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Education and CO_2 emissions through the macroeconomic lens:

Assessing their relationship in developing countries from 1996 to 2014

by

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Abstract: This thesis investigates the macroeconomic relationship between education and CO_2 emissions in developing countries. Building on existing literature, a framework is constructed that tries to identify the links underlying this relationship. Education is postulated to affect CO_2 emissions in developing countries indirectly through inducing growth, fostering technological change, driving structural transformation, and influencing demographic change. Furthermore, education is assumed to affect CO_2 emissions directly through substituting for energy use and by inducing sustainable behavior. The first two indirect links of growth and technological change are tested indirectly and directly, drawing on a panel of 81 developing countries for the period from 1996 to 2014, and differentiating between the short- and the long-run effect. The empirical analyses show that there is likely a short-run increasing effect of education on the level and intensity of CO_2 emissions, whereas a consistent long-run effect could not be found.

Keywords: education, CO_2 emissions, developing countries

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“Climate change is no longer some far-off problem; it is happening here, it is happening now” – Barack Obama, 2015.

1 Introduction

Combating global warming is seen as one, if not the major challenge that today’s world is facing, as it would have huge negative consequences for the lives of all mankind. The urgency to meet this challenge is apparent, with thousands of scientists alerting the public to act sustainable and preserve the environment in order to prevent major ecological consequences. At the same time, another major challenge of today’s society is to decrease poverty, visible in several of the United Nations sustainable development goals such as ‘No Poverty, Zero Hunger, and Good Health and Well-being’ (United Nations Development Programme, 2015). This, however, creates the following dilemma: While developing countries have made substantial income gains, these go hand in hand with increased Greenhouse Gas (GHG) emissions of CO_2, causing global warming (figure 1). Thus, in order to prevent further global warming, not only does the developed world need to reduce their current level of emissions, as they have by far the highest per capita emission levels (World Bank, 2014a), but additionally the developing world will likely need to find a growth path that does not increase emissions accordingly.

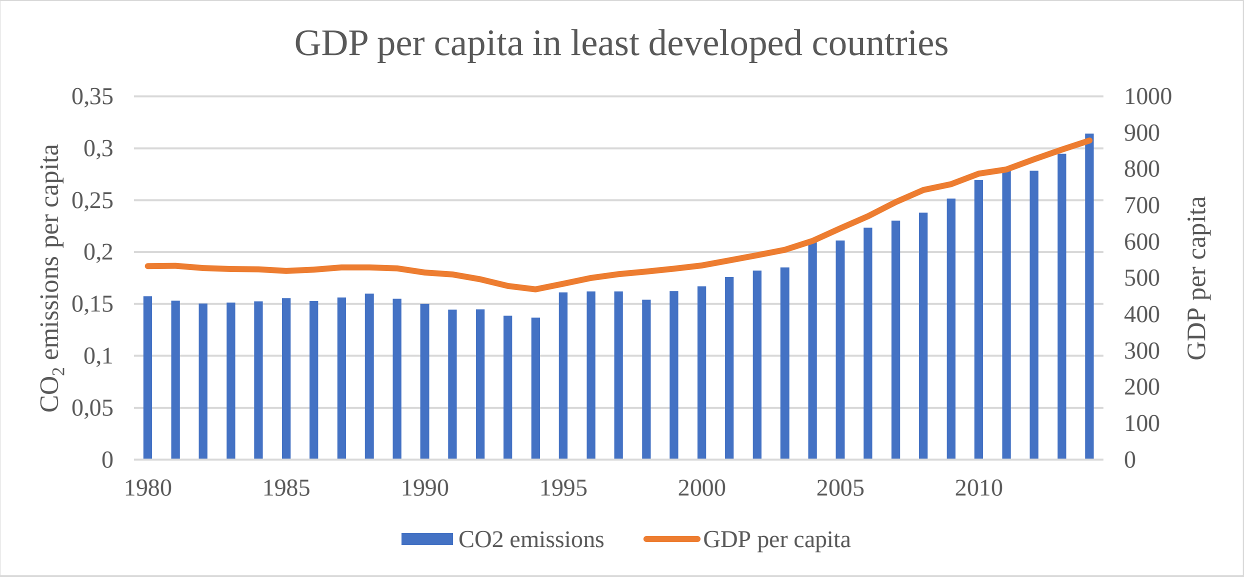

Figure 1: GDP per capita and CO_2 emissions in least developed countries

Note: Data taken from World Bank (2014a) – World Development Indicators. GDP per capita in constant 2010 USD, CO_2 emissions in metric tons per capita

In assessing how to achieve environmentally sustainable growth, a factor that is rarely discussed is education. In 1992, the United Nations Framework Convention on Climate Change stated that "Education is an essential element for mounting an adequate global response to climate change" (UNFCCC, 1992). However, while the link between education and growth has been relatively well researched (see for example Krueger & Lindahl, 2001), the link to environmental emissions has been investigated far less. The only study here comes from O'Neill et al. (2018), who find higher levels of education to be associated with increased resource use and thus higher levels of GHG emissions.

According to macroeconomic theory, there are various channels through which education may affect emissions: For example, from a sociological perspective, education dealing in any way with the topic of emissions could affect the pupil's or student's consumption behavior, as well as their actions on the job, in business or in politics (Lester et al., 2006). Moreover, education could also have a direct effect on the level of emissions in developing countries, as human capital can substitute for energy usage (Stern, 2012). Furthermore, education may indirectly influence pollution levels by driving several factors that in turn affect CO_2 emissions themselves. Firstly, education can foster growth, which is theorized to lead to initial increases and later decreases in emission levels. Secondly, higher levels of education may enable countries to adopt new cleaner technologies such as solar energy, not to lose sight of the fact that not every new technology adopted may always be more energy-efficient than existing ones. Thirdly, education could potentially contribute to both an 'emission increasing' structural change, from agriculture to industry, and an 'emission reducing' structural change, from industry to services. Lastly, education, especially in developing countries, can affect demographic factors, decreasing fertility and mortality, while increasing life expectancy (Barro, 1991; Barro & Lee, 1994). This can influence CO_2 emissions as well since more people years ceteris paribus equals more resource use and thus more emissions.

This thesis thus revolves around the potential links from education to CO_2 emissions, focusing on developing countries, as these are projected to be the major centers of future CO_2 emission growth. The central research question is the following: Does the level of education have an effect on the level of CO_2 emissions in developing countries?

Given that there is very little existing research on this relationship, a framework has to be built first in order to identify the channels through which education may potentially affect the level of emissions in developing countries. The research question is therefore accompanied by a sub-research question, namely: What are the main potential channels through which education can affect CO_2 emissions in developing countries? The focus of this thesis is viewing the relationship between education and CO_2 emissions through the lens of macroeconomic and human capital theory. This means that education is seen as a tool that can stimulate other economic factors such as growth, technological-, structural- and demographic change, which in turn affect emission levels. While the sociological factor of education influencing the behavior of individuals is acknowledged, the focus of this paper lies elsewhere, namely on the macroeconomic factors driven by education.

The purpose is to investigate whether education has driven CO_2 emissions in any way, and how this may have varied given differing income levels and time periods applied. A more exhaustive understanding of this relationship can possibly aid strategies to decrease the emission levels of developing countries in view of future growth prospects.

The first step of this thesis is a theoretical contribution, where I build a framework of the potential links from education to CO_2 emissions in developing countries on the basis of relevant literature. The identified channels of this relationship are growth, technological-, structural-, and demographic change. Moreover, education is postulated to have a direct effect on CO_2 emissions either through substituting for energy usage or through influencing pupils and students in a way that affects their CO_2 footprint. Furthermore, the other factors that are assumed to be major determinants of the level of CO_2 emissions in developing countries are trade, regulatory quality, resource endowments, resource prices, population density, and a country's climate.

The second step is a practical contribution through an empirical analysis. As testing all identified channels between education and CO_2 emissions is beyond the scope for this thesis, and an assessment of the behavioral effect of education would likely be impossible to quantify through a macroeconomic approach without undertaking massive surveying, the focus lays instead on testing the first two channels of growth and technological change. I apply a fixed-effects regression analysis on a panel of 81 upper-middle, lower-middle, and low-income countries for the period of 1996-2014. Both channels are tested, with the first regression of each being a more general assessment of the relationship between education and CO_2 emissions, and the second regression testing a more direct effect of each channel. These regressions are subsequently repeated for different samples split by income group and for different time lags for education (five-, ten-, and twenty years) as changes in the latter arguably take a long time to affect CO_2 emissions significantly.

The most important results are that higher levels of education are correlated with higher levels of CO_2 emissions and intensity. While there are some indications for a long-run decreasing effect of education on both factors, these cannot consistently be identified in the five-, ten-, and twenty-year lagged regression-specifications. The conclusion from these findings is that while education seems to have the potential to affect CO_2 emissions, whether and in what direction it does may be entirely dependent on the underlying circumstances.

The outline of this thesis is the following: section two provides a literature review, assessing the existing academic literature associated with the potential channels affecting CO_2 emissions in developing countries that are in some way affected by education. This is used to build a conceptual framework of the relationship between education and CO_2 emissions. Section three is concerned with the analysis of the relationship between education and CO2 emissions using the channels of growth and technological change, describing the data and applied methods as well as reporting the results. The fourth section discusses these results, showing possible limitations to the study and suggestions for further research, the fifth section then ending with the conclusion.

2 Literature Review

Climate change, its causes and effects, is arguably one of the most imperative issues of today's global community. It is thus unsurprising that a large body of economic literature is dedicated to environmental issues. Usually, these studies focus on the main of the Greenhouse Gas emissions, carbon dioxide (CO_2), as it is responsible for about 76% of global GHG emissions (EPA, 2011). A large share of the economic literature dealing with the issue of GHG emissions focuses on developed economies. This can largely be attributed to data being more widely available and these countries having far larger CO_2 emissions per capita than developing countries.

Yet, a growing body of the literature has started to investigate the developing world as well, since it is forecasted that within the next 25 to 30 years the majority of growth in the demand of energy, use of fossil fuels, emissions of greenhouse gases, and associated local pollution is going to stem from there (Wolfram et al., 2012). However, the question is whether developing countries will follow the energy-intensive growth path, once embarked upon by the nowadays developed economies, or whether they will follow a different path that is less damaging to the environment (Dasgupta et al., 2002; Marcotullio & Schulz, 2007; Fouquet, 2014).

While many links to CO_2 emissions in developing countries such as growth and technological change have been investigated so far, one potential link has only rarely been examined, that of education. Although it is questionable whether education directly drives the emissions of CO_2 in developing countries, O'Neill et al. (2018) find higher levels of education to be coupled tightly with higher resource use and thus higher CO_2 emissions. Hence it is possible that education influences certain channels, such as growth, that in turn affect the emissions of CO_2. Thus, in order to identify this potential indirect effect of education on CO_2 emissions of a country, one should first distinguish the main factors driving CO_2 emissions in developing countries, followed by an investigation of whether and how these are potentially influenced by education. Various channels are reviewed in the following sections.

2.1 Economic growth and CO_2 emissions in developing countries

The first and most simple link between education and emissions would be that education fosters growth, which in turn leads to higher levels of environmental degradation. The notions of emissions being a by-product of economic activity have led to the formation of the 'pollution-income relationship literature' (PIR), studying the potential links between pollution and income (Lieb, 2003; Kaika & Zervas, 2013a). Indeed, Goldenberg and Reddy (1990) state that conventional wisdom depicts economic growth to be in proportion to the growth in consumption of energy and raw materials. This seems to be confirmed in figure 1, where GDP per capita and CO^2 emissions in developing countries follow each other almost perfectly.

However, in addition to creating a larger need for inputs and thus leading to more environmental degradation, Grossman and Krueger (1991) further postulate that economic growth has two channels that have a positive effect on the environment. The first channel is the composition effect, where the structure of the economy over the process of growth tends to change towards focusing on activities that are less pollution-emitting (Dinda, 2004). The second channel is the technological effect, where the wealthier a nation gets, the more it can spend on R&D (Komen et al., 1997), replacing 'dirtier' technologies with 'new and cleaner' technologies, and improving environmental quality.

Taking this into account, it may be that the effect of income growth on growth in emissions is not entirely linear. This assumption underlies the 'Environmental Kuznets Curve' (EKC) framework, where an inverted-U-shaped relationship between pollutants and income per capita is suggested (Dinda, 2004). Appearing in the early 1990s, the main idea behind the EKC is that while economic growth leads to increases in environmental degradation in its early phases of progress, the only way to reduce emissions in the long-run is to increase incomes (Beckerman, 1992; Ekins, 1993; Kaika & Zervas, 2013a; Panayotou, 2016).

The justification for this EKC pattern stems largely from the application of the structural change process of economic growth: In the first stage of industrialization, a transformation from an agrarian to an industrial economy, the focus lays on increasing material output, as those at the subsistence level are largely more concerned with increasing their income in order to stay alive rather than with maintaining the environment (Dasgupta et al., 2000; Dinda, 2004). The growth triggered by industrialization then leads to increased use of natural inputs and greater emissions of pollutants. In the second stage, where the economy transforms from industry to services, it is postulated that as income grows, people increasingly care about the environment, while regulatory institutions grow more effective, which leads to declining pollution levels (Pezzey, 1989; Selden & Song, 1994; Baldwin, 1995; Dinda, 2004). This goes along with the service sector generally being seen as cleaner than the industry sector (Dinda, 2004), as well as the latter increasingly focusing on lighter manufactures with growing incomes, further driving down emission-intensity (Kander et al., 2013a). Furthermore, some authors do argue that this decrease is, at least to an extent, due to higher-income economies outsourcing their production to developing countries (e.g. Panayotou et al., 2000) Thus, incomes and environmental degradation should, in theory, follow an inverted-U-shaped-relationship, depicted in figure 2.

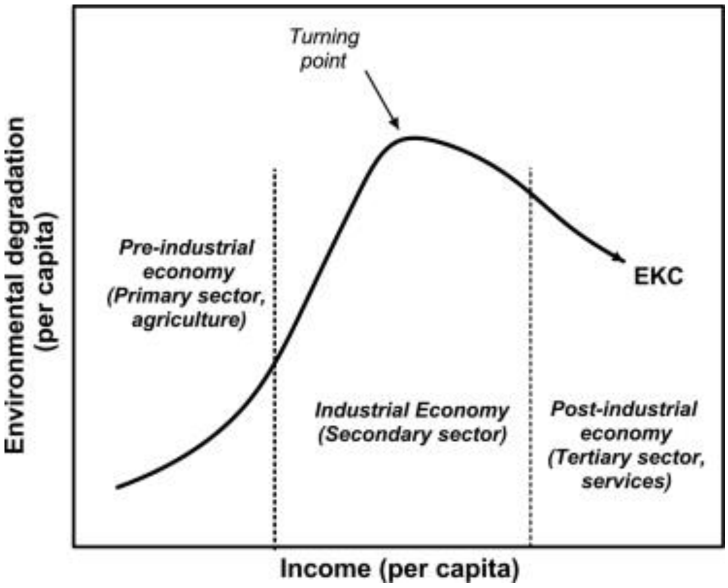

Figure 2: The Environmental Kuznets Curve

Note: Taken from Kaika and Zervas (2013a), figure 1

With regard to empirical evidence however, findings on the EKC-hypothesis have been mixed. Shafik and Bandyopadhyay (1992); Selden and Song (1994); and Krueger and Grossman (1995) all find that income is the main driver of environmental quality, with many environmental indicators deteriorating initially upon rising incomes, but tending to improve as countries grow richer. However, Kaika and Zervas (2013a) collect a large body of empirical investigations of the EKC curve and conclude that while the results are mixed at best, CO_2 emissions appear to be increasing monotonically with income in most cases. Furthermore, in the empirical assessments of the EKC only some air quality indicators have been aligning with its trend (Dinda, 2004).

Finding a clear, generally holding empirical relationship between income and environmental degradation is difficult, potentially impossible. As both Arrow et al. (1995) and Stern et al. (1996) note, the economy should not be seen as having a unidirectional causality towards the environment. Environmental degradation itself has the potential to negatively affect economic growth, with for example droughts halting economic activity and therefore lowering overall output. Thus, both the economy and the environment can be seen as jointly determined, meaning that the pattern of the relationship between pollution and income will likely differ between countries and regions (Perrings, 1987; Kaika & Zervas, 2013b).

So overall, what can one conclude about the relationship between economic growth and environmental degradation? It seems clear that ceteris paribus, the growth-induced increase in material use leads to an increase in energy use and therefore environmental degradation. However, increased income, in turn, provides countries with a number of tools to lower the environmental effect of their growth, for example through technology and regulations. Whether this happens and at which stage is likely dependent on several country-specific factors. For example, Gertler et al. (2013) find that pro-poor growth is more energy-intensive than growth that is non-pro-poor, as once the incomes of poor households increase, they acquire energy-using assets and goods for the first time, meaning their energy demand increases more extensively compared to the rest. Furthermore, Magnani (2000); Bimonte (2002); and Cantore and Padilla (2010) find that the level of income inequality is a factor in determining whether high-income countries are able to decrease their emissions, as high inequality can lead to a decrease in demand for pollution abatement. Additionally, a government’s inclination to enforce environmental regulations in the first place obviously affects environmental degradation as well (e.g. Panayotou, 1997; Bhattarai & Hammig, 2001; Leitão, 2010).

Thus, while growth may be an important determinant for the level of CO_2 emissions, it is far from being the only one and countries may not be path dependent on the EKC. A simple example of two developed and two developing countries shows that both the level and trend of CO_2 emissions within each pair differ quite strongly (figures 4 and 5). Here, both Australia and

South Africa, while having similar levels of GDP per capita compared to Germany and Brazil respectively, have much higher levels of CO_2 emissions than their counterparts, which among others can be attributed to their higher dependence on mining (UNdata, 2019). Complementary to growth and the aforementioned factors, technological change is generally seen as being of importance in determining a countries' level of CO_2 emissions.

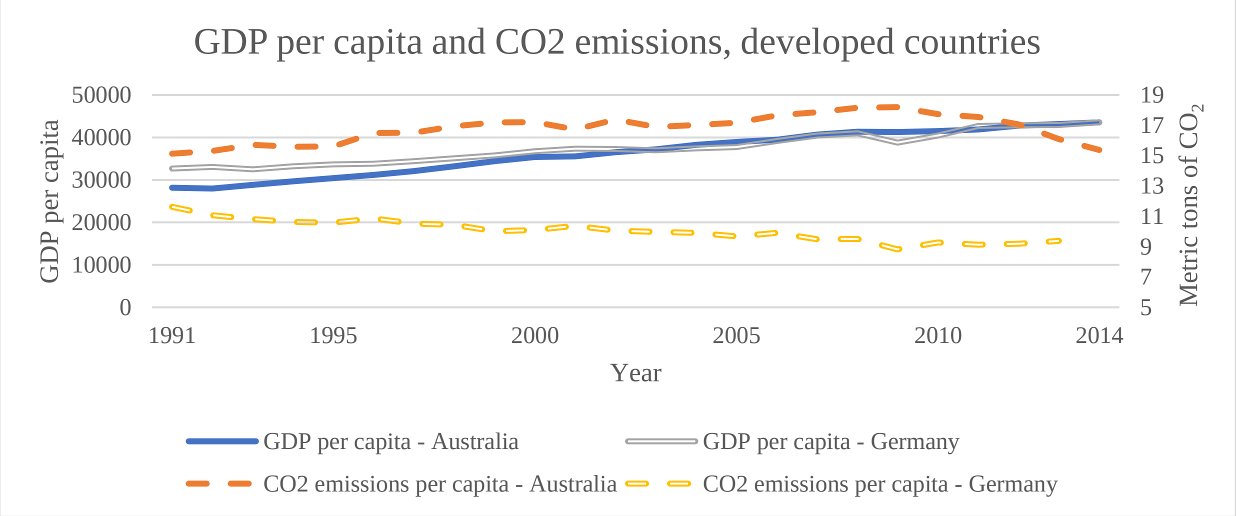

Figure 3: GDP per capita and CO_2 emissions for two developed countries – Germany and Australia, from 1991 to 2014

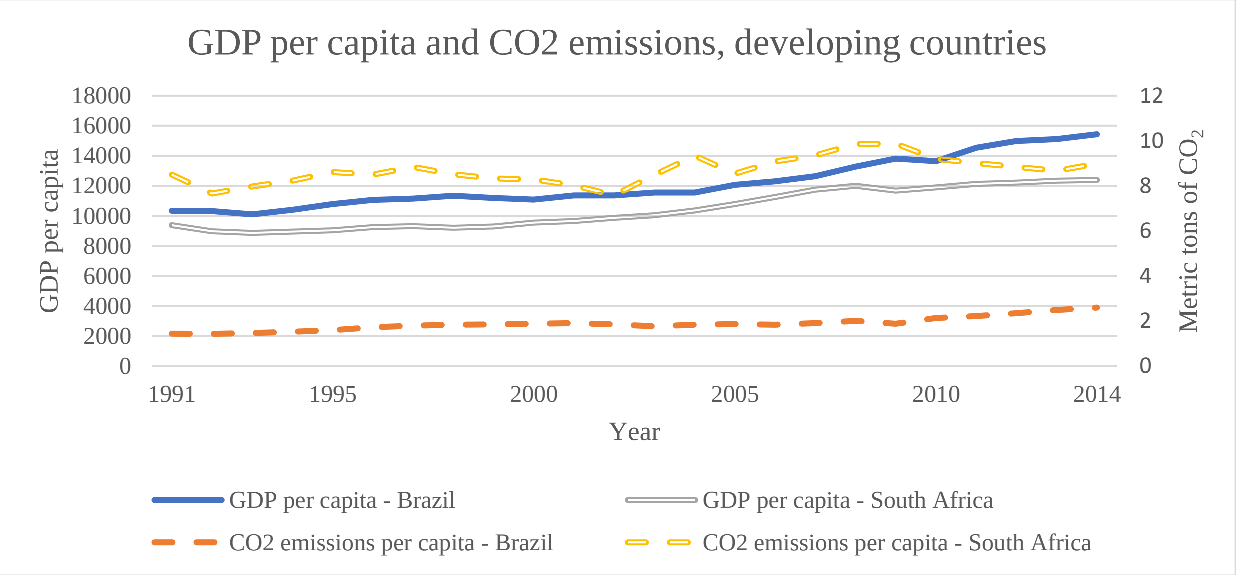

Figure 4: GDP per capita and CO2 emissions for two developing countries – Brazil and South Africa, from 1991 to 2014

Note for both figures: GDP per capita in PPP constant 2011 international USD and CO_2 emissions in metric tons per capita both taken from the World Bank (2014a) – World Development Indicators. Time interval chosen based on data availability.

2.2 Technological change's role in determining CO_2 emissions in developing countries

Many authors argue that technological change is a fundamental driver of CO_2 emissions (e.g. Shafik & Bandyopadhyay, 1992; de Bruyn et al., 1998). Technological progress here would include any kind of improvements in production techniques, potentially leading to a decreased use of inputs and/or the adoption of technologies in the production process of goods that are less polluting (Kaika & Zervas, 2013a).

According to Goldenberg and Reddy (1990), developing countries face a choice: they can follow the standard growth path of industrialized nations, leading to stark increases in environmental pollution, or they can leapfrog over certain steps followed by industrialized nations previously. Technological leapfrogging here refers to the fact that developing countries can use modern and more efficient technologies accessible from developed countries that had not been available to rich countries at similar stages of economic development in the past. This kind of technological leapfrogging can happen in both process and product cases (Goldemberg, 1998). In situations where this does lead to reductions in the energy intensity of growth for developing countries, for example through employing solar panels as an alternative to fossil fuels, technological leapfrogging is seen as energy leapfrogging (Ockwell & Mallett, 2012; World Resources Institute, 2013). As the energy efficiency of many products in areas such as electric appliances, lighting, industrial processes, and passenger vehicles has improved substantially throughout the past decades, the potential for developing countries to perform this type of energy leapfrogging is certainly in place (Fouquet & Pearson, 2006; Fouquet, 2011; Millard-Ball & Schipper, 2011; Mauer et al., 2013).

According to van Benthem (2015), these more energy-efficient technologies are making their way into developing countries, leading to within-technology leapfrogging. As an example, he illustrates the case of the Ford Model T: This model was one of the few select cars available during the early 1900s when the United States had a level of per capita income that is comparable to that of developing countries in Asia today. At that time, it had a fuel economy of 13 miles per gallon (mpg). Today, the Suzuki Maruti Alto 800, the bestselling car in India in 2015, has much higher energy efficiency, reaching 40 mpg in 2015, with other small family cars being able to achieve 56 mpg. At the same time, the average fuel economy in China was 30 mpg. This shows that the typical passenger vehicle in a developing country like India or China is more fuel efficient compared to past common vehicle models of developed countries.

However, while van Benthem (2015) notes that one may see a large potential in this type of leapfrogging, he further states that the extent and success of it is lower than expected.

As Goldenberg and Reddy (1990) show, prices for technology can only fall where there is at least anticipated demand, which may not emerge if that technology is uncompetitive at current prices. Furthermore, if weak environmental policies and energy subsidies are in place, then this can hinder the implementation of energy-efficient technologies (Gallagher, 2006; IEA, 2012; Gertler et al., 2013; Davis et al., 2014). Additionally, any technology that is developed for the skill- and capital-intensive production processes in developed economies, may not be suitable for the labor-abundant developing countries (Basu & Weil, 1998). Technological adoption is thus also dependent on the availability of skilled human capital (usually in the form of competent technical personnel), as well as strong institutions (especially with regard to property rights), and supporting infrastructure (Goldemberg, 1998; Acemoglu & Zilibotti, 2001; Ho, 2005). Thus, as Gallagher (2006) argues, just because leapfrog technologies are available, this does not necessarily imply that they will be adopted if the necessary fundamentals are not in place.

Turning to empirical evidence, several studies conclude that in developing countries technological changes in the form of leapfrogging are occurring (Judson et al., 1999; Antweiler et al., 2001; Stern, 2002). Mielnik and Goldemberg (2002) show that foreign direct investment and globalization have fostered several cases of leapfrogging in the energy area. Gallagher (2003) adds that innovations in higher income countries seem to be implemented in developing economies with a relatively short time lag. For developing Asia, Angel et al. (2000) provide some evidence of the trend of industries implementing cleaner processes and production technologies. Lastly, several authors applying decomposition analyses arrive at the finding that technological change itself had been majorly responsible for the overall decline within the energy intensity of China's industry[1].

Despite the empirical evidence showing some extent of leapfrogging, van Benthem (2015), in his study on 29 OECD and 47 non-OECD countries from 1960 to 2006, concludes that there is simply no indication that developing countries of the current time are less energy-intensive compared to industrialized economies at similar levels of income in the past. He argues that this is due to developing countries today consuming a more energy-intensive basket of goods and services than developed countries used to at similar income levels. This falls somewhat in line with the rebound effect of energy efficiency on energy found by Greening et

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[1] According to Sinton and Levine (1994, from 1980 to 1990); Lin and Polenske (1995, from 1981 to 1987); Garbaccio et al. (1999, from 1978 to 1995); Zhang (2003, from 1980 to 2000); and Fisher-Vanden et al. (2004, from 1997 to 1999) ranging from 50 to 100% of the overall decline.

al. (2000). According to them, a multitude of studies show that improvements in energy efficiency are often followed by an increase in energy use and consumption.

Thus, while technological change through leapfrogging does certainly pose a possibility for developing countries to reduce their energy-intensity and embark on a cleaner growth path, these reductions may not be significant enough to counteract the overall increase in energy intensity through growing consumption and production. Furthermore, the possibility of leapfrogging depends crucially on country-specific endowments of factors like human capital, institutions, and infrastructure. Lastly, arguably not every new technology that is leapfrogged into a developing country is necessarily ‘cleaner’ and less energy-intensive than the one in place. If, for example, a non-electrified water mill is being replaced by an electrified one, then this may, on the one hand, improve its efficiency, but on the other hand, it would lead to increased overall energy usage. Hence, the type of leapfrogged technology matters as well when one wants to assess its effect on a country’s level of emissions.

2.3 Other important factors determining CO_2 emissions

Complementary to growth and technological change, structural change is deemed to be one of the main factors to drive a country’s emission levels. As mentioned previously, the standard notion of structural change affecting CO_2 emissions is that of an initially increased use of energy and machines stemming from the phase of industrialization, followed by a de-industrialization towards services, where this process is reversed and energy use decreases (Panayotou, 1993; Smil, 2005; Panayotou, 2016). This relatively simple explanation has naturally drawn criticism. While there is general agreement that a transition from agriculture to industry increases energy use, the extent of the decrease in the transition from industry to services is not fully accepted.

Kaika and Zervas (2013b) argue that while services may be intangible, the places where these activities are being conducted (e.g. office towers, warehouses, and shopping malls) are tangible, requiring energy to function, and for their construction and maintenance (Stern & Cleveland, 2004). Moreover, it has been argued that it is the industrial sector becoming cleaner that contributes to the decrease in CO_2 intensity, rather than a transition to the service sector (Kander, 2005; 2013a,b). Furthermore, Henriques and Kander (2010) state that the service transition in developed countries itself is largely a price illusion similar to Baumol’s disease (Baumol, 1967). They find that while service employment and share of GDP in current prices have risen throughout recent decades, the share for real service production, measured in constant prices, was smaller. Nevertheless, in the same study, Henriques and Kander (2010) find that in some developed countries structural change toward the service sector did lead to modest decreases in energy intensity. Hence, while the transition to services may not be as pronounced in developed economies as often claimed, and while it may not universally drive down energy usage and thus CO_2 emissions, one may argue that it still offers a possibility to somewhat reduce emissions in a growth process.

Another aspect that can affect the level of CO_2 emissions in developing countries is that of demographics. Reductions in mortality and subsequent increases in life expectancy, while being a positive indicator of development, also naturally lead to an increase in aggregate CO_2 emissions in a country, as an increase in overall people-years in a country also means increased overall resource use. On the other hand, a decrease in fertility has the opposite effect.

Furthermore, a factor that has important implications for the level of emissions in a country is trade. According to the 'pollution haven hypothesis' (Dinda, 2004), the more open to trade a country is, the higher is its production of goods to support its exports. With rising incomes and environmental degradation, governments are likely to impose stricter environmental regulations on the economy. This leads to a shift of domestic production, from a focus on highly pollution-intensive to less pollution-intensive goods and services. While developed countries thus import emission-intensive goods, developing countries, having less strict environmental regulations, export these goods[2]. Thus, some authors argue that developed countries simply 'outsourced' their pollution to developing countries, creating a large academic debate on whether the application of a consumption-based pollution accounting method, taking into account if a country purely outsourced the production of its 'dirty gods', should be taken over a pure production-based one (e.g. Hermele, 2002; Baumert et al., 2019)[3]. While the debate on this issue, as well as the validity of the pollution haven hypothesis, continues, a key takeaway point is simply that if a country is generally exporting more than it imports, then ceteris paribus it should produce a larger amount of goods and potentially emissions than would be required by its domestic consumption needs.

There are several other important factors that can have an effect on the emissions of CO_2 in a country. For instance, a country's endowments in fossil fuels and renewables, as well as their prices arguably have an effect on its energy mix, and thus its level of pollution (Neumayer,

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[2] Whether this hypothesis holds or not is highly debated in the literature. Some authors (Hettige et al., 1992; Ekins et al., 1994; Suri and Chapman, 1998; Panayotou et al., 2000; and Peters et al., 2011) find it to hold, while others (Cole, 2004; and Kearsley and Riddel, 2010) find no or little evidence for the pollution haven hypothesis.

[3] For most developed economies, consumption-based emissions are much higher than their officially reported production-based emissions, as a result of increasing emissions embodied in international trade flowing from the developing to the developed world, which are not considered in production-based emissions (Davis and Caldera, 2010; and Peters et al., 2011). However, one drawback of the consumption-based emission accounting method is that it does not give credit to countries for exporting 'cleaner' goods to other countries, which would have a positive effect on overall global emissions (Jakob and Marschinski, 2013; Kander et al., 2015; and Jiborn et al., 2018).

2004). Additionally, the regulatory quality of institutions can be a determinant in enacting legislations that further stimulate declining levels of pollution. (Baldwin, 1995; Dinda, 2004). Moreover, a country's climate may influence energy use and thus emissions, as a warmer climate can substitute for energy (since less energy has to be used, for example for heating) and contribute to economic activity (Stern, 2012). Lastly, a higher density of population can affect CO_2 emissions through the increased usage of coal and other fuels in activities outside the scale of normal economic activity (such as heating and cooking), while on the other hand, these populations potentially worry more about abating CO_2 emissions of their corresponding level of income (Panayotou, 1997).

Concluding, it seems clear that the factors that drive country-CO_2 emissions are highly interrelated and country-specific. The question remains, which of these factors that drive CO_2 emissions are affected by education, and if so, to what extent. Moreover, the question stands whether there are even any potential direct channels through which education can drive emissions.

2.4 Education's channels to CO_2 emissions

To my knowledge, the only study that directly examines the relationship between a country's level of education and its average level of CO_2 emissions is one by O'Neill et al. (2018). While not focusing on this particular relationship, they quantify resource use necessary to meet basic human needs within eleven social indicators in the safe and just space framework (Raworth, 2012). For each social indicator, they construct a threshold value representing a 'good life' for a country's citizen. These indicators include education, the good life threshold here being "95% enrollment in secondary school" (O'Neill et al., 2018, p. 3). These indicators are then compared to downscaled planetary boundaries for approximately 150 countries in the year 2011. They find that secondary education is one of the indicators (next to sanitation, access to energy, income, and nutrition) that is most strongly associated with higher resource use and thus environmental pollution. This is a first indication that education may drive CO_2 emissions, the question being through which direct and indirect factors.

Looking at the factors having an effect on the level of CO_2 emissions of a country, one can indeed argue that some of them are inter alia driven by education. Beginning with growth, a large body of literature is concerned with the question of whether education can be beneficial for growth in general and in developing countries more specifically.

While there are some arguments that education has so far done little to drive growth (Pritchett, 1999; Temple, 2001), most researchers agree that generally, education should be beneficial for growth, especially in the long-run, and several findings have so far confirmed this relationship (For example Topel, 1999; Krueger & Lindahl, 2001; Sianesi & Reenen, 2003)[4]. Disagreement is largely revolving around how high this return is, with findings ranging from 0.28 (Mankiw et al., 1992) to 11 (Judson, 1998) percent of the growth in GDP per capita from a 1 percent increase in education.

The role of education for economic growth, education here being viewed as the determinant for the quality and quantity of human capital, is referred to in the endogenous growth models (Aghion et al., 1998). Here it can be divided into two categories: First a simple accumulation of human capital that sustains growth over time (Uzawa, 1965; Lucas Jr, 1988). Second an existing stock of human capital generating innovations (Romer, 1990) and improving a country's capabilities to adopt new technologies which foster technological progress leading to sustained growth (Nelson & Phelps, 1966). Rosenzweig (1995), building on Thomas et al. (1991) and Schultz (1975), adds that schooling may enhance productivity either through improving access to information sources (for example newspapers or instruction manuals) or by increasing the ability to interpret new information.

While the neo-classical revival (Mankiw et al., 1992) and the 'revisionist view' (Benhabib & Spiegel, 1994; Bils & Klenow, 2000) both argue that the role played by human capital in economic growth is largely overstated and may be unable to generate endogenous growth by itself, Cohen and Soto (2007) show that these authors arrive at their results largely because their data is too noisy and their assumed formulation to represent human capital is inappropriate. However, whether a nation is able to foster human capital accumulation is largely dependent on the presence of high-quality institution especially with regards to property rights, and the form of government and religion (Goldin, 2016). It should also be noted that improvements in education take time to form an effect in the economic performance of a country and should therefore be viewed over the long-run (Krueger & Lindahl, 2001). This is especially important since measurements of education that take into account some form of attainment of education are showing past inflows of schooling, which form a future stock of educational attainment (Lee & Lee, 2016). Moreover, in countries where child labor is common, increases in education could potentially have an initial adverse effect on growth, as these

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[4] Sianesi and Reenen (2003) conduct a large survey on empirical studies aiming to estimate the effect of education on growth, some focusing on developing and some on developed countries. They find that studies by Barro (1991); Murphy, Schleifer and Vishny (1991); Levine and Renelt (1992); Mankiw, Romer and Weil (1992); Englander and Gurney (1994); Barro and Lee (1994); Benhabib and Spiegel (1994); Hanushek and Kim (1995); Barro (1996); Gemmel (1998); Bassanini and Scarpetta (2001); and de la Fuente and Doménech (2006) all arrive at the conclusion that education leads to an increase in GDP per capita, showing that there is a large agreement on a positive effect of education on growth.

children are taken out of the labor force, lowering overall economic output. Further, it goes without saying that the relationship between education and growth is bi-causal, as increased productivity growth leads to both larger investments into- and increased demand for education (Sianesi & Reenen, 2003).

Next to growth, it is likely that education plays a crucial role in the adoption of new technology. Easterlin (1981), interpreting earlier findings by Svennilson (1964); Arrow (1969); and Rosenberg (1970;74) finds that they emphasize the personal factor in the transfer of technology:

> “This emphasis on the personal element in the transfer of technology suggests that understanding of it might usefully be approached by analogy with a situation in which most of us here have some relevant experience, namely, as an educational process, in which a new and difficult subject-"modern" technology-must be taught and learned. From this point of view, explanation of the limited spread of modern economic growth turns into a question of identifying the factors that have constrained the dissemination of a new type of knowledge-that of modern technology” (Easterlin, 1981, p. 5)

Thus, he concludes that the level of schooling is crucial in determining how well a country does in adopting and mastering modern technologies. This falls in lines with arguments by Benhabib and Spiegel (1994); Cameron et al. (1998); Griffith et al. (2000); and Sianesi and Reenen (2003) stating that human capital raises productivity growth through increasing the rate at which leading technologies are adopted. New technologies therefore promote the demand for superior skills in human capital. As an example from the past, technologies introduced in the late nineteenth and early twentieth centuries drove up the demand for workers that were numerate and literate enough to read blueprints and type from notes and dictated letters, while also possessing some knowledge of electricity (Goldin, 2016). Furthermore, Rosenzweig (1995) argues that technological change can drive educational differences as well. For example, enrollment rates in India grew stronger in those areas that experienced technological change compared to those that did not. Here, schools reacted to the increased learning payoffs from the introduction of new technologies (Foster & Rosenzweig, 1993). Schooling and technological change can therefore form a reinforcing cycle, improvements in education increasing the speed of technological change and technological change increasing the payoffs of schooling.

Furthermore, education can have an effect on the speed of structural change. Within the structural change framework, it can be argued that the industrial sector generally requires more skilled labor than does the agricultural sector, although the extent of this is debatable. Likewise, high-productivity service sectors require more skilled labor than most sectors in industry. If one accepts this view, then the assertion can be made that, in the classic structural change framework, an increase in education would likely facilitate either structural change from agriculture towards industry or from industry towards services[5].

Moreover, education may well influence environmental degradation and resource use, as it can lead to reductions in population growth, suggesting that in developing countries women that complete secondary education have on average one child fewer per lifetime compared to women that only have completed primary education (Barro, 1991; Barro & Lee, 1994; Cohen, 2008; O'Neill et al., 2018). This decrease in fertility would ceteris paribus lead to less overall emissions. At the same time, increased education, by itself and through its implied effect on income growth, can lead to reductions in mortality and increases in life expectancy, which would then drive emissions (Barro, 1991; Barro & Lee, 1994). Which of these effects is stronger is likely dependent on the demographic stage of development of a country, as well as other factors such as religious and cultural beliefs.

Taking these relationships into account, if education does foster growth, and growth induces environmental degradation at least in the earlier stages of development, then one could assume an indirect effect of education on environmental degradation through economic growth. Furthermore, if increases in the level of education allow a country to adopt existing technologies more quickly, then this could enable increased technological leapfrogging. This could affect CO_2 emission levels if these technologies are more or less energy efficient than previous ones. Additionally, if education does play a role in partially determining the speed of structural change, fostering industrialization at an early stage of development and de-industrialization at a later one, then this can influence emission levels as well. Lastly, if education leads to reductions in fertility and thus population growth, it leads to decreases in CO_2 emissions, whereas the reverse occurs if education leads to reductions in mortality.

Thus, four main indirect channels through which education can affect environmental degradation are identified: growth, technological-, structural-, and demographic change. It goes without saying that these four channels are not exclusive to each other and rather strongly complementary. Technological-, structural-, and demographic change are also largely driven by the state of development of a country and may, in turn, affect productivity and growth. Hence, testing for these channels would not give four separate links from education to pollution, but rather four highly interrelated relationships.

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[5] This argument is loosely based on the works by Nelson and Phelps (1966); and Silva and Teixeira (2011).

In terms of the direct effect of education on CO_2 emissions in developing countries, Stern (2012) notes that an important factor affecting energy and emission intensity is the substitution of energy for human capital. If a country's level of human capital is low, it will have to increase energy and emission intensity in order to compensate for this shortcoming. Thus, education may be affecting emissions directly through substituting energy usage with skilled human capital.

Lastly, education can be emission-reducing if it manages to raise awareness about the importance of sustainability, either through directly educating about environmental issues or by enabling the pupils and students to attain the necessary information themselves, potentially leading people to behave more environmentally-friendly (Bimonte, 2002). This can affect not only their consumption patterns but also their decisions for example in management and politics. It has been shown that, at least in developed countries, higher levels of education can lead to a better understanding for example of the GHG effect (Boyes & Stanisstreet, 1993). Indeed, a more scientifically educated population can make more informed decisions about how and what they purchase, dispose, consume, and invest (Lester et al., 2006).

However, studies show that education only leads to behavioral change under certain conditions (Kollmuss & Agyeman, 2002; Lyons et al., 2006). Multiple papers challenge the association of education leading to awareness and action with regard to climate change, arguing that it is rather factors such as personal relevance to the issue and a deep connection to nature that are more important in contributing to more sustainable behavior (Hungerford & Volk, 1990; Bamberg & Möser, 2007; Bray & Cridge, 2013). Nevertheless, two studies in the United States by Craig and Allen (2015, in elementary schools) and Cordero et al. (2018, in universities), show that courses designed to improve the students' understanding of environmental issues and energy-saving behavior did lead to significant and long-run decreases in self-reported energy consumption and thus CO_2 emissions of those taking these courses. Therefore, while the effect of education itself on students' energy-consuming behavior is questionable, the potential of an effect is certainly in place, especially if it is education dealing with environmental issues and energy-saving behavior. This is the second 'direct' effect that education can have on the level of CO_2 emissions.

2.5 Conceptual Framework and hypotheses

The ties have been made, the next step is to put all the aforementioned relationships into one comprehensive framework, showing the links of how education can possibly affect the level of CO_2 emissions in developing countries. This is done in figure 5 below. Furthermore, hypotheses concerning the first two indirect channels of growth and technological change are formed as the basis of the following empirical analysis.

The first link here (denoted by ‘A’ in figure 5) is from education to growth. If education generally fosters economic growth and economic growth is seen to drive CO_2 emissions through increased resource use, at least in the early stages of development, then one could assume that an increase in education indirectly leads to an increase of CO_2 emissions. Because it takes time for education flows to take the form of stocks however, these relationships should mainly be viewed in the long-run perspective:

Hypothesis 1a: Education has a CO_2 *emissions-increasing effect in developing countries in the long-run*

However, a general association between education and CO_2 emissions may also depend on all the other channels, such as technological-, structural-, and demographic change. Therefore, H1a is more concerned with the general relationship between education and CO_2 emissions. In order to arrive at an indication of whether education leads to increases in CO_2 through inducing growth, one can rather look specifically at the effect of growth caused by education on CO_2 emissions. This does not necessarily have to be exclusive to the long-run, as growth itself likely has a more imminent effect on CO_2 emissions than does education. Therefore, contrary to the other hypotheses, hypothesis 1b mainly focuses on the short-run implications:

Hypothesis 1b: Economic growth driven by gains in education has a CO_2 *emissions-increasing effect in developing countries*

The second link (channel ‘B’) assessed here is technological change. While education through driving growth may generally lead to increases in CO_2 emissions, it may further enable countries to follow a less polluting growth path. If higher levels of education enable a country to leapfrog existing technologies more quickly, and these technologies are ‘cleaner’ or less energy-intensive than the ones used prior, then countries with a higher level of education may be able to reduce the emission content of their growth. Thus, education could potentially foster a lower level of CO_2 emissions relative to a country’s income level, at least in the long-run.

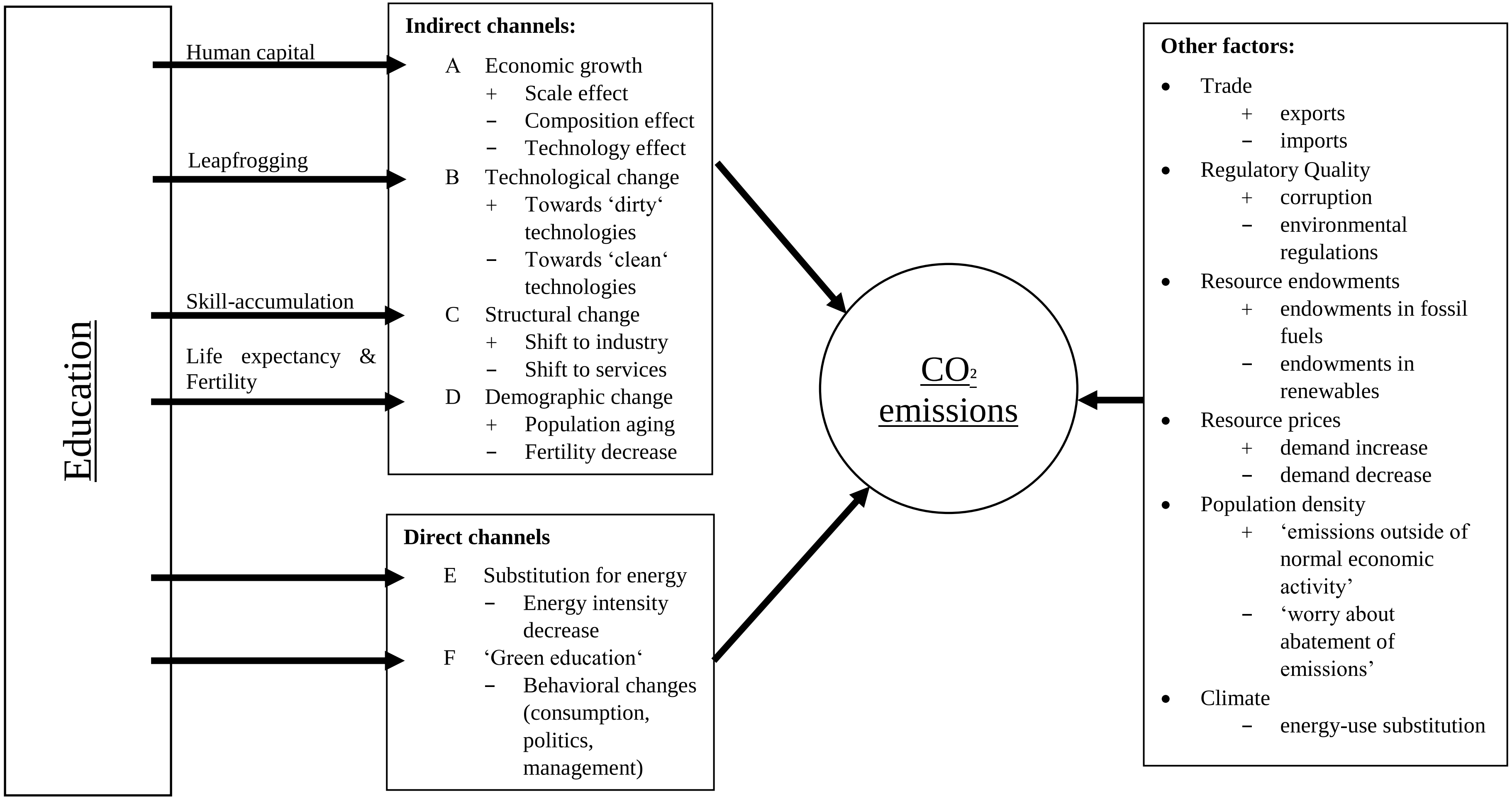

Figure 5: Overview of the potential relationships between education and CO_2 emissions

Hypothesis 2a: Education has a decreasing effect on the CO_2 emissions content in GDP per capita of developing countries in the long-run

This effect could partially also stem from the two direct channels of education, namely through education making people more aware of environmental issues and the substitution for energy via human capital.

Furthermore, the potential reduction of the CO_2 emission content in GDP through education could be illustrated by education determining the speed of the adoption of technologies that use renewable energies from developed countries. This relationship, if found to be true, would point towards education, regardless of its effect on CO_2 emissions through growth, potentially leading to reductions in the emission content of that growth, if it allows a faster adoption of cleaner technologies.

Hypothesis 2b: Gains in education have an increasing effect on the share of renewable energy in the generation of electricity in developing countries in the long-run

These four main hypotheses concerning the first two links of the conceptual model in figure 5 are being tested in this thesis. In both cases, the first hypothesis (‘a’) assesses a more general relationship that, while likely mainly driven by the corresponding channel, is probably also influenced by the other factors in the model, whereas the second hypothesis (‘b’) then assesses the effect of each channel in a more direct way.

With regards to the other factors, as argued above, education has the potential to drive structural change through an increased requirement of skills in industry and, even more so, in services (channel ‘C’). However, an analysis of this kind lies beyond the scope of this research. Concerning demographic change driving CO_2 emissions (channel ‘D’), while they are in part driven by education, it would be difficult to identify the effect of education on CO_2 emissions through demographic factors. Decreases in fertility would lead to overall reductions, whereas decreases in mortality and subsequent increases in life expectancy would lead to overall increases. To understand which effect is more dominant, one would probably need to look at the effect of education on overall person-years-lived of a country, while also considering different age structures and corresponding levels of emissions in different age groups. Even though the theoretical basis is given, an analysis of this kind falls outside of the scope of this paper as well. Likewise, the direct effects of education (channels ‘E’ and ‘F’), despite being somewhat embodied in H1a and H2a, are likely impossible to quantify on the macro level.

Lastly, other factors that have been found to drive CO_2 emissions are trade, regulatory quality, resource endowments and prices, population density, and climate. While one may argue that education can have an effect on trade, regulatory quality, resource prices, and population density, this effect is likely so shallow that only a very dedicated empirical analysis could identify it, with case studies having a higher potential to shed more light on these relationships.

3 Analysis

3.1 Methodology

In order to test the four main hypotheses, I use four fixed-effects regressions. Here, a measure of education is regressed on CO_2 emissions while controlling for the other factors identified in the previous section. This procedure is then repeated with a long-run perspective of five-, ten-, and twenty years. As a dataset I use panel data with 81 developing countries for the period of 1996 to 2014, having a strongly balanced panel structure. According to Alderson and Nielsen (1999), and Hsiao (2014), this type of panel data is potentially subject to heterogeneity bias which affects the estimates of a standard ordinary least squares regression. Therefore, to correct for this potential bias one can either use a fixed- or a random-effects model. These models simulate unmeasured time-invariant factors, displaying them as country-specific intercepts to correct for potential heterogeneity bias (Alderson & Nielsen, 1999). The fixed-effects model regression can be understood as performing an ordinary least squares regression with the data being modified through subtracting the country-, and year-mean from the data, whereas the random-effects regression only subtracts a fraction of that mean (Hsiao, 2014). As Hausman tests for the main regressions rejected the null hypothesis of no correlation between unique errors and regressors in the models, the fixed-effects model is preferred for these regressions.

H1a, of the general effect of education to CO_2 emissions through growth is tested through the following regression specification:

$$CO_2\, pc_{it} = \beta_1 + \beta_2\, HC_{it} + \beta_3\, HC^2_{it} + \beta_4\, GDP\, pc_{it} + \beta_5\, Indust_{it} + \sum \beta_6 X_{it} + \mu_i + \mu_t + \varepsilon_{it} \tag{1}$$

$$i = 1, \dots N\ countries;\ t = 1, \dots T\ years$$

Where $CO_2\, pc_{it}$ stands for CO_2 emissions per capita (in metric tons), HC_{it} stands for Human capital, $GDP\, pc_{it}$ denotes GDP per capita, $Indust_{it}$ stands for the share of Industry value added in GDP, X_{it} signifies the control variables, μ_i represents country-fixed effects, μ_t the year-fixed effects, and ε_{it} denotes the error term. It should be noted that $_t$ for the lagged regressions stands for the corresponding time periods of five, ten, or twenty years, where human capital is denoted as HC_{it-1} and the squared term disappears. For the twenty-year lag, all variables are solely denoted with '$_i$', and both μ_i and μ_t disappear as it is now an ordinary least squares regression. The effects of β_2 and β_3 are used to test H1a.

In this case, the dependent variable is CO_2 emissions. I regress the independent variable, human capital, on the former in the first model, in the second model adding a squared term as a first test of whether the relationship is monotonically linear or has a turning point. Following that, I introduce several controls step-by-step in order to see whether a potential found effect changes when controlling for specific factors. These controls are based on the 'other factors' hypothesized to affect CO_2 emissions in developing countries as identified before. I start controlling for the effect of trade with the balance of exports to imports, followed by PPP-adjusted fossil fuel prices. Afterward, population characteristics are introduced, starting with population growth as a 'demographic factor', and followed by population density, controlled for through the average amount of people per square kilometers in a country. Next, I control for regulatory quality, following Stern (2012) with one indicator for the control of corruption and one for democracy. Lastly, I control for climate through using the average winter temperatures. Unfortunately, resource endowments could not be controlled for, as complete data on oil, gas, and coal reserves was only available from 2008 onwards.

Afterward, to test whether a potential found effect of human capital is driven by two of its main channels, income growth and structural change, I introduce both GDP and Industry value added, first separately and then jointly. Following, I re-run the complete model for the 'upper-middle-', 'lower-middle-', and 'low'-income sample. This sample split is performed to test whether any effect found may be confined to a group of countries with a certain level of income, as one could argue that a country like Albania (upper-middle-income) cannot be compared to a country like Burundi (low-income).

Next, I repeat these regressions with lagging human capital values. These are the main regressions of interest here, as they are displaying a potential long-run effect of human capital, being the more theoretically relevant relationship. I run regressions with a five-, ten-, and twenty-year lag separately, in order to test for whether the found results change when taking the long-run effect of human capital on CO_2 emissions instead. For these 'lagged' regressions, I use each variable's average of the corresponding period for the corresponding country, lagging the human capital variable to the prior period. The difference between these lagged regressions and the squared term of the short-run regression is that the latter just indicates a potential turning point in the education and CO_2 emission relationship that may lie at any long-run level of human capital, whereas the former test specific time intervals for a long-run effect.

I test H1b, of the more direct effect of education induced growth on CO_2 emissions in a regression similarly to (1), with the following equation:

$$\Delta CO_2\ pc_{it} = \beta_1 + \beta_2\ Labquan_{it} + \beta_3\ Labquan^2_{it} + \beta_4\ Labqual_{it} + \beta_5\ Labqual^2_{it} + \beta_6\ Cap_{it} + \beta_5\ \Delta Indust_{it} + \beta_7\ CO_2\ pc_{it-1} + \sum \beta_8 \Delta X_{it} + \mu_i + \mu_t + \varepsilon_{it} \tag{2}$$

$$i = 1, \ldots N\ countries;\ t = 1, \ldots T\ years$$

Where Δ denotes the change of the corresponding variable compared to the previous year/period, $Labquan_{it}$ denotes the contribution of labor quality and $Labqual_{it}$ that of labor quantity to growth in GDP per capita in the corresponding years, standing as proxies for growth through improvements in education. The squared term here is again used to test for potential linearity of the relationship. Cap_{it} stands for the remaining, capital growth in GDP per capita in the corresponding year, and $CO_2\ pc_{it-1}$ for the level of CO_2 emissions of the previous year/period, which may have an effect on the corresponding year's/period's CO_2 growth. Both these factors should be controlled for, as otherwise the information provided is not complete and results could potentially be biased. The effects of β_2, β_3, β_4, and β_5 are used to test H1b.

In order to work around the difficulty of measuring the contribution of education to growth and how this is translated into changes in CO_2 emissions, I analyze how high the contribution of the labor force was to the overall level of growth in emissions in a country. Education, though not being the sole determinant, takes a crucial part in shaping the quality of a functioning workforce. Therefore, if the growth caused by improvements in the labor force led to increases in CO_2 emissions, then this could give some implications of the 'education influencing CO_2 emissions through economic growth' effect, as outlined above. For this purpose, the Total Economy Database (The Conference Board, 2019) supplies data that outlines how much growth in quantity and quality of labor contributed to growth in GDP in a given country and year[6]. Labor quality is likely affected by human capital as argued above. Labor quantity, while evidently being influenced by various demographic factors such as population growth, can also be linked to human capital, as when more people are educated, more people can potentially enter the workforce. Thus, both variables function as proxies for education-induced growth.

As the variable measuring the labor contributions to growth is, in this case, a 'change variable' (how much growth is caused each year by labor quantity and quality), for this

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[6] A detailed description on the source of both indicators as well as how they are calculated in the dataset used can be found in appendix A, table 10, in the corresponding variable's section.

regression the values of the variables represent the absolute changes of these variables compared to the previous year[7]. Furthermore, I only re-run this regression for a five-year lag, as I suspect that economic growth, caused by improvements in education, would not have a significantly differing effect over much longer time periods than five years.

In order to test H2a of education's effect on CO_2 emission intensity, I simply re-run regression (1), this time with CO_2 intensity as the dependent variable. CO_2 intensity measures how many kgs of CO_2 emissions are embodied in one dollar of GDP. The regression is again re-run for a five-, ten-, and twenty-year lag:

$$CO_2/GDP_{it} = \beta_1 + \beta_2\, HC_{it} + \beta_3\, HC^2_{it} + \beta_4\, GDP\ pc_{it} + \beta_5\, Indust_{it} + \sum \beta_6\, X_{it} + \mu_i + \mu_t + \varepsilon_{it} \tag{3}$$

$$i = 1,\ \dots\ N\ countries;\ t = 1,\ \dots\ T\ years$$

Where CO_2/GDP_{it} denotes CO_2 intensity. The effects of β_2 and β_3 are used to test H2a.

Lastly, I test H2b, of the effect of education on the share of renewable energy in electricity similarly to (1) and (3), this time with the overall share of renewable energy used in electricity generation as the dependent variable. This regression functions as an assessment of whether education is important in determining how much renewable energy is used in a country. However, a problem with this regression is the distribution of the dependent variable. Figure 6 shows that there is a large share of countries that either have close to 0 or close to 100 percent of renewable energy in their overall electricity output. This is a first indication that the level of human capital does not seem to be a significant determinant of the overall share of renewables in electricity, which is further confirmed by figure 7, showing their relationship.

However, as an alternative I take the change in human capital as a potential determinant of increases or decreases in the share of renewables in electricity (similarly to regression (2)). Holding the initial level of the latter constant, the question is whether an increase in human capital over time leads to increases in the share of renewables in electricity, which would be an indication of technological leapfrogging:

$$\begin{gathered} \Delta\%\ renew_{it} = \beta_1 + \beta_2 \Delta\ HC_{it} + \beta_3\ \Delta HC^2_{it} + \beta_4\ \Delta GDP\ pc_{it} + \beta_5\ \Delta Indust_{it} + \beta_6\ \%\ renew_{it-1} \\ + \sum \beta_7 \Delta X_{it} + \mu_i + \mu_t + \varepsilon_{it} \end{gathered} \tag{4}$$

$$i = 1,\ \dots\ N\ countries;\ t = 1,\ \dots\ T\ years$$

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[7] Absolute changes are used here as the growth in GDP per capita contributed by improvements in labor quantity and quality also represents an absolute change

Where $\Delta\%\ renew_t$ denotes the change in the share of renewable energy generated in overall electricity output and $\%\ renew_{t-1}$ gives the level of the latter in the previous year, therefore controlling for its initial level. The effects of β_2 and β_3 are used to test H2b.

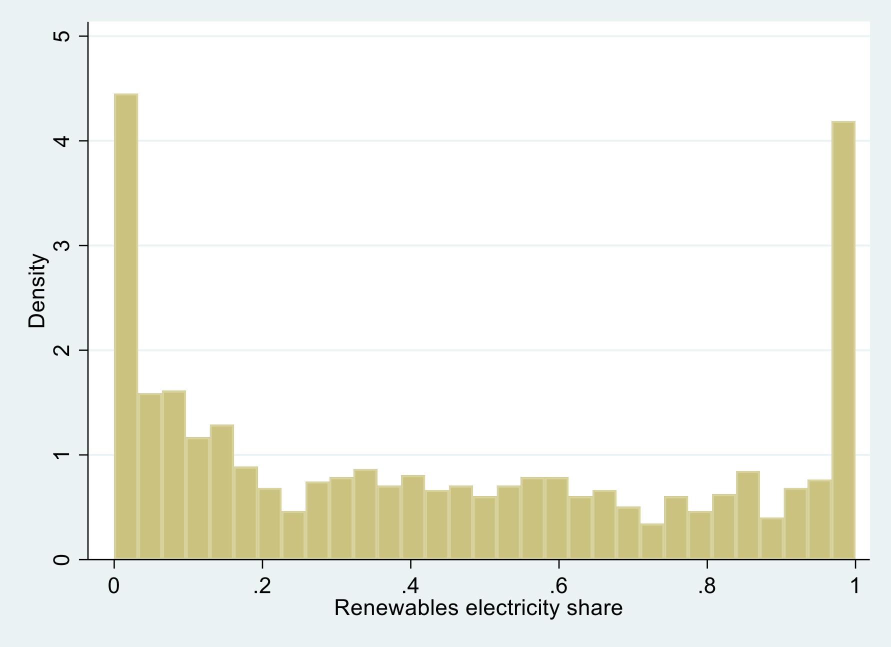

Figure 6: Histogram of the share of renewables in electricity

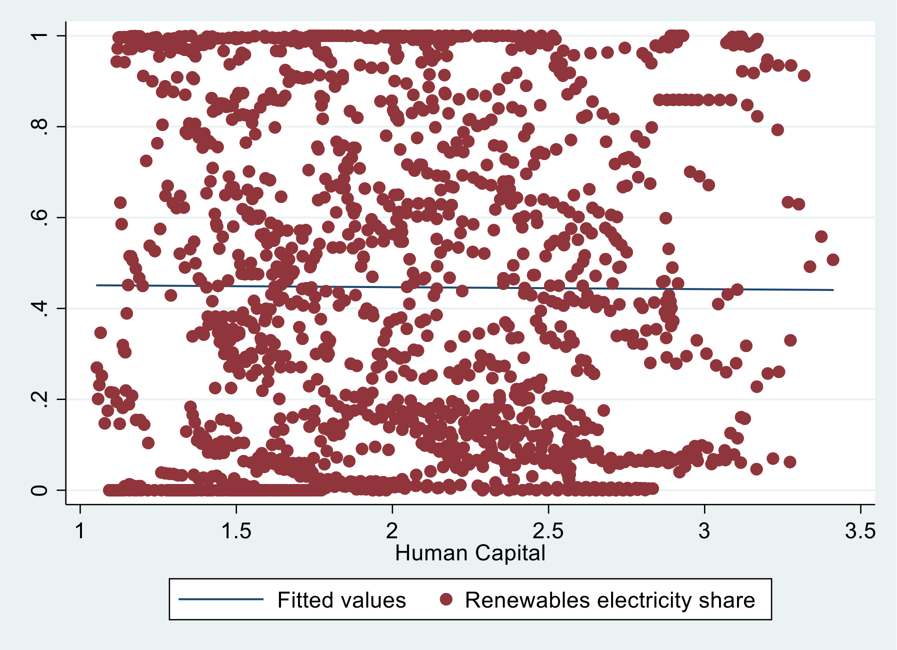

Figure 7: Fitted observations of the share of renewables in electricity and human capital

3.2 Data

The panel data collection started with all 137 countries classified by the World Bank (2019) as ‘low-‘, ‘lower-middle-‘, or ‘upper-middle-income’ countries, for the period of 1970 to 2014. Data was collected for the following variables: CO_2 emissions, CO_2 intensity, share of renewables in electricity output, human capital, labor quantity and quality contribution to growth, GDP per capita, industry value added, capital contribution to growth, trade balance, fossil fuel prices, population growth, population density, control of corruption, democracy, and average winter temperatures. Sources and descriptions for each of these variables can be found in table 11, appendix A.

Specific attention should be paid to the human capital variable here. As described in table 11, appendix A, the index, stemming from the Penn World Tables version 9.1, is based on the average years of schooling (taken either from Barro and Lee, 2013, or Cohen and Lecker, 2014). It further utilizes linear interpolation between observations, and an assumed rate of return to a year of schooling, based on Mincer equation estimates from around the world from Psacharopoulos (1994). The Mincer equation uses average earnings as a function of years of schooling and potential labor market years in order to arrive at the “average private rate of return to one additional year of education, regardless of the educational level to which this year of schooling refers” (Psacharopoulos, 1994, p.1). This measure is taken to not only account for average attainment of schooling but further to factor in the differences in quality of schooling between countries, as one year of schooling may arguably not give the same return for example in Ethiopia as in Bulgaria.

However, according to Lee and Lee (2016), this type of index has a shortcoming, namely that measured school enrollments exclude education from home and informal schools, including indigenous, non-Western, and traditional religious schools from the enrollment data. This leads to an underestimation of the true primary school enrollment ratio, whereas Lee and Lee (2016) believe it to be fairly insignificant for the estimates concerning secondary and tertiary education. Nevertheless, the shortcomings of this variable, as well as the interpolations between data points mean that while the indicator of human capital used here may be one of the best available proxies to measure education, it is still imperfect.

I dropped countries that did not have complete data for all variables, not counting labor quantity and quality, for at least five continuous years from 1990 onward. This left 87 countries within the sample. Furthermore, Kazakhstan, Mongolia, Russia, South Africa, Ukraine, and Venezuela were dropped from the sample, as they showed to have severe outliers, leaving 81 countries. Additionally, for regression (2), I included only those countries in the sample that had observations for both labor quantity and quality contribution to growth, leaving 39 countries for this regression in total. Tables 12 and 13 in appendix A show all the countries in the sample, sorted by income group and region classification from the World Bank (2019), including information on which countries were included in regression (2) and which were not.

Tests for normality showed, that the main dependent variable, CO_2 emissions, is skewed right and leptokurtic (skewness of 1.956 and kurtosis of 7.086). Moreover, Jarque-Bera tests indicated that the assumption of normality for the variable would be rejected (Jarque-Bera statistic of 2737.07, p-value of 0). Furthermore, a Breusch-Pagan test (reported in table 14, appendix B) showed that the null hypothesis, which states that the variance of the residuals is homogenous, had to be rejected (p-value of 0), indicating heteroscedasticity. Thus, in order to deal with non-normality and heteroscedasticity, I apply cluster-robust standard errors.

With regard to time-intervals, for the standard regressions I choose the time period of 1996 to 2014, as all variables have observations at least starting from 1996 onwards and reaching until 2014. While more recent and longer time-series data would have been preferred, this is the longest possible dataset that could be constructed with the data available. For the five-year lag, I average all variables aside from human capital over the following 5-year periods: 1995-1999, 2000-2004, 2005-2009, and 2010-2014. In turn, I average human capital (or labor quantity and quality, dependent on the regression) for the previous five-year period (so for 1995-1999, human capital is averaged from 1990-1994). For the ten-year lag, I apply the same principle (1995-2004 and 2005-2014), the same working for the twenty-year lag (1995-2014, where human capital was taken from 1975-1994). This means that the number of observations is heavily reduced, while the number of countries remains the same. Lastly, table 15, appendix B shows the correlations between all non-dependent variables.

3.3 Summary Statistics

Table 1displays the number of observations, means, and minimum and maximum values of all variables used in the four main regressions for the narrowed down sample of 81 countries from 1996 to 2014. The average CO_2 emissions across the sample are 1.387 tons per person and year, ranging from as low as 0.021 (Burundi in 2005) to as high as 8.28 (Iran in 2014). For CO_2 intensity, the average kg of CO_2 per USD of GDP in the sample is 0.213, with 0.031 (Republic of Congo in 2002) being the lowest and 1.245 (Republic of Moldova in 1996) being the highest. The share of renewable energy in overall electricity generation is somewhat close to 50% (0.447), however possessing a wide range, with several countries having a 0% or 100% share at some point in time. The average value for human capital is 2.017, ranging from 1.053

(Burkina Faso in 1996) to 3.411 (Belize in 2014). For the absolute values of the labor quantity and quality contribution to growth, while their averages are relatively moderate (59.04 and 26.95 respectively), they have very large ranges (from -549.27 (Serbia in 2010) to 906.82 (Algeria in 2004) for labor quantity, and from -661.78 (Colombia in 1996) to 409.61 (Colombia in 2006)) for labor quality) and thus one should be careful when interpreting their effects.

Table 1: Summary Statistics

Variable	Observations	Mean	St. Dev.	Min	Max
Dependent variables					
$CO_2\ pc_{it}$	1,529	1.3866	1.5905	0.0207	8.283
$CO_2/GDP\ pc_{it}$	1,528	0.2126	0.143	0.0308	1.2446
$\%\ renew_{it}$	1,539	0.4468	0.3559	0	1
Independent variables					
HC_{it}	1,539	2.0171	0.5386	1.0533	3.4112
$Labquan_{it}$	759	59.04	127.026	-549.272	906.822
$Labqual_{it}$	759	26.952	52.838	-661.778	409.606
Control variables					
$GDP\ pc_{it}$	1,539	5,616.972	4,473.864	173	21,683
Cap_{it}	759	95.014	298.726	-1,058.048	1,945.25
$Industry_{i}$	1,525	0.2787	0.1205	0.0253	0.848
Exp/imp_{it}	1,529	-0.0542	0.1474	-0.5431	0.9298
$FFPrice_{it}$	1,532	355.5836	175.7067	40.9411	1043.679
ΔPop_{it}	1,539	1.9353	1.1016	-3.1072	7.9179
ρPop_{it}	1,539	111.0478	153.5299	2.0728	1,224.593
Cor_{it}	1,539	-0.5845	0.5009	-1.7222	1.2167
Dem_{it}	1,526	2.4961	5.6827	-10	10
$Temp_{it}$	1,539	18.4582	8.8	-14.2793	29.2496

Tables 16 and 17 in appendix C show the means and standard deviations of all variables for the separate income groups and regions. For both CO_2 emissions and CO_2 intensity, the values increase when moving up the income group. Remarkably, the opposite is the case for the share of renewable electricity in overall electricity output, hinting that there might not be a clear-cut relation between the latter and the level of income. Human capital, labor quality and quantity contribution to growth, capital contribution to growth, and the share of industry all increase with increasing income groups. As for the different regions. East Asia and Pacific, Europe and Central Asia, and Middle East and North Africa have higher average levels of CO_2 emissions and intensity, Latin America and the Caribbean being somewhat of a middle ground, while

South Asia and Sub-Saharan Africa have lower levels. For the share of renewable energy in electricity, Europe and Central Asia, Latin America and the Caribbean, and Sub-Saharan Africa all have averages above 50%, whereas East Asia and the Pacific, and South Asia have an average below 50%, and the Middle East and North Africa only have an average of around 5.5%.

3.4 Results

The next sections review the results from regressions (1) to (4). It should be noted that the coefficients of the control variables are only reported for regression (1), thereafter being indicated as to whether they are applied or not in order to save space.

3.4.1 Testing the general hypothesis between Human capital and CO_2 emissions

While the long-run results are of main interest, it is helpful to assess the short-run results first. Table 2 below shows the results for testing H1a, applying no time lag. Human capital enters the regression in model 1 with the expected significant emissions-increasing effect (1.178, $p < 0.01$). However, this changes when adding the squared term of human capital into the regression, making both coefficients insignificant. These coefficients stay insignificant with the introduction of control variables (models 3-8), however the squared term does change to a negative sign in model 6. Moreover, upon entering GDP per capita into the equation, not only does it enter with a positive (CO_2 emission-increasing) sign and significantly, but further both human capital terms become significant now, if only at the 10% level. Furthermore, adding GDP per capita highly raises the overall statistic power of the model (from an R^2 of 0.177 to 0.49), showing how important it is to account for GDP per capita when one wants to investigate the level of CO_2 emissions in a country. Industry value added enters insignificantly and negatively into the equation. However, the sign becomes positive again when accounting for GDP. As for the controls, only the price of fossil fuels (negative and significant only when accounting for GDP) and the average temperatures in Winter (significant and negative across all full-sample regressions) seem to be important in determining CO_2 emissions in developing countries.

When using the low-income sample, human capital has a strongly significant and CO_2 emission-increasing effect, its squared term having a strongly significant and negative effect. For the lower-middle-income countries, neither of the two human capital coefficients show significant values. For the upper-middle-income countries, both human capital coefficients have weak significance (10% level) and the same signs as in the low-income sample.

Table 2: Results Regression (1), no lag

Model	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
Sample	full	full	full	full	full	full	full	full	full	full	full	low	lower	upper
HC_{it}	1.178***	1.056	1.161	1.027	0.948	1.296	1.416	1.489	2.039*	1.613	2.139*	2.077***	0.710	5.876*
	(0.318)	(1.076)	(1.079)	(1.377)	(1.398)	(1.607)	(1.630)	(1.626)	(1.199)	(1.618)	(1.189)	(0.584)	(0.995)	(3.198)
HC_{it}^2		0.0281	0.0023	0.0324	0.0474	-0.0190	-0.0345	-0.0450	-0.480*	-0.0685	-0.503**	-0.591***	-0.0906	-1.292*
		(0.251)	(0.250)	(0.283)	(0.287)	(0.318)	(0.321)	(0.320)	(0.244)	(0.317)	(0.242)	(0.145)	(0.244)	(0.645)
$GDP\ pc_{it}$									0.0003***		0.0003***	0.0001*	0.0001***	0.0003***
									(-0.0001)		(-0.0001)	(-0.0001)	(0)	(-0.0001)
$Industry_{it}$										-0.576	0.400	0.286***	0.151	0.342
										(0.424)	(0.330)	(0.0918)	(0.442)	(0.826)
Exp/imp_{it}			0.0616	0.0355	0.0236	0.0171	0.0108	0.0142	-0.0273	0.0626	-0.0295	0.0212	-0.0735	0.256
			(0.188)	(0.186)	(0.184)	(0.182)	(0.179)	(0.179)	(0.158)	(0.179)	(0.155)	(0.0777)	(0.153)	(0.620)
$FFPrice_{it}$				0.0001	0.0001	0.0001	0.0001	0.0001	-0.0003**	0.0001	-0.0003**	-0.0001	-0.0001	-0.0007*
				(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0001)	(0.0001)	(0.0002)	(0.0001)	(0)	(0.0001)	(0.0003)
ΔPop_{it}					-0.0418	-0.0454	-0.0383	-0.0389	-0.0342	-0.0538	-0.0398	0.0081	-0.0543	-0.0842
					(0.0396)	(0.0382)	(0.0364)	(0.0364)	(0.0248)	(0.0415)	(0.0289)	(0.005)	(0.0552)	(0.0664)
ρPop_{it}						-0.0015	-0.0016	-0.0016	-0.0011	-0.0018	-0.0011	-0.0002	-0.0001	-0.0070
						(0.0014)	(0.0014)	(0.0014)	(0.001)	(0.0014)	(0.001)	(0.0005)	(0.0006)	(0.0113)
Cor_{it}							0.0166	0.0162	-0.0749	0.0300	-0.0680	-0.0114	0.0953	-0.222
							(0.0982)	(0.0980)	(0.0693)	(0.101)	(0.0708)	(0.0473)	(0.0899)	(0.208)
Dem_{it}							-0.0121	-0.0121	-0.00371	-0.0116	-0.00254	-0.00120	0.00126	-0.006
							(0.0109)	(0.0109)	(0.00632)	(0.0107)	(0.0062)	(0.0014)	(0.00468)	(0.0111)
$Temp_{it}$								-0.0325*	-0.0307**	-0.0326*	-0.0325**	0.000747	-0.0348**	-0.0329
								(0.0183)	(0.0152)	(0.0187)	(0.0154)	(0.00323)	(0.0155)	(0.0335)
Constant	-0.984	-0.860	-0.949	-0.829	-0.649	-0.905	-1.048	-0.537	-1.220	-0.469	-1.398	-1.625***	0.0556	-5.597
n	1,529	1,529	1,519	1,512	1,512	1,512	1,509	1,509	1,509	1,499	1,499	445	586	468
R^2	0.152	0.152	0.149	0.162	0.165	0.168	0.174	0.177	0.490	0.184	0.499	0.301	0.530	0.562

*** p<0.01, ** p<0.05, * p<0.1, standard errors in parentheses. ‘Low’ indicates low-, ‘lower’ indicates lower-middle, and ‘upper’ indicates upper-middle-income sample

The key takeaway point of this first regression seems to be that the level of human capital only matters for CO_2 emissions when accounting for the different levels of GDP per capita. As for human capital itself, in the full sample the short-run effect appears to be CO_2 emissions increasing (this however only being weakly significant), while there is some statistical evidence of a decreasing effect at higher levels of human capital. However, this only holds strongly for low-income countries and weakly for upper-middle-income countries. Thus, the findings give the impression that in the lower-middle-income stage of development, human capital may not play a critical role in influencing how much CO_2 is emitted per person in the short-run.

The finding that there seems to be a non-linear relationship between human capital and CO_2 emissions, with the squared term indicating a turning point at higher levels of human capital, at least for low and upper-middle-income countries, requires some further investigation. Hence, table 3 shows a re-run of models 11, 12, 13, and 14 from Regression (1), while lagging human capital five, ten, and twenty years backward respectively. The values of the variables now take the form of five-, ten-, or twenty-year period averages. Lagging human capital five years behind gives it a significant emission-decreasing effect in the low and upper-middle-income sample, having a weakly significant positive effect in the lower-middle-income sample. For the ten-year lag, only the low-income sample shows a weakly significant effect, which stays negative[8]. This remains consistent for the twenty-year lag, where furthermore the lower-middle-income sample shows a significant and negative effect, while the upper-middle-income sample shows a significant and positive effect of education on CO_2 emissions

In sum, the results are not entirely straight forward to interpret. First, the only consistent finding here is that for the low-income sample, gains in human capital increase emissions in the short-run while decreasing them in the long-run. For the lower-middle-income sample, there seems to be no short-run effect of human capital, while in the long-run, the effect appears to depend on the length of the time lag. When lagging for five years, gains in human capital seem to lead to increases in CO_2 emissions, while this is reversed when lagging for twenty years. The opposite appears to apply for upper-middle-income countries. Thus, one may carefully conclude that how human capital drives CO_2 emissions depends on the level of income and time period specified. For the poorest countries in the world, gains in education may lead to initial increases in CO_2 emissions but can work to drive those down from as early as five years afterward. For lower-middle-income countries, it seems that gains in education take more time

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[8] Interestingly this is the only case across all models where GDP per capita is significant and negative.

Table 3: Results Regression (1), five-, ten-, and twenty-year lag

Lag	5-years	10-years	20 years	5-years	10-years	20 years	5-years	10-years	20 years	5-years	10-years	20 years
Model	(11)	(11)	(11)	(12)	(12)	(12)	(13)	(13)	(13)	(14)	(14)	(14)
Sample	full	full	full	low	low	low	lower	lower	lower	upper	upper	upper
HC_{it-1}	-0.469	0.627	-0.141	-0.511**	-0.509*	-0.608*	0.585*	0.473	-0.551**	-0.854**	-2.130	2.800**
	(0.332)	(0.543)	(0.456)	(0.237)	(0.283)	(0.287)	(0.293)	(0.316)	(0.258)	(0.408)	(1.253)	(0.963)
$GDP\ pc_{it}$	0.0003***	0.000134**	0.000185***	0.0001*	-0.000128*	0.000453***	0.0002***	0.000160***	0.000212***	0.0004***	0.000146*	0.000195***
	(0.0001)	(0.00001)	(0.0001)	(0)	(0.000001)	(0.000132)	(0)	(0.000001)	(0.0001)	(0.0001)	(0.00001)	(0.0001)
$Industry_{it}$	0.560*	0.633	0.992	0.526	1.694***	-1.918	0.288	0.337	1.064	2.287**	-2.266	-8.739*
	(0.296)	(0.696)	(1.833)	(0.328)	(0.549)	(1.368)	(0.279)	(0.476)	(1.385)	(1.004)	(2.171)	(4.231)
Exp/imp_{it}	0.202	1.583*	0.689	0.176	0.654	2.018	-0.395	-1.167**	-0.270	0.544	5.202**	10.57***
	(0.299)	(0.887)	(1.395)	(0.141)	(0.545)	(2.217)	(0.254)	(0.502)	(0.826)	(0.800)	(2.017)	(3.498)
$FFPrice_{it}$	0.000473*	0.000886**	0.000549	0.000351***	0.000293*	-0.00325**	-0.000144	0.00001	0.00184**	0.00138**	0.00569***	0.0177***
	(0.000248)	(0.000435)	(0.00174)	(0.000120)	(0.000153)	(0.00129)	(0.000172)	(0.000233)	(0.000815)	(0.000641)	(0.00180)	(0.00518)
ΔPop_{it}	0.0274	-0.0362	-0.451**	0.0795**	0.0136	-0.124	-0.0666	-0.0323	-0.240	-0.0254	0.210	-0.394
	(0.0587)	(0.0929)	(0.188)	(0.0320)	(0.0332)	(0.198)	(0.0493)	(0.116)	(0.161)	(0.105)	(0.222)	(0.294)
ρPop_{it}	-0.00106	-0.00222	-0.0001	0.000356	0.000329	-0.000291	-0.000243	-0.000351	-0.0001	-0.0233**	-0.0154	0.0148***
	(0.000723)	(0.00136)	(0.000399)	(0.000606)	(0.000870)	(0.000818)	(0.000449)	(0.000763)	(0.000327)	(0.0109)	(0.0211)	(0.00482)
Cor_{it}	0.0677	0.153	0.898**	0.137*	0.0241	0.188	0.0304	-0.0750	0.531**	-0.294	-0.675	2.139***
	(0.0833)	(0.190)	(0.380)	(0.0689)	(0.0778)	(0.190)	(0.106)	(0.194)	(0.237)	(0.420)	(0.896)	(0.688)
Dem_{it}	0.00183	-0.0215	-0.0142	-0.00442	-0.00649	-0.0206	-0.0001	0.00121	0.0179	0.0241	-0.0201	-0.0325
	(0.00901)	(0.0154)	(0.0236)	(0.00487)	(0.00904)	(0.0216)	(0.00726)	(0.0136)	(0.0168)	(0.0336)	(0.0676)	(0.0380)
$Temp_{it}$	-0.146	-0.667**	-0.0289	-0.0699**	0.0832	-0.0218	-0.0505	-0.0926	-0.0215*	-0.156	-2.353**	-0.0679**
	(0.115)	(0.310)	(0.0209)	(0.0321)	(0.0985)	(0.0139)	(0.0470)	(0.0978)	(0.0108)	(0.350)	(0.947)	(0.0283)
Constant	3.416	12.21**	2.306	2.010**	-0.856	3.030**	0.273	1.160	1.269*	4.504	45.00**	-4.138
n	318	160	81	94	48	24	124	62	31	100	50	26
R^2	0.499	0.463	0.646	0.508	0.630	0.852	0.745	0.795	0.778	0.556	0.730	0.792

*** p<0.01, ** p<0.05, * p<0.1, standard errors in parentheses. ‘Low’ indicates low-, ‘lower’ indicates lower-middle, and ‘upper’ indicates upper-middle-income sample.

to manifest in increasing CO_2 emissions, while in the very long-run of twenty years, they may further act to decrease them. For the richest developing countries however, CO_2 emissions appear to increase in the short- and very-long-run, only showing decreases for a specific time lag.

As for the other variables, GDP per capita is the only one with a consistent significant emission-increasing effect (though with one exception). This consistency indicates that there is likely a relationship between a developing country's level of income and its level of CO_2 emission. Furthermore, there is some evidence that a higher share of industry in overall value added is indicative of higher CO_2 emissions, yet this is only significant in some cases and not consistent for any sample or time period. Increases in fossil fuel prices seem to decrease CO_2 emissions in the short-run, but in the long-run they lead to increases in most of the models. The amount of exports relative to imports seem to matter only in the long-run (ten-years onwards) and the coefficients are of differing signs depending on the sample.

One thing to keep in mind, however, is that the regression applying a twenty-year lag is effectively a cross-country regression with one averaged observation per country. This means that time trends may highly influence the results, while unobservable variables that could have an effect on CO_2 emissions are not controlled for. Hence, perhaps the finding that the signs of human capital for both lower-middle and upper-middle-income countries are the opposite in the 20-year lag regression compared to the 5-year lag regression is solely due to the former being a simple OLS- and the latter a fixed-effects regression. However, at least for low-income countries, the long-run effect is consistently significant and negative, showing that there is likely a long-run effect at least for a certain group of countries. Adding that for the full, low-, and upper-middle-income sample, the short-run effect of human capital is CO_2 emission-increasing, one may accept a specification of H1a, of the general effect of education increasing CO_2 emissions through growth for the short-run, while adding that this is dependent on the level of income in a country and that for low-income countries the long-run effect is emission decreasing. However, a consistent general long-run effect of education increasing or decreasing CO_2 emissions could not be found.

3.4.2 Human capital's effect on CO_2 through growth

The short-run results for regression (2) are reported in table 4. Both labor quantity and quality enter insignificantly into the regression, labor quantity negatively and labor quality positively. However, the latter becomes significant upon adding the squared terms in model 2 (0.0005, $p < 0.05$), whereas labor quantity now becomes positive while staying insignificant. Although the coefficient here seems small, one should be reminded that this is the effect of one dollar of growth caused by labor quality on CO_2 emissions. For example, if labor quality contributed to a growth of 20$ in GDP per capita in a year, then, given the coefficient of 0.0005, this would lead to a growth of 0.01 metric tons of CO_2 emissions per capita.

Model 3 controls for the initial level of CO2 emissions and all the other controls, however both the normal terms for labor quantity and quality do not change, whereas the squared terms now become weakly significant (labor quantity² with -0.0000001, $p < 0.10$ and labor quality² with -0.0000002, $p < 0.10$). Labor quantity only becomes weakly significant (0.000195, $p<0.10$) when accounting for the rest of the growth in the corresponding country and year, which itself is also positive and significant. Simultaneously, the squared terms of both labor quantity and quality now become insignificant.

Table 4: Results Regression (2), no lag

Model	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Sample	full	full	full	full	low	lower	upper
$Labquan_{it}$	-0.00001	0.00001	0.000114	0.000195*	-0.00113	0.00001	0.000214*
	(0.000224)	(0.000184)	(0.000125)	(0.000105)	(0.000955)	(0.00001)	(0.000117)
$Labquan_{it}^2$		-0.0000001	-0.0000001*	-0.00000001	0.00001**	0.00000001	-0.0000004*
		(0.0000001)	(0.00000002)	(0.00000002)	(0.000001)	(0.00000002)	(0.00000002)
$Labqual_{it}$	0.000122	0.000471**	0.000346*	0.000628***	0.00120	0.000449	0.000712**
	(0.000215)	(0.000217)	(0.000204)	(0.000207)	(0.000787)	(0.000319)	(0.000256)
$Labqual_{it}^2$		-0.0000003	-0.0000002*	-0.0000001	-0.00022**	-0.0000005	-0.0000001
		(0.0000001)	(0.0000001)	(0.0000001)	(0.00001)	(0.000001)	(0.0000001)
Cap_{it}				0.000254***	-0.000001	0.000224***	0.000267***
				(0.00001)	(0.000187)	(0.00001)	(0.00001)
$CO_2\ pc_{it-1}$			-0.0679	-0.0731**	-0.468**	-0.187***	-0.0541*
			(0.0420)	(0.0358)	(0.174)	(0.0378)	(0.0301)
$\Delta Industry_{it}$			-0.455	-0.644*	-0.355	-0.0780	-1.449***
			(0.400)	(0.369)	(0.253)	(0.633)	(0.183)
Controls applied?	No	No	Yes	Yes	Yes	Yes	Yes
Constant	0.0404**	0.0429**	0.266**	0.155	0.202**	0.230***	0.258
n	730	730	705	705	126	283	296
R^2	0.001	0.013	0.066	0.175	0.341	0.260	0.231

*** $p<0.01$, ** $p<0.05$, * $p<0.1$, standard errors in parentheses. ‘Low’ indicates low-, ‘lower’ indicates lower-middle, and ‘upper’ indicates upper-middle-income sample.

Both labor quantity and quality, when significant, have positive values, indicating that growth through improvements in the labor force leads to growth in CO_2 emissions in the short-run.

While the squared terms are significant and negative in model 3, a possible long-run decreasing effect seems to be dependent on whether the rest of the growth is accounted for or not.

However, the picture is a very different one when splitting the sample into the three income groups. Here, labor quantity and quality seem to only be CO$_2$ emission increasing for the upper-middle-income sample. Furthermore, the squared term of labor quantity is significant and positive for the low-income sample, and significant and negative in the upper-middle-income sample, while the squared term for labor quality is only significant and negative for the low-income sample. Furthermore, capital contribution to growth is consistently significant in increasing CO$_2$ emissions, aside from the low-income sample. Moreover, it seems that the higher the initial level of CO$_2$ the lower the increases of CO$_2$ in the next year.

Overall, one may interpret the results as to be giving some evidence that growth through labor quantity and quality improvements leads to growth in CO$_2$ emissions in the short-run, but only in upper-middle-income countries. However, the long-run effect is ambiguous, as for the low-income coefficient, the squared term here for labor quantity is positive and significant and for labor quality it is negative and significant, whereas for the upper-middle-income sample only the squared term of the labor quantity coefficient is significant and negative, all other coefficients being insignificant. Hence, I apply a five-year lag to both labor quantity and quality for further investigation, reported in table 5.

Table 5: Results Regression (2), five-year lag

Model	(1)	(3)	(4)	(5)	(6)	(7)
Sample	full	full	full	low	low	upper
$Labquan_{it-1}$	0.000160	-0.000252	-0.000382	0.000002	0.000813	-0.00104
	(0.000588)	(0.000968)	(0.00103)	(0.00180)	(0.000654)	(0.00216)
$Labqual_{it-1}$	0.00001	0.000002	0.0000001	-0.000725	-0.000397	0.000110
	(0.000306)	(0.000315)	(0.000307)	(0.00173)	(0.000264)	(0.000474)
Cap_{it}			-0.000156	-0.000539	-0.00001	-0.000179
			(0.000140)	(0.000662)	(0.000246)	(0.000279)
$\Delta Industry_{it}$		-0.167	-0.151	-4.588	0.117	0.238
		(0.145)	(0.146)	(2.434)	(0.748)	(0.893)
$CO2\ pc_{it-1}$		0.0217	0.0431	-0.207	-0.0163	0.0561
		(0.0454)	(0.0581)	(0.154)	(0.0679)	(0.0647)
Controls?	No	No	Yes	Yes	Yes	Yes
Constant	0.0433**	-0.0581	-0.0782	-0.232	0.190*	-0.322
n	116	113	113	21	45	47
R^2	0.001	0.059	0.066	0.976	0.381	0.114

*** $p<0.01$, ** $p<0.05$, * $p<0.1$, standard errors in parentheses. ‘Low’ indicates low-, ‘lower’ indicates lower-middle, and ‘upper’ indicates upper-middle-income sample.

However, when I apply this lag it does turn all observations of labor quantity and quality insignificant. It seems thus that in a five-year long-run perspective, growth through labor quality and quantity does not lead to a significant change in CO_2 emissions. Therefore overall, I reject H1b of the direct effect of education-induced growth on emissions, with the exception of upper-middle-income countries in the short-run. I do not apply further time lags as growth itself arguably does not take as much time to affect CO_2 emissions as does education.

3.4.3 Human capital and CO_2 intensity

So far, evidence points to there being possible links from education to CO_2 emissions, however these are very circumstantial in nature. The next step is to test whether human capital can influence the CO_2 emission intensity of GDP per capita. I test this in regression (3) and report the results in table 6 below.

Table 6: Results Regression (3), no lag

Model	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Sample	full	full	full	full	full	full	low	lower	upper
HC_{it}	-0.0733**	0.339**	0.506**	0.492**	0.538***	0.526***	0.826**	0.595*	0.462
	(0.0308)	(0.166)	(0.197)	(0.191)	(0.188)	(0.184)	(0.355)	(0.326)	(0.278)
HC_{it}^2		-0.0948**	-0.118**	-0.107**	-0.124***	-0.114***	-0.214**	-0.131	-0.0936*
		(0.0414)	(0.0452)	(0.0441)	(0.0435)	(0.0428)	(0.0830)	(0.0821)	(0.0545)
GDP pc_{it}				-0.000001		-0.000001	-0.000004	-0.0000003	-0.000001
				(0.0000004)		(0.0000004)	(0.000002)	(0.000001)	(0.000001)
$Industry_{it}$					0.139**	0.118*	0.129**	0.195	0.103
					(0.0575)	(0.0643)	(0.0469)	(0.156)	(0.116)
Controls?	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Constant	0.360***	-0.0580	-0.205	-0.188	-0.254	-0.234	-0.556*	-0.196	-0.157
n	1,528	1,528	1,508	1,508	1,498	1,498	445	585	468
R^2	0.037	0.085	0.111	0.123	0.139	0.149	0.162	0.163	0.252

*** p<0.01, ** p<0.05, * p<0.1, standard errors in parentheses. ‘Low’ indicates low-, ‘lower’ indicates lower-middle, and ‘upper’ indicates upper-middle-income sample.

Human capital enters model 1 with a negative and significant coefficient (-0.073, $p < 0.05$). However, this coefficient becomes positive upon adding the squared term, indicating that the direction of the effect may be different between the short- and the long-run. This effect holds when introducing all the controls into the sample. Nevertheless, when I split the sample into the different income groups, this effect only holds for the low-income sample. For the lower-middle-income sample, only the standard term is significant and positive, whereas for the upper-middle-income sample only the squared term is significant and negative. Hence, the initial conclusion is that human capital gains lead to increases in CO_2 emission intensity in the short-run in low and lower-middle-income countries, and to decreases in the long-run in low and upper-middle-income countries. However, this long-run effect requires some further investigation.

The long-run results (table 7), with lagging human capital for five, ten, and twenty years do not give much conclusive evidence. None of the coefficients for human capital show consistency and only the upper-middle-income sample has a coefficient that is significant and positive for more than one of the lags (five- and twenty-years). The full sample here only shows a significant effect for human capital in the ten-year lag period, and the low and lower-middle-income samples do not show any significance for any lag. To conclude, the short-run effects seem to be relatively clear, with gains in human capital leading to increases in the intensity of CO_2 emissions at least for the low and lower-middle-income sample. However, the long-run effect's interpretation is problematic. While the standard regression shows a decreasing effect of the squared term for low and upper-middle-income countries, this seems not to be manifested in a five-, ten-, or twenty-year lag regression, the only significant result being that of an increasing effect in upper-middle-income countries in the five- and twenty-year lag. Furthermore, for the full sample, it seems that only the ten-year lag is significantly negative, indicating that the effect of human capital on CO_2 intensity may be dependent on a very specific time period to hold.

Thus, while largely leading to increases in the short-run, the effect of human capital on the intensity of CO_2 emissions in the long-run is inconsistent across samples and length of lags, making it impossible to generalize. It may be that the reducing effect for low and lower-middle-income countries occurs at a point that is beyond the length of the lag that I apply this analysis. However, testing for that is out of the scope of this paper and, given current data availability, almost impossible. Thus, H2a of the effect of education on CO_2 emission intensity is rejected.

Table 7: Results Regression (3), five-, ten-, and twenty-year lag

Model	(6)	(7)	(8)	(9)
Sample	full	low	lower	upper
Lag	5-years	5-years	5-years	5-years
HC_{it-1}	0.0175	-0.126	-0.0392	0.0775***
	(0.0578)	(0.0754)	(0.0731)	(0.0149)
$GDP\ pc_{it}$	0.0000002	0.000002	0.0000005	0.000001**
	(0.000003)	(0.000001)	(0.0000005)	(0.0000003)
$Industry_{it}$	0.161**	0.225*	0.135	0.300*
	(0.0731)	(0.119)	(0.0914)	(0.147)
Controls?	Yes	Yes	Yes	Yes
Constant	0.0175	-0.126	-0.0392	0.0775***
n	318	94	124	100
R^2	0.499	0.508	0.745	0.556
Lag	10-years	10-years	10-years	10-years
HC_{it-1}	-0.104***	0.00730	0.00790	0.175
	(0.0355)	(0.128)	(0.0639)	(0.142)
$GDP\ pc_{it}$	0.000001**	-0.000002	0.000001	0.000001**
	(0.0000003)	(0.000002)	(0.000001)	(0.000005)
$Industry_{it}$	0.194	0.507**	-0.0475	0.506***
	(0.139)	(0.201)	(0.187)	(0.160)
Controls?	Yes	Yes	Yes	Yes
Constant	0.0111	-1.271	0.237	-1.080
n	160	48	62	50
R^2	0.303	0.524	0.160	0.768
Lag	20 years	20 years	20 years	20 years
HC_i	-0.00643	-0.0634	-0.0782	0.246***
	(0.0480)	(0.0807)	(0.0458)	(0.0690)
$GDP\ pc_i$	0.0000004	0.00001	-0.00001	0.0000002
	(0.0000005)	(0.000004)	(0.000002)	(0.000001)
$Industry_i$	0.373	0.191	0.272	-0.107
	(0.248)	(0.487)	(0.359)	(0.381)
Controls?	Yes	Yes	Yes	Yes
Constant	0.292	0.452	0.640***	-0.239
n	81	24	31	26
R^2	0.439	0.647	0.695	0.833

*** $p<0.01$, ** $p<0.05$, * $p<0.1$, standard errors in parentheses. 'Low' indicates low-, 'lower' indicates lower-middle, and 'upper' indicates upper-middle-income sample.

3.4.4 Human capital and the share of renewable energy in overall electricity output

The last regression, regression (4), tests the theory of increased technological leapfrogging as a consequence of gains in education, which then should lead towards cleaner technology being used in a country. The first test of this was regression (3), but a second test would be to simply assess whether gains in education led to an increased usage of renewable technologies, potentially through leapfrogging. I use renewable electricity output (the share of electricity generated by renewable power plants) as an, arguably imperfect, indicator here.

The results, reported in table 8, show human capital to have no significant effect across any model specification aside from the upper-income sample, where it seems that the short-run effect of human capital is renewable energy share-increasing, whereas the squared term shows a decreasing effect. As for the long-run effects, reported in table 9, the majority of them are insignificant, aside from the decreasing effect in the upper-middle-income sample in the very long-run (twenty years). Overall, these results show that there is not much of a link between gains in human capital and increases in the share of renewables in energy output, neither in the short- nor the long-run. Thus H2b, of education affecting the share of renewable energy in electricity generation is rejected.

Table 8: Results Regression (4), no lag

Model	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Sample	full	full	full	full	full	full	low	lower	upper
HC_{it}	0.0194	-0.0707	0.142	0.132	0.138	0.128	-1.345	0.116	0.866***
	(0.112)	(0.134)	(0.140)	(0.138)	(0.141)	(0.140)	(1.245)	(0.145)	(0.224)
HC^2_{it}		2.678	-1.526	-1.319	-1.528	-1.371	7.192	1.569	-11.72**
		(2.696)	(2.334)	(2.246)	(2.405)	(2.317)	(20.94)	(2.717)	(4.461)
$GDP\ pc_{it}$				-0.000001*		-0.000001*	-0.0002**	-0.000001	-0.000001
				(0.000001)		(0.000001)	(0.00001)	(0.000002)	(0.000001)
$Industry_{it}$					0.125**	0.126**	0.215*	0.0436	0.142
					(0.0562)	(0.0572)	(0.105)	(0.0570)	(0.171)
$\%\ renew_{it-1}$			-0.210***	-0.211***	-0.210***	-0.211***	-0.184***	-0.216***	-0.329***
			(0.0308)	(0.0308)	(0.0307)	(0.0307)	(0.0292)	(0.0665)	(0.0451)
Controls?	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Constant	-0.0035	-0.0034	0.095***	0.096***	0.093***	0.095***	0.15***	0.103***	0.118***
Observations	1,436	1,436	1,345	1,345	1,336	1,336	358	551	427
R-squared	0.000	0.000	0.108	0.110	0.111	0.113	0.151	0.113	0.185

*** p<0.01, ** p<0.05, * p<0.1, standard errors in parentheses. ‘Low’ indicates low-, ‘lower’ indicates lower-middle, and ‘upper’ indicates upper-middle-income sample

Table 9: Results Regression (4), five-, ten- and twenty-year lag

Model	(6)	(7)	(8)	(9)
Sample	full	low	lower	upper
Lag	5-years	5-years	5-years	5-years
HC_{it-1}	0.0309	-0.210	0.110	0.0963
	(0.124)	(0.568)	(0.209)	(0.129)
$GDP\ pc_{it}$	-0.000001*	-0.000173**	0.000001	-0.000001
	(0.000001)	(0.000001)	(2.63e-05)	(0.000001)
$Industry_{it}$	0.0377	0.467	0.134	-0.171*
	(0.0998)	(0.298)	(0.133)	(0.0886)
$\%\ renew_{it-1}$	-0.0545***	-0.0676**	-0.0272	-0.0213
	(0.0170)	(0.0294)	(0.0383)	(0.0269)
Controls?	Yes	Yes	Yes	Yes
Constant	0.0305***	0.0368	0.0369	-0.00529
n	296	81	120	95
R-squared	0.065	0.143	0.175	0.140
Lag	10-years	10-years	10-years	10-years
HC_{it-1}	-0.131	-1.421	-0.285	-0.775
	(0.362)	(0.840)	(0.532)	(0.485)
$GDP\ pc_{it}$	0.000001	0.00001	-0.000001	-0.000002
	(0.000001)	(0.00001)	(0.00001)	(0.000002)
$Industry_{it}$	-0.321	-1.017***	0.361	-0.223
	(0.313)	(0.222)	(0.572)	(0.362)
$\%\ renew_{it-1}$	-0.0168	-0.0249*	-0.0486	-0.0801
	(0.0222)	(0.0135)	(0.0483)	(0.0619)
Controls?	Yes	Yes	Yes	Yes
Constant	0.0245	0.0661***	0.110**	0.0616
n	150	41	60	49
R-squared	0.140	0.697	0.417	0.207
Lag	20 years	20 years	20 years	20 years
HC_{i}	-0.0901	0.607	-0.447	-0.484**
	(0.149)	(0.369)	(0.289)	(0.194)
$GDP\ pc_{i}$	-0.000001	-0.000342**	0.0000003	-0.0000001
	(0.000001)	(0.000146)	(0)	(0.0000001)
$Industry_{i}$	-0.0870	-0.163	-0.130	-0.451
	(0.238)	(0.868)	(0.336)	(0.357)
$\%\ renew_{i-1}$	-0.00426	0.00912	-0.00239	-0.0139*
	(0.00315)	(0.0117)	(0.00861)	(0.00643)
Controls?	Yes	Yes	Yes	Yes
Constant	-0.000791	-0.0208	-0.0104	0.00742
n	74	21	29	24
R-squared	0.231	0.789	0.394	0.501

*** p<0.01, ** p<0.05, * p<0.1, standard errors in parentheses. ‘Low’ indicates low-, ‘lower’ indicates lower-middle, and ‘upper’ indicates upper-middle-income sample.

3.4.5 Overall findings

Table 10 sums up the general findings on the four hypotheses, differentiated by sample used and short-run versus long-run view. Overall, findings only support a few of the hypothesized links. For the general relationship between education and CO_2 emissions in developing countries, the results are showing that at least for the short-run, gains in human capital seem to lead to increases in CO_2 emissions, whereas for the long-run, the effects are largely inconsistent, only low-income countries showing a decline across all lag lengths, which goes against expectations. For the hypothesis concerning the more direct effect of education on growth and thus CO_2 emissions, the evidence here only points to that notion holding for upper-middle-income countries, while no long-run effect is found, which may also be due to problems in the data itself. For testing the effect of gains in human capital on CO_2 intensity in GDP, it seems that in the short-run for low and lower-middle-income countries, the effect is emission intensity-increasing, whereas, for the long-run, only the upper-middle-income country sample shows an effect that is however inconsistent. Lastly, no relationship was found between education and the share of renewable electricity, with the exception of upper-middle-income countries actually having a decrease in renewable electricity through gains in human capital in the very long-run.

Table 10: Overview of hypotheses acceptations and rejections.

Hypothesis	**Sample**	**Short-run**	**Long-run**
H1a: Education increasing CO_2	full	accepted	rejected (no effect)
	low	accepted	rejected (opposite effect)
	lower-middle	rejected (no effect)	rejected (inconsistent effect)
	upper-middle	accepted	rejected (inconsistent effect)
H1b: Education increasing CO_2 through growth	full	accepted	rejected (no effect)
	low	rejected (no effect)	rejected (no effect)
	lower-middle	rejected (no effect)	rejected (no effect)
	upper-middle	accepted	rejected (no effect)
H2a: Education decreasing CO_2 intensity	full	rejected (opposite effect)	rejected (limited to ten-year lag)
	low	rejected (opposite effect)	rejected (no effect)
	lower-middle	rejected (opposite effect)	rejected (no effect)
	upper-middle	rejected (no effect)	rejected (opposite effect)
H2b: Education increasing the share of renewables in electricity generation	full	rejected (no effect)	rejected (no effect)
	low	rejected (no effect)	rejected (no effect)
	lower-middle	rejected (no effect)	rejected (no effect)
	upper-middle	accepted	rejected (opposite effect)

4 Discussion

When reviewing the results of regressions (1) to (4), it is not possible to confidently draw many decisive conclusions on the relationship between human capital and CO_2 emissions in developing countries. One finding that is largely consistent across tests however, is that both CO_2 emissions per capita and the intensity of CO_2 in GDP are positively related with human capital in the short-run in developing countries. This seems to fall in line with the theory revolving around the ‘pollution-income relationship’ and models like the ‘Environmental Kuznets Curve’, if one sees human capital as an indicator of development, signaling higher income and thus resource use, which leads to higher pollution. The found relationship holds even when controlling for GDP per capita and various other controls, and largely applies to at least two different income groups for each CO_2 indicator (low- and upper-middle-income countries for CO_2 emissions, and low- and lower-middle-income countries for CO_2 emission intensity). Hence these findings imply that higher education can itself drive CO_2 emissions in developing countries, even when holding the level of income and other factors constant, which is somewhat in line with the findings O’Neill et al. (2018) arrive at. Interesting here is that lower-middle-income countries seem not to be affected by education with regard to their emission level. This may solely imply that at this stage of development, other factors like GDP itself, as well as potentially factors that drive industrialization are more important in determining the level of CO_2 emissions than education. Furthermore, this is the only group of countries that are affected by the temperature variable, implying that in this stage of development, climate conditions could potentially play a more crucial role than factors like education in affecting overall energy usage and therefore emission levels.

However, one should be cautious with taking these results at face-value, as human capital and GDP per capita, as well as GDP per capita and industry value added, are variables that are highly correlated with each other, meaning that potentially the effect attributed to human capital may in fact ultimately stem from the effect of income. Given the literature’s strong assertion of education and GDP driving each other, determining which of the two factors increases CO_2 emissions more significantly proves to be a difficult task. At least when putting GDP in the denominator, assessing the intensity of CO_2 in GDP, human capital seems to be the more determinant force than the level of GDP itself, indicating that at the same level of income, countries with higher levels of education have higher average levels of CO_2 emissions than less educated ones. Nonetheless, future research is required to fully distinguish between those two factors in the determination of CO_2 emissions.

With regard to the long-run effect of human capital on CO_2 emissions, the results prevent any confident conclusion. The findings for both absolute CO_2 emissions and intensity are largely insignificant, inconsistent, or in the case of upper-middle-income countries in the intensity regression, of opposite sign than expected. The only consistent effect shown comes from gains in human capital decreasing average CO_2 emissions in low-income countries in the long-run, but even here the results are only weakly significant. The implication could be that since child labor is relatively higher in low-income countries (IPEC, 2013), education works to reduce emissions in the long-run, as it takes these children out of the labor force. This would mean that overall production decreases for a certain time period, leading to decreased resource use and thus CO_2 emissions. The expected increase in emissions then stemming from the effect of these children becoming more educated, potentially attaining better jobs, increasing both overall economic output and their individual consumption, and therefore overall resource use may potentially just lie outside of the 20-year time perspective.

However, overall a general and consistent long-run decreasing effect of education on CO_2 emissions for developing countries could not be found. While the results for the squared term of human capital largely do show a decrease across most income groups, consistent with similar analyses of the EKC with regard to growth and CO_2 emissions, it seems that the chosen time intervals do not confirm this. An interpretation of this finding could be that education does lead to a decrease in CO_2 emissions and emission intensity, however for the effect to manifest itself it may take way more than the 20 years applied in this analysis. This could be due to education taking time at the start of development to ‘create’ a stock of educated population in poorer countries which would make decisions that affect CO_2 emissions.

Another interpretation could be that education has the potential to both increase or decrease CO_2 emissions in developing countries, but that that effect depends on the country’s level of income as well as on the time period under investigation. A relationship like the EKC, showing an inverted u-shape, however, has to initially be rejected. Rather, one should see education as giving countries the possibility to reduce their CO_2 emissions in the long-run, but only if the right conditions are in place.

Furthermore, as noted in the conceptual framework of the relationship between education and CO_2 emissions, and supported by Barro (1991) and Barro and Lee (1994) among others, education can affect both changes in fertility and mortality. If, for example, education led to a decrease in fertility and thus less population growth while not affecting CO_2 itself, then this would ceteris paribus actually lead to higher CO_2 emissions per capita, as now fewer people produce the same amount of CO_2 emissions as before. Lastly, the effects of education may just disseminate across a multitude of channels making it impossible to capture a direct effect in the long-run.

When two of these channels were tested directly, however, significant results could not be found. Regarding the growth channel, while some short-run results show a relationship, this does not hold for most income groups or for the long-run. A finding like this stands in contrast to a simple association between the ‘pollution-income relationship’ and the hypothesis of human capital being beneficial for growth. It may be that, while both theorems technically hold, one cannot draw a simple connection between them. Yet, the method of simply applying growth rates of labor quantity and quality to overall GDP per capita growth may be insufficient in truly showing how much growth was caused by improvements in the labor force, let alone improvements in education. Furthermore, the underlying values of labor quantity and quality contribution to growth fluctuate highly[9] and are based on many assumptions and extrapolations, making their results less reliable. Perhaps an improved indicator of this channel would show stronger results. Until then, this imperfect method of the ‘education causing CO_2 emissions through growth’ channel shows that there is not much of a relationship in place.

Moreover, for the technology channel, the change in the share of renewable energy in overall electricity was taken as a proxy for technological leapfrogging towards cleaner energy. Results were largely insignificant, which goes against the potential relationship of education fostering the adoption of cleaner technologies through energy leapfrogging. While these results are somewhat disappointing, it may simply be that instead of specifically fostering the adoption of technologies related to renewable energy, education instead generally increases the speed at which new technologies are being adopted. New technologies are not always those utilizing renewable energy and may instead simply be more energy saving than older technologies. While this relationship is certainly possible, it could not be tested in this research and is furthermore not reflected in the results of the CO_2 emission intensity regression. Hence, although the potential of the relationship between education and technological leapfrogging that reduces CO_2 emissions is still in place, evidence for education at least driving up the share of renewable technologies used could not be found.

Lastly, it is crucial to stress that in the end, the problem of global warming following increased CO_2 emissions is of global scope, both in its causes and consequences. This means that while this thesis stresses the national perspective, it is undeniable that one should not solely

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[9] See the summary statistics section

focus on individual countries in this matter, as their overall contribution is minuscule in most cases and in the end, the whole world is affected by climate change.

4.1 Further limitations and suggestions for future research

The analysis of the association between education and CO_2 emissions in developing countries has several limitations, which could be addressed in future research concerned with this topic.

With regard to the developed framework, future research could explore the channels between education and CO_2 emissions further. For example, one could make the argument that education drives political change, which in turn affects the level of pollution for example through increased environmental regulations. On the other hand, one could also contest some of the proposed links, for example assessing that structural change is mainly driven by economic growth and change-inducing policies rather than education itself. As this framework is new, it will likely require a lot of nuances and academic assessment in the future.

As for the analysis of this framework, fixed-effects regressions were used to generally assess the first two channels, of growth and technology. This analysis can be improved. A first issue is that of data, with human capital being an imperfect indicator of the quality of education. Next to the previously mentioned problem identified by Lee and Lee (2016), the data also does not give any information on the type of education. Murphy et al. (1991) show that this matters for an economy. According to them, the share of college enrollment in engineering, standing as a proxy for productive activities, is positively related to growth, whereas the share of college enrollment in law, standing as a proxy for rent-seeking activities, is unrelated or negatively related to growth. If one were therefore to assume that the type of education is important for growth, and growth itself drives CO_2 emissions, then this would be important to consider in any analysis of the effects of education on CO_2 emissions. However, while college enrollment data is available by the UNESCO (2019), this data is very incomplete, especially for developing countries.

A better indicator of human capital may be able to provide more conclusive results or at the very least, make the results drawn from such an analysis more valid. Furthermore, the currently available data does not allow for a very long time lag to be applied. Potentially taking a longer time lag could give better results, however, the further one goes to the past, the more assumptions about the data would have to be drawn. Future research could try to extrapolate the human capital variable further to the past, while also improving the measure (for example including the different occupations). With a longer time lag of human capital, the effects on

CO_2 emissions may be more visible and one would not have to draw on pure cross-country regressions.

Another problem in the analysis is the association between human capital and GDP per capita which may bias the results as either indicator could take away the predictive power of the other on the dependent variable. Future research could deal with this in potentially two ways: First, apply an instrumental variable approach, for example using resource endowments as an instrument, as they are likely not affected by education, in order to get a clearer effect of human capital on CO_2 emissions. Second, following a similar approach as Becker and Woessmann (2009), subtract the effect of GDP on CO_2 emissions from the latter in order to gain estimates of the effect of human capital on CO_2 emissions net of the effect of economic growth. The problem with this bounding analysis, however, is that Becker and Woessmann (2009) limit the effect of their predictor variable (in their case literacy) on their outcome variable (in their case economic outcomes) to estimates that are in line with those found in previous well-recognized studies. The magnitude of the effect of GDP on CO_2 emissions in developing countries is arguably not as well researched yet, and thus finding these estimates for such an analysis may prove to be problematic and require many assumptions.

Moreover, on the micro-level, one could use natural experiments, for example in regions undertaking a major educational reform or heavily investing into education, following these regions through time and assessing whether these reforms affect the level of pollution there. Generally, case studies, for example on the country level or perhaps even looking at specific branches or firms, could provide interesting and more specific results on the education to CO_2 emission relationship, and further help in assessing the channels through which education can affect the latter.

Lastly, the two channels of growth and technology were tested more directly, with both analyses wielding unclear results. Future research could aim at finding better ways of testing both channels. For the growth channel, either better growth-accounting data could be used, or a version of the previously mentioned Becker and Woessmann (2009) analysis, where one takes the growth in CO_2 emissions caused by economic growth and then assesses how much this was driven by increases in education. Furthermore, for testing the technological leapfrogging channel, while one could take CO_2 emission intensity and the share of renewable energy in electricity generation as a proxy, there are certainly more possible indicators that could be applied. Specifically, one could pick an industry or sector of a country and evaluate if its emission intensity is changing over time, and whether this is for example related to the number of college graduates with a degree suited for that industry or sector. Furthermore, if one can somehow track technology flows to developing countries, linking this to education could potentially indicate a leapfrogging effect.

Future research could also concentrate on testing the other channels identified in this thesis. First of all, one could assess the effect of education on structural change simply through running a regression with the share of industry value added in GDP as the dependent variable. However, here the sample should be split into the different income groups, as according to structural change theory, the least developed countries would likely increase their share of industry value added as they move out of agriculture, whereas the more developed countries would likely decrease their share, as they move into services (Lewis, 1954). If education were to drive industrialization, the argument could be made for it to drive CO_2 emissions, the opposite applying if it drives de-industrialization. At the same time, one could also test whether education has an effect on the emission intensity of industry, or any of the other sectors, in order to get more specific insights into education's effects on emission intensity.

A tool that would be of great aid here is decomposition analysis, as in Henriques and Kander (2010). If one can decompose the changes in CO_2 emissions driven by structural change and intensity changes between the different sectors, then using these coefficients as dependent variables in a regression with education could give very detailed results on whether education drives emission increasing structural change and drives up or down emission intensity in these sectors. However, sufficient data for this kind of exercise seems to not yet be available to construct a panel of developing countries.

Second, for the demographics channel, one could simply run an analysis of education on the fertility rate. A decrease in this fertility rate, as postulated by Barro (1991), and Barro and Lee (1994) may have an ambiguous effect on CO_2 emissions per capita, however, a smaller population ceteris paribus simply means less CO_2 emissions. The same could be tested as to whether education drives mortality decreases, which, if found to be holding, would imply the opposite as to the fertility decrease. Third, to test the direct effect of human capital decreasing CO_2 emissions through substituting for energy, one could simply assess whether increases in the level of education lead to decreases in the capital share of a country, indicating that gains in education lead to substitutions away from capital-intensive, and thus likely energy-intensive, production. Fourth, it is difficult to test the effect of education on people's behavior in consumption, management, and politics. However, sociological studies surveying individuals may be the answer in order to find whether their self-assessed behavior with regard to environmental degradation is somewhat dependent on their education.

Lastly, for education, future research may use alternative variables to human capital that indicate skills instead, such as literacy or numeracy, as well as different measures of enrollment ratios, such as the “adjusted enrollment ratios” compiled by Lee and Lee (2016). For environmental degradation, many other measures than CO_2 emissions exist as well. For example, O’Neill et al. (2018) use phosphorus, nitrogen, blue water, eHANPP, ecological footprint, and material footprint as alternative measures. Using these indicators would possibly give a rounder picture of how education influences environmental degradation overall.

5 Conclusion

This thesis dealt with the relationship between education and pollution, represented by CO_2 emissions, in developing countries, a link which so far has rarely been investigated. The issue at hand is the dilemma of growth in developing countries creating increasing CO_2 emissions and therefore necessitating an investigation into other factors that could potentially mitigate such an increase. The factor under investigation in this research has been education.

In order to assess the potential effect of education on CO_2 emissions, a framework around this relationship was built, identifying four ‘channels’ through which education can indirectly drive CO_2 emissions – growth, technological-, structural-, and demographic change - as well as two ways for it to have a direct effect – via substituting for energy and through providing ‘green education’. These channels all have been identified in the literature to have an effect on the emissions of CO_2 at least in developing countries, and further, the literature suggests for education to influence these six factors. The first part of the empirical analysis was to assess the first channel of growth, hypothesizing education to increase CO_2 emissions in developing countries through inducing growth. This was first tested through a general relationship between education and CO_2 emissions in developing countries. The findings show that there is likely a short-run increasing effect of education on the level of CO_2 emissions, whereas a consistent long-run effect could not be found. A second test was performed for a more direct assessment of the growth channel, where education was hypothesized to increase CO_2 emissions via the contribution of labor quantity and quality to growth. However, conclusive evidence of a relationship here could not be found.

The second part of this thesis was, to somewhat test the second channel of technological change. Here, education was hypothesized to lead to a decrease in CO_2 intensity as well as to an increase in the share of renewables in the generation of electricity output. The results indicate a short-run CO_2 emission-intensity increasing effect of education, whereas no long-run effect could be found. Furthermore, education does not seem to drive the share of renewable energy in developing countries.

I have no doubt that the model of the relationship between education and CO_2 emissions presented here can be refined and improved in future research. One should therefore view the represented results as tentative and preliminary, giving indications rather than confirmations of proposed trends. However, the postulations and findings of this thesis should serve as a thought-provoking ground for further research dealing with environmental pollution and its underlying economic culprits, while being valuable for formulating questions regarding this topic. Thus, this thesis suggests that work on an issue of this kind can be a fruitful exercise.

While this thesis dealt with developing countries, this is not because of their current extent of emissions, as the average high income-country citizen produces CO_2 emissions higher than that of upper-middle-income-, and way beyond that of low- and lower-middle-income-country-citizens. Rather, the issue at hand is that these countries are prospected to be the center of future CO_2 emission growth in the future, as they are expected to experience high economic growth rates in the upcoming decades. Nevertheless, at this current time, countries of the developed world have a far larger effect on global warming than those of the developing world. Therefore, the focus should not shift away from decreasing their effect on the environment, while also being mindful of how to circumvent future emission increases from the developing world.

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7 Appendix

7.1 Appendix A – data description and country overviews

Table 11: Sources and Descriptions of the variables

Variable	**Description**
Dependent Variables	
CO_2 pc_{it}: CO_2 emissions	Measured in metric tons per capita, the World Bank defines carbon dioxide emissions as "those stemming from the burning of fossil fuels and the manufacture of cement. They include carbon dioxide produced during consumption of solid, liquid, and gas fuels and gas flaring" (World Bank, 2014a). The data is taken from the World Development Indicators provided by the World Bank (2014a), who base it on the Carbon Dioxide Information Analysis Center, Environmental Sciences Division, Oak Ridge National Laboratory, Tennessee, United States.
CO_2/GDP pc_{it}: CO_2 intensity	CO_2 intensity is based on author's calculations, taking CO_2 emissions in kg per capita and dividing it by GDP per capita. This creates a value that indicates how much kg of CO_2 is embodied in one dollar of GDP per capita.
% $renew_{it}$: Renewable electricity output	Renewable electricity output (as a percentage of total electricity output) is defined by the World Bank as "the share of electricity generated by renewable power plants in total electricity generated by all types of plants" (World Bank, 2014a). The data is taken from the World Development Indicators provided by the World Bank (2014a), who base it on IEA Statistics
Independent Variables	
HC_{it}: Human Capital	Human capital is an index that is based on the average years of schooling as well as the average returns to education in a country. The data is taken from the Penn World Tables version 9.1 (Feenstra et al., 2015). It is based on the average years of schooling (using Barro and Lee, 2013, for 95 and Cohen and Lecker, 2014, for 55 countries) , with linear interpolation between observations, and an assumed rate of return to education, which is based on Mincer equation estimates around the world (Psacharopoulos, 1994)[10].
$Labquan_{it}$ and *$Labqual_{it}$*: Labor quantity and quality contribution to growth	Labor quantity input measures the "Quantity of employment, either obtained from total hours worked (whenever available) or total persons engaged" (The Conference Board, 2019). Labor quality input is a "Measure of the changes in the composition of the workforce. This indicator is based on underlying data on employment and wages by educational attainment, which are estimated econometrically in some cases" (The Conference Board, 2019). The data is taken from the adjusted version of the Total Economy Database from The Conference Board (2019). Here, the natural log of the growth in the inputs of labor quantity

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[10] For more information on how the Human Capital Index in the Penn World Tables is constructed, please refer to their documentation of 'Human capital in PWT 9.0', available on: https://www.rug.nl/ggdc/productivity/pwt/pwt-documentation

	and quality are taken and then multiplied with the labor share of total compensation in GDP and averaged over two years to generate their contribution to growth in percentage. Multiplying this percentage with GDP per capita of the previous year then gives the growth measured in US dollars caused by growth in labor quantity and quality. It should be noted that data was only taken when both data for labor quantity and quality was available.
Control Variables	
GDP pc$_{it}$: GDP per capita	Real GDP per capita in 2011 US$, is based on the 2011 benchmark and taken from the Maddison Project Database, 2018 (Bolt et al., 2018).
Industry$_{it}$: Industry value added	Industry (including construction) value added is measured as a percentage of GDP. According to the World Bank "Industry corresponds to ISIC divisions 10-45 and includes manufacturing (ISIC divisions 15-37). It comprises value added in mining, manufacturing (…), construction, electricity, water, and gas. Value added is the net output of a sector after adding up all outputs and subtracting intermediate inputs. It is calculated without making deductions for depreciation of fabricated assets or depletion and degradation of natural resources." (World Bank, 2014a). Data is taken from the World Development Indicators from the World Bank (2014), who base it on their own national accounts data, and OECD National Accounts data files.
Cap$_{it}$: Capital contribution to growth	Capital contribution to growth in GDP is based on authors calculations, taking the absolute growth in GDP each year and subtracting the growth caused by labor quantity and quality growth, effectively making it a measure of GDP growth caused through growth in capital.
Exp/imp$_{it}$: Trade balance	The trade balance is calculated by taking the GDP share of merchandise exports at current PPPs and subtracting the GDP share of merchandise imports at current PPPs from it (both are taken from the Penn World Tables, version 9.1, Feenstra et al., 2015). This gives how much higher exports were than imports in a given country and year, measured as a share of GDP.
FFPrice$_{it}$: Fossil Fuel Prices	Fossil Fuel Prices are based on two indices: the Fuel (Energy) Index from the International Monetary Fund (2018), which combines Crude oil (petroleum), Natural Gas, Coal Price, and Propane Indices, using 2016 as a benchmark. An average of the monthly values is taken for each year. However, these prices may affect countries differently. A barrel of oil costing 60USD internationally may be much more expensive within one country compared to another, due to purchasing power parity differences. Thus, fuel prices are adjusted for PPP. For that, the Price level ratio of PPP conversion factor (GDP) to the market exchange rate from the World Development Indicators, World Bank (2014), is taken to adjust for this discrepancy. "Purchasing power parity conversion factor is the number of units of a country's currency required to buy the same amount of goods and services in the domestic market as a U.S. dollar would buy in the United States. The ratio of PPP conversion factor to market exchange rate is the result obtained by dividing the PPP conversion factor by the market exchange

	rate. The ratio, also referred to as the national price level, makes it possible to compare the cost of the bundle of goods that make up gross domestic product (GDP) across countries. It tells how many dollars are needed to buy a dollar's worth of goods in the country as compared to the United States. PPP conversion factors are based on the 2011 ICP round" (World Bank, 2014a). Thus, the calculation for the Fossil Fuel prices is 1 divided by this PPP conversion times the average commodity price of that year.
ΔPop_{it}: Population Growth	According to the World Bank "Annual population growth rate for year t is the exponential rate of growth of midyear population from year t-1 to t, expressed as a percentage. Population is based on the de facto definition of population, which counts all residents regardless of legal status or citizenship" (World Bank, 2014a). Data is taken from the World Development Indicators (World Bank, 2014a)
ρPop_{it}: Population Density	Population density (people per sq. km of land area) "is midyear population divided by land area in square kilometers. Population is based on the de facto definition of population, which counts all residents regardless of legal status or citizenship – except for refugees not permanently settled in the country of asylum, who are generally considered part of the population of their country of origin. Land area is a country's total area, excluding area under inland water bodies, national claims to continental shelf, and exclusive economic zones. In most cases the definition of inland water bodies includes major rivers and lakes" (World Bank, 2014a). Data is taken from the World Development Indicators (World Bank, 2014a), which are based on the Food and Agriculture Organization and World Bank population estimates.
Cor_{it}: Control of Corruption	Data for corruption control is taken from the Worldwide Governance Indicators (World Bank, 2014b). "Control of Corruption captures perceptions of the extent to which public power is exercised for private gain, including both petty and grand forms of corruption, as well as "capture" of the state by elites and private interests. Estimate gives the country's score on the aggregate indicator, in units of a standard normal distribution, ranging from approximately -2.5 to 2.5" (World Bank, 2014b). Data was interpolated linearly between observations.
Dem_{it}: Democracy	For the sake of complete data, the 'political regime' database compiled by Roser (2016), who combines data from Wimmer and Min (2006), Gapminder.org, UN Population Division (2015 Rev), and Our World in Data is taken. The measure goes from -10, representing a full autocracy, to +10, representing a full democracy.
$Temp_{it}$: Average Winter Temperatures	For constructing this variable, two main datasets are being used. First, following Stern (2012), temperature data gridded by country from Mitchell *et al*. (2004), taken from the Climate Change Knowledge Portal from the World Bank (2011) is used. This data is available as means for the period 1960-90 by month. In order to assess the temperature during the winter season, the time of year where, due to increased heating, energy usage increases significantly, the average of the three months of December, January, and February,

	or June, July, and August, depending on the hemisphere that the country is mostly located in, is taken. Next, in order to have yearly fluctuations, the Temperature Change dataset from FAOSTAT (2019) is taken. This set gives "data on observed mean surface temperature changes by country, over the period 1961-2017 with annual updates. The data provide information on monthly, seasonal and annual mean temperature anomalies, i.e. temperature changes with respect to a baseline period, 1951-1980. Data are based on GISTEMP, the Global Surface Temperature Change data of the National Aeronautics and Space Administration Goddard Institute for Space Studies (NASA-GISS)" (FAOSTAT, 2019) The average temperature change of the corresponding year and winter period is then added/subtracted from the mean temperature of each country for each year. Given that the FAOSTAT dataset bases its change data on the period from 1951-1980, adding/subtracting it from the average of the period from 1960-90 does not give the exact values for temperature in the corresponding country and year. However, to the author's knowledge, this is the only way to get a time trend of temperature for developing countries that is somewhat close to the actual values. Moreover, the relative time trend will still be the same, regardless of the underlying base period.

Table 12: Countries in the sample by income group

Income group	Countries	Total amount of countries (for regression 2)
Low	*Burundi, Benin, Burkina Faso, Ethiopia, Gambia, Haiti, Liberia, Madagascar, Mali, Mozambique,* Malawi, *Niger, Nepal, Rwanda,* Senegal, *Sierra Leone,* Syrian Arab Republic, *Togo, Tajikistan,* U.R. of Tanzania: Mainland, Uganda, Yemen, *Central African Republic,* and Zimbabwe	24 (7)
Lower-middle	*Angola,* Bangladesh, Bolivia, *Côte d'Ivoire, Cameroon, Congo,* Egypt, Ghana, *Honduras*, Indonesia, India, *Kenya*, Kyrgyzstan, Cambodia, *Lao People's DR*, Sri Lanka, *Lesotho,* Morocco, Republic of Moldova, *Mauritania, Mauritius, Nigeria, Nicaragua,* Pakistan, Philippines, *Sudan (Former), El Salvador*, *Swaziland,* Turkey, Viet Nam, and *Zambia*	31 (15)
Upper-middle	Albania, Bulgaria, *Belize,* Brazil, *Botswana,* China, *Colombia*, Costa Rica, Dominican Republic, Algeria, Ecuador, *Fiji*, *Gabon*, Guatemala, Iran (Islamic Republic of), *Iraq*, Jamaica, *Jordan*, Mexico, Malaysia, *Namibia,* Peru, *Paraguay,* Serbia, Thailand, and Turkey	26 (17)

Note: countries in italic are excluded from regression (2), as they have no data observations for both labor quantity and quality contribution to growth

Table 13: Countries in the sample by region

Region	Countries	Total amount of countries (for regression 2)
East Asia and Pacific	Cambodia, China, *Fiji*, Indonesia, *Lao People's DR,* Malaysia, Philippines, Thailand, and Viet Nam	9 (7)
Europe and Central Asia	Albania, Bulgaria, Kyrgyzstan, Republic of Moldova, Serbia, *Tajikistan,* and Turkey	7 (6)
Latin America and the Caribbean	*Belize*, Bolivia, Brazil, *Colombia*, Costa Rica, Dominican Republic, Ecuador, *El Salvador*, Guatemala, *Haiti*, *Honduras*, Jamaica, Mexico, *Nicaragua*, *Paraguay,* and Peru	16 (9)
Middle East and North Africa	Algeria, Egypt, Iran, *Iraq, Jordan,* Morocco, Syrian Arab Republic, Tunisia, Yemen	9 (7)
South Asia	Bangladesh, India, *Nepal*, Pakistan, Sri Lanka	5 (4)
Sub-Saharan Africa	*Angola*, *Benin, Botswana, Burkina Faso, Burundi, Cameroon, Central African Republic, Congo, Côte d'Ivoire, Ethiopia, Gabon, Gambia,* Ghana, *Kenya, Lesotho, Liberia, Madagascar,* Malawi, *Mali, Mauritania, Mauritius, Mozambique, Namibia, Niger, Nigeria, Rwanda,* Senegal, *Sierra Leone, Sudan (Former), Swaziland, Togo,* U.R. of Tanzania: Mainland, Uganda, *Zambia*, and Zimbabwe	35 (6)

Note: countries in italic are excluded from regression (2), as they have no data observations for both labor quantity and quality contribution to growth

7.2 Appendix B – correlation and heteroskedasticity tests

Table 14: Breusch-Pagan / Cook-Weisberg test for heteroskedasticity

H_0: Constant Variance

Variables: fitted values of $CO_2\,pc$	Values
Chi2(1)	1059.52
Prob > chi2	0.0000

Table 15: Pair-wise correlations, all independent and control variables

	HC_{it}	$Labquan_{it}$	$Labqual_{it}$	$GDP\ pc_{it}$	Cap_{it}	$Industry_{i}$	Exp/imp_{it}	$FFPrice_{it}$	ΔPop_{it}	ρPop_{it}	Cor_{it}	Dem_{it}
HC_{it}												
$Labquan_{it}$	-0.067*											
$Labqual_{it}$	0.101***	0.139***										
$GDP\ pc_{it}$	0.575***	0.269***	0.427***									
Cap_{it}	0.225**	-0.16***	-0.12***	0.188***								
$Industry_{i}$	0.185***	0.214***	0.188***	0.456***	0.093**							
Exp/imp_{it}	-0.1***	0.129***	0.13***	0.19***	-0.042	0.583***						
$FFPrice_{it}$	0.061***	0.003	0.001	0.022	0.086**	0.035**	-0.028					
ΔPop_{it}	-0.54***	0.151***	-0.12***	-0.38***	-0.23***	-0.05***	0.168***	-0.016*				
ρPop_{it}	0.007	-0.11***	-0.13***	-0.056**	0.035	-0.09***	-0.11***	0.133***	-0.18***			
Cor_{it}	0.28***	0.15***	0.224***	0.418***	0.129***	-0.09***	-0.27***	-0.19***	-0.22***	-0.007		
Dem_{it}	0.293***	0.002	0.061*	0.169***	0.081	-0.23***	-0.29***	-0.048*	-0.22***	0.115***	0.321***	
$Temp_{it}$	-0.41***	0.106***	-0.049	-0.19***	-0.14***	-0.11***	0.072***	-0.062**	0.4***	0.068***	-0.011	0.127***

*** p<0.01, ** p<0.05, * p<0.1

7.3 Appendix C – summary statistics

Table 16: Variable means for separate income groups, dependent and independent variables

Income Group, Region/Variable	$CO_2\ pc_{it}$	$CO_2/GDP\ pc_{it}$	$\%\ renew_{it}$	HC_{it}	$Labquan_{it}$	$Labqual_{it}$
Low	0.33	0.156	0.505	1.57	25.872	5.304
	(0.574)	(0.133)	(0.39)	(0.447)	(27.184)	(7.18)
Lower-middle	0.921	0.202	0.436	2.022	46.331	15.353
	(0.659)	(0.122)	(0.319)	(0.441)	(85.122)	(26.486)
Upper-middle	2.948	0.279	0.406	2.424	82.291	45.002
	(1.845)	(0.145)	(0.358)	(0.371)	(168.68)	(70.584)
East Asia and Pacific	2.248	0.275	0.322	2.254	45.935	26.678
	(2.236)	(0.179)	(0.295)	(0.365)	(81.689)	(34.799)
Europe and Central Asia	2.656	0.336	0.509	2.853	5.062	31.912
	(2.212)	(0.179)	(0.391)	(0.344)	(185.43)	(42.932)
Latin America and the Caribbean	1.62	0.21	0.535	2.301	95.736	34.484
	(0.995)	(0.091)	(0.286)	(0.404)	(111.44)	(85.044)
Middle East and North Africa	2.894	0.317	0.055	1.997	109.349	41.293
	(1.639)	(0.112)	(0.058)	(0.389)	(166.89)	(42.06)
South Asia	0.62	0.172	0.393	1.93	32.238	11.477
	(0.404)	(0.103)	(0.338)	(0.496)	(59.533)	(17.851)
Sub-Saharan Africa	0.545	0.154	0.535	1.677	26.084	3.208
	(0.766)	(0.119)	(0.361)	(0.398)	(21.718)	(2.735)

Standard deviation in parentheses

Table 17: Variable means for separate income groups, control variables

Income Group, Region\Variable	GDP pc$_{it}$	Cap$_{it}$	Industry$_{i}$	Exp/imp$_{it}$	$FFPrice_{it}$	ΔPop_{it}	ρPop_{it}	Cor_{it}	Dem_{it}	$Temp_{it}$
Low	1,629.9	-27.823	0.202	-0.091	372.385	2.67	101.519	-0.756	1.138	20.434
	(1,111)	(158.97)	(0.09)	(0.102)	(178.21)	(1.035)	(101.08)	(0.38)	(4.618)	(7.917)
Lower-middle	4,685.1	99.189	0.295	-0.03	388.477	1.793	153.061	-0.684	1.78	19.138
	(2,776)	(156.76)	(0.112)	(0.163)	(184.25)	(0.847)	(217.94)	(0.442)	(6.142)	(8.504)
Upper-middle	10,408.3	139.326	0.328	-0.049	300.659	1.427	69.75	-0.307	4.643	15.834
	(3,655)	(392.37)	(0.121)	(0.157)	(148.01)	(1.076)	(59.616)	(0.548)	(5.404)	(9.298)
East Asia and Pacific	7,026.94	189.026	0.339	-0.024	402.241	1.331	130.25	-0.498	0.561	20.64
	(4,630)	(316.05)	(0.102)	(0.111)	(192.23)	(0.593)	(88.433)	(0.479)	(6.368)	(9.635)
Europe and Central Asia	7,740.87	228.81	0.242	-0.119	355.431	0.409	79.261	-0.662	5.163	-1.914
	(4,912)	(424.49)	(0.04)	(0.082)	(152.71)	(1.073)	(31.637)	(0.438)	(4.682)	(4.941)
Latin America and the Caribbean	7,648.07	58.764	0.279	-0.105	284.39	1.565	100.954	-0.501	7.444	22.196
	(3,392)	(245.72)	(0.067)	(0.111)	(139.36)	(0.597)	(104.29)	(0.48)	(2.091)	(2.583)
Middle East and North Africa	8,984.3	-0.912	0.389	-0.011	400.394	1.988	59.978	-0.604	-3.614	11.887
	(3,493)	(305.8)	(0.138)	(0.146)	(202.54)	(1.182)	(24.619)	(0.488)	(3.854)	(3.076)
South Asia	3,696.6	121.525	0.2403	-0.034	499.096	1.49	432.685	-0.676	4.347	16.201
	(2,049)	(164)	(0.049)	(0.03)	(342.03)	(0.558)	(342.03)	(0.36)	(4.724)	(7.219)
Sub-Saharan Africa	3,309.58	6.428	0.249	-0.041	344.086	2.615	84.246	-0.611	1.541	22.275
	(3,875)	(69.342)	(0.135)	(0.177)	(156.75)	(0.901)	(119.09)	(0.54)	(5.14)	(4.43)

Standard deviation in parentheses