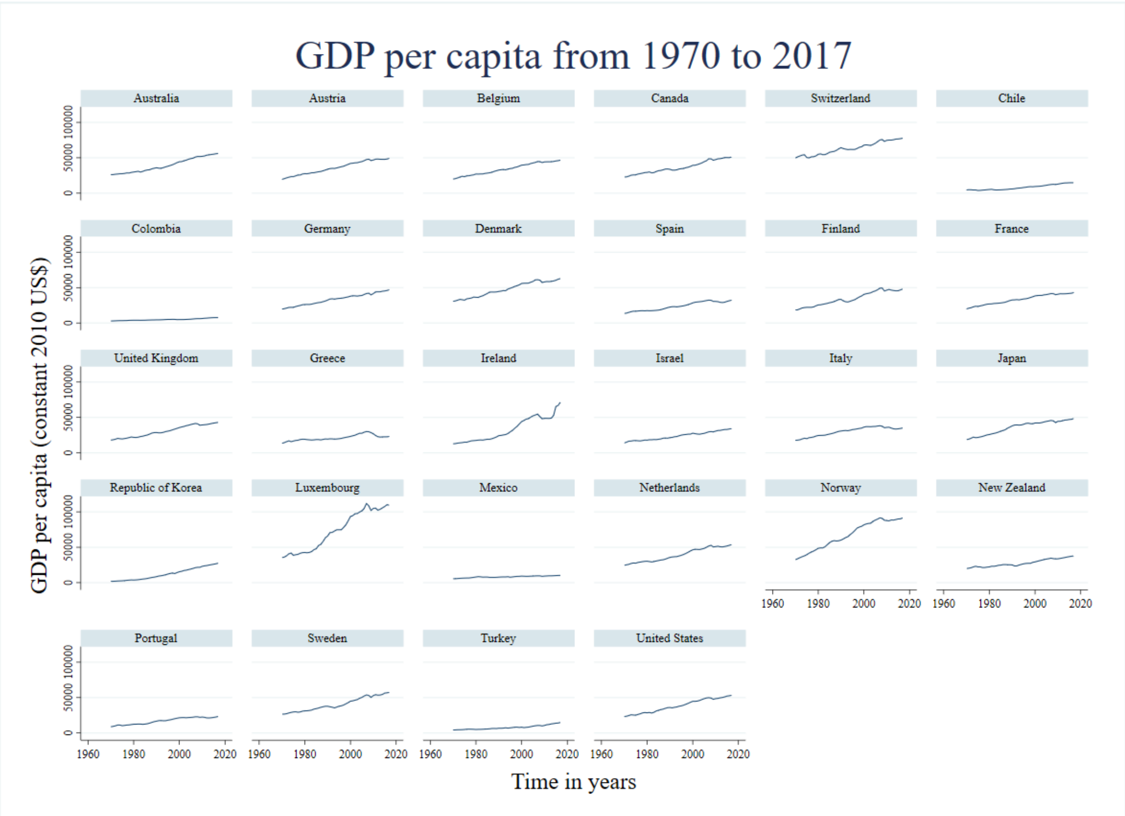

Figure 2. The development of GPD per capita from 1970 to 2017 for all 28 countries in the sample.

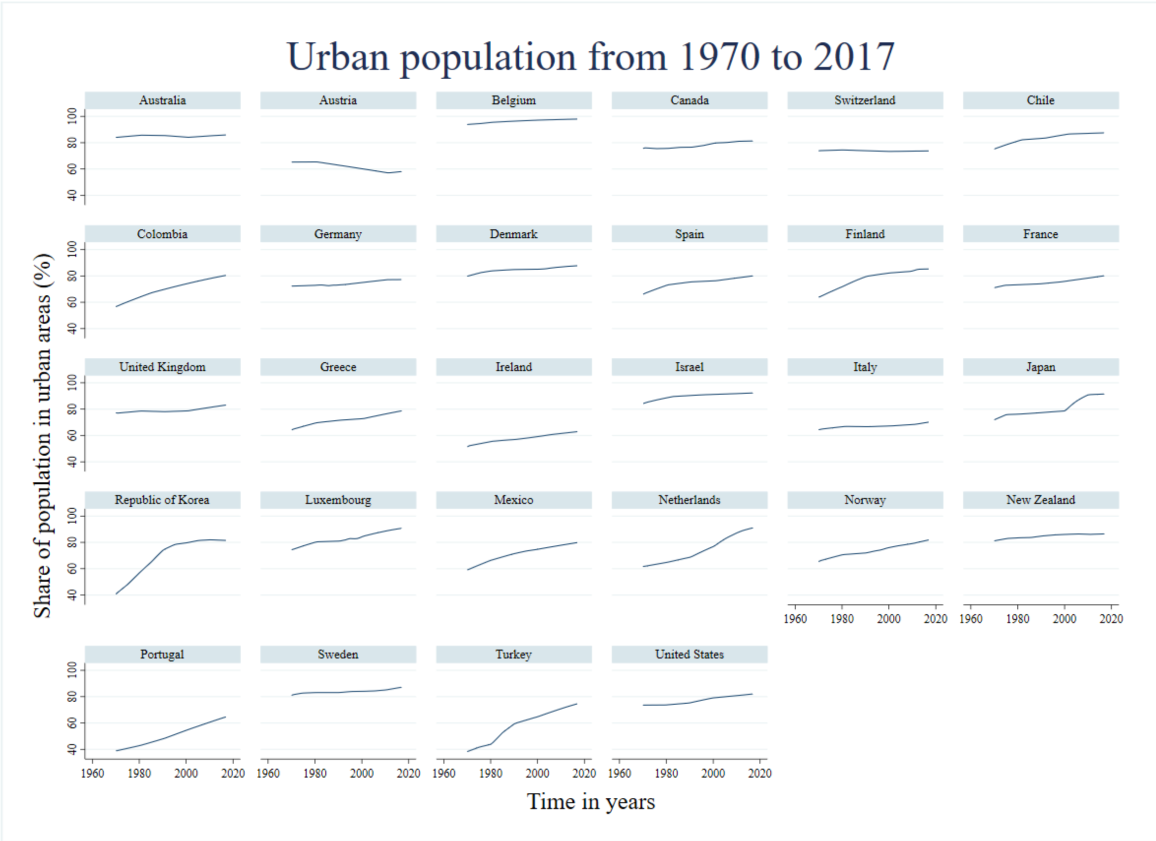

Figure 3. The development of share of population living in urban areas from 1970 to 2017 for all 28 countries in the sample.

Table 1. Hausman test taken from STATA output.

	Coefficients (b) fe	(B) re	(b-B) Difference	sqrt(diag(V_b-V_B)) S.E.
SharePop65~r	-.0033135	-.004213	.0008994	.
ShareUrban~p	.0446842	.0423261	.0023581	.0007809
PopGrowth1	.1002377	.0694816	.0307561	.
GPDpercapi~1	-.0000147	-.0000116	-3.10e-06	.

```
                           b = consistent under Ho and Ha; obtained from xtreg
            B = inconsistent under Ha, efficient under Ho; obtained from xtreg

    Test:  Ho:  difference in coefficients not systematic

                  chi2(3) = (b-B)'[(V_b-V_B)^(-1)](b-B)
                          =        5.25
                Prob>chi2 =      0.1545
                (V_b-V_B is not positive definite)
```

Table 2. Fixed effects regression results taken from STATA.

```
Fixed-effects (within) regression               Number of obs     =      1,343
Group variable: newid                           Number of groups  =         28

R-sq:                                           Obs per group:
     within  = 0.0627                                         min =         47
     between = 0.0096                                         avg =       48.0
     overall = 0.0137                                         max =         48

                                                F(5,1310)         =      17.54
corr(u_i, Xb)  = -0.0890                        Prob > F          =     0.0000
```

EF	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
SharePop65andover	-.0333608	.0152487	-2.19	0.029	-.0632753	-.0034463
PopGrowth1	.1251432	.0575637	2.17	0.030	.0122161	.2380702
GPDpercapita1	.0000186	8.40e-06	2.21	0.027	2.12e-06	.0000351
GDPsquared	-2.91e-10	6.82e-11	-4.27	0.000	-4.25e-10	-1.57e-10
ShareUrbanPop	.0429356	.0059498	7.22	0.000	.0312634	.0546078
_cons	2.730019	.398055	6.86	0.000	1.949124	3.510914
sigma_u	2.4410647					
sigma_e	.79106688					
rho	.90496183	(fraction of variance due to u_i)				

```
F test that all u_i=0: F(27, 1310) = 205.58                  Prob > F = 0.0000
```

Table 3. Woolridge test, xtserial output from STATA.

```
Wooldridge test for autocorrelation in panel data
H0: no first-order autocorrelation
    F(  1,      27) =     24.508
           Prob > F =      0.0000
```

Table 4. Heteroskedasticity test xttest3 output from STATA.

```
. xttest3

Modified Wald test for groupwise heteroskedasticity
in fixed effect regression model

H0: sigma(i)^2 = sigma^2 for all i

chi2 (28)  =   11125.61
Prob>chi2 =      0.0000
```