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A cross-country analysis of the effect of economic preferences and financial structures on nitrous oxide emissions

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Abstract

Recent discussions about nitrous oxide emissions put pressure on agricultural and industrial sectors. The impact this less-known greenhouse gas has on climate change is larger than initially thought. This study investigates the influence of socio-economic drivers and financial structures on N_2O emissions through various regression analyses. The baseline results show inconsistent outcomes which demand for further investigation. Patience, trust, and financial structures cannot explain cross-country variations. The cross-sectional analyses reveal a significant impact of negative reciprocity on N_2O emissions. Robustness tests yield significant results when the dependent variable is changed. Interestingly, the country sample matters when explaining cross-country variation in N_2O emissions. A Relatively more bank-based financial structure decreases N_2O emissions per capita in the adjusted country-sample, emphasizing that different country characteristics could reveal crucial insights in climate change mitigation. The findings of this paper regarding factors affecting nitrous oxides show inconsistency. Therefore, further research is recommended to investigate causes of N_2O emissions.

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1. Introduction

Climate change is arguably one of the biggest problems ever faced by humankind. So-called "greenhouse gases" have an adverse impact on global warming, and need to be tackled strategically to prevent the sanctity of global environmental distinction, biodiversity loss, and other urgent matters (Latake, 2015). Last decade, climate change has proven to be a major area for research. Various drivers are examined, including socio-economic behavior and the role of finance. The 2015 Paris Climate Conference has emphasized the importance of finance in the battle against environmental degradation (De Haas & Popov, 2019). The European Union even commits itself to achieve climate-neutrality by 2050 (Capros et al., 2019). Most research is focused on one particular greenhouse gas, which is carbon dioxide (CO_2). The emission of this primary greenhouse gas leads to irreversible effects on the planet, and without urgent climate action, future emissions would imply further irreversible effects (Solomon et al., 2009). Limited to no rigorous empirical work exists on the association between economic preferences, the role of finance, and the aggregate effect of pollution in terms of other greenhouse gas emissions across countries.

Recently, a relatively new political and social discussion has risen in The Netherlands regarding nitrous oxide (N_2O) emissions. Nitrous oxide is one of the greenhouse gases, together with carbon dioxide, carbon monoxide, methane, and sulfur oxide. Nitrous oxide consists of two nitrogen molecules and one oxygen molecule (N_2O), and is a reactive form of nitrogen which is emitted by fertilizer production, traffic, and industrial manufacturing. Rockström *et al.* (2009) pointed out that disturbance of the nitrogen cycle is one of the three major threats of ecological stability on planet Earth. Too much nitrogen is detrimental to our health, as it acidifies the ground, is toxic to some plants which causes them to extinguish, and can pollute drinking water. Globally, nitrous oxide emissions can damage the ozone layer, which pollutes the air, and has negative health effects. A recently published study by Tian *et al.* (2024) describes the key components of nitrous oxide emissions. There are two major sources of N_2O emissions. First, emissions come from natural sources, including microbial processes in soils and oceans. Second, anthropogenic sources, which can be seen as the contribution of human activity. Nevertheless, human activity has a large scope. The authors distinguish between three major anthropogenic sources. The first one comes from agricultural activities. Nitrogen-based fertilizer production increases N_2O emissions. Integrating sustainable agricultural practices can help mitigating N_2O emissions while supporting economic growth (Kwakwa et al., 2023). The second source comes from industrial manufacturing and fossil fuel combustion, which cause extensive N_2O emissions. Thirdly, biomass burnings have both intentional and unintentional effects. Farming methods in agriculture use burnings as an intentional way of vegetation management. Furthermore, unintentional fires release nitrous oxides too. This greenhouse gas has a huge global warming potential, significantly larger than that of CO_2, and plays an evident role in destructing the ozone layer (Tian et al., 2024; Griffis et al., 2017). N_2O molecules possess a higher capability for absorbing infrared radiation compared to CO_2, thereby enabling them to capture more heat.

Research published by the Dutch Government shows that humankind has doubled nitrogen concentrations in the environment (Rijksoverheid, 2021). Within The Netherlands, the agricultural sector feels that they are blamed in particular for this increase in nitrogen since the measures were disproportionally harsh in this sector (NOS Nieuws, 2020). The discussion in the agricultural sector also rises due to extensive ammonia (NH_3) deposition. Both ammonia and nitrous oxide emissions have large effects on mitigating nitrogen nutrient loss. Nonetheless, nitrous oxide is the major problem. Not only the agricultural sector feels blamed. The construction industry has significant anthropocentric environmental impact, and nitrous oxide emissions is one that can be derived from civil construction. Adopting sustainable concrete production and usage reduces greenhouse gas emissions, and decreases consumption of energy and water, two essential commodities which are affected by climate change (Akan, 2017). The COVID-19 pandemic holds key insights for the influence humankind has on climate change. The shutdowns for a limited period of time show that there was a significant decline in greenhouse gas emissions globally. However, the urge of getting back to normal stabilizing global economies shows a rapid increase in the emissions after the pandemic (Kumar, 2022).

The majority in literature focusses on carbon dioxide where other greenhouse gases are relatively being neglected. Anthropogenic sources of nitrous oxide have destructive effects on planet Earth. But which economic determinants can explain cross-country variation in N_2O emissions? These variables remain unexplored while the effects are detrimental. Socio-economic factors require a deepened understanding since human activity is the major problem. The Global Preference Survey (GPS) has proven to find key insights in substantial variation across countries for different studies. The dataset of 76 countries represents 90 percent of both the world's population and global income (Falk et al., 2018). Linking the socio-economic factors of this survey to nitrous oxide emissions could reveal new important insights, and contributes to the literature on the relationship between socio-economic determinants and N_2O emissions. By now, an extensive amount of empirical work has shown that human behavior affects climate change. Up until today, the focus on nitrous oxide emissions remains unexplored. Yet, discussions rise in various countries regarding this less known greenhouse gas.

Not only socio-economic factors play an important role in climate change. The financial landscape across countries has proven to be of major importance (De Haas & Popov, 2019). The authors found that the structure of financial systems significantly affect CO_2 emissions. Considering the similarities of the greenhouse gases CO_2 and N_2O, particularly their environmental harm and strong dependence on human activities, the configuration of financial systems might play a crucial role in explaining differences in N_2O emissions. In other words, the structure of a financial system could matter in understanding cross-country variation in N_2O emissions. Market-based economies typically exhibit lower emissions than bank-based systems, aligning with growing scientific evidence that equity investors prioritize and value sustainable environmental practices by companies (Galema et al., 2008). If this finding is applicable to N_2O emissions, governments can leverage it to promote the growth of market-based economies. Generally, financial intermediaries like banks are more conservative and tend to favor established industries. Additionally, banks often lack the expertise to evaluate new technologies. But what is the effect on N_2O emissions? Finance is more important than ever as economies continue to expand. The link between finance and greenhouse gas emissions can reveal crucial insights. If one financial structure is better in mitigating environmental degradation, interventions methods can be implemented. Different learnings can be drawn in the fundamentals tackling the climate crisis.

Taking the economic determinants mentioned above, economic preferences and financial system structures, as a starting point for addressing the academic relevance, this thesis distinguishes itself through investigating effects on nitrous oxide emissions per capita. This research aims to investigate the relationship between predefined drivers across countries, and to which extent these drivers affect nitrous oxide emissions. By empirically exploiting cross-sectional and panel data, this thesis seeks to answer the following research question:

What factors explain cross-country variation in nitrous oxide emissions per capita?

Essential aspects of economics potentially explain why certain countries have relatively higher emissions of nitrous oxide per capita. Chapter 2 of this thesis elaborates on the background of all variables and develops three hypotheses.

2. Background and hypotheses development

2.1 Current state of literature explaining cross-country variation in N_2O emissions

The climate has changed significantly under the influence of human behavior. It leads to a gradual increase in temperate on the planet. The emission of greenhouse gases has grown significantly over the years, and can be explained by high levels of manufacturing and economic activity (Albergel et al., 2010). Human activity is a significant new factor, which has been influencing Earth's climate. The so-called greenhouse effect is a natural process and can be seen as the conversation of inbound and outward-bound radiation that warms the Earth (Kweku et al., 2018). Nevertheless, this natural process is influenced by human behavior and emissions are rapidly accelerating (Chen and Chen, 2016). Economists are increasingly analyzing the interdependent relationship between economic growth and global warming. One greenhouse gas that remains relatively unexplored, is nitrous oxide. Nitrous oxide (N_2O) has a global warming potential that is 300 times that of carbon dioxide (Griffis et al., 2017). N_2O molecules have a greater capacity to absorb infrared radiation than CO_2, resulting in each N_2O molecule trapping more heat in the Earth's atmosphere, and have longer atmospheric lifetime. The authors underpin that the climate sensitivity of nitrous oxide emissions is poorly known, which makes it demanding to understand its climate impact. In this chapter, a literature review demonstrates the background of potential influencers on one critical greenhouse gas affected by humans, namely nitrous oxide. These influencers are described separately in the next paragraphs. Hereby, the scarce knowledge in literature regarding this topic is expanded. First, economic preferences across countries are explored. Second, the effect of countries' financial system structures, market-based versus bank-based, on nitrous oxide emissions is investigated.

2.1.1 The effect of patience on climate change

Various drivers exist influencing greenhouse emissions. Following literature in explaining the anthropogenic sources increasing greenhouse gas emissions, a deepened understanding of socio-economic behavior gives key insights in reversing climate change. Acting sustainable is a social dilemma between personal and collective interests. Recent literature argues that the level of patience is an essential driver in collaborating amongst citizens within countries. Future-oriented countries, or patient countries, are more likely to adopt mitigating actions against climate change

(Cai et al., 2020). But why are patient countries more future-orientated? First, introducing the concept of myopia. Myopic behavior refers to decision-making that focuses on short-term benefits at the expense of long-term consequences (Brown & Lewis, 1981). Or in other words, myopia can lead to choices that are detrimental in the long-run, as future benefits and risks are not adequately considered. Davidson and Kanter (2014) emphasize the importance of comprehensive mitigation strategies to decrease N_2O emissions. The authors state that under business-as-usual emission scenarios, anthropogenic N_2O emissions will nearly double by 2050. Emphasizing the statement of The European Union committing itself to climate-neutrality by 2050, it is essential to stabilize or revert N_2O concentrations. In line with the concept of myopia, Cai *et al.* (2020) suggest that patient countries are more likely to accept current costs to tackle the climate crisis in the longer-run. Other research by Manoussi and Xepapadeas (2017) consistently shows that greenhouse gas emissions increase for higher discount rates within countries. In general, the more future gains are discounted, the more impatient people are for receiving such a gain. This holds that a more impatient country has increasing emission numbers and a less impatient country has decreasing numbers. This is in line with Cai *et al.* (2020). One potential explanation for having higher discount rates regarding environmental impact can be that environmental gains are likely to be further away in the future. Climate-neutral or nature-positive projects have longer maturities on average, and therefore it is likely to affect discount rates (Gollier & Hammit, 2014). Taking the environmental study of Cai *et al.* (2020) as a starting point, patience has a highly significant influence on climate change policies. These policies consist of preventions and adaption. Thorough institutions are necessary to overcome the tragedy of the commons, which is a metaphoric label and leads to, inter alia, destroying Earths' valuable resources. The authors estimated a model specified as follows: $CLIMI_i = a_0 + a_1 Patience_i + \beta X + \varepsilon_i$, where CLIMI proxies for climate change policies in country *i*. The values for patience are retrieved from the Global Preference Survey, and this thesis uses the same database. The main statistical results in the first model show that the used bivariate regression is statistically significant and positively associated with CLIMI. In other words, if the country becomes more patience, it is more likely that this country adopts policies to mitigate climate change. The theory suggests that institutions can improve society's ability to address complex problems. Now that this pioneering research has found that patience is an essential driver behind climate change mitigation, this thesis takes a retrograde step. Where Cai *et al.* (2020) focus on institutional changes, this thesis focuses on the direct effects of patience on emissions per capita.

As briefly introduced in the previous paragraph, Manoussi and Xepapadeas (2017) emphasize discount rates. Delving deeper into this concept, discount rates are examined by economists for a long period of time. A variety of effects is examined, and literature states that lower discount rates lead to a higher present value. Therefore, a person is considered to be more patient the lower the discount rate, and can be considered impatience when the discount rate is higher. Briefly, one is prepared to delay rewards in exchange for immediate rewards. Now that the concept of patience is introduced, a deep dive can reveal fundamental links explaining the concept of patience and the effect on climate change. Curry *et al.* (2008) find that patient people are more cooperative. The study shows that reciprocal altruism involves foregoing immediate rewards for the sake of long-term benefits. So, the relationship between patience, altruism and reciprocity is made. But why is this understanding essential in reversing climate change? As pointed out before, human activity is a major problem for global warming and environmental degradation. Evseeva *et al.* (2021) argue that all of the negative impact is the result of human actions. This automatically implies that the solution of reversing the negative impact is also within the hands of humans. The authors point out the importance of all greenhouse gas emissions, including nitrous oxide. Alarming is the fact that the greenhouse gas activity of nitrous oxide is almost 300 times higher than that of carbon dioxide (Evseeva et al., 2021). Releasing extensive nitrous oxides is harmful for planet Earth. This greenhouse gas is released during industrial and agricultural activities, trough solid waste, and the combustion of fossil fuels.

Enduring on socio-economic theories, a recent study by Andre *et al.* (2021) writes about fighting climate change, and the behavioral determinants of individual willingness. Fundamental human traits, namely patience, altruism, and positive reciprocity are strongly correlated with the individual willingness to combat climate change. As described above, patience is a fundamental human trait and is proven to be a social norm. Following main literature, altruistic behavior is interconnected with choices people make in order to fight climate change. Curry *et al.* (2008) demonstrates the relationship between patience, altruism and reciprocity. Therefore, it is wise to include these economic preferences in the literature overview and give a brief outline. All are essential in investigating human interaction and underpinning policymaking decisions. Prosocial behavior is of utmost importance to solve the global climate crisis (Klein et al., 2022). Collective action is desperately needed, and it ultimately benefits all humankind. Altruism is a driver of prosocial behavior and Smith (2010) connects this theory to nitrous oxides. The author states that the growing world population will require a continued growth of livestock production. Decreasing nitrous oxide emissions are not only dependent on new developed technologies in this industry. Policy decisions and dietary changes are essential in mitigating nitrous oxide emissions. Society has to change its behavior, and think in a more altruistic way. Positive reciprocity should be the new way of thinking embedded in humans' behavior. Curry *et al.* (2008) verifies the significant influence that altruistic behavior and positive reciprocity have on fighting climate change. The outcome of this study is in line with Cai *et al.* (2020) supporting the theory that patience has significant influence on climate change behavior. The major difference in setup is the dependent variable used in both researches. Andre *et al.* (2021) looks at the effect on donations made by individuals. The effect of patience is statistically significant for the 1% level. Robust standard errors are used in the regression. Furthermore, the paper shows that the relationship is positive. This means that if the level of patience increases, the quantity of donations increases too. Summarizing, the conclusions of the authors is in line with current literature. While there is now a clear consensus among academics regarding the positive relationship between patience and human action against climate change, this thesis addresses the knowledge gap concerning N_2O emissions. The majority of empirical work studies behavioral effects on carbon dioxide, but limited to no rigorous work exists on other greenhouse gases. Nearly all academic background is focused on the overall effects on climate change. The singular effect of patience on nitrous oxide emissions remains unexplored. This thesis extracts single determinants of human behavior and potentially clarifies N_2O influencers.

2.1.2 The effect of trust on climate change: inconsistency in literature

In an attempt to clarify the effect of economic preferences on nitrous oxide emissions per capita, another personal trait is investigated in this thesis. Yearley (2009) shows that investigating social variables is essential in the business of predicting greenhouse emissions and policy-making. Climate analysts fear that the rapid rise in emissions would mean that outlined forecasts might come faster than initially thought, which makes this topic more relevant than ever. Choices made by contemporary society can tackle this phenomenon, and contribute to a future richer world. Elaborating on the impact of human behavior, there is another potential effect that influences climate change. It is not only the level of patience which partially explains the greenhouse gas effect, but the level of trust within countries also influences emissions. It is the firm believe in reliability, truth, or ability of someone or something. For example, Leiserowitz *et al.* (2013) demonstrates that the trust in climate scientists has significant effect on public beliefs in global warming. The authors examined the Climategate scandal[1], which is a specific incident, and thus could imply that this was a self-contained event which cannot be generalized. Nevertheless, the research shows that the level of trust could significantly affect human behavior and public views on climate change. Despite the overwhelming scientific consensus that climate change is a real risk, some literature shows a paradox. One would suggest and claim that if the level of trust in people increases, the emitted greenhouse gases per capita should decrease. However, frequently cited research in literature by Kellstedt *et al.* (2008) shows opposing results. The authors find that the more confidence an individual has in scientists, the less responsible one tends to feel for global warming, and the less concerned one is. This is a surprising outcome, and simultaneously an urgent call for further investigation. A thorough understanding is necessary to steer human behavior and enable intervention purposes. If one can understand the building blocks of trust, then society can act towards a more sustainable way of living. Trust goes further, and does not only indicate trust in academics. The Global Preference Survey describes this firm believe as the assumption that other people only have the best intentions. Thus, one could see trust as reliability and a key driver of human interaction. Cologna and Siegrist (2020) show that overall trust plays an important role when it comes to both adaption and mitigation. The authors distinguish between different measurements of trust, whereas this thesis looks at overall trust as mentioned in the Global Preference Survey. Respondents who show greater trust in government expertise feel less efficacious for climate change. The paradox in the results is that generally more trust leads to better outcomes. An important note that needs emphasis, is the difference in political systems and expert cultures[2]. Trust is a social construct that can be measured differently across countries.

The link between trust and institutions is popular amongst researchers. Institutional trust is a valuable resource which socio-economic systems need to utilize (Zaheer et al., 1998; Bachmann, 2018). Trust is fundamental to the functioning of institutions since it fosters compliance with regulations and rules. It encourages innovation, and protects people's interests. The Global Preference Survey does not distinguish between institutional trust, and interpersonal

[1] The Climate Research Unit email controversy. Climate change denialists argue that leaked emails show that scientists manipulated climate dates.

[2] Chapter 5 will elaborate on potential limitations.

trust. Nonetheless, the scores of the respondents indicate if people think others only have the best intentions. Therefore, this thesis establishes a link between different scopes of trust. Kulin and Johansson Sevä (2021) demonstrate that individuals who express concern about climate change are more inclined to support climate policies in countries with high levels of trust. The escalating challenges posed by rising greenhouse gas emissions and climate change are unlikely to be resolved without regulatory and incentive-driven policies. These measures would either penalize polluting activities or promote sustainable practices (IPCC, 2018). In line with the latter two papers, earlier research indicates that countries with greater trust in government tend to have lower greenhouse gas emissions (Tjernström & Tietenberg, 2008), thus suggesting that effective climate policies rely on public trust.

Summarizing, trust is an essential variable in mitigating climate change. Carattini *et al.* (2015) reveals that there is a non-negligible impact of trust on greenhouse gas emissions. The authors find a negative effect of trust on emissions based on a panel of 29 European countries. The results show that a 1% increase in trust would decrease emissions by 0.24%. The Eurostat database used by Carattini *et al.* (2015) does not distinguish between the different greenhouse gases. Furthermore, comparable to this thesis, the unit of trust is measured as the overall statement that people can be trusted. It is interesting to see that literature is not consistent in the effects trust can have. Although a variety of studies use different dependent variables, the main goal is identical. Get an understanding of the determinants, and ultimately reverse climate change. Nevertheless, nitrous oxide emissions are less popular among researchers. The main focus in literature is about the agricultural or industrial effects the greenhouse gas has.

2.1.3 The influence of financial system structures on climate change

Now that socio-economic determinants in potentially explaining nitrous oxide emissions are described, another element can be outlined. Whereas Yearly (2009) emphasizes the influence of human behavior on greenhouse gas emissions, De Haas and Popov (2019) suggest another vantage point. The primary drivers of environmental degradation are not the socio-economic factors, but rather the structure of the financial system. Inspired by the empirical work of De Haas and Popov (2019), this thesis seeks to answer the question whether a country's financial system structure affects nitrous oxide emissions per capita. The limited understanding in current literature between the greenhouse gas effect and the role of finance mitigating environmental degradation is somewhat paradoxical. Several studies and theories exist examining sustainable finance. However, empirical work of the effect of a country's financial system structure, market-based or bank-based, is quite rare. Bank-based financial structures suggest that credit to the private sector is primarily extended through deposit money banks and other credit institutions. In other words, financial intermediaries play an important role in financial activities, and allocating capital to businesses and individuals. In market-based financial structures stock markets provide this role. The distinction between the two financial structures lies in how financial resources are allocated.

The structure of a country's financial system significantly matters in tackling environmental degradation. De Haas and Popov (2019) find that carbon dioxide (CO_2) emissions tend to be significantly lower in countries with relatively higher levels of equity-based finance compared to bank-based finance. The authors show that carbon-intensive sectors produce more green patents as stock markets deepen. This finding is in line with Galema *et al.* (2008) who state that equity investors tend to value environmentally sustainable behavior. Nevertheless, except for the inquiry of Haas and Popov (2019), the link between finance and pollution is relatively new in academic research. Carbon dioxide emissions are widely considered to be the main source of global warming as they account for over half of all radiative forcing by the Earth (IPCC, 1990; 2007). This extensively emitted gas also proxies for other air pollutants, such as nitrous oxide. Linking this interesting finding to N_2O emissions, a deepened understanding of the relationship towards the structure of a country's financial system could be essential in decreasing N_2O emissions. Ravishankara *et al.* (2009) shows that N_2O emissions are majorly harmful in ozone depletion. Financial systems are essential for economic development. Economists have long recognized the importance of the financial system. It is not a passive channel anymore that allocates scarce resources or can simply be seen as a sideshow (Stiglitz, 1998). In order to reverse climate change, it is essential to get a detailed understanding of financial system structures and their role. It is not a secret anymore that large financial institutions and markets have a major influence on modern economics.

The International Commission on Climate Change has calculated the average global temperature in the next century and shows that the temperature will rise by 6 degrees Celsius if current trends are not reversed (Mikhaylov et al., 2020). De Haas and Popov (2019) find that the size of the financial sector has no impact on carbon dioxide emissions, but that the financial structure significantly affects these emissions. Market-based economies tend to have lower emissions compared to bank-based systems, and these findings are consistent with the increasing scientific evidence that equity investors tend to value sustainable environment behavior by firms (Galema et al., 2008). Stock markets could play an important role in making future growth greener by stimulating innovation that leads to cleaner production processes within industries (De Haas & Popov, 2019). On the other side, Allen and Gale (2004) find that banks are more conservative, have more interest in existing industries, and lack skills to asses new technologies. Green developments involve a high degree of uncertainty. Markets allow for diversity of opinion, and therefore, are able to finance new industries and technologies. Diversity of opinion implies that given the same set of information one has about a company, individuals can make heterogenous investment decisions (market-based), whereas managers, generally bank-based, tend to make decisions with 'one size fits all' (Allen & Gale, 1999). Contradictory, another study by Dasgupta *et al.* (2002) argue that bank-based financial systems are better for reducing pollution. Banks use certain screening processes to detect and avoid polluting firms. This has two major reasons. The first reason relates to reputational repercussions (Zeller, 2010). The second reason relates to the transitional risk of financial institutions (Park & Kim, 2020). Restrictions for greenhouse gas emissions are rapidly expanding, and banks desire to avoid the transition risk. This risk occurs when policy and regulatory changes are implemented. When firms do not comply in time with new rules and polices, transitional risks are applicable. Therefore, screening, monitoring and avoiding lacking enterprises becomes crucial. An example given is the purpose of the ABN AMRO Bank, a large Dutch listed bank: 'Banking for better, for generations to come'. The ABN AMRO Bank encourages clients to accelerate the sustainability shift and aims to guide firms' transition.

Existing work on the effect of the financial system structure as driver of environmental degradation is characterized by inconsistency. Current literature shows opposing results whether a market-based or bank-based financial system is more suitable to tackle environmental degradation. There are basically two strands in literature arguing why one financial system structure is more efficient in combatting climate change than another. The majority of empirical studies is focused on the effect of carbon dioxide, which pollutes Earths' lower-level atmosphere. Nonetheless, empirical work on other greenhouse gas emissions is less popular. Several studies show that nitrous oxide emissions are more harmful to planet Earth than other greenhouse gases. Ravishankara *et al.* (2009) argue that nitrous oxide (N_2O) is the single most important ozone-depleting emission and remains to be the largest throughout the 21^{st} century. Global economies are increasingly growing over time, and thus it is essential investigating financial system structures of countries which could mitigate environmental degradation. The link between nitrous oxide emissions and finance however, remains unexplored.

2.2 Hypotheses development

This thesis tests three hypotheses in order to gain insights into cross-country variation in nitrous oxide emissions per capita. The first socio-economic determinant potentially affecting nitrous oxide emissions, is patience. The literature review in paragraph 2.1.1 reveals the importance of patience, and introduces the concept of myopia. If one can reveal a significant effect on nitrous oxide emissions, the outcome could be used for human intervention and behavioral insights. Departing from the theory of myopia, and the research by Cai *et al.* (2020), who state that future-orientated countries are more likely to adopt mitigating actions against climate change, the first hypothesis can be formed:

H1: Countries with relatively higher levels of patience are expected to emit less nitrous oxide per capita.

There is consensus in literature that patience is negatively related to climate change. Or more clearly, the higher the level of patience an individual has, the more one is prepared to combat climate change. Interestingly is that Curry *et al.* (2008) find evidence on the actual effort individuals put into this. Altruistic behavior in combination with adapted future-oriented state of minds result into benefits for the long-term environmental horizon. A country's population that exhibits less myopic behavior, emits less N_2O per capita. Consistency in literature proposes the importance of long-term thinking. Therefore, this thesis hypothesizes that if the level of patience increases, emissions decrease.

Secondly, this thesis considers another essential socio-economic driver affecting N_2O emissions. Different strands in literature exhibit the inconsistency researchers have in the effects trust can have on emissions. Whereas by Kellstedt *et al.* (2008) and Leiserowitz *et al.* (2013) do not find beneficial effects of trust on climate change, Carattini *et al.* (2015) finds the opposite. The latter is relatively comparable with this thesis since the authors look at the direct effects on greenhouse gas emissions. Furthermore, Tjernström and Tietenberg (2008) show that trust matters in mitigating greenhouse gas emissions through climate institutions. Despite the inconsistency in literature, this thesis expects similar results of Carattini *et al.* (2015). The effect trust has on nitrous oxide emissions per capita is expected to be rather slight. Higher levels of trust have a beneficial impact on nitrous oxide emissions. Departing from this theory, the second hypothesis is formed:

H2: Countries with relatively higher levels of trust are expected to emit less nitrous oxide per capita.

Lastly, departing from earlier empirical work of De Haas & Popov (2021) on carbon dioxide, and diversity of opinion by Allen & Gale (1999), the last hypothesis of this thesis regarding the effect of financial system structures of countries on nitrous oxide emissions is formed:

H3: Countries with a relatively more market-based financial structure are expected to emit less nitrous oxide per capita.

Whereas the main focus of De Haas & Popov (2021) is on carbon dioxide emissions, this thesis equivalently expects that the per capita emission quantities are lower in market-based financial system structures. Since there is consensus on the statement that carbon dioxide is far more known than nitrous oxide (N_2O), the expected N_2O emissions have relatively smaller impacts due to a knowledge gap. This thesis is one of the first researches that emphasizes the detrimental effects of this less known polluter. Evseeva *et al.* (2021) exhibited the influence anthropogenic sources have, and the importance to get a deeper understanding of nitrous oxide emissions. Now that all three hypotheses are developed, this thesis allows to elaborate on the used data and empirical methodology in the next chapter. The results of the analyses will be discussed in chapter 4.

3. Data & method

3.1 Exploring the data

This chapter introduces the main data sources used in this research. A quantitative research method suits the analyses. For the first and second hypotheses, cross-country comparisons will be made over 76 countries for the year 2012[3]. Therefore, cross-sectional data is appropriate to test the second hypothesis. Fundamental socio-economic preferences will be used to examine the effect on nitrous oxide emissions per capita. Since the fact that there is only data for 2012, no corrections have to be made for fixed or random effects, and thus OLS-regressions are suitable. For the third hypothesis regarding financial system structures, cross-country comparisons have to be made over time. Therefore, panel data is the appropriate way, as it allows the combination of cross-sectional and time-series dimensions (Wooldridge, 2013, p.488). The data include 85 countries across the world that will be examined from 2000 to 2015.

3.1.1 Data sources and sample

Data will be retrieved from various data sources. The variables will be further explained in the next paragraphs. N_2O emissions will be obtained from the world development indicators sourced from the World Data Bank. In order to measure fundamental drivers of socio-economic preferences, data will be obtained from the Global Preference Survey. This data source contains values for levels of patience, trust, altruism, reciprocity, and risk preference. Since all variables from this database are determinants of human traits, altruism, positive and negative reciprocity, and risk preference are additionally taken into account. Measuring the financial system structure of a country, data will be obtained from the Financial Structure Database sourced from the World Data Bank. The control variables, gross domestic product growth, gross domestic product per capita, total population, and recession will be obtained from the world development indicators sourced from the World Data Bank. Table 1 shows a complete overview of all definitions and sources of the included variables.

[3] There is only data available for this specific year.

3.1.2 Variables and measures

Paragraph 3.1.2 addresses the different variables and measures used in this thesis. Nitrous oxide (N_2O) emissions per capita will be calculated as thousand metric tons of CO_2 equivalent, divided by the country's population: $\frac{N_2O_{c,(t)}}{Pop_{c,(t)}}$. Countries differ in population size, and thus it is necessary to look at the outcomes per capita. Furthermore, the variable is calculated using the natural logarithm of $\frac{N_2O_{c,(t)}}{Pop_{c,(t)}}$. Transforming variables into natural logarithms can help in normalizing data that is skewed. It improves the validity and fit.

This thesis tests three hypotheses. Departing from the cross-sectional analyses, six explanatory variables are used. The level of patience can be described as the willingness to give up something that is beneficial for you today in order to benefit more from that in the future, and is measured at one point in time: Pat_c. Trust is described as the firm believe in reliability, truth, or ability of someone or something, and is measured at one point in time: $Trust_c$. For the other four secondary explanatory variables, the definitions are described in table 1 on the next page. For the panel data analysis, the explanatory variable represents the financial system structure of a country (FS). The financial system structure of a country equals the value of all traded stocks on the market, divided by the sum of credit extended to the private sector (by deposit money banks and other credit institutions) and the value of all traded stocks in the market: $\frac{Stock_{c,t}}{Stock_{c,t} + Credit_{c,t}}$. The higher this value, the more market-based the financial structure of a country is.

Control variables are crucial in regression analyses, and are kept the same throughout the analyses and could potentially influence the outcomes. It is essential to control for any variable that causally affects both an independent variable and the dependent variable. Control variables help to ensure that the estimated relationship between explanatory variables and the dependent variable is both accurate and unbiased. It makes the research more reliable and valid. The first control variable used is a country's gross domestic product growth: $GDPg$. The second control variable is a country's population in absolute numbers: Pop. The third control variable is recession and will be used as a dummy variable. The dummy equals 1 if a country experiences negative GDP growth in a given year: Rec. Finally, gross domestic product per capita will be used as the last control variable: $GDPc$.

Table 1: Definitions of included variables

Variable	*Definition*	*Source*
Nitrous oxide (N_2O) emissions per capita	Aggregate emissions of nitrous oxide, in metric tons of CO_2 equivalent, divided by a country's population	World Development Indicators
Financial Structure (FS)	Value traded on stock markets, divided by credit to the private sector plus the value traded on stock markets	Financial Structure Database
Patience (Pat)	Time preference or the ability/ capacity to accept delay	Global Preference Survey *Falk et al. (2018)*
Trust (Trust)	Firm believe in the reliability, truth, or ability of someone or something	Global Preference Survey *Falk et al. (2018)*
Risk preference (Risk)	Amount of risk someone is willing to Take based on the expected utility or satisfaction of the outcome	Global Preference Survey *Falk et al. (2018)*
Positive Reciprocity (PosR)	Social norm of responding to a positive action with another positive action	Global Preference Survey *Falk et al. (2018)*
Negative reciprocity (NegR)	Social norm of responding to a negative action with another negative action	Global Preference Survey *Falk et al. (2018)*
Altruism (Altr)	Disinterested and selfless concern for the wellbeing of others	Global Preference Survey *Falk et al. (2018)*
GDP growth (GDPg)	Annual percentage growth rate of GDP at market prices based on constant local currency	World Development Indicators
Recession (Rec)	Dummy variable that equals 1 if a country experiences negative GDP growth	World Development Indicators
GDP per capita	GDP per capita is gross domestic product divided by midyear population (current $)	World Development Indicators
Population (Pop)	Sum of all residents regardless of legal status or citizenship	World Development Indicators

3.1.3 Descriptive statistics

In table 2, the data used in this thesis is summarized. For the panel dataset there are 1304 observations. Nitrous oxide emissions are measured in metric tons per capita. Initially, the dataset contained 1360 observations (85 countries measured over 16 years). However, there were 56 missing fields calculating the financial system structures of countries. Table 1 on this page presents the equation calculating the financial structure. If one value is missing in the formula, the outcome will automatically equal 0 or 1. Therefore, creating a clean overview of the statistics, the values for 0 and 1 are omitted. The reason why the minimum of the financial structure variable is still 0 is due to rounding, and thus it is negligible. The summary statistics give a brief overview of the observations, means, standard deviations, minimums, medians, and maximums.

As a departing point, the dependent variable values require a relatively more extended description. As shown in table 2, the natural logarithm of nitrous oxide emissions per capita is taken. One of the advantages of taking the natural logarithm is the fact that it transforms skewed data into a more symmetric way. Additionally, it reduces the impact of outliers. For example, China and Iceland differ drastically in population size. Therefore, for population size in the panel data analysis and the cross-sectional data analyses the natural logarithm is taken too. Returning to the dependent variable interpreting the logarithmic values, there are mathematical rules that can be implied. The natural logarithm, also known as 'e', equals the rounded number of 2.718. If the value needs to be interpreted in context of the real data, a transformation can be made by taking the inverse of the natural logarithm: $real\ data\ value = e^x$, where *x* equals the logarithmic values in table 2. Proceeding on the summary statistics of nitrous oxide emissions per capita in the panel dataset, the mean value equals approximately (rounded) 0.000445 metric tons of CO2 equivalent. 1 metric ton equals 1000 kilograms. Now that it is clear how to interpret logarithmic values in the context of real data, table 2 presents a minimum value that nearly reaches 0, and a maximum value of approximately 0.0056. For the cross-sectional dataset the emission numbers differ since the fact that data is only measured for 2012. Intuitively the explanation is similar. Greenhouse gas emissions per capita is additionally described as a substituted dependent variable[4]. Chapter 4 elaborates on different emissions numbers, and the results.

For the explanatory variables, this thesis examines various factors influencing N_2O emissions. Additionally, all economic preferences of the Global Preference Survey are taken into account. For the first hypothesis, the effect of patience across countries is investigated. The higher the value, the more patience a country is considered to be. The Global Preference Survey dataset compares the difference to the worlds' mean in standard deviation of respective preferences. The maximum value equals 1.071 which implies a highly patient country (Sweden), whereas the minimum value of -0.613 implies that a country is distinctly impatient (Nicaragua). These values exhibit substantial

[4] Paragraph 4.2 elaborates on the robustness tests, and clarifies the reason why greenhouse gas emissions per capita are considered.

differences across countries. For the second hypothesis, the effect of trust is tested. All respondents filled in a questionnaire whether they assume that other people only have the best intentions. The higher the value, the more trustworthy the respondent thinks other people are. The mean value is slightly negative (-0.022), and the gap between the minimum and maximum is again substantial. Looking at the four secondary explanatory variables used in the Global Preference Survey, altruism, positive and negative reciprocity, and risk preference of individuals respectively have means of -0.038; -0.022; 0.013; 0.013. Again, for these variables the same procedure is maintained. For example, the higher the value of altruism, the more altruistic an individual behaves. Lastly, in the panel dataset, financial structure has a value between 0 and 1, where 1 means that a country entirely relies on a market-based financial system, and 0 means that a country' financial system structure entirely relies on deposit money banks and other credit institutions. The mean value is 0.199, which equals in percentages to a 19.9% market-based system. Notably, the minimum and maximum value differ significantly. Since all missing values are filtered out, the minimum value of 0 is due to rounding. This means that the value nearly reaches zero, and the country is almost entirely bank-based. A critical note, it could be due to data quality in certain countries. Therefore, it is essential to elaborate on this finding in the discussion chapter.

Table 2: Summary statistics of includes variables

Variables	*N*	*Mean*	*SD*	*Min*	*Median*	*Max*
Panel data						
Log N2O per capita	1304	-7.716	0.758	-9.129	-7.806	-5.178
Log GHG per capita	1304	-5.065	0.804	-7.175	-4.922	-3.162
Financial structure	1304	.199	0.193	0	.137	.878
GDP growth	1304	3.713	3.652	-15.136	3.773	19.681
Recession (dummy)	1304	.	.	0	0	1
GDP per capita ($)	1304	17.225.337	20.383.079	223.712	8.157.358	123678.7
Log population	1304	16.526	1.680	12.547	16.36	21.045
Cross-sectional data						
Log N2O per capita	76	-3.229	0.733	-4.406	-3.273	-.758
Log GHG per capita	76	-.692	0.934	-3.114	-.54	1.111
Patience	76	-.003	0.370	-.613	-.093	1.071
Trust	76	-.022	0.278	-.706	-.081	.609
Altruism	76	-.038	0.343	-.94	-.097	.906
Positive reciprocity	76	-.022	0.322	-.886	.024	.57

Negative reciprocity	76	.013	0.275	-.489	.004	.739
Risk preference	76	.013	0.302	-.792	-.02	.971
GDP growth	76	3.117	3.951	-7.087	3.001	15.745
Recession (dummy)	76	.	.	0	0	1
GDP per capita ($)	76	16.140.215	18.947.257	563.062	8.251.436	85.836.208
Log population	76	17.073	1.438	13.232	17.204	21.026

3.2 Empirical approach

This research uses two empirical baseline models. The empirical models analyze which explanatory variables potentially explain the dependent variable. The Global Preference Survey uses six different variables. This thesis estimates different versions of the baseline model. Chapter 4 elaborates on the different models, and the outcomes. The first model accurately measures the effect of economic preferences on nitrous oxide emissions per capita, and is specified as follows:

$$\text{Log}\left(\frac{N2O_c}{Population_c}\right) = \beta_0 + \beta_1 Patience_c + \beta_2 Trust_c + \beta_3 Altruism_c + \beta_4 Reciprocity\ positive_c + \beta_5 Reciprocity\ negative_c + \beta_6 Risk\ preference_c + \beta_7 GDPgrowth_c + \beta_8 Recession_c + \beta_9 GDPcap_c + \beta_{10} \log population_c + \varepsilon_c$$

In order to accurately measure the effect of a country's financial system structure on nitrous oxide emissions per capita, the second model is specified:

$$\text{Log}\left(\frac{N2O_{c,t}}{Population_{c,t}}\right) = \beta_0 + \beta_1 Financial\ structure_{c,t} + \beta_2 GDPgrowth_{c,t} + \beta_3 Recession_{c,t} + \beta_4 GDPcap_{c,t} + \beta_5 \log population_{c,t} + \varepsilon_{c,t}$$

Now that the baseline models are specified, the empirical method can be further described. For the first two hypotheses, cross-sectional data is used to measure the effect of economic preferences on nitrous oxide emissions per capita. OLS -regressions suit this research, as it is not necessary to correct for fixed or random effects. To run this type of regression, it is crucial to test if the Gauss Markov assumptions are met. The Gauss Markov theorem explains that the OLS estimate for regression coefficients shows the *best linear unbiased estimate* (BLUE) possible. Following Shaffer (1991) and other literature, there are specific points to address in order to guarantee that all assumptions have been met. On the next page, the assumptions for both datasets are further explained. For the third hypothesis, various models can be used to process panel data. Literature exhibits the fixed effects model, and the random effects model. This thesis addresses cross-country variation in N_2O emissions over time. For each country there could be a specific random or fixed effect. The fixed effect model looks at the relationship of the dependent and independent variables within a country. Each country has different and specific characteristics that might or might not affect the variable. The fixed effects model assumes that some characteristics of a country influence the dependent variables, which have been corrected by removing the effect of these time-independent variables. An important assumption is that time-independent properties are unique per individual and do not correlate with other properties. The error term and the constant should not correlate with the other country (Hsiao, 2007) Torres, 2007). The random effects model assumes that the variance between countries is random and has no correlation with the dependent and unknown variables in the model. As a result, parameters are kept constant within the whole, which allows to derive efficient estimates that make use of variation within and outside the group and to estimate the impact of time-independent variables (Hsiao, 2007). The disadvantage of this method is that properties are country-specific, or that these properties differ across countries, which is a bias. A Hausman test can be used to determine which model should be used. It tests whether the unique errors are correlated with the regressors (Torres, 2007). The null hypothesis implies that the fixed effects model has to be used. If this hypothesis is rejected, the random effects model shall be used. The Hausman test (appendix 1) shows that the null hypothesis cannot be rejected (P equals 0). This reveals that the fixed effects model has to be used. This statistical model assumes that the parameters are fixed, or non-random quantities. Briefly, as this thesis seeks to investigate cross-country variation of financial system structures on N_2O emissions per capita, the fixed effects model will be used in chapter 4 measuring the statistical significance and direction of the effect.

Now that it is clear which models are used, different assumptions can be tested. Departing from the first assumption, it is necessary to test for multicollinearity. First, appendix 2 and 3 show the pairwise correlations. High correlations suggest multicollinearity. Second, running VIF tests is crucial to test for multicollinearity. The VIF test shows if each variable is sufficiently distinct. Multicollinearity is a statistical phenomenon and demonstrates if two or more independent variables are highly correlated in a multiple regression model (Daoud, 2017). The formula stated: $VIF = \frac{1}{1-R^2}$. If the VIF value for a variable is larger than 5, it is considered excessive. Briefly, the variable is highly correlated and not sufficiently distinct (Lavery et al., (2019). The majority in literature suggests that a VIF value larger than 5 is the boundary for high correlation (Daoud, 2017). Appendix 4 shows that for the cross-sectional dataset all variables are not excessing the boundary of 5, and thus declaring each variable as sufficiently distinct. Appendix 5 shows that the explanatory variable for the panel dataset, a country's financial system structure, is slightly above 5, which can be accepted. The VIF value for GDP per capita is considered excessive, and conclusions need to be drawn carefully. Lastly, the natural logarithm of population size is omitted for the panel data regression since the VIF value was excessively high. In a year fixed effects model, a high variance inflation factor (VIF) associated with population size indicates significant correlation with other variables within the model, which is to be expected.

Secondly, solely for the panel dataset, the assumption of no autocorrelation is tested. To meet this assumption, it is essential to run a Wooldridge test for autocorrelation in panel data. The null hypothesis suggests that there is autocorrelation, and indicates that there is correlation between the residuals of two observations. Appendix 6 shows that the test is statistically significant for nitrous oxide emissions per capita, which means that the null hypothesis cannot be rejected. This conclusion violates the assumptions for a regression analysis, and to revise the model, it is necessary to cluster the standard errors. Therefore, when conducting the regression analysis for the effect of the financial structure of a country on nitrous oxide emissions, the standard errors will be clustered.

Lastly, the assumption of homoscedasticity is tested for both datasets. The variability of the dependent variable has to be equal across the range of value of a second predicting value to meet the assumption of homoscedasticity (Cook & Weisberg, 1983). If the variability is unequal across this range, heteroscedasticity is present. Consulting appendix 7 for the cross-sectional dataset, the test is not statistically significant for the 1% and 5% level, but there is prove for the 10% level. Different variables are regressed on nitrous oxide emissions per capita. This research estimates different models in chapter 4 for this dataset, and thus it is not seen as problematic. Nevertheless, it is worth emphasizing in the discussion chapter. Consulting appendix 8 for the panel dataset, the test is statically significant. Nevertheless, as a mitigating condition, the standard errors in the regression will be clustered.

4. Results

This chapter consists of two subsections. In subsection 4.1, the main results of the three tested hypotheses are reported. Subsection 4.2 presents robustness tests. The first robustness test substitutes the dependent variable. Whereas the majority in literature focuses on the effects on greenhouse gases, this thesis extracts nitrous oxide emissions. Therefore, as a robustness check, greenhouse gas emissions per capita is used as a substitute for nitrous oxide emissions per capita. The second robustness test is solely used for the panel dataset, and reduces the 85-country sample used in thesis to 43 countries[5] examined by De Haas and Popov (2019).

4.1 Baseline results

As mentioned in chapter 3, this research focuses socio-economic determinants, and financial system structures, affecting nitrous oxide emissions per capita. For the first and second hypotheses, socio-economic preferences are regressed on nitrous oxide emissions per capita. Departing from the first hypothesis, countries with higher levels of patience are expected to emit less nitrous oxide per capita. The results of column (1) in table 3 demonstrate that the effect of patience is not statistically significant. Therefore, patience cannot explain nitrous oxide emissions per capita. Solely, the natural logarithm of population size shows a statistically significant result for the 10% level. It exhibits a negative association with nitrous oxide emissions per capita. What happens if the four secondary explanatory variables are appended to the regression? Column 2 shows that negative reciprocity is statistically significant, and negatively associated to nitrous oxide emissions per capita. If negative reciprocity increases by 1%, the natural logarithm of N_2O emissions per capita decreases by 0.628. Negative reciprocity is formulated as the social norm of responding to a negative action with another negative action. In other words, following the Global Preference Survey, the willingness to punish someone for unfair behavior or taking revenge if one feels treated very unjustly. Briefly, if the level of negative reciprocity within a country increase, nitrous oxide emissions per capita decrease. The primary explanatory variable of the first hypothesis is patience, and therefore the hypothesis is rejected.

[5] De Haas and Popov (2019) used a 48-country sample in their study. This thesis uses 43 countries of their sample since not all 48 countries are examined in the total dataset. Appendix 12 shows the country samples.

Continuing on the second hypothesis, column (3) shows the effect trust has on the dependent variable. Whereas the third hypothesis estimates a negative association between trust and nitrous oxide emissions, the regression analysis in the third column does not find a statistically significant relationship. GDP per capita and the natural logarithm of population size are the only variables that show statistically significant effects. Extending the model by adding the four secondary explanatory variables, negative reciprocity is statistically significant. Again, the variable is negatively associated with nitrous oxide emissions per capita. Additionally, column (5) shows the regression results of all economic preferences combined. Negative reciprocity is the only explanatory variable that is statistically significant, and can be used for further research.

Consecutively, the financial system structure across 85 countries is regressed on nitrous oxide emissions per capita over 16 years. Correction have been made for fixed effects. Additionally, robust standard errors are used as explained in chapter 3. Whereas the third hypothesis argues that countries with more market-based financial structures tend to emit less N_2O per capita, the results in column (6) do not show statistically significant results. Therefore, this thesis does not find the expected association between the explanatory variable and N_2O emissions per capita. Three control variables are regressed on the dependent variable. GDP growth and recession are not statistically significant. Nevertheless, there is one variable that explains N_2O emissions per capita. GDP per capita is negatively associated with the dependent variable, and statistically significant for the 1% level. This means that if GDP per capita increases, nitrous oxide emissions per capita decrease. The R-squared, which represents the explanatory power of the model, is relatively on the lower side. The data explains the regression model for 14.1%. Summarizing, the third hypothesis is rejected.

Table 3: N_2O emissions and economic preferences in countries across the world (2012), and financial structures in countries across the world (2000-2015)

VARIABLES	lnN_2Opop (1)	lnN_2Opop (2)	lnN_2Opop (3)	lnN_2Opop (4)	lnN_2Opop (5)	lnN_2Opop (6)
Patience	0.343	0.453			0.442	
	(0.346)	(0.376)			(0.379)	
Altruism		-0.309		-0.325	-0.302	
		(0.349)		(0.352)	(0.351)	

Positive reciprocity		0.115		0.193	0.163	
		(0.392)		(0.405)	(0.405)	
Negative reciprocity		**-0.628***		**-0.564***	**-0.594***	
		(0.324)		**(0.333)**	**(0.333)**	
Risk preference		-0.0106		0.128	-0.0119	
		(0.317)		(0.297)	(0.319)	
Financial structure (FS)						0.0735
						(0.0635)
GDP growth	-0.0201	-0.0160	-0.0110	-0.0102	-0.0134	-3.44e-05
	(0.0299)	(0.0301)	(0.0300)	(0.0307)	(0.0307)	(0.00243)
Recession	0.0856	0.184	0.168	0.236	0.193	-0.0248
	(0.277)	(0.293)	(0.277)	(0.294)	(0.296)	(0.0188)
GDP per capita	3.37e-06	3.37e-06	**1.02e-05****	**1.11e-05****	4.24e-06	**-5.28e-06*****
	(7.14e-06)	(7.42e-06)	**(4.87e-06)**	**(4.93e-06)**	(7.65e-06)	**(1.87e-06)**
Log population	**-0.116***	-0.0856	**-0.100***	-0.0715	-0.0836	
	(0.0590)	(0.0614)	**(0.0590)**	(0.0612)	(0.0619)	
Trust			-0.285	-0.191	-0.169	
			(0.306)	(0.331)	(0.330)	
Constant	-1.257	-1.810	-1.689	-2.212**	-1.871	-7.642***
	(1.066)	(1.115)	(1.052)	(1.092)	(1.127)	(0.0316)
Observations	76	76	76	76	76	1304
R-squared	0.168	0.226	0.167	0.213	0.229	0.141
Number of country						85
year fe						yes
Robust standard errors						yes

Standard errors in parentheses

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

4.2 Robustness tests

For the first robustness test, both the cross-sectional dataset and the panel dataset are used. The variables are regressed on total greenhouse gas emissions per capita[6]. The cross-sectional analyses seek a relationship between economic preferences, and greenhouse gas emissions per capita. Column (2) in table 4 shows that the explanatory power of the model almost doubles (R-squared equals 46.6%). Again, patience has no significant effect on emissions. Furthermore, negative reciprocity loses its significance when looking at total greenhouse gas emissions. Notably, the

[6] Appendix 9-11 prove that different tests do not differ from N_2O emissions.

outcome of trust is statistically significant for the 10% level. The positive coefficient implies that if the level of trust in a country increase, total greenhouse gas emissions per capita increase too. Additionally, GDP per capita is highly significant for the 1% level, and is positively associated with greenhouse gas emissions. This means that if GDP per capita increases, greenhouse gas emissions per capita increase too.

Table 4: Greenhouse gas emissions and economic preferences in countries across the world (2012)

VARIABLES	lnN_2Opop	lnGHGpop
	(1)	(2)
Patience	0.442	-0.0513
	(0.379)	(0.402)
Trust	-0.169	**0.686***
	(0.330)	**(0.350)**
Risk preference	-0.0119	0.266
	(0.319)	(0.338)
Positive reciprocity	0.163	0.531
	(0.405)	(0.429)
Negative reciprocity	**-0.594***	0.391
	(0.333)	(0.353)
Altruism	-0.302	-0.528
	(0.351)	(0.372)
GDP growth	-0.0134	-0.0496
	(0.0307)	(0.0325)
Recession	0.193	-0.150
	(0.296)	(0.313)
GDP per capita	4.24e-06	**2.24e-05*****
	(7.65e-06)	**(8.11e-06)**
Log population	-0.0836	-0.0164
	(0.0619)	(0.0656)
Constant	-1.871	-0.591
	(1.127)	(1.195)
Observations	76	76
R-squared	0.229	0.466

Standard errors in parentheses

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

The statistically significant positive coefficient of financial structure in column (2) below shows that the more market-based a country is, the more greenhouse gas per capita is emitted. Furthermore, GDP per capita and recession show significant results which are negatively associated with the dependent variable. The explanatory power of the re-estimated model is slightly lower than the baseline model in column (1).

This thesis takes the country-sample of De Haas and Popov (2019) as a second robustness test for the panel dataset[7]. The authors found that deepened stock-markets are tightly associated with lower carbon dioxide emissions. Column (3) in table 5 shows that the results differ significantly from the baseline model (1). The effect of a country's financial system structure is statistically significant for the 5% level. The coefficient has a positive value, and thus the re-estimated model shows that the more market-based a financial structure is, the more nitrous oxide a country emits. Whereas this thesis hypothesized an opposite effect, the results present the importance of bank-based financial structures in mitigating N_2O emissions. Furthermore, all control variables in the panel dataset are statistically significant, and negatively associated to the dependent variable. This means for instance that if GDP growth or GDP per capita rises, nitrous oxide emissions per capita decrease. As shown in table 5, the explanatory power of the re-estimated model is higher, than the baseline model (28.9%).

Table 5: GHG emissions and financial structures in countries across the world (2000-2015)

VARIABLES	lnN2Opop	lnGHGpop	lnN2Opop
	(1)	(2)	(3)
Financial structure	0.0735	**0.146****	**0.175****
	(0.0635)	**(0.0693)**	**(0.0831)**
GDP growth	-3.44e-05	0.00108	**-0.00554***
	(0.00243)	(0.00196)	**(0.00320)**
Recession	-0.0248	**-0.0434****	**-0.0537****
	(0.0188)	**(0.0199)**	**(0.0216)**
GDP per capita	**-5.28e-06*****	**-4.11e-06*****	**-3.90e-06***
	(1.87e-06)	**(1.01e-06)**	**(2.21e-06)**
Constant	-7.642***	-5.095***	-7.416***

7 The country sample used in this research is shown in appendix 12.

	(0.0316)	(0.0220)	(0.0526)
Observations	1,304	1,304	668
R-squared	0.141	0.121	0.289
Number of country	85	85	43
year fe	yes	yes	yes

Robust standard errors in parentheses

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

Overall, the effect economic preferences and financial system structures have on greenhouse gas emissions differ from nitrous oxide emissions. The findings of the three main analyses are not in line with the literature this thesis supports. The discussion chapter elaborates on the differences in outcomes. Additionally, limitations and future research recommendations are outlined carefully.

5. Discussion

5.1 Findings and contribution to the literature

Diving into the results of this thesis, all three hypotheses are rejected. For the first and second hypotheses, no significant impact on nitrous oxide emissions per capita is found for patience and trust. Patient, more future-orientated, countries were expected to emit less N_2O per capita. Countries exhibiting less myopic behavior were expected to care more about future benefits. Where Cai *et al.* (2020) and the majority in literature find significant effects of patience on climate change, no evidence is found affecting nitrous oxide emissions. Looking at greenhouse gas emissions, no relationship is found between patience and this substituted dependent variable. Consecutively, trust has no impact on nitrous oxide emissions per capita. Whereas this thesis hypothesized that higher levels of trust decrease these gas emissions, no significant relationship is found. Literature demonstrates inconsistency amongst researchers. Interestingly, whereas Carattini *et al.*, (2015) found a negative relationship between greenhouse gas emissions and trust, this thesis demonstrates the opposite when testing for robustness in chapter 4.2. This outcome supports the strand in literature that suggests that higher levels of trust increase emissions. Nevertheless, the explicit definitions measuring trust is worth mentioning in chapter 5.2. Interestingly, altruistic behavior is found to be significantly related to climate change following Curry *et al.* (2008). This thesis does not find such a relationship. Notably, negative reciprocity has an impact on N_2O emissions, and is negatively associated with the gas. If people within a country feel a greater urge to take revenge on negative actions of others, N_2O emissions per capita will decrease. The results of testing the first two hypotheses, contribute to the literature in various ways. Economic preferences of the Global Preference Survey do not reveal underlying factors explaining cross-country variation in N_2O emissions. A deeper understanding is demanded.

Contradictory, another study by Dasgupta *et al.* (2002) argue that bank-based financial systems are better for reducing pollution. Banks use certain screening processes to detect and avoid polluting firms. This has two major reasons. The first reason relates to reputational repercussions (Zeller, 2010). The second reason relates to the transitional risk of financial institutions (Park & Kim, 2020). Restrictions for greenhouse gas emissions are rapidly expanding, and banks desire to avoid the transition risk. This risk occurs when policy and regulatory changes are implemented. When firms do not comply in time with new rules and polices, transitional risks are applicable. Therefore, screening, monitoring and avoiding lacking enterprises becomes crucial.

Departing from the third hypothesis, the financial system structure of countries has no significant impact on nitrous oxide emissions per capita. Deepened stock-markets do not affect these emissions in the baseline model. This is not the expected outcome. However, the regressions results in the country sample of De Haas and Popov (2019) find that the financial structure impacts N_2O emissions per capita. The positive association between the explanatory variable and the dependent variable show that the financial structure matters. Nevertheless, the direction of the effect shows opposite results of the hypothesized expectation. If the financial structure of a country becomes relatively more market-based, the N_2O emissions per capita increase. Vice versa, the more bank-based a country is, the less N_2O is emitted per capita. This finding is in line with the study by Dasgupta *et al.* (2002), who argue that bank-based financial systems are better for reducing pollution. Additionally, taking total greenhouse gas emissions per capita as the independent variable, this thesis finds a similar direction for the effect a financial structure has. This finding contributes to the literature since the panel data regression reveals that the financial structure matters in different country samples.

5.2 Limitations and future research

There are some limitations to this paper. First, the Global Preference Survey only shows data for the year 2012. Therefore, it is not possible to measure cross-country variation over time for economic preferences. The variables examined in this thesis could be biased due to several events. For instance, the measured value for N_2O emissions in 2012 could significantly deviate compared to previous years, and thus poorly reflect reality. A recommendation for future research would be to calculate the average of a specified time window. The possibility that the observed value in 2012 is an outlier will decrease. Furthermore, this thesis demonstrates that the level of trust affects greenhouse gas emissions. If the level of trust increases, greenhouse gas emissions per capita increase. It could be interesting to examine why this effect has been found for total greenhouse gases, and not for N_2O emissions. Perhaps this has something to do with the perception of control. If trust in scientists or governments increase, the feeling of urgency could potentially decrease for individuals. People expect experts or policies to effectively address the problem and take action. This could be interesting for further research.

Another limitation can be found observing the robustness tests outcomes. The country sample of De Haas and Popov (2019) demonstrate a statistically significant relationship between

N_2O emissions and the financial system structure across countries. This thesis does not distinguish between different economic or cultural areas. It matters which countries are taken into account since the original country sample does not find such a relationship. Furthermore, this research does not distinguish between developed and developing counties. Disturbance of the nitrogen cycle is well-known in various developed countries. One theory potentially explaining cross-country variation could be due to knowledge gaps between countries. A well-educated and informed population could help in mitigating environmental degradation. Furthermore, it could be interesting to investigate if developing countries have the financial abilities to focus on N_2O emissions. Additionally, literature demonstrates that corporate construction, and agricultural businesses have significant influence on nitrous oxide emissions. Some countries have a larger agriculture sector, and most likely emit more nitrous oxide. For future research it could be wise to add a variable measuring the size of the agricultural, and industrial sector within countries. Looking at the first two hypotheses, this thesis observed direct effects socio-economic factors have on nitrous oxide emissions. Therefore, it could be that individuals within countries do not significantly influence these emissions directly. Adding institutional variables could reveal new insights into the relationship between N_2O emissions and socio-economic behavior (Zaheer et al., 1998; Bachmann, 2018). This paper eventually compared greenhouse gas emissions and nitrous oxide emissions. It could be wise to additionally compare carbon dioxide emissions as a robustness test. Lastly, as mentioned in chapter 3, values in the panel dataset that nearly reach zero could be due to data quality issues. If data is not adequately collected, it could deviate from real values. Therefore, conclusions need to be drawn carefully.

6. Conclusion

In this paper, determinants of cross-country variation in N_2O emissions are investigated. This research aims to answer the stated research question, "What factors explain cross-country variation in nitrous oxide emissions per capita?" By investigating socio-economic factors, and financial structures across countries, this research contributes to the literature exploring effects on N_2O emissions. To analyze cross-country variation, this research focuses on different economic determinants. The primary factors are patience, trust, and financial system structures across countries. The Global Preference Survey considers four additional economic preferences which are taken into account too, namely altruism, positive and negative reciprocity and risk preference. The main result of this research is divided into two sections. The first baseline model shows that there is no significant relationship between the explanatory variables patience, trust, altruism, positive reciprocity and risk preference and the dependent variable N_2O emissions. This is surprising since literature suggests that associations between socio-economic preferences and climate change does exist. Hence, the majority in research does not focus solely on nitrous oxides. Negative reciprocity is the only factor explaining cross-country variation in N_2O emissions. Since there is only data for the year 2012 conducting the Global Preference Survey, the outcomes could be biased due to lack of data.

Financial system structures do not explain cross-country variation in N_2O emissions. Whereas some studies find that market-based economies are better in enhancing climate change mitigation, other research suggests that bank-based systems are preferable. Nevertheless, this paper does not find a significant relationship between financial structures and N_2O emissions per capita. The baseline results of this paper are not in line with past research. Interestingly, the robustness tests for both the cross-sectional dataset and the panel dataset show different outcomes. When regressing the level of trust on greenhouse gas emissions per capita, a positive association between the variables is found. This implies that the higher the level of trust within a country is, the higher the greenhouse gas emissions per capita is. This result is in line with several studies clarifying the lack of trust in climate scientists. Nevertheless, this research does not distinguish between different measures of trust. Therefore, it is hard to say whether this theory can be linked to this thesis. Additionally, investigating the country sample of De Haas and Popov (2019), market-based economies emit more N_2O which is contradictory to the hypothesized relationship in this research. The same results are found in the robustness test regarding greenhouse gas emissions per capita.

Without distinguishing between economic or cultural areas, or developing and developed countries, it is hard to say whether cross-country variation in N_2O emissions is the results of financial system structures.

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Appendices

APPENDIX 1

Hausman (1978) specification test (N_2O)

	Coef.
Chi-square test value	43.249
P-value	0

APPENDIX 2

Pairwise correlations: cross-sectional data

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
(1) lnN2Opop	1.000											
(2) lnGHGpop	0.509***	1.000										
(3) Pat	0.265**	0.464***	1.000									
(4) Trust	-0.049	0.342***	0.190*	1.000								
(5) Altr	-0.140	-0.056	-0.010	0.273**	1.000							
(6) PosR	0.030	0.126	0.006	0.341***	0.672***	1.000						
(7) NegR	-0.125	0.258**	0.258**	0.160	-0.132	-0.180	1.000					
(8) Risk	-0.041	-0.010	0.230**	-0.061	-0.015	-0.291**	0.193*	1.000				
(9) GDPg	-0.259**	-0.397***	-0.251**	-0.013	0.125	-0.131	-0.185*	0.211*	1.000			
(10) Rec	0.228**	0.239**	0.141	0.064	-0.121	0.187*	0.243**	-0.119	-0.669***	1.000		
(11) GDPc	0.281**	0.601***	0.769***	0.269**	-0.001	0.079	0.187*	-0.033	-0.390***	0.157	1.000	
(12) lnpop	-0.259**	-0.072	0.040	0.094	0.210*	0.037	0.087	-0.010	0.181	-0.305***	-0.050	1.000

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

APPENDIX 3

Pairwise correlations: panel data

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)
(1) lnN2Opop	1.000						
(2) lnGHGpop	0.495***	1.000					
(3) StockCreditStock	0.028	0.271***	1.000				
(4) GDPg	-0.025	-0.134***	-0.079***	1.000			
(5) Rec	0.024	0.076***	0.009	-0.633***	1.000		
(6) GDPc	0.289***	0.555***	0.314***	-0.275***	0.099***	1.000	
(7) lnpop	-0.241***	-0.255***	0.437***	0.048*	-0.064**	-0.227***	1.000

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

APPENDIX 4

Variance inflation factor (cross-sectional data)

	VIF	1/VIF
GDPc	3.298	.303

Pat	3.082	.324
PosR	2.658	.376
Rec	2.31	.433
GDPg	2.309	.433
Altr	2.282	.438
Risk	1.456	.687
Trust	1.32	.757
NegR	1.318	.759
lnpop	1.242	.805
Mean VIF	2.127	.

APPENDIX 5

Variance inflation factor (panel data)

	VIF	1/VIF
Financial structure	5.863	.171
GDPg	2.689	.372
Rec	2.16	.463
GDPc	15.354	.065
Mean VIF	2.423	.

APPENDIX 6

N_2O test

Wooldridge test for autocorrelation in panel data

H0: no first order autocorrelation

F(1, 84) = 10.197

Prob > F = 0.0020

APPENDIX 7

Hettest: cross-sectional data

Breusch,ÄiPagan/Cook,ÄiWeisberg test for heteroskedasticity

Assumption: Normal error terms

Variable: Fitted values of lnN2Opop

H0: Constant variance

chi2(1) = 3.55

Prob > chi2 = 0.0595

APPENDIX 8

Hettest: panel data

Modified Wald test for groupwise heteroskedasticity

in fixed effect regression model

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

chi2 (85) = 45888.77

Prob>chi2 = 0.0000

APPENDIX 9

Hausman (1978) specification test (GHG)

	Coef.
Chi-square test value	60.539
P-value	0

APPENDIX 10

Greenhouse gas

Wooldridge test for autocorrelation in panel data

H0: no first order autocorrelation

F(1, 84) = 10.681

Prob > F = 0.0016

APPENDIX 11

Greenhouse gas

Modified Wald test for groupwise heteroskedasticity

in fixed effect regression model

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

chi2 (85) = 22159.17

Prob>chi2 = 0.0000

APPENDIX 12

List of countries included in this thesis

i. Cross-sectional data

Afghanistan	Czech Republic	Japan	Romania	United States
Algeria	Egypt	Jordan	Russia	Venezuela
Argentina	Estonia	Kazakhstan	Rwanda	Vietnam
Australia	Finland	Kenya	Saudi Arabia	Zimbabwe
Austria	France	Korea, Rep.	Serbia	
Bangladesh	Georgia	Lithuania	South Africa	
Bolivia	Germany	Malawi	Spain	
Bosnia and Herzegovina	Ghana	Mexico	Sri Lanka	
Botswana	Greece	Moldova	Suriname	
Brazil	Guatemala	Morocco	Sweden	
Cambodia	Haiti	Netherlands	Switzerland	
Cameroon	Hungary	Nicaragua	Tanzania	

Canada	India	Nigeria	Thailand
Chile	Indonesia	Pakistan	Turkey
China	Iran	Peru	Uganda
Colombia	Iraq	Philippines	Ukraine
Costa Rica	Israel	Poland	United Arab Emirates
Croatia	Italy	Portugal	United Kingdom

ii. Panel data (bold countries refer to the country sample of De Haas and Popov (2019))

Argentina	El Salvador	Jordan	**Netherlands**	South Africa
Australia	**Estonia**	**Kazakhstan**	Nigeria	**Spain**
Austria	**Finland**	Kenya	**Norway**	Sri Lanka
Belgium	**France**	Korea, Rep.	Oman	**Sweden**
Bolivia	Georgia	Kuwait	Pakistan	**Switzerland**
Botswana	**Germany**	Kyrgyz Republic	Panama	**Thailand**
Brazil	Ghana	Latvia	Paraguay	Trinidad and Tobago
Bulgaria	**Greece**	Lebanon	Peru	Tunisia
Chile	**Hungary**	**Lithuania**	**Philippines**	**Turkey**
China	Iceland	**Luxembourg**	**Poland**	**Ukraine**
Colombia	**India**	Malaysia	**Portugal**	**United Kingdom**
Costa Rica	Indonesia	Malta	Romania	**United States**
Cote d'Ivoire	Iran, Islamic Rep.	Mauritius	**Russian Federation**	**Zambia**
Cyprus	**Ireland**	**Mexico**	Saudi Arabia	
Czech Republic	Israel	Mongolia	Serbia	
Denmark	**Italy**	**Morocco**	Singapore	
Ecuador	Jamaica	Namibia	Slovak Republic	
Egypt, Arab Rep.	**Japan**	Nepal	**Slovenia**	