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METHANE EMISSIONS AND FINANCIAL STRUCTURES

The role of Finance in mitigating Environmental Degradation

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Abstract

Inspired by the empirical work of De Haas and Popov (2021), this thesis examines how the financial structure of countries – bank-based versus market-based financial systems – affects their aggregate emissions of methane (CH_4). Conducting a fixed effects analysis on a 105-country panel over the period of 1990-2012, the data shows that, while holding both economic and financial development constant, per capita CH_4 emissions are significantly higher (lower) in economies with deeper stock (credit) markets. An explanation for this finding may be that (ordinary) equity investors are to a lesser extent aware of methane's detrimental impact on the world's environment than (often well-informed) financial intermediaries, consequently being less capable to stimulate methane-intensive firms to lower their emissions of the gas. Importantly, this finance-methane link also survives the inclusion of an additional controlling factor for the stringency of countries' environmental regulation and is robust to multiple alternative measurements. Moreover, by documenting these results alongside the finance-CO_2 link as studied by De Haas and Popov (2021), it is shown that both the per capita emissions of CO_2 and CH_4 need to be accumulated if one wants to come up with valid implications regarding the association between conventional finance and environmental degradation in general.

Keywords: Financial Development, Financial Structure, Methane Emissions, Environmental Kuznets Hypothesis

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1. Introduction

One of the biggest collective action problems ever faced by humankind is putting a stop to the ongoing catastrophic climate change of today (Tavoni *et al.*, 2011). Endeavouring to address this global phenomenon, the 2015 Paris Climate Conference (COP21) has emphasized the importance of finance in the 'battle' against environmental degradation (De Haas & Popov, 2021). During this conference, the leaders of the G20 asserted their intention to scale up so-called green-finance initiatives to fund 'environmentally conscious' projects, with the European Union even committing itself to achieve climate-neutrality by 2050 (Capros *et al.*, 2019). A key example of such an initiative is the burgeoning market of green bonds to finance environmentally targeted projects such as alternative energy, energy efficiency, pollution prevention and control, and many more (Anderson, 2016, p.308). Other green-finance initiatives include the establishment of the British Green Investment Bank and the creation of a green-credit department by one of the world's largest banks, the ICBC in China (De Haas & Popov, 2021).

Yet, somewhat paradoxically, the limited understanding of the current academic society regarding the relationship between finance and (the state of) the environment has progressively been revealed by this increased interest in green finance. Except for the inquiry of De Haas and Popov (2021), limited to no rigorous empirical work exists on the association between a country's overall financial development and, in particular, financial structure – the relative share of an economy's total (private) funding accounted for by (1) equity markets versus (2) credit institutions - on the one hand, and pollution expressed in terms of greenhouse gas (GHG) emissions on the other. Controlling for both economic development and environmental protection, these authors find that financial sector size has no impact on carbon dioxide (CO_2) emissions, but that these emissions tend to be significantly lower in economies where equity financing is more important relative to bank lending. Their finding is consistent with the increasing scientific evidence that equity investors tend to value environmentally sustainable behaviour by firms (e.g. Galema *et al*., 2008), and attempt to reduce their carbon-footprint by (1) engaging with investee firms with the goal of mitigating their CO_2 emissions, or (2) by divesting in carbon-intensive stocks (De Haas & Popov, 2021). Nevertheless, up until today, this finance-pollution link remains unexplored for GHGs other than CO_2, even though their detrimental impact on the state of the environment is increasingly recognized.

In particular, with its emissions accounting for 20% of the additional climate forcing since 1750 (Saunois *et al*., 2016a), the deteriorating effect of methane (CH_4) has recently been put at the heart of the debate around environmental degradation[1]. Although its atmospheric concentration is relatively low

[1] De Haas and Popov (2021, p.1) state that CO_2 emissions originating from the combustion of *fossil fuels* also serve as a proxy for other air pollutants such as methane. Yet, the fact that fossil-fuel-related activities only rank third behind agriculture and waste management in the list of main contributors to the anthropogenic emissions of methane warrants the gas to be examined in isolation (Karakurt *et al*., 2012; Saunois *et al*., 2020).

compared to that of CO_2, its high radiative efficiency – the capacity to trap and reradiate heat downwards – causes its overall climate forcing to be 120 (28) times stronger than that of CO_2 immediately (during the 100-year period) after its emission (Balcombe *et al*., 2018; Saunois *et al*., 2020). In addition, despite the coronavirus pandemic bringing much of the world's economy to a halt, methane levels in the atmosphere surged to record highs during 2020, transcending the already disquieting approximations of most environmental scientists (Hook, 2021). Yet, the GHG's relatively short atmospheric lifetime makes reducing its emissions an effective means to achieve climate change mitigation rapidly (IEA, 2021b; Shindell *et al*., 2012). Hence, in the light of meeting the 1.5-2°C target as set out in the Paris Agreement, finding ways to abate methane emissions and consequently translating them into concrete policy interventions should deserve a prominent place at the current academic research agenda.

Therefore, against a background where the detrimental impact of methane emissions on the world's environment is gaining attention in both academic and policy spheres (Key & Tallard, 2012), and where a potentially mitigating role of conventional equity markets is accentuated (De Haas & Popov, 2021), this study aims to investigate the relationship between financial structures – the ratio between equity and credit - and pollution, the latter being expressed in terms of methane emissions. By empirically exploiting a 105-country, 23-year panel, this thesis seeks to answer the question: *What is the influence of countries' financial structure – the relative importance of stock markets versus banks and other financial institutions as corporate funding sources - on their per capita emissions of methane?*

To preview the results, this thesis demonstrates that for given levels of economic and financial development, CH_4 emissions per capita are significantly higher (lower) in economies where equity-based (credit-based) financing is relatively more important. This finance-methane link also survives when the estimations are (1) controlled for the state of countries' environmental regulation and (2) exposed to sample and specification changes[2]. A rationale for this positive association between deepening stock markets and CH_4 emissions is that (ordinary) equity investors may to a lesser extent be aware of the climate forcing caused by methane than financial intermediaries, consequently being less capable to stimulate methane-intensive firms to lower their emissions of the gas (Le Fevre, 2017). Banks, on the other hand, often have longstanding ties with the agricultural sector (Grant & MacNamara, 1996), which is the main source of anthropogenic methane emissions (Karakurt *et al*., 2012; Saunois *et al*., 2020). Consequently, banks can use their frequently thorough understanding of this sector, attained from these enduring ties, to adequately support and finance the sector's transition towards a (more) sustainable system of food production (Dasgupta *et al*., 2002), for example by encouraging the development and adoption of technologies that are less methane intensive (Viatte, 2001; Yusuf *et al*., 2012). Furthermore, by reporting these findings alongside those of the finance-CO_2 association as

[2] To put this finding into perspective, a back-of-the-envelope calculation suggests that shifting the financial structure of all countries in the world to at least 50-percent equity financing would result in an increase in current worldwide per capita CH_4 emissions of about 0.151 metric tons of CO_2-equivalents, which would adversely impact the Paris Agreement's 40% reduction target in overall GHG emissions to achieve by 2030 with 2%.

examined by De Haas and Popov (2021), this study shows that the mitigating effect of deepening stock markets on CO_2 emissions that is reported by these authors reverses when their 48-country sample is enlarged to the 105-country sample of this thesis. Lastly, this thesis's results show the importance of accumulating the per capita emissions of both GHGs rather than using CO_2 as a proxy for CH_4 if one wants to come up with valid implications regarding the finance-pollution link in general.

Based on these results, this thesis contributes to (and connects) two strands of literature within the scientific profession. First, it explores the role of finance in shaping the relationship between economic development and environmental pollution. This relationship has typically focused on the environmental Kuznets hypothesis, according to which pollution increases at early stages of development but declines once a country surpasses a certain income level (De Haas & Popov, 2021). As stated by Levinson (2009), two mechanisms cause this relationship to be inversely U-shaped. First, as a country develops economically, a shift towards an industrial phase characterized by high levels of pollution is followed by a shift towards less-polluting, service-oriented sectors. Second, within a given sector, dirty technologies tend to be increasingly replaced by cleaner ones as economic development causes breakthroughs at the technological frontier to take place.

Prior empirical work has applied the Kuznets hypothesis to a variety of pollutants, yielding mixed results (Dasgrupta *et al*., 2002). For the domain of methane, however, the empirical work of Benavides *et al*. (2017) provides evidence for an inversely U-shaped relationship in Austria. By applying the autoregressive distributed lag (ARDL) method, the authors show that methane emissions have gone up with per capita GDP and subsequently stabilized when Austria researched a certain level of income. The contribution of this thesis is to investigate the role of finance in shaping this relationship between economic growth and emissions of methane. In particular, it assesses whether the two channels that underpin the Kuznets hypothesis – (1) a shift towards sectors that are less methane-intensive and (2) a reduction in CH_4 emissions within sectors due to technological advancements – are better facilitated by equity markets or banks, an inquiry similar to that conducted by De Haas and Popov (2021) for CO_2 emissions.

Second, this thesis also contributes to the literature on the relationship between financial structure and economic development. By now, an extensive amount of empirical work has shown that growing financial systems causally contribute to economic development (King & Levine, 1993)[3]. In addition, recent studies suggest that the impact of banking (securities markets) on economic growth declines (increases) as national income rises (Demirguc-Kunt *et al.*, 2011; Gambacorta *et al.*, 2014). Therefore, another contribution of this study is to show that the structure of financial systems – bank-based versus market-based - might not only influence the process of economic growth on its own, but possibly also the degree of environmental degradation (expressed in terms of methane emissions) that accompanies this growth.

[3] See Popov (2018) for a comprehensive survey of this literature.

The remainder of this thesis is structured as follows. First, an extensive review of the relevant literature is provided in section 2. Subsequently, sections 3 and 4 describe the empirical methodology and data, respectively. Then, the empirical results are presented in section 5, after which they are discussed in section 6. Section 7 concludes.

2. Literature Review

2.1 Methane emissions: environmental impact and main contributors

With a global warming potential (GWP) that is 120 times as powerful as that of carbon dioxide (CO_2) immediately after being emitted and 28 times as potent when measured over a 100-year lifespan, methane (CH_4) can reasonably be considered to be an important driver of today's environmental degradation (Balcombe *et al*., 2018). Hence, large reductions in its global anthropogenic emissions – predominately caused by agricultural activities, waste management, and the combustion of fossil-fuels – are required to achieve the environmental targets as set out in the Paris Agreement (Saunois *et al*., 2020).

With a direct impact equal to approximately 20% of the additional climate forcing since 1750, CH_4 ranks second behind CO_2 in the list of greenhouse gasses (GHGs) contributing the most to the catastrophic climate change that has taken place during the past three centuries (Saunois *et al*., 2016a). Its direct and indirect forcing effects (including oxidation to CO_2 and impact on ozone creation) are estimated to be 58% of that of CO_2 (Balcombe *et al*., 2018). Additionally, although annual anthropogenic methane emissions represent only 3% of those associated with CO_2 on a global scale, its radiative forcing is about 120 times that of CO_2 immediately after emission (Balcombe *et al*., 2018; Saunois *et al*., 2020)[4]. To further quantify this relative strength of CH_4 with respect to absorbing the earth's emitted thermal infrared radiation, the gas's global warming potential (GWP) – considering no climate feedbacks and a 100-year time horizon - amounts to 28 carbon dioxide-equivalents (CO_2eq) (Saunois *et al*., 2020). This basically indicates that, averaged over a 100-year time horizon, emitting one kilogram of methane creates 28 times as much warming as the emission of one kilogram of CO_2. Moreover, as the current anthropogenic methane emissions trajectory is estimated to further increase the global temperature level with more than 3°C by the end of the century, large reductions in the emission of methane are required to meet the 1.5-2°C target of the Paris Agreement (Collins *et al*., 2013; Nisbet *et al*., 2019; Saunois *et al*., 2020). According to Shindell *et al*. (2012), this reduction of CH_4 emissions

[4] A greenhouse gas (GHG)'s total radiative forcing is obtained by multiplying that particular gas's atmospheric concentration with its radiative efficiency. In turn, radiative efficiency reflects the capacity of an atmospheric concentration of gas to trap and reradiate heat downwards (Balcombe *et al*., 2018). Given methane's high radiative efficiency, combined with the fact that it comes with various detrimental, indirect effects, an additional emission of the gas has a much larger radiative forcing effect than CO_2 (Neubauer & Megonigal, 2015).

is also a *remarkably effective* manner to achieve rapid climate change mitigation, especially on a decadal basis. Following their line of reasoning, the short atmospheric lifetime of methane, which is estimated at 12.4 years as compared to CO_2's potentially indefinite perturbation life (Balcombe *et al*., 2018), allows for a quick reduction of its atmospheric concentration and consequently radiative forcing when its emissions are stabilized or, even better, brought down. Hence, methane can plausibly be considered as one of the most important GHGs when it comes to the (battle against) environmental degradation, a major collective action problem faced by the current global society.

Methane, formed as a result of the decomposition of organic materials in a zero-oxygen environment, is released from both natural and anthropogenic sources with proportions of about 40% and 60%, respectively (Karakurt *et al.*, 2012). Following the definitions of Saunois *et al*. (2020, p.1567), the former refers to pre-agricultural methane emissions even if they are agitated by anthropogenic climate change (e.g. emissions related to wetlands and other natural sources such as wild animals and terrestrial permafrost). The latter, on the other hand, is *directly* caused by human activities since pre-industrial/pre-agricultural time (3000-2000 BCE), and includes those emissions stemming from agriculture, waste management, and fossil-fuel-related activities. Since, in the light of this thesis, we are particularly interested in the sources that involve human interference, we will break down the anthropogenic emissions-component into its main contributors and their corresponding severities.

For the period 2008-2017, Saunois *et al*. (2020) document that the agriculture accounted for 56% of total anthropogenic methane emissions. This is also consistent with Karakurt *et al.*'s (2012) claim that agricultural emissions – which they approximated at an average of 50.63% of total anthropogenic emissions over the period 1990-2010 – are characterized by a substantially larger growth rate than the emissions from other human activities. Furthermore, by distinguishing between different subcategories of agricultural activities, the main category in terms of methane emissions – livestock production (i.e. the combination of enteric fermentation and manure management) – accounts for around one-third (two-third) of total global anthropogenic (total agricultural) emissions, followed by rice cultivation with an 8% (16%) stake (Saunois *et al*., 2020, p.1574-1575).

Waste management, a second important sector in the anthropogenic category, was responsible for a proportion of total human-based emissions ranging between 11% and 21% depending on the timeframe used (Karakurt *et al.*, 2012; Kirschke *et al*., 2013; Saunois *et al*., 2020). The sector of waste management includes the methane emissions from managed and non-managed landfills (solid waste disposal on land), and the handling of domestic and industrial wastewater. Whereas methane production from waste depends on the material's moisture, temperature and pH - with an optimal pH varying between 6.8 and 7.4 (Thorneloe *et al*., 2000) - , the generation potential of wastewater is determined by its level of degradable organic material (André *et al*., 2014).

The third major contributor to anthropogenic methane emissions consists of fossil-fuel-related activities. The burning of (1) biomass (e.g. the burning of forests, savannahs, and grasslands to clear land for agricultural purposes or to maintain pastures and rangelands) and (2) biofuel (used to produce energy for domestic, industrial, commercial, or transportation purposes) on average accounted for 5% and 3% of total global anthropogenic emissions over the period 2008-2017, respectively (Saunois *et al*., 2020, p.1576-1577).

2.2 Financial intermediaries, stock markets, and pollution: an inconsistent literature

Financial structure, or the relative importance of stock markets versus credit facilities as sources of corporate funding, may be an important determinant of a country's environmental impact if different forms of finance affect polluting activities dissimilarly with respect to magnitude and/or channels of operation. The existing work on bank-based versus market-based financial systems as drivers of environmental degradation is characterised by inconsistency, resulting in often opposing reasons as to why banks or stock markets would be more suitable to limit environmental deterioration in an efficient manner (De Haas & Popov, 2021).

A first strand of the scientific literature argues that the capability of banks to effectively reduce pollution is limited, as they might be hesitant to finance technological innovations that could foster the 'green capabilities' of contaminating industries and economic entities. This reluctance may be due to several reasons. First, as argued by Minetti (2011), banks may be technologically conservative: by financing innovative (and often cleaner) technologies they might reduce the collateral that underlies their already outstanding loans, which then represents older (and probably more polluting) technologies. Second, when the innovation related to new green technologies involves assets that are characterised by intangibility, firm-specificity, and strong ties to specific types of human capital, banks may be hesitant to provide the necessitated credit as these assets are difficult to redeploy and, as a consequence, hard to collateralize (Carpenter & Petersen, 2002; Hall & Lerner, 2010). Allen and Gale (1999), for example, illustrate that pharmaceutical industries, typified by these particular asset types, often tend to be located in countries in which stock markets are the primary financier. Third, banks may lack necessary skillsets to accurately evaluate (green) technologies that are in the early phase of the development process (Ueda, 2004). In line with this third reasoning, Hsu *et al.* (2014) provide cross-country evidence that less patents are filed by technologically oriented, financially intensive industries when they are located in countries with better developed credit markets. Fourth, banks may have a shorter investment horizon than equity investors and might therefore be less concerned about whether or not certain funded assets become less valuable in the more distant future (De Haas & Popov, 2021). Only after 2015, banks have started to incorporate the price of climate risk into the interest rate that they charge on loans to firms with high fossil fuel reserves (Ongena *et al*., 2018).

However, a second strand of the literature propagates several reasons why bank-based systems could reduce pollution. For instance, Dasgupta *et al*. (2002) argue that banks that care about environmental wellbeing use their screening processes to detect and consequently avoid lending to the (visibly) most emitting enterprises. In addition, out of fear for potential financial and reputational repercussions, banks and other financial intermediaries have started to scrutinize high-pollution industries more thoroughly (Zeller, 2010). An example of such a repercussion is provided by Homanen (2018), who argues that banks that visibly cause environmental damage face a higher propensity of being disciplined by their (existing) depositors. Nevertheless, as reasoned by De Haas and Popov (2021), banks that consider a potential borrower's environmental impact primarily for reputational purposes might still be willing to provide funding to industries of which the polluting nature is not directly noticeable, such as those emitting large amounts of methane or other types of GHGs in a less obvious manner.

A third part of the scientific literature is relatively more optimistic about stock markets compared to financial intermediation with respect to the funding of high risk-high return innovative projects. Brown *et al*. (2017), for example, show that market-based financial systems have a comparative advantage over their bank-based counterparts in the financing of technology-led growth. In line with this finding, Kim and Weisbach (2008) illustrate that a large part of the funds raised by firms via public stock issuances is invested in R&D. Furthermore, empirical evidence has illustrated that whereas stock markets tend to punish firms with a negative environmental impact (e.g. when they are held responsible for a particular environmental disaster) (Krüger, 2015; Salinger, 1992), firms with a positive impact tend to be rewarded (Klassen & McLaughlin, 1996; Ferrell *et al.*, 2016). Lastly, using a cross-country firm level dataset, Trinks *et al.* (2017) show that the cost of equity is negatively associated with a firm's level of emission. Especially institutional investors with a longer-term investment horizon tend to hold firms with a good environmental footprint in their equity portfolios (Gibson Brandon & Krueger, 2018), and are more inclined to vote against management whose behaviour does not comply with the firm's environmental standard (Krueger *et al.*, 2018).

To the contrary, some empirical evidence has shown that equity investors might not be capable enough to properly evaluate long-term investment projects. Hong *et al.* (2019), for example, illustrate that stock markets only anticipate the effects of predictably worsening droughts on agricultural firms after they have well materialized. This 'inadequacy' of equity investors regarding the assessment of long-term projects may imply that firm managers become more short-term oriented and, as a consequence, less incentivized to enhance the long-term environmental impact of their firms (Asker *et al.*, 2015; De Haas & Popov, 2021). Moreover, Hart and Zingales (2017) developed a model that predicts that closely held private firms make socially responsible decisions more often than publicly listed firms, since the latter's higher degree of ownership diffusion and therefore lower personal responsibility of each individual (voting) shareholder tends to incur a drift away from prosocial decision-making. In line with this reasoning, privately held firms that are located in the U.S. (1) emit less GHGs and (2) encounter less fines related to environmental regulation than their comparable public counterparts (Shive & Forster, 2020).

2.3 Methane versus carbon dioxide: are different financial structures warranted?

In an attempt to deal with the dispersed and inconclusive literature regarding the effect of financial structures on environmental degradation, De Haas and Popov (2021) examined the link between a country's overall financial development and financial structure (i.e. market-based versus bank-based financial systems), on the one hand, and the amount of CO_2 its industries emit on the other. Their empirical findings yield promising and congruent results, both at a country and industrial level. At the country level, the authors find that, after controlling for both economic and financial development, CO_2 emissions per capita are significantly lower in economies where equity financing is more important relative to bank lending. Their industry-level analysis then confirms these aggregated results by showing that carbon intensive industries start to emit relatively less CO_2 where and when stock markets expand. Seeking for the underlying mechanisms behind these results, De Haas and Popov (2021) then reveal two distinct channels that are at play. First – holding cross-industry differences in technology constant – stock markets are characterized by a tendency to reallocate investments towards more carbon-efficient (read less polluting) sectors. Second, being less conservative in nature, stock markets facilitate the adoption of greener technologies within polluting industries. Overall, to put their results into perspective, a back-of-the-envelope calculation of the authors suggests that shifting the financial structure of all countries in the world to at least 50-percent equity financing would facilitate a reduction in current worldwide per capita CO_2 emissions equal to half of the 40% reduction target to achieve by 2030 as set out in the Paris Agreement[5].

To get a better understanding of these two mechanisms that connect finance, industrial composition, and CO_2 emissions as put forward by De Haas and Popov (2021), we have to consider these mechanisms in combination with the environmental Kuznets hypothesis with which they are closely associated. This hypothesis states that the relationship between economic development and environmental pollution is inversely U-shaped, suggesting that pollution increases at early stages of development but declines once a country surpasses a certain income level. According to Levinson (2009), two mechanisms underlie this hypothesis. First, when developing over time, a country's economy is prone to two subsequent transitions: (1) a transition from agriculture to manufacturing and heavy industry, and (2) a move from manufacturing and heavy industry towards light industry and services. Whereas the first transition is characterised by more pollution per capita (often expressed in terms of CO_2 emittance), the latter goes hand-in-hand with a levelling off and succeeding reduction in pollution. The pace in which this process of economic development takes place basically determines the *width* of the Kuznets curve and, as indicated by the first channel of De Haas and Popov (2021), could be improved by a deepening of stock markets. Second, breakthroughs at the technological frontier (or

[5] However, the authors also report that the outsourcing of dirty technologies to foreign countries partly explains the negative association between domestic stock market development and the amount of CO_2 emitted. Yet, this pollution-outsourcing effect is dominated by the domestic-greening effect by a factor of 10.

the adoption of technologies from more advanced countries) during a country's process of development - which determines the *steepness* of (the downward sloping part of) the curve – may replace dirty technologies with clean ones and hence reduce pollution per unit of output (within a given sector). Again, an increase in the importance of a country's stock market relative to its banking sector could stimulate this process, as illustrated by De Haas and Popov's (2021) second mechanism.

Yet, the two mechanisms, as proposed by De Haas and Popov (2021), via which a deepening of stock markets could mitigate environmental degradation – (1) the facilitation of investment reallocations to less polluting sectors, and (2) the funding of the R&D-activities required to develop and implement 'green' technologies (in polluting industries) – are solely based on the anthropogenic emissions of CO_2, a GHG that has been standing at the core of environmental research and international climate negotiations for many decades[6] [7]. Therefore, the general public's understanding of this particular gas type and the climate forcing it causes has progressively advanced over time. CH_4, on the other hand, has only recently been put at the heart of the debate around global warming. Even in the years following the 2015 Paris Climate Conference (COP21), there remained substantial uncertainty in the academic society regarding the relative contribution of different (anthropogenic) methane sources to the ongoing increase in the atmospheric concentration of the gas (Saunois *et al*., 2016b). In addition, Le Fevre (2017) states that, even though the impact of methane emissions is currently receiving growing attention in wider 'environmental circles', most industries still consider the expenditures required to reduce these emissions to outweigh the benefits. This reluctance to reduce emissions of CH_4, Le Fevre continues, is largely caused by the fact that the gas's detrimental impact on the state of the environment is only marginally recognised outside the borders of the scientific community, consequently lowering the fear of firms to be penalized for their high levels of methanic emissions. Therefore, he argues, mitigating the emissions of methane usually is at best a minor consideration for firms and commonly persists to be an 'industry blind spot'.

Hence, the frequently scarce knowledge among the general public about methane's harmful nature for the state of the world's environment, and, consequently, the absence of substantial financial and reputational incentives for firms to invest in technologies that are less methane intensive, could cause the cleansing effect of increased equity-based financing relative to bank lending as accentuated by De Haas and Popov (2021) to disappear or even reverse when CH_4 rather than CO_2 emissions are being examined. For instance, Asker *et al.* (2015) argue that firm managers tend to be less inclined to

[6] Already in the late 1930s, Callendar (1938) advocated that increasing atmospheric concentrations of CO_2 had been causing the (global) temperature to rise, and would continue to do so in the (distant) future. Although being heavily doubted at that time, his theory received more adherence from the early 1950s onwards.

[7] De Haas and Popov (2021, p.1) state that CO_2 also serves as a proxy for other air pollutants caused by *fossil fuels*, such as, amongst other GHGs, methane. Yet, since fossil-fuel-related activities only rank third behind agriculture and waste management in the list of main contributors to the anthropogenic emissions of methane (Karakurt *et al*., 2012; Saunois *et al*., 2020), and as the gas's emissions have accounted for 20% of the additional climate forcing since 1750 (Saunois *et al*., 2016a), it is warranted to study the impact of financial structures on the emissions of methane in isolation in order to be able to draw conclusions on the finance-methane link validly.

improve the emission levels of their firms when [ordinary] equity investors do not have the necessary acquaintance to adequately assess the long term [environmental] impact of their investment decisions, something that is presumably the case when the fund-receiving firm heavily emits a relatively newly inquired GHG such as methane. Additionally, banks (and other financial institutions), being more conservative in nature than stock markets (Allen & Gale, 1999), often have close ties with and are commercially attracted by stable, low risk sectors, of which the agricultural sector is an important example (Grant & MacNamara, 1996). These close ties between banks and the agricultural sector – the latter being the main emitter of anthropogenic methane (Karakurt *et al*., 2012; Saunois *et al*., 2020) – could well cause a country's CH_4 emissions to be lower when its financial system is more bank-based for two reasons.

Firstly, the close, longstanding relationships between banks and (large) agricultural enterprises has resulted in a thorough understanding of the agricultural sector by these financial intermediaries (CBA, 2021). Whilst realizing that the sector faces increasing consumer demands and more stringent environmental regulations (Rabobank, 2020; World Bank, 2020), banks can use the knowledge attained from these abiding ties to *adequately* support and finance the sector's transition towards a (more) sustainable system of food production (Dasgupta *et al*., 2002), for example by stimulating the development of *effective* and *efficient* green technologies (Bierbaum *et al*., 2020; Viatte, 2001; Yusuf *et al*., 2012). In line with this reasoning, Beukers *et al.* (2010) emphasize that technological progress in the agricultural sector, for instance in the forms of improved feeding mechanisms or animal genetics, could enhance the feed conversion efficiency and consequently reduce enteric emissions of methane[8].

Secondly, due to their advanced internal information systems (Allen & Gale, 1999), and strengthened by the close ties with the agricultural sector, banks are to a greater extent aware of the detrimental impact of methane emissions on the world's climate compared to the general public. Yet, once the ordinary people gradually start to recognize the environmental forcing of the gas, as also progressively happened for CO_2 in the past, banks could face financial and reputational repercussions when they 'consciously' kept providing credit to excessively methane-intensive (agricultural) enterprises, or if they did not sufficiently stimulate these companies to (innovate to) cut their levels of CH_4 emissions (Zeller, 2010). The depositors of these banks, for example, who largely belong to the general public, could then decide to discipline their bank(s) once, in hindsight, they also learn about methane and its influential impact on the world's climate (Homanen, 2018). Hence, out of fear for these potential 'disciplinary actions', banks (and other financial intermediaries) have started to scrutinize the agricultural sector more thoroughly and adjusted their credit flows to it accordingly, a procedure they also put into practice for other high-pollution industries, such as those emitting large quantities of methane via waste management or the combustion of fossil fuels (Zeller, 2010). Therefore, departing

[8] Feed conversion efficiency indicates how effectively animal feed is converted into consumer products, such as meat and milk (Beukes *et al*., 2010).

from this earlier scientific work, the following hypothesis regarding the effect of a country's financial structure on its per capita CH_4 emissions is formed:

H_1: *Whereas De Haas and Popov (2021) emphasize the importance of deepening stock markets in mitigating CO_2 emissions, countries with a financial system that is more equity-based are expected to emit more methane per resident.*

2.4 Measuring environmental impact: a debate

The current scientific literature is typified by a discussion around the correct measurement of the environmental impact of different greenhouse gasses (GHGs). So far, there is no uniformity regarding a single best metric, which should be taken into account when interpreting the results as presented in this thesis later on. In addition, exchange rate fluctuations and inflation have recently been proposed as vital components for the construction of a harmonized global environmental disclosure framework.

Up until this day, the global warming potential (GWP) is the standard metric used to compare GHG emissions stemming from different products and services. It is defined as the time-integrated radiative forcing of an emission pulse of gas, relative to that of CO_2, over a defined time horizon (Balcombe *et al*., 2018). The most common variant of this metric, the GWP_{100}, measures the average radiative forcing of a GHG's single pulse emission over the 100 years after its emittance [excluding climate feedbacks or, i.e., indirect effects], and expresses it in so-called CO_2-equivalents (CO_2eq) (Saunois *et al*., 2020)[9]. However, there are several criticisms levelled at the use of this particular metric relating to three of its key aspects: (1) it requires an arbitrary timespan to be set, (2) it is modelled on a single pulse emission, and (3) it measures time-integrated radiative forcing (Balcombe *et al*., 2018). As a consequence, the last 20 years have been characterised by the creation of multiple alternative climate metrics[10].

The criticisms aimed at GWP's fist key aspect - the necessity to select an arbitrary timeframe - are particularly relevant for methane as its GWP value tend to change tremendously for different time intervals. Whereas the selection of a too short timeframe for methane's GWP metric would ignore the relatively stronger long-term impact of CO_2 – methane's perturbation life is estimated at only 12.4 years compared to carbon dioxide's partially indefinite one (Balcombe *et al*., 2018) -, a too long timeframe would result in a systematically underrepresentation of methane's short-term forcing, which is about 120 times that of CO_2 immediately after emission (Saunois *et al*., 2020). Furthermore, regarding the criticisms on the second key aspect of the metric, Alvarez *et al.* (2012) emphasize that the design of GWP to equate pulse or one-off emissions rather than sustained or developing emissions results in the fact that the measure is not able to adequately capture and reflect the consequences of real-world

[9] For methane, the GWP_{100} is set equal to 28 CO_2eq.
[10] See (Balcombe *et al*. (2018, p.1327-1330) for an overview of these alternative metrics.

investment and policy decisions. Lastly, as GWP measures time-integrated radiative forcing, which is a precursor of temperature change rather than a synonym, the measure itself cannot solely capture temperature (or other climate) change (Balcombe *et al.*, 2018)[11]. Hence, setting out real-world policy interventions predominantly based on this particular metric, for example with respect to global temperature control as highlighted in the Paris Agreement, could lead to sub-optimal and misguided interferences.

Furthermore, by addressing the need for robust statistical metrics for Dutch pension funds and insurance companies to enable them to adequately manage their climate-related risks and to correctly determine their sustainability improvements over time, Janssen *et al*. (2021) emphasize that both absolute and relative metrics fulfil important roles. Whereas absolute metrics measure the total emissions of a portfolio in (tonnes of) CO_2-equivalent emissions - for example by using the GWP of different GHGs - and are consequently able to determine climate-related risks and portfolio alignment with the Paris Agreement, relative metrics normalize emissions to a common factor and therefore allow for the (international) comparison of portfolios of specific financial institutions or sectors[12]. Additionally, by taking a closer look at three different, commonly used relative metrics, the authors illustrate that the sustainability improvements of the different Dutch financial institutions tend to be significantly lower when these metrics are adjusted for inflation and exchange rate fluctuations. Hence, Janssen *et al*. (2021) stress the importance of the incorporation of these two factors when one wants to correctly measure sustainability improvements of different institutions and sectors over time.

3. Empirical methodology

Since the goal of this thesis is to examine whether the cleansing effect of deepening stock markets as reported by De Haas and Popov (2021) persists or, to the contrary, reverses once environmental degradation is measured in terms of methane rather than CO_2 emissions, the units of observation are 105 countries across the world from 1990 to 2012. This means that cross-country comparisons have to be made over time. Therefore, a panel data approach is the appropriate method of analysis, as it allows the combination of cross-sectional and time-series dimensions (Woolridge, 2013, p.448). Additionally, in line with the methodological approach of De Haas and Popov (2021) and, consequently, to enhance the comparability of the findings of this study with those of these authors, the fixed effects estimator of Correia (2016) is used to correct the estimations for the impact of time-invariant omitted variables. As this thesis seeks to investigate the impact of financial structures – equity markets versus bank lending

[11] Balcombe *et al.* (2018) stress that (1) temperature change is governed by a variety of factors and therefore only partly caused by radiative forcing, and that (2) there tends to be a lag between radiative forcing and temperature change of approximately 15–20 years.
[12] However, in line with the third criticism of Balcombe *et al.* (2018) on the GWP, the portfolio alignments based on absolute metrics should be assessed with caution.

(and other private credit facilities) as sources of corporate funding – on methane emissions *within* countries and not *between* countries, this fixed effects estimator can soundly be used here (Correia, 2016; Woolridge, 2013).

To accurately check whether the methane emissions of countries are affected by the structure of their financial systems, the main analysis of this thesis consists of two phases. In the first phase, a base model is estimated using an extensive sample of 105 countries to assess whether the mitigating effect of deepening stock markets on per capita CO_2 emissions as documented by De Haas and Popov (2021) perseveres or, as hypothesized, reverses in the 'domain of methane'. Departing from the country-level analysis of these authors, the baseline model for this first phase can be specified as follows:

$$\frac{CH_{4c,t}}{Population_{c,t}} = \beta_1 FD_{c,t-1} + \beta_2 FS_{c,t-1} + \beta_3 logGDPcap_{c,t} + \beta_4 logGDPcap^2_{c,t} + \beta_5 Population(billions)_{c,t} + \beta_6 Recession_{c,t} + \theta_c + \phi_t + \epsilon_{c,t} \quad (1)$$

Here, $\frac{CH_{4c,t}}{Population_{c,t}}$ denotes the total CH_4 emissions per capita in country c during year t. Additionally, following De Haas and Popov (2021), this regression equation distinguishes between the size and the structure of the financial system. Firstly, the variable *Financial Development (FD)* captures the overall size of the financial sector and is defined as the sum of private credit and stock market capitalization divided by the country's gross domestic product (GDP):

$$FD_{c,t} = \frac{\left(Credit_{c,t} + Stock_{c,t}\right)}{GDP_{c,t}} \quad (2)$$

Next, the main explanatory variable of this thesis, *Financial Structure (FS)*, is defined as the share of total financing through both credit facilities and stock markets that happens via stock markets:

$$FS_{c,t} = \frac{Stock_{c,t}}{\left(Credit_{c,t} + Stock_{c,t}\right)} \quad (3)$$

In the construction of both these 1-year lagged 'financial proxies', *Credit* is the sum of credit extended to the private sector by financial institutions (both deposit money banks and other credit institutions), while *Stock* reflects the value of all traded shares. Furthermore, subscript c indicates the country, and t the year[13].

[13] De Haas and Popov (2021) find that only the structure of a country's financial system (FS) and not the overall size of it (FD) has an impact on that country's carbon dioxide emissions. Therefore, Financial Structure (FS) is the main variable of interest in this thesis. Nevertheless, to replicate the country-level analysis of these authors as closely as possible, FD and FS are defined as the $\beta 1$ and the β_2, respectively.

Moving on to the control variables in the base model of the first stage, multiple country-specific variables that fluctuate over time and are likely to account for a substantial portion of the variance in CH_4 emissions per capita are included. To start off with, $logGDPcap_{c,t}$ and $logGDPcap_{c,t}^2$ represent the natural logarithm of per capita GDP and its squared variant, respectively. These two controls are added to the specification to incorporate the environmental Kuznets hypothesis. Their combination incorporates the different stages of economic development and their pollution impact in terms of methane emissions, which is – based on the finding of Benavides *et al.* (2017) - expected to be positive at early stages of development, and negative at later stages when the economy innovates to reduce emissions of methane. An additional control variable is $Population(billions)_{c,t}$, which measures, in billions, the number of residents that populate a particular country in a given year. Since the size of the population is also used as the denominator in the construction of the dependent variable, it is expected to have a negative impact on per capita emissions of methane. Following the reasoning of De Haas and Popov (2021), such a negative causation would suggest a negative pollution premium to market size. A last controlling factor is $Recession_{c,t}$, which takes into account the premise that pollution might be affected by the phase of the business cycle. During recessions, environmental cleansing may occur when companies with inferior (read dirtier) technologies are the least efficient ones and face bankruptcy (Caballero & Hammour, 1994; De Haas & Popov, 2021). This is also in line with Gali and Hammour's (1991) "pit-stop" view of recessions, which reflects the idea that productivity-improving activities (such as technological advancements) come with lower opportunity costs in times of an economic downturn. However, this environmentally favourable effect might be (partly) offset if investments in cleaner technologies are put on hold during a recession (Campello *et al.*, 2010). To account for the potential effects of recessions, a dummy variable is included that equals 1 if a country c experiences negative GDP growth during a particular year t.

To complete the benchmark model of the first phase, θ_c and ϕ_t are added to the specification, which are vectors of country dummies and year dummies, respectively. The former nets out the independent impact on methane emissions of unobservable country-specific and time-invariant influences, such as comparable advantages or the appetite for (environmental) regulation by voters (De Haas and Popov, 2021). The latter cleanses the model's estimates from the impact of unobservable global trends that are common to all countries, for example the adoption of new green technologies across countries at roughly the same time, or natural phenomena that increase the atmospheric concentration of methane all around the world, such as the thaw of terrestrial permafrost (O'Connor *et al.*, 2010). Lastly, $\epsilon_{c,t}$ reflects the idiosyncratic error term. Here, it is important to mention that the standard errors are clustered by country. This does not only account for the possibility that the standard errors are correlated within a country over time, but also that they are consistent for heteroskedasticity.

Next, to put into perspective the methane-finance relationship central to this study with the CO_2-finance association as examined by De Haas and Popov (2021), the country-level model of these authors is recreated and subsequently estimated for the same 105-country sample as is done for the baseline model of the first phase (specification 1). This yields the following specification:

$$\frac{CO_{2c,t}}{Population_{c,t}} = \beta_1 FD_{c,t-1} + \beta_2 FS_{c,t-1} + \beta_3 logGDPcap_{c,t} + \beta_4 logGDPcap^2_{c,t} \qquad (4)$$
$$+ \beta_5 Population(billions)_{c,t} + \beta_6 Recession_{c,t} + \theta_c + \phi_t + \epsilon_{c,t}$$

Note that, except for the different greenhouse gas (GHG) in which environmental degradation is expressed – CH_4 is replaced by CO_2 -, specification (4) is identical to the first phase's baseline model (1).

As a final methodological step for the first phase of the main analysis, we want to come up with a model that allows us to accurately examine the influence of financial structures on total GHG emissions. Although De Haas and Popov (2021, p.1) state that CO_2 emissions also serve as a proxy for other air pollutants caused by *fossil fuels*, the facts that (1) fossil-fuel-related activities only rank third behind agriculture and waste management in the list of main contributors to the anthropogenic emissions of methane (Karakurt *et al*., 2012; Saunois *et al*., 2020), and (2) CH_4 emissions accounted for 20% of the additional climate forcing since 1750 (Saunois *et al*., 2016a) imply that CO_2 emissions resulting from the combustion of fossil fuels might not adequately proxy for anthropogenic emissions of methane. Hence, to effectively examine the relationship between financial structures (FS) and overall levels of GHG emissions, the per capita emissions of CH_4 and CO_2 are accumulated. This results in the following specification:

$$\frac{GHG_{c,t}}{Population_{c,t}} = \beta_1 FD_{c,t-1} + \beta_2 FS_{c,t-1} + \beta_3 logGDPcap_{c,t} + \beta_4 logGDPcap^2_{c,t} \qquad (5)$$
$$+ \beta_5 Population(billions)_{c,t} + \beta_6 Recession_{c,t} + \theta_c + \phi_t + \epsilon_{c,t}$$

Here, $\frac{GHG_{c,t}}{Population_{c,t}}$ reflects the total per capita emissions of both methane and carbon dioxide in country c during year t, and is calculated as follows:

$$\frac{GHG_{c,t}}{Population_{c,t}} = \frac{(CH_{4c,t} + CO_{2c,t})}{Population_{c,t}} \qquad (6)$$

Again, except for the difference in which the outcome variable expresses environmental degradation, specification (5) is similar to regression equations (1) and (4).

In the second phase of the main analysis, an extra consideration comes into play. Here, in line with De Haas and Popov (2021), the OECD's Environmental Policy Stringency Index (EPS) is added to the three different models of the first phase – specifications (1), (4), and (5) – to control for the state of countries' environmental regulation and, consequently, to prevent for a possible omitted variable bias. The EPS, developed by Botta and Kozluk (2014), captures the degree to which (the policies of) a country put(s) an implicit or explicit price on environmentally harmful or polluting behaviour. Hence, the more stringent a country's environmental policies, the lower its emissions of methane, carbon dioxide, and the accumulation of these two GHGs are expected to be. The inclusion of this index as an additional controlling factor results in the following three specifications:

$$\frac{CH_{4c,t}}{Population_{c,t}} = \beta_1 FD_{c,t-1} + \beta_2 FS_{c,t-1} + \beta_3 logGDPcap_{c,t} + \beta_4 logGDPcap^2_{c,t} + \beta_5 Population(billions)_{c,t} + \beta_6 Recession_{c,t} + \beta_7 EPS + \theta_c + \phi_t + \epsilon_{c,t} \quad (7)$$

$$\frac{CO_{2c,t}}{Population_{c,t}} = \beta_1 FD_{c,t-1} + \beta_2 FS_{c,t-1} + \beta_3 logGDPcap_{c,t} + \beta_4 logGDPcap^2_{c,t} + \beta_5 Population(billions)_{c,t} + \beta_6 Recession_{c,t} + \beta_7 EPS + \theta_c + \phi_t + \epsilon_{c,t} \quad (8)$$

$$\frac{GHG_{c,t}}{Population_{c,t}} = \beta_1 FD_{c,t-1} + \beta_2 FS_{c,t-1} + \beta_3 logGDPcap_{c,t} + \beta_4 logGDPcap^2_{c,t} + \beta_5 Population(billions)_{c,t} + \beta_6 Recession_{c,t} + \beta_7 EPS + \theta_c + \phi_t + \epsilon_{c,t} \quad (9)$$

Note that, besides the inclusion of the EPS, these three specifications are equivalent to their 'phase one forms'. Yet, given that data on this particular index are only available for 27 (out of currently 37) OECD member-states, it does not cover the entire sample of 105 countries. Therefore, the incorporation of this control reduces the number of countries examined substantially. As a result, the index is not included in the three models of the first phase, causing these extended models of phase 2 to function similarly to a robustness check with the results from specifications (1), (4), and (5) serving as a benchmark. Thus, the extended models of phase 2 are estimated for a subsample of 27 OECD countries during the period of 1990-2012. Comparing these results with those of the models that exclude the EPS (phase 1) could then provide insights in the importance of this stringency index in keeping emission levels down and, also, how this affects the finance-emissions relationship.

4. Data

This section is divided into two subsections. The first subsection, being provided with a quick overview of all variables and their definitions, introduces the main data sources that are used in this thesis. It also outlines how the final 105-country, 23-year dataset is determined. Subsequently, both a numerical and a visual exploration of the data are carried out in the second subsection, presenting some first insights into the relationships central to this study.

4.1 Construction of the dataset

To construct the dataset necessary to perform the analyses of this inquiry, datasets from a variety of data sources are combined. On the next page, Table 1 provides a quick overview of all variables used in the analyses, their definitions and sources included. Starting off, data on emissions of methane (CH_4), the greenhouse gas (GHG) central to this thesis, are gathered from the World Development Indicators. This set of data is expressed in metric Kilotons (kt) of CO_2-equivalents and consists of those anthropogenic emissions resulting from agricultural and industrial activities[14] [15]. It covers a total of 206 countries across the world over the period 1970-2012. Moving on to the second GHG, data on carbon dioxide (CO_2) emissions stemming from the combustion of fossil fuels are, similarly to De Haas and Popov (2021), sourced from the International Energy Agency (IEA)[16]. The IEA's original dataset, covering the period 1971-2019 and expressing the emissions in million metric tons of CO_2, contains information for 143 out of the 206 countries for which methane data is available. Then, both the data series on CH_4 and CO_2 emissions are transformed to their final per capita forms by converting them to metric tons (t) and dividing them by the size of the population, respectively. The therefor necessitated population data are also retrieved from the World Development Indicators and count a country's residents regardless of their legal status or citizenship. Subsequently, the variable 'greenhouse gas (GHG) emissions per capita' is created by summing up the final per capita forms of both these GHGs.

The proxies for financial system size and structure, FD and FS, are calculated using two country-specific data series which are – in line with De Haas and Popov (2021) - both retrieved from Beck *et al.*'s (2019) widely recognized and frequently used Financial Development and Structure Database. The first data series is the value of total credit by deposit money banks and other financial institutions to the private sector (lines 22d and 42d in the IMF International Financial Statistics), normalized by GDP. These data exclude credit by central banks, credit to the public sector, and cross claims of one group of intermediaries on another. The second data series is the value of all publicly traded stocks in the economy, normalized by GDP. This is a measure of the total value of traded stock, not the intensity with which trading occurs. Both these data series are available for 105 out of the 143 countries for which data

[14] The standard metric used to quantify emissions of non-CO_2 greenhouse gasses is 'CO_2-equivalents'. This metric, adopted by the United Nations Framework Convention on Climate Change (UNFCCC), multiplies the mass of a particular GHG that is emitted with its 'global warming potential' over a 100-year timescale (GWP_{100}), which is 28 for methane (Ritchie & Roser, 2020; Saunois *et al*., 2020). However, bear in mind the limitations of this metric as discussed in subsection 2.4 of this thesis.

[15] As agricultural activities, [agricultural and industrial] waste management, and the industrial combustion of fossil fuels are the three primary sources of anthropogenic emissions of methane (Saunois *et al*., 2020), this dataset of the World Development Indicators, originating from the European Commission's Emissions Database for Global Atmospheric Research (EDGAR), adequately measures the human-based emissions component we are interested in.

[16] Today, the IEA, founded by some of the world's most advanced economies, is at the heart of the global dialogue on energy by providing authoritative statistics and analyses, and through its examination of the full spectrum of energy issues. The IEA also advocates policies that will enhance the reliability, affordability, and sustainability of energy in its 30 member-countries and beyond (IEA, 2021a).

Table 1: Variable Definitions and Sources

Variable	*Definition*	*Source*
Emissions data		
Methane (CH_4) emissions per capita	Aggregate emissions of methane, in metric tons (1000kg) of CO_2-equivalents, divided by the country's population.	The World Development Indicators (2021)
Carbon dioxide (CO_2) emissions per capita	Aggregate emissions of carbon dioxide, in metric tons (1000kg), divided by the country's population.	International Energy Agency (IEA); the World Development Indicators
Greenhouse gas (GHG) emissions per capita	The sum of methane (CH_4) and carbon dioxide (CO_2) emissions, in metric tons (1000kg) of CO_2-equivalents, divided by the country's population.	International Energy Agency (IEA); the World Development Indicators
Financial proxies		
Financial development (FD)	Sum of private-sector credit and value of all listed stocks, divided by the country's Gross Domestic Product (GDP).	Financial Structure Database (Beck *et al*., 2019)
Financial structure (FS)	Value of all listed stocks, divided by the sum of credit to the private sector and the value of all listed stocks.	Financial Structure Database (Beck *et al*., 2019)
Controls		
GDP per capita	A country's per capita Gross Domestic Product (GDP), in current USD.	The World Development Indicators (2021)
Population (billions)	Country's population, in billions of inhabitants.	The World Development Indicators (2021)
Recession	Dummy variable equal to 1 if a country experiences negative annual GDP growth in a given year.	The World Development Indicators (2021)
Environmental protection index	Index that measures the stringency of environmental regulation ranging from 0 (not stringent) to 6 (very stringent).	OECD; Botta & Kozluk (2014).

on the two different GHGs are also accessible. However, although the dataset covers the period 1960-2017 after its most recent update, both data series are patchy before 1990, especially for many Central and Eastern European countries. Therefore, following the procedure of De Haas and Popov (2021), the observations prior to 1990 are dropped, resulting in a final dataset for the estimation of the benchmark model that comprises 105 countries observed between 1990 and 2012[17]. [18]

Continuing with the control variables, data on per capita GDP and recessions (defined as an instance of negative annual GDP growth) are collected from the World Development Indicators. Additionally, data on the OECD Environmental Policy Stringency Index (EPS) are used, which is a country-specific and internationally-comparable measure of the stringency of environmental policy that covers 27 OECD countries for the period 1990-2015. It captures the degree to which environmental policies put an explicit or implicit price on polluting or environmentally harmful behavior and ranges from 0 (lowest degree of stringency) to 6 (highest degree of stringency)[19].

4.2. Exploring the data

In Table 2 on the next page, the data used in this thesis are summarized. Both the emissions of methane and carbon dioxide are measured in metric tons (t) per capita. Hence, it can be seen that whereas the average country emits 5.89t of CO_2 per capita each year, per capita methane emissions are on average only 1.74t of CO_2-equivalents on an annual basis. Additionally, annual per capita CO_2 emissions tend to vary more heavily between countries and over the years than per capita methane emissions do, with respective ranges of 0.05t – 41.44t and 0.19t – 23.93t. Regarding total GHG emissions, which, in this thesis, is defined as the sum of both CH_4 and CO_2 emissions, the average country emits a quantity of 7.62t per capita annually.

Continuing with the two financial proxies, the mean of FD equals 1.05, indicating that the average country has a financial system size – the sum of private credit and stock market capitalization – that exceeds its gross domestic product (GDP). Yet, there is a large dispersion in FD, with a minimum value as small as 0.03 (3%) in Azerbaijan in 1999, and a maximum value reaching 12.50 (1250%) in Hong Kong in 2010. A similar pattern can be seen in FS: while stock markets on average account for approximately 39% of a country's total financial system, this fraction ranges from one-tenth of a percent in Bulgaria in 1997 up to 99% in Zimbabwe in the year 1993.

Regarding the control variables, data on per capita GDP indicate that the dataset of this thesis contains a good mixture of developing countries, emerging markets, and industrialized economies, as this series of data is characterized by a high variability (standard deviation equal to $16,243) and is widely ranged with a minimum and maximum value of $95 and $115,761, respectively. Yet, combining these data properties with the facts that (1) the mean value is approximately $8,000 higher than the

[17] See appendix A(i) for an overview of these 105 countries.
[18] Although FD does not significantly affect carbon dioxide emissions (De Haas & Popov, 2021), this thesis still studies the impact of FD and FS on per capita methane emissions separately. As the coefficient of correlation between the two proxies in the sample is 0.34 (Appendix B), there is no sign of excessive correlation. Hence, it is important to examine the influence of FD and FS on methane emissions simultaneously.
[19] For more details on the EPS, see Botta and Kozluk (2014).

median value, and (2) both the mean and the median are relatively closely situated to the minimum, a clear indication that GDP per capita is positively skewed is given. This warrants the transformation of this particular variable to its logarithmic form - as is also done by De Haas and Popov (2021) -, resulting in a distribution that is more normal. This is shown by Log GDP per capita's roughly equivalent mean (8.51) and median (8.44). Furthermore, the average country counts around 52 million residents and is in a recession about once every seven years. Lastly, the OECD's Environmental Protection Index is characterized by a mean of 1.74, indicating that there is still quite some room for improvement when it comes to putting a price on environmentally harmful behavior. Note, however, that it has substantially fewer observations than the other variables, as it only contains data on 27 OECD countries in our 105-country sample.

Table 2: Summary statistics of included variables

Variables	*Obs.*	*Mean*	*Median*	*Std. Dev.*	*Min*	*Max*
Emissions data						
CH_4 emissions per capita	2434	1.736	1.125	2.161	0.193	23.932
CO_2 emissions per capita	2434	5.886	4.281	6.078	0.047	41.443
Greenhouse gas (GHG) emissions per capita	2434	7.622	5.895	7.628	0.616	64.906
Financial proxies						
Financial development (FD)	1956	1.053	0.763	1.011	0.029	12.502
Financial Structure (FS)	1956	0.386	0.381	0.192	0.001	0.992
Controls						
GDP per capita	2405	12,469.82	4,623.75	16,243.53	95.19	115,761.50
Log GDP per capita	2405	8.510	8.439	1.491	4.556	11.659
Population (billions)	2435	0.052	0.010	0.163	0.0003	1.3507
Recession	2378	0.138	0.000	0.345	0.000	1.000
Environmental Protection Index	603	1.743	1.604	0.895	0.208	4.133

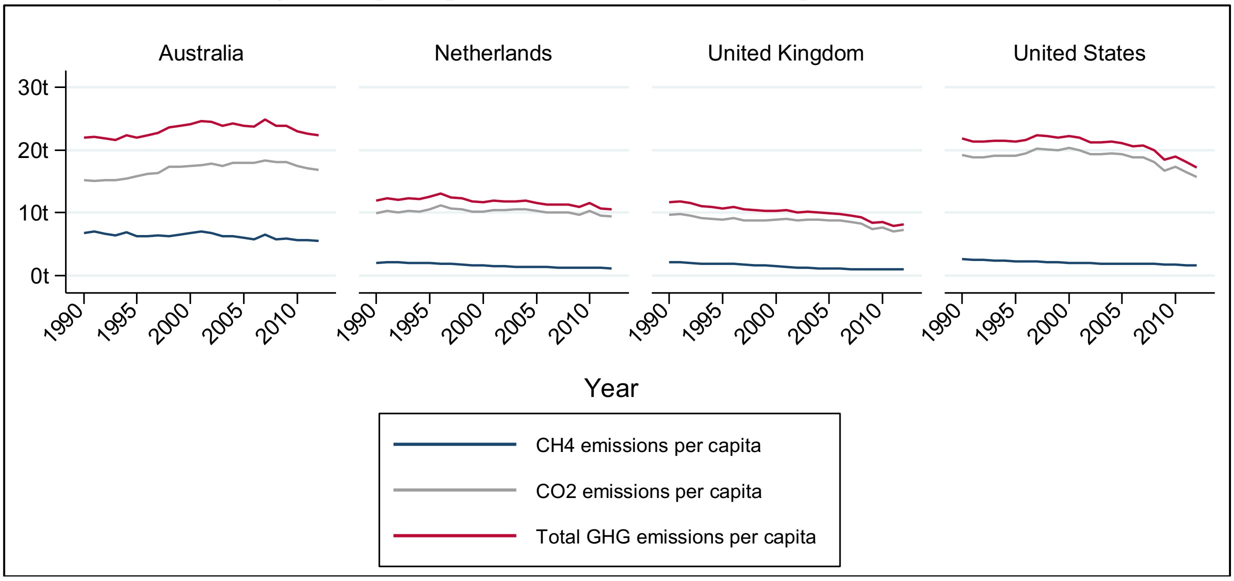
Note: the data on the different variables as summarized in this table cover the period 1990-2012.

To get a first (visual) impression of the relationship between GHG emissions and finance, figures 1a through 2b show examples of how, on the one hand, per capita emissions of CH_4, CO_2, and the accumulation of these two GHGs, expressed in metric tons (t) of CO_2-equivalents, and, on the other hand, the size and structure of the financial system – FD and FS - have changed over time for 4 developed as well as 4 developing countries[20]. As shown in figure 1a, per capita emissions of CO_2 exceed

[20] Here, this dichotomy between developed (OECD) and developing (non-OECD) countries, based on the country classifications of the United Nations (2020) and the OECD (2020), is made to check for the potential presence of so-called 'outsourcing effects' (De Haas and Popov, 2021, p.28-30). Departing from the environmental Kuznets hypothesis, this phenomenon implies that economically developed countries that are in the transition from the heavy industry and manufacturing phase to the light industry and service-oriented phase may outsource the production of methane- and/or carbon-intensive products to developing countries that are in the agricultural phase

those of CH_4 in the 4 developed countries during the period 1990-2012. Yet, whereas per capita CO_2 emissions slightly increased in Australia, remained moderately constant in the Netherlands, and gradually decreased in both the United Kingdom and the United States, all 4 advanced economies have been characterized by steadily decreasing emission levels of per capita methane. In addition, on first sight, Australia's per capita emissions of both GHGs seem to be surprisingly high relative to those of the other 3 countries. Nevertheless, as the emission-variables are denotated in their *per capita* forms and Australia ranks fourth in the list of the world's least densely populated countries (Ritch, 2019), the GHG emissions of the oceanic country are divided by vastly fewer residents than those of the other 3 countries, consequently yielding higher values. Furthermore, zooming in on methane, the GHG central to this thesis, 55% of Australia's land area (427 million hectares, excluding timber production) is accounted for by agriculture (ABARES, 2021), the number one contributor to anthropogenic emissions of methane (Karakurt *et al.*, 2012; Saunois *et al.*, 2020). Hence, the country's relatively high levels of per capita CH_4 emissions can logically be explained[21].

Figure 1a: per capita GHG emissions in developed countries

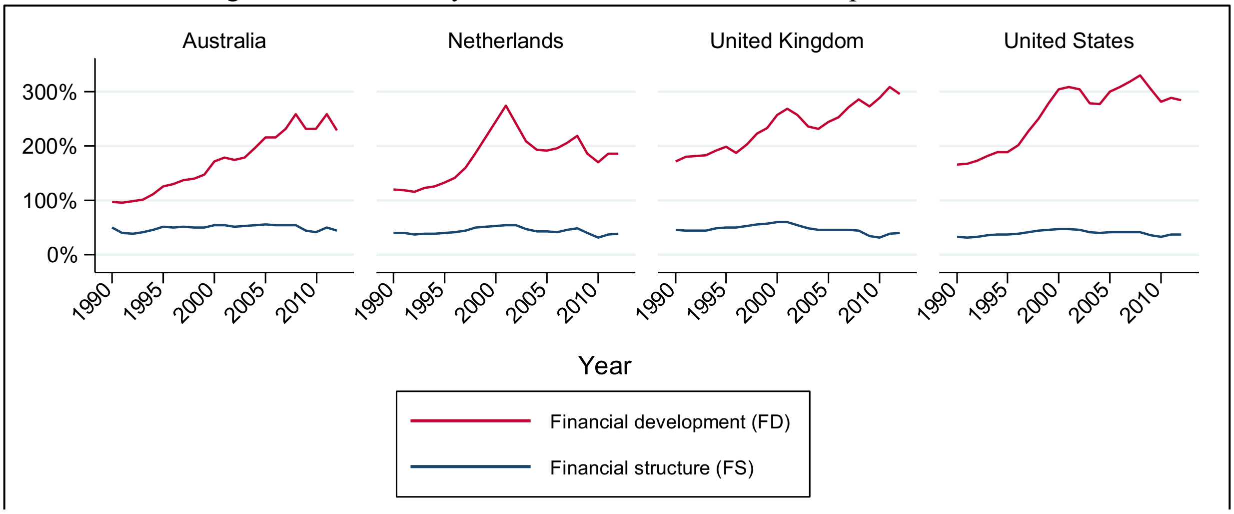


Note: this figure visualizes the change in the per capita emissions of both CH_4 and CO_2 seperately, as well as for their accumulation. All three emission-variables are denoted in metric tons (t) (of CO_2-equivalents).

or transitioning from agriculture to heavy industry and manufacturing. Additionally, given their geographic locations, the combination of these 8 countries also provides a fair representation of the change in GHG emissions and financial structures around the world.

[21] Using data sourced from the CAIT Climate Data Explorer, Ritchie and Roser (2020) report similar levels of per capita CH_4 emissions and the development thereof for these 4 advanced economies during the period 1990-2012. Therefore, these higher levels of per capita methane emissions in Australia cannot be attributed to potential errors in the methane data from the World Development Indicators that are used in this thesis.

Figure 1b: financial system size and structure in developed countries



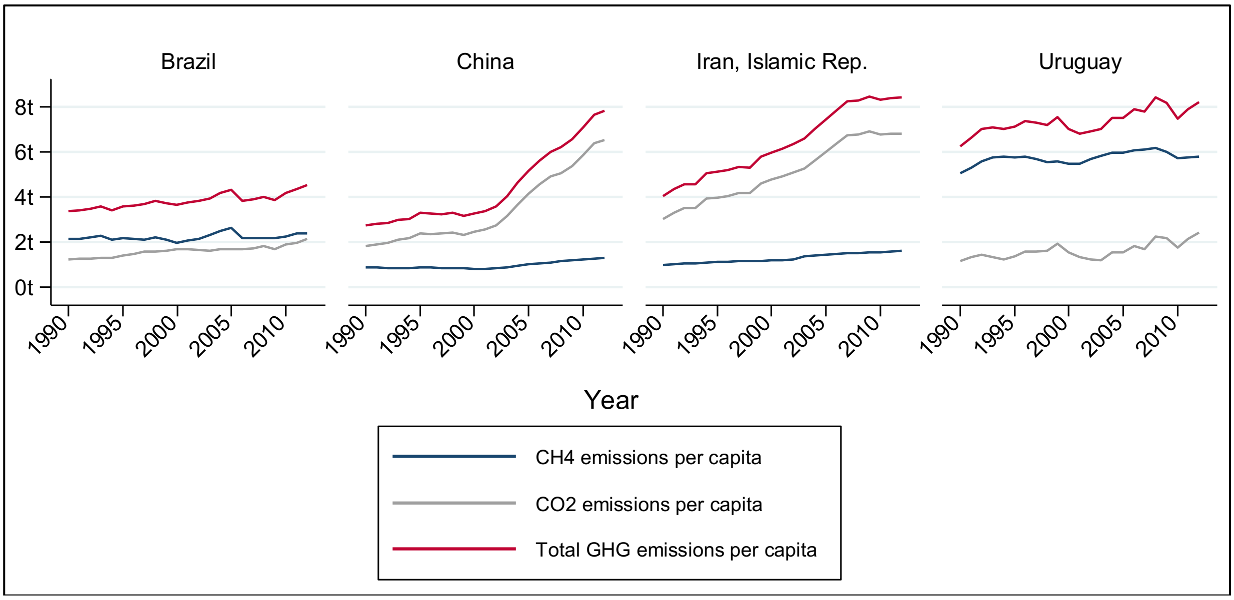
Note: this figure shows the change in financial development (FD) – the sum of private credit and stock market capitalization, normalized by GDP – and financial structure (FS) – the share of stock market financing out of total financing through credit and stock markets. Both FD and FS are 1-year lagged.

Moving on to the 1-year lagged financial proxies FD and FS, figure 1b illustrates that the 4 advanced economies have seen their financial systems grow in size during the period 1990-2012. In addition, as FS only marginally fluctuated within these countries throughout this timeframe, with a minimum and maximum value of 0.32 (32%) in the Netherlands in 2009 and 0.60 (60%) in the United Kingdom in 1999, respectively, both stock and credit markets accounted for this financial development in roughly similar proportions. Yet, the intermediate peaks in FD around the years 2000-2001, especially visible in the Netherlands, the United Kingdom, and the United States, accompanied by the simultaneous increase in the relative importance of stock markets as sources of corporate funding (FS), adequately reflect the Dotcom Bubble of 1998-2000 (Ofek & Richardson, 2003). Nevertheless, combining figures 1a and 1b, a clear link between these countries' financial structures and their per capita emissions of CH_4 (and CO_2) is not directly seen.

Continuing with the GHG emissions in the 4 developing countries, figure 2a shows, as opposed to figure 1a, that these countries have been characterised by increasing levels of per capita emissions of both CH_4 and CO_2. Hence, departing from the inversely U-shaped relationship between economic development and environmental degradation as advocated by the Kuznets hypothesis (Dasgrupta *et al.*, 2002; Levinson, 2009), the combination of figures 1a and 2a indicates that economically developed countries that are in the transition from the heavy industry and manufacturing phase to the light industry and service-oriented phase might outsource the production of methane- and carbon-intensive products to developing countries that are in the agricultural phase or transitioning from agriculture to heavy industry and manufacturing. These 'outsourcing effects', already reported for CO_2 by De Haas and Popov (2021, p.28-30), may then also be at play for other GHGs such as methane[22]. Furthermore, in

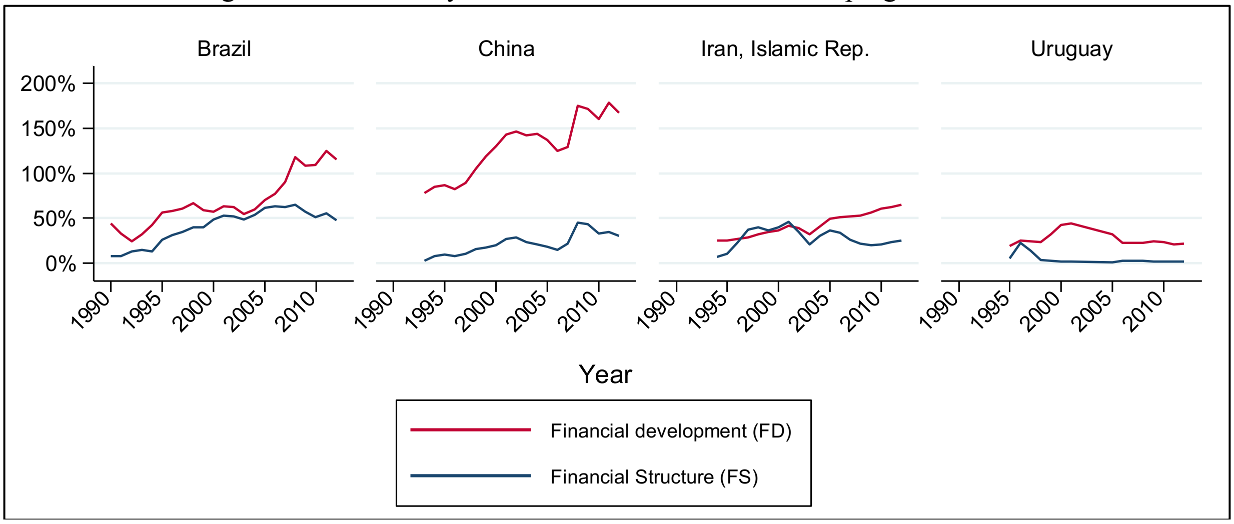
[22] Formally testing whether these outsourcing effects are also present in the context of methane is conditional on reliable industry-level methane data being available. However, as such data series are currently non-existing, future

Figure 2a: per capita GHG emissions in developing countries



Note: this figure visualizes the change in the per capita emissions of both CH_4 and CO_2 seperately, as well as for their accumulation. All three emission-variables are denoted in metric tons (t) (of CO_2-equivalents).

Figure 2b: financial system size and structure in developing countries



Note: this figure shows the change in financial development (FD) – the sum of private credit and stock market capitalization, normalized by GDP – and financial structure (FS) – the share of stock market financing out of total financing through credit and stock markets. Both FD and FS are 1-year lagged.

both Brazil and Uruguay, per capita emissions of CH_4 exceed those of CO_2 during the timeframe shown. In Brazil, this phenomenon can be explained by the fact that almost all of the country's overall GHG emissions during the period 1990-2012 originated from (1) agricultural activities and (2) changes in land-use and forestry, of which the burning of biomass to clear land for agricultural purposes or to maintain pastures and rangelands is a vital example (Ritchie & Roser, 2020). Concomitantly, these two groups of activities also belong to the list of largest emitters of anthropogenic methane (Saunois *et al.*,

research is encouraged to statistically test whether this 'methane-leakage' is truly the case (for more details, see subsection 6.3).

2020). Regarding Uruguay, this pattern can be explained by the fact that its agricultural sector, which is one of the most important creators of economic value within the country, is strongly oriented towards the production of livestock, wood, and the cultivation of soybeans (Alonso, 2019; Ritchie & Roser, 2020). Within the agricultural sector, these subcategories of agricultural activities account for the highest emissions of CH_4 (Saunois *et al.*, 2020).

Connecting the trends in GHG emissions in the 4 developing countries with the size (FD) and structure (FS) of their financial systems, figure 2b displays that, except for Uruguay, these countries have financially developed during the sample period considered. In addition, whereas the funding of the private sector has almost completely been facilitated by banks and other credit providing institutions in Uruguay, FS has, with some intermediate fluctuations, increased in Brazil, China, and (to a lesser extent in) Iran. Hence, based on these less advanced economies, it could well be the case that FS and per capita emissions of CH_4 (and CO_2) are positively correlated. Nevertheless, although graphs 1a through 2b provide some first, mixed insights into the overall behaviour of the main variables of interest, further analyses that control for any other influential factors are required before any conclusions regarding the relationship between FS and the emissions of CH_4 (and CO_2) can be drawn.

5. Results

This section consists of two subsections. In subsection 5.1, the results of this thesis's two-phased main analysis are reported. Section 5.2 presents two robustness tests. The first robustness test reduces this study's 105-country sample to the 48 countries that are examined by De Haas and Popov (2021). The second test solely focusses on the finance-methane link and checks whether this association survives if the two financial proxies - FD and FS – are specified in a less contemporaneous manner (i.e. have multiple-year lags).

5.1 Main analysis

As was mentioned in the methodological section, the main analysis consists of two phases. In the first phase, specifications (1), (4), and (5) are estimated using an extensive sample of 105 countries[23]. The corresponding results are shown in columns (1), (2), and (3) of Table 3 on the next page, respectively[24]. Note that, because not all data are available for each country-year, the number of observations is reduced to 1,953 (out of a possible 2,415).

[23] See appendix A(i) for an overview of these 105 countries.
[24] The standard errors of each estimation are clustered by country to make them consistent for heteroskedasticity. These standard errors have the beneficial property of controlling for any autocorrelation present as well. Additionally, pairwise correlations show that the (main) variables of interest are not plagued by high collinearity (see appendix B), just as the Variance Inflation Factors (VIFs) of the explanatory variables do not raise any suspicion of problematic multicollinearity (see appendix C).

In column (1), per capita methane emissions, measured in metric tons (t) of CO_2-equivalents, are regressed on FD, FS, and the other 4 country controls, while controlling for both country and year fixed-effects. Similar to the country-level results of De Haas and Popov (2021), we fail to reject the null hypothesis that financial system size (FD) is uncorrelated with per capita CH_4 emissions. Yet, as hypnotized, per capita emissions of methane are significantly higher in countries where a higher proportion of the private sector receives its funding from stock markets (FS). Its point estimate, being significant at the .01 level, numerically suggests that increasing the share of equity financing (at the cost of credit) by 1 percentage point, while holding the size of the financial system constant, would increase aggregate per capita methane emissions by approximately 0.00755t (= 7.55kg). Hence, compared to financial intermediaries (such as deposit money banks), (ordinary) equity investors may to a lesser extent be able to incorporate methane's detrimental impact on the world's environment into their long-term investment decisions (Asker *et al.*, 2015), and, as a consequence, stimulate methane-intensive (agricultural) firms less rigorously to innovate to reduce their emissions of the gas (Yusuf *et al.*, 2012; Zeller, 2010).

What are the aggregate implications of this finding regarding the FS-methane relationship? Similar to the country-sample of De Haas and Popov (2021, p.19), several countries included in this thesis that are not financial centers and have large banking sectors, such as Australia, Canada, Finland, and the Netherlands, are characterized by a FS that is roughly 0.5 throughout the sample period. Following the procedure of these authors, we leave all countries with FS > 0.5 unchanged, but lift the countries with a FS-value below this threshold to FS = 0.5. For about 70% of the countries in this thesis's dataset, this implies an average increase in FS of approximately 0.2 (20%), as the current average FS value of these countries is nearly 0.3 (30%). Multiplying FS's point estimate (0.00755t) with this 20% yields an increase in the per capita emissions of CH_4 that is roughly equal to 0.151 metric tons (t) of CO_2-equivalents. Given average total per capita GHG emissions – the accumulation of both CH_4 and CO_2 emissions, expressed in metric tons of CO_2-equivalents – of 7.622t (Table 2), this would mean an increase in these emissions with about 2%, adversely impacting the 40% reduction target to be achieved by 2030 as set out in the Paris Agreement.

Moreover, whereas De Haas and Popov (2021) document a mitigating effect of deepening stock markets on the per capita emissions of CO_2, column (2) shows that the positive association between FS and pollution as found in column (1) persists when the latter is expressed in the per capita emissions of CO_2 rather than CH_4. In addition, the coefficient of FS, still being statistically significant at the .01 level, has increased about 0.1t in magnitude compared to its 'methanic variant'. Consequently, by accumulating the per capita emissions of CH_4 (column 1) and CO_2 (column 2), column 3 documents that overall greenhouse gas (GHG) emissions increase with 1.6t (1600kg) when countries would increase the fraction of total funding through both credit and stock that happens via stock markets from 0 to 100 percent (ceteris paribus). Similar to its 'individual GHG components', this combined point estimate of FS (column 3) is statistically significant at the .01 level.

Table 3: Greenhouse gasses (GHGs) and financial structures in countries across the world (1990-2012)

	CH_4 emissions per capita	CO_2 emissions per capita	Greenhouse gas (GHG) emissions per capita
	(1)	(2)	(3)
Financial Development $(FD)_{t-1}$	-0.0143 (0.0214)	-0.0278 (0.0494)	-0.0421 (0.0625)
Financial Structure $(FS)_{t-1}$	**0.755***** **(0.153)**	**0.845***** **(0.224)**	**1.600***** **(0.343)**
Log GDP per capita_t	0.0136 (0.183)	**0.911**** **(0.451)**	**0.925*** **(0.540)**
Log GDP per capita squared_t	**0.0265**** **(0.0132)**	0.0434 (0.0302)	**0.0699*** **(0.0374)**
Population $(\text{billions})_t$	**-0.936**** **(0.379)**	-0.365 (0.787)	-1.301 (0.976)
Recession_t	**0.0928**** **(0.0448)**	-0.0643 (0.0761)	0.0285 (0.109)
Country fixed-effects	Yes	Yes	Yes
Year fixed-effects	Yes	Yes	Yes
No. Observations	1953	1953	1953
No. Countries	105	105	105
F-statistic	9.964	35.30	31.21
Adj. R-squared	0.940	0.971	0.967
Adj. R-squared (within)	0.061	0.114	0.118

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Note: This table reports estimates from three OLS regressions, all including fixed effects as specified. The dependent variable in column (1) is 'CH_4 emissions per capita'. The predicted variable in column (2) is 'CO_2 emissions per capita'. 'Greenhouse gas (GHG) emissions per capita' – the sum of per capita CH_4 and CO_2 emissions – is the response variable in column (3). All three emissions variables are expressed in metric tons (1000kg) of CO_2-equivalents. 'Financial Development (FD)' is defined as the sum of private credit and stock market capitalization, normalized by GDP. The other financial proxy, 'Financial Structure (FS)', reflects the share of stock market financing out of total financing through credit and stock markets. The sample period is 1990-2012. Robust standard errors are included in parentheses.

Furthermore, in all three regressions, we account for the fact that financial development correlates with general economic development, and so the former may pick up the effect of higher incomes on the demand for pollution (De Haas & Popov, 2021; King & Levine, 1993; Popov, 2018). Hence, the logarithm of GDP per capita as well as the square thereof are added as controls. Whereas per capita emissions of CO_2 (column 2) increase with 0.0091t (= 9.1kg) for every 1 percent increase in per capita income, the effect of per capita income on CH_4 emissions is mainly attributed to the squared term as the magnitude of both GDP-coefficients is particularly small for each percentage increase (0.000136t and 0.000265t, respectively). Therefore, looking at the effect of general economic development on the gasses' combined emissions (column 3), a positive causation is shown that is slightly exponentially increasing and marginally significant at the .1 level. Consequently, the reversed U-shape of the environmental Kuznets hypothesis is not found in this large sample of countries.

The final two controls, population size and the recession dummy, only reach statistical significance (at the .05 level) when pollution is expressed in the per capita emissions of methane (column 1). The former indicates that more populous countries emit fewer methane per capita, suggesting a negative pollution premium to market size. The latter suggests that recessions are associated with higher per capita CH_4 emissions. This phenomenon might be explained by firms putting on hold the (often already infrequent) investments in methane-mitigating technologies in times of recession (Campello *et al.*, 2010; Le Fevre, 2017).

However, it seems that the adjusted R-squared (within) of all three models is on the lower side, varying between 6.1% for CH_4 and 11.8% for total GHG emissions. This means that only 6.1% of all variations in the per capita emissions of methane, the GHG central to this study, can be explained by our model. Therefore, to address this lack of explanatory power, and, in addition, to check whether the estimations of the first phase as reported in Table 3 are not affected by a potential omitted variable, we include an additional control for the state of countries' environmental regulation in the second phase, for which the OECD's Environmental Policy Stringency Index (Environmental Protection Index) serves as a proxy. The results of these second phase estimations, based on specifications (7), (8), and (9), are shown in Table 4 on the next page[25].

Since data on the Environmental Protection Index are only available for 27 OECD member-states, the number of countries (and, as a consequence, the total number of observations) is (are) substantially lower than in phase 1. Therefore, to properly distinguish whether any statistical differences to the first phase are caused by (1) the inclusion of the additional control variable or (2) the considerably smaller subsample of countries, we also re-estimate first phase specifications (1), (4), and (5) solely for these 27 advanced economies and document their results alongside those of phase 2 in Table 4.

As can be seen, the positive association between FS and pollution as documented in the first phase only persists for these 27 OECD countries when the latter is expressed in the per capita emissions of methane (columns (1) and (2)). Yet, the point estimate, being statistically significant at the .05 level, has become about 4 times smaller in magnitude than in phase 1, independent of whether we control for the Environmental Protection Index (0.182) or not (0.183). Hence, whereas countries with a financial system that is tilted more towards equity-based (credit-based) financing emit more (fewer) CH_4 per capita, the CO_2 (columns (3) and (4)) and accumulated GHG (columns (5) and (6)) emissions of these OECD members are not significantly affected by the structure of their financial systems.

Continuing with the influence of general economic development on environmental degradation, strong statistical evidence (at the .01 level) for the environmental Kuznets hypothesis is found when pollution is measured by the per capita emissions of methane (columns (1) and (2)). While controlling for FD, FS, (and the protection index), and, in line with the empirical work of Benavides *et al.* (2017),

[25] Again, there is no sign of either excessive correlation (appendix B) or multicollinearity (appendix C(ii)) among the variables of interest when we control for this additional factor.

Table 4: Per capita greenhouse gas (GHG) emissions and financial structures in 27 OECD countries (1990-2012)

	CH_4 Emissions per capita		CO_2 Emissions per capita		Greenhouse gas (GHG) Emissions per capita	
	(1)	(2)	(3)	(4)	(5)	(6)
Financial Development $(FD)_{t-1}$	-0.00763	-0.0105	0.158	0.181	0.151	0.170
	(0.0232)	(0.0237)	(0.155)	(0.157)	(0.156)	(0.159)
Financial Structure $(FS)_{t-1}$	**0.182****	**0.183****	0.511	0.504	0.693	0.687
	(0.0769)	**(0.0770)**	(0.479)	(0.476)	(0.504)	(0.502)
Log GDP per $capita_t$	**1.962*****	**1.935*****	1.893	**2.107***	**3.855*****	**4.042*****
	(0.368)	**(0.366)**	(1.156)	**(1.172)**	**(1.363)**	**(1.386)**
Log GDP per capita $squared_t$	**-0.108*****	**-0.106*****	-0.0404	-0.0563	**-0.148****	**-0.162****
	(0.0210)	**(0.0210)**	(0.0604)	(0.0618)	**(0.0709)**	**(0.0730)**
Population $(billions)_t$	**-6.968*****	**-6.924*****	-12.83	-13.19	**-19.80****	**-20.11****
	(1.091)	**(1.094)**	(9.713)	(9.895)	**(10.01)**	**(10.16)**
$Recession_t$	0.0261	0.0236	-0.109	-0.0894	-0.0832	-0.0657
	(0.0295)	(0.0293)	(0.131)	(0.130)	(0.142)	(0.140)
Environmental Protection $Index_t$		-0.0208		**0.165***		0.144
		(0.0189)		**(0.0966)**		(0.105)
Country fixed-effects	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed-effects	Yes	Yes	Yes	Yes	Yes	Yes
No. Observations	571	571	571	571	571	571
No. Countries	27	27	27	27	27	27
F-statistic	13.61	11.58	5.590	5.361	5.479	5.172
Adj. R-squared	0.985	0.985	0.962	0.962	0.971	0.971
Adj. R-squared (within)	0.131	0.131	0.0597	0.0634	0.0696	0.0715

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Note: This table reports estimates from six OLS regressions, all including fixed effects as specified. The dependent variable in columns (1) and (2)) is 'CH_4 emissions per capita'. The predicted variable in columns (3) and (4) is 'CO_2 emissions per capita'. 'Greenhouse gas (GHG) emissions per capita' – the sum of per capita CH_4 and CO_2 emissions – is the response variable in columns (5) and (6). All three per capita variables are expressed in metric tons (1000kg) of CO_2-equivalents. 'Financial Development (FD)' is defined as the sum of private credit and stock market capitalization, normalized by GDP. The other financial proxy, 'Financial Structure (FS)', reflects the share of stock market financing out of total financing through credit and stock markets. The sample period is 1990-2012. Robust standard errors are included in parentheses.

per capita CH_4 emissions increase and then decrease with economic development in this subsample of OECD countries. Interestingly, this Kuznets-relationship also persists when the outcome variable sums up the per capita emissions of CH_4 and CO_2, as is done in columns (5) and (6). Comparing these findings regarding the income-pollution relationship with those of the extensive sample of the first phase (Table 3), a possible explanation for the Kuznets-argument not surviving in the 105-country sample may be that most of these countries are still in early stages of development and therefore positioned in the upward sloping part of the inversely U-shaped curve.

Concerning the last three controls, the 'cleansing' effect of an increasing population size is, similar to the Kuznets hypothesis, only found for methane and total GHG emissions per capita. In addition, both the recession dummy and the Environmental Protection Index fail to reach statistical significance (at the .05 level), with the latter only having its expected sign in the case of CH_4. Furthermore, when comparing the adjusted R-squared (within) values of the two phases (Table 3 and 4), those of the second phase are only higher if the outcome variable solely measures the per capita emissions of methane (13.1% versus 6.1% in the first phase). Yet, whereas this higher R-squared value for the methane estimations in Table 4 is obtained independent of whether we control for the Environmental Protection Index (column 1) or not (column 2), this value increase can reasonably be attributed to the substantially smaller country sample rather than to the inclusion of this additional control.

5.2 Robustness tests

In their empirical work, De Haas and Popov (2021) emphasize that stock-market based financial systems are tightly associated with fewer CO_2 emissions. Yet, in phase 1 of our main analysis, we find the opposite relationship between deepening stock markets and the emissions of per capita carbon dioxide, which subsequently does not survive when the number of countries examined is greatly reduced in the second phase. Hence, as a first robustness test, we want to re-estimate phase 1 specifications (1), (4), and (5) using De Haas and Popov's (2021) 48-country sample. The results of these estimations are visualized in Table 5 on the next page. Note, however, that as the time interval studied by these authors covers the period 1990-2015, we estimate regression equation (4) for this larger timeframe as well (column 3)[26]. Doing so allows us to check whether the country-level model of De Haas and Popov (2021) has correctly been replicated and, as a consequence, whether this study's results can reliably be compared with those of these authors.[27]

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[26] Specifications (1) (CH_4 emissions) and (2) (accumulated emissions of CH_4 and CO_2) cannot be estimated for the period 1990-2015, as data on methane emissions are only available up to and including the year 2012.

[27] Regarding the estimations that are controlled for the Environmental Protection Index (phase 2), the mitigating impact of deepening stock markets on the per capita emissions of CO_2 as reported by De Haas and Popov (2021) is not found for the period 1990-2012 (Table 4, column 4). Using the more extensive sample period of these authors (1990-2015), again no statistical evidence for this negative association is found. For transparency purposes, the results of these two estimations are jointly documented in appendix D.

Table 5: Per capita greenhouse gas (GHG) emissions and financial structures using the country-sample of De Haas and Popov (2021) (1990-2012 & 1990-2015)

	CH_4 Emissions per capita	CO_2 Emissions per capita		Greenhouse gas (GHG) Emissions per capita
	Period 1990-2012	Period 1990-2012	Period 1990-2015	Period 1990-2012
	(1)	(2)	(3)	(4)
Financial Development $(FD)_{t-1}$	0.00932 (0.0215)	-0.0781 (0.128)	0.00707 (0.140)	-0.0688 (0.131)
Financial Structure $(FS)_{t-1}$	**0.262***** **(0.0842)**	**-0.540*** **(0.291)**	**-0.729**** **(0.284)**	-0.277 (0.332)
Log GDP per capita_t	**0.683**** **(0.287)**	**3.897***** **(0.843)**	**5.039***** **(0.869)**	**4.580***** **(0.994)**
Log GDP per capita squared_t	**-0.0274*** **(0.0161)**	**-0.146***** **(0.0525)**	**-0.204***** **(0.0545)**	**-0.174***** **(0.0600)**
Population $(\text{billions})_t$	-0.325 (0.461)	-1.479 (1.242)	**-1.986*** **(1.205)**	-1.804 (1.526)
Recession_t	0.0272 (0.0225)	**-0.189**** **(0.0906)**	**-0.180**** **(0.0875)**	**-0.162*** **(0.0982)**
Country fixed-effects	Yes	Yes	Yes	Yes
Year fixed-effects	Yes	Yes	Yes	Yes
No. Observations	971	971	1084	971
No. Countries	48	48	48	48
F-statistic	23.70	21.43	36.44	22.46
Adj. R-squared	0.982	0.972	0.967	0.975
Adj. R-squared (within)	0.113	0.153	0.205	0.173

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Note: This table reports estimates from four OLS regressions, all including fixed effects as specified. The dependent variable in column (1) is 'CH_4 emissions per capita'. The predicted variable in columns (2) and (3) is 'CO_2 emissions per capita'. 'Greenhouse gas (GHG) emissions per capita' – the sum of per capita CH_4 and CO_2 emissions – is the response variable in column (4). All three per capita variables are expressed in metric tons (1000kg) of CO2-equivalents. 'Financial Development (FD)' is defined as the sum of private credit and stock market capitalization, normalized by GDP. The other financial proxy, 'Financial Structure (FS)', reflects the share of stock market financing out of total financing through credit and stock markets. For carbon dioxide, two sample periods can be distinguished, namely the one of this thesis (1990-2012), and the period used by De Haas and Popov (2021) (1990-2015). Robust standard errors are included in parentheses.

As is shown in column (3) of Table 5, using the same 48-country, 26-year panel as De Haas and Popov (2021) yields a negative association between FS and aggregate per capita CO_2 emissions that is statistically significant at the .05 level[28]. This mitigating effect on per capita carbon dioxide emissions

[28] The point estimate of FS, being equal to -0.729, slightly differs from the one reported in column (1) of Table 2 by De Haas and Popov (2021, p.46), which is -0.734. This is also the case for the other variables of interest. An

persists when the sample period is shortened to that of this thesis (column (2)), although its point estimate decreases in magnitude with about 1.89t in absolute figures and only reaches a marginal significance at the .1 level. Furthermore, once again, per capita methane emissions are significantly higher (at the .01 level) when a larger fraction of the private sector receives it funding via stock markets, holding the overall size of the financial system (FD) constant (column (1)). As a result, the cleansing effect of deepening stock markets does not survive when the per capita emissions of CH_4 and CO_2 are accumulated (column (4)), accentuating that CO_2 emissions do not comprehensively proxy for methane emissions as De Haas and Popov (2021, p.1) asserted.

Regarding the control variables, the environmental Kuznets-curve effect survives for both GHGs individually as well as for their combined emissions: controlling for financial system size and structure, per capita GHG emissions increase and subsequently decrease with economic development. Furthermore, during recessions, countries emit fewer CO_2 per capita (columns (2) and (3)), an effect that is strong enough to reach a marginal significance when pollution is expressed in total GHG emissions (column (4)). There are two explanations for this. First, output declines during a recession, reducing CO_2 emissions (and overall pollution) too. Second, firms may use downturns to purge themselves from obsolete (and more carbon-intensive) technologies (Caballero & Hammour, 1994); De Haas & Popov, 2021). Overall, as our results are largely in line with those of De Haas and Popov (2021) when the same 48-country, 26-year panel is exploited, the results of this thesis, especially those of the first phase of the main analysis, can reliably be compared with those of these authors.

For the second robustness test, we want to zoom in on the GHG central to this thesis: methane (CH_4). So far, following the methodological approach of De Haas and Popov (2021), we assumed the impact of shocks to financial sector size (FD) and structure (FS) to be relatively contemporaneous (1-year lag). However, these changes in overall financing and in the equity share thereof may take more time to fully propagate through the economy and, in turn, affect the emissions of GHGs (De Haas and Popov, 2021, p.33). In line with this reasoning, Bierbaum *et al*. (2020) mention two financially intensive "novel entities" (i.e. new green technologies) in the agricultural sector – the main emitter of anthropogenic methane on a worldwide scale (Karakurt *et al*., 2012; Saunois *et al*., 2020 – that would require at least five years to achieve their desired environmental impact, namely (1) active, integrated, and molecular nano-systems, and (2) cellular agriculture. Whereas the former can be used to prevent food contamination and to control the release of agrochemicals such as pesticides and fertilizers (Kim *et al*., 2018; Mishra *et al*., 2017; Sertova, 2015; Zambrano-Zaragoza *et al*., 2018), the latter enables the production of meat and other livestock products from cell cultures with little to no animal involvement

explanation for this phenomenon is the fact that the data sources used in both studies have been updated in the time interval between these inquiries. An important example is Beck *et al*.'s (2019) Financial Structure Database - used to construct the financial proxies FD and FS -, which has been renewed in September 2019.

(Mattick, 2018; Stephens *et al.*, 2018)[29]. Yet, Viatte (2001, p.14-21), who has been director for Food, Agriculture and Fisheries at the OECD for more than ten years, argues that sustainable technologies in the agricultural sector often yield their desired [environmental and financial] benefits within one to two years after assimilation and implementation. Hence, according to Viatte, the adoption of new technologies by agricultural enterprises often happens at a pace substantially more rapid than commonly anticipated.

Therefore, to test whether the positive association between FS and the per capita emission of CH_4 survives when externally financed, methane-mitigating technologies indeed take two (Viatte) or five (Bierbaum *et al.*) years to propagate their cleansing effect through the economy, we re-estimate specifications (1) (phase 1) and (7) (phase 2), but now with FD and FS both being 2-year lagged and 5-year lagged, respectively. In addition, similar to the procedure performed in phase 2 of the main analysis, we want to estimate specification (1) while only including the 27 OECD countries for which data on the Environmental Protection Index is available. This allows us to adequately assess the influence of this additional controlling factor. The results of this second robustness test are shown in Table 6 on the next page.

Controlling for the size of financial systems (FD), per capita CH_4 emissions are still higher (lower) in countries where firms get more of their funding from stock markets (credit providing financial intermediaries, such as deposit money banks), independent of whether we lag the impact of both financial proxies with 2 years (columns (1)-(3)) or 5 years (columns (4)-(5)). The magnitude of FS's point estimate varies between 0.703 and 0.180 in column (1) and (6), respectively, and is statistically significant at the .01 level in all six estimations. Furthermore, in line with the findings of Benavides *et al.* (2017), the association between general economic development and methanic emissions follows the reverse U-shape of the Kuznets hypothesis when estimated for the subsample of 27 OECD member-states (columns (2), (3), (5), and (6)). Also, more populous countries tend to emit fewer CH_4 per capita. Lastly, an increase in the index that measures the stringency of countries' environmental regulation with 1 causes per capita methane emissions to be reduced with 0.0326t (= 32.6kg) in column (3), and with 0.0484t (= 48.4kg) in (column (6), ceteris paribus. Note, however, that the explanatory power of the models persists to be on the lower side, especially for the extensive 105-country sample (columns (1) and (4)).

[29] See Bierbaum *et al*. (2020, p.139) for further details on these two innovations.

Table 6: per capita methane (CH_4) emissions and multiple-year lagged financial proxies (1990-2012)

	2-year lagged financial proxies (T=2)			5-year lagged financial proxies (T=5)		
	Full sample of countries	Subsample of 27 OECD countries excluding the protection index	Subsample of 27 OECD countries including the protection index	Full sample of countries	Subsample of 27 OECD countries excluding the protection index	Subsample of 27 OECD countries including the protection index
	(1)	(2)	(3)	(4)	(5)	(6)
Financial Development $(FD)_{t-T}$	-0.0121	-0.0293	-0.0336	0.0315	-0.00856	-0.0142
	(0.0218)	(0.0238)	(0.0242)	(0.0208)	(0.0234)	(0.0234)
Financial Structure $(FS)_{t-T}$	**0.703*****	**0.200*****	**0.201*****	**0.491*****	**0.195*****	**0.180*****
	(0.150)	**(0.0736)**	**(0.0739)**	**(0.161)**	**(0.0591)**	**(0.0591)**
Log GDP per $capita_t$	0.0457	**2.058*****	**2.012*****	0.281	**2.224*****	**2.121*****
	(0.182)	**(0.344)**	**(0.340)**	(0.185)	**(0.298)**	**(0.290)**
Log GDP per capita $squared_t$	**0.0237***	**-0.112*****	**-0.109*****	0.00990	**-0.121*****	**-0.113*****
	(0.0131)	**(0.0199)**	**(0.0197)**	(0.0127)	**(0.0178)**	**(0.0174)**
Population $(billions)_t$	**-1.032****	**-6.397*****	**-6.288*****	**-1.234****	**-5.737*****	**-5.536*****
	(0.420)	**(1.105)**	**(1.114)**	**(0.593)**	**(1.174)**	**(1.246)**
$Recession_t$	**0.0779***	0.0296	0.0258	**0.0749***	0.0120	0.00377
	(0.0445)	(0.0284)	(0.0281)	**(0.0441)**	(0.0226)	(0.0217)
Environmental Protection $Index_t$			**-0.0326***			**-0.0484*****
			(0.0184)			**(0.0149)**
Country fixed-effects	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed-effects	Yes	Yes	Yes	Yes	Yes	Yes
No. Observations	1856	546	546	1570	470	470
No. Countries	105	27	27	105	27	27
F-statistic	7.984	15.70	13.35	5.293	23.74	21.92
Adj. R-squared	0.940	0.987	0.987	0.937	0.990	0.990
Adj. R-squared (within)	0.0580	0.152	0.155	0.0462	0.187	0.200

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Note: This table reports estimates from six OLS regressions, all including fixed effects as specified. The dependent variable in each column is 'CH_4 emissions per capita', which denotes aggregate per capita emissions of methane in metric tons (1000kg) of CO_2-equivalents 'Financial Development (FD)' is defined as the sum of private credit and stock market capitalization, normalized by GDP. The other financial proxy, 'Financial Structure (FS)', reflects the share of stock market financing out of total financing through credit and stock markets. Both these financial proxies are either 2-year (columns (1)-(3)) or 5-year (columns (4)-(6)) lagged. The sample period is 1990-2012. Robust standard errors are included in parentheses.

6. Discussion

6.1 Discussing the results

Quantifying the link between conventional finance and CH_4 emissions, the estimations of the main analysis reveal that for a given level of economic development and environmental protection, financial sector size (FD) has no impact on per capita methane emissions, but that deeper stock (credit) markets (FS) increase (reduce) emissions of the gas significantly. This role of FS turns out to be robust when the estimations are based on the 48-country sample of De Haas and Popov (2021), and when, in line with the reasonings of Viatte (2001) and Bierbaum *et al*. (2020), the impact of shocks to FD and FS are less contemporaneous. These findings are in conformity with our hypothesis that, compared to financial intermediaries (such as deposit money banks), (ordinary) equity investors may to a lesser extent be aware of the main sources of anthropogenic methane and, additionally, of the detrimental impact of the gas on the world's environment. Therefore, these investors may lack the necessary knowledge to incorporate methane's environmentally harmful nature into their long-term investment decisions (Asker *et al*., 2015), consequently stimulating methane-intensive (agricultural) firms less rigorously to innovate to reduce their emissions of the gas (Yusuf *et al.*, 2012; Zeller, 2010).

However, the results regarding the emissions of CO_2 are lacking consistency. In contradiction to the cleansing effect of deepening stock markets as reported by De Haas and Popov (2021), the results of phase 1 of this thesis's main analysis show a strong, positive association between FS and per capita emissions of carbon dioxide. Yet, this discrepancy in the finance-CO_2 link may be attributed to the fact that both studies differ substantially with respect to the size and composition of their country samples. Whereas this study's 105-country sample contains a good mixture of developed and developing countries, the latter are to a lesser extent represented in the 48-country sample of De Haas and Popov (2021)[30]. Consequently, as the national socio-cultural environment and the level of national economic development are important determinants of socially [and, thus, environmentally (Galema *et al*., 2008)] responsible behavior (Jones, 1999), and, extending this reasoning to a financial context, as socially responsible investing (SRI) is mainly practiced in developed (and often Western) societies (Ataur, 2001; Jamali & Mirshak, 2007), the positive association between FS and the per capita emissions of CO_2 as documented in column (2) of Table 3 may emphasize the reluctance of equity investors in developing countries to incorporate the non-financial dimensions of companies in their financial decision-making,

[30] As can be seen in summary statistics Table 2, data on the variables 'Financial development (FD)' and 'GDP per capita' respectively demonstrate a large variation in financial and economic development between the 105 countries included in this study (see also appendix A(i) for a list of these countries). However, out of the 48 countries central to the inquiry of De Haas and Popov (2021) (appendix A(ii)), 32 countries are OECD member-states (OECD, 2020), and 35 countries are classified as countries that are (well underway to become) economically developed (United Nations, 2020).

even when it concerns a GHG of which the climate forcing is commonly well-known[31]. Banks, on the other hand, often force the incorporation of environmental considerations in both the public and private sectors of these advancing economies as part of lending and grant-issuing conditions (Alshuwaikhat, 2005, p.311), exemplified by the operations of the World Bank and the Asian Development Bank (ADB) in Sri Lanka and Bangladesh (Briffett *et al*., 2003; Momtaz, 2002).

Nevertheless, the FS – CO_2 link fails to reach statistical significance when estimated for the subsample of 27 OECD members, independent of whether we control for the stringency of environmental policies or not (Table 4, columns (3) and (4)). This might indicate that, in line with the reasonings of Jones (1999), Ataur (2001), and Jamali and Mirshak (2007), equity investors in developed countries adhere more to SRI principals than those in advancing ones, and, similar to banks and other financial intermediaries, increasingly incorporate the *carbon* intensity of firms into their capital allocation decisions (Dasgupta *et al*., 2002).

However, using the same 48-country (26-year) panel as De Haas and Popov (2021), an approximately similarly sized mitigating effect of deepening stock markets on the per capita emissions of CO_2 as reported by these authors is found (Table 5, columns (2) and (3)), suggesting that financial systems that are more equity-intensive (1) reallocate investments towards less carbon-intensive industries and (2) finance carbon-mitigating technologies (within high-pollution industries) more adequately than their credit-based counterparts (De Haas and Popov, 2021). Yet, as shown by this thesis, this cleansing effect does not seem to survive alterations in the country sample. Also, as to De Haas and Popov's claim that CO_2 emissions also proxy for other air pollutants such as methane, the fact that the negative point estimate of FS no longer reaches statistical significance when the per capita emissions of methane are added to those of carbon dioxide - Table 5, column (4) - supports the claim of this thesis that a separate examination of the former GHG is warranted. Furthermore, this absence of statistical significance when the emissions of both GHGs are accumulated also suggests that stimulating the development of conventional equity markets – a policy implication proposed by De Haas and Popov (2021, p.36) for countries that wish to green their economies – might not yield the desired effects when methane emissions become an explicit part of the analysis as well.

6.2 Policy implications

Building forth on the results of this thesis, numerous policy implications that could be beneficial to policymakers within governments or financial institutions in their battle against environmental degradation can be enumerated. With respect to the emissions of methane, governments could join forces with environmental scientists to raise awareness among the general public about the gas's main

[31] The non-financial dimensions of corporate performance are, for example, a company's environmental impact, its (internal and external) social relations, and its corporate governance (Galema *et al*., 2008). Hence, when considering these dimensions, investors do not solely focus on the 'standard' risk-return characteristics of investment alternatives.

anthropogenic sources and the climate forcing it causes, for example via broadcasting informative readings or appealing documentaries on different channels of communication[32]. As (ordinary) shareholders (in developed economies) increasingly incorporate the environmental dimensions of firms into their investment decisions (Ataur, 2001; Galema *et al*., 2008; Jamali & Mirshak, 2007), but, at the same time, their often-scarce knowledge about CH_4's environmentally harmful impact lowers the stimulus for methane-intensive firms to cut their emissions of the gas (Asker *et al.*, 2015; Le Fevre, 2017), this amplified awareness among the general public could reduce the methanic emissions that come with deepening stock markets.

In addition, as a financial system that is more reliant on debt financing significantly reduces the emissions of CH_4, countries could green their economies through the promotion of green bonds or via other green-finance initiatives, such as the establishment of 'green' (credit departments within) banks. Recent examples of such activities include the green guidelines introduced by China and Brazil to stimulate the environmental performance of their banking sectors (De Haas & Popov, 2021). However, as De Haas and Popov (2021, p.36) state that (middle-income) countries could lower their CO_2 emissions by stimulating the development of conventional equity markets [at the cost of credit markets] and, in addition, as this thesis reports mixed evidence regarding the link between finance and (the accumulation of) CO_2 (and CH_4) emissions, it may be more fruitful to lower CH_4 emissions in an alternative way. Viatte (2001), for instance, argues that a well-educated agricultural sector is required for complex methane-mitigating technologies to be adopted and rightly implemented, with active, integrated, and molecular nano-systems and cellular agriculture as key examples (Bierbaum *et al*., 2020). Therefore, educational programs that provide agricultural enterprises with the necessary knowledge to adequately utilize such complex and often financially intensive innovations could make the agricultural sector – the main source of anthropogenic methane emissions (Karakurt *et al*., 2012; Saunois *et al*., 2020) – less reliant on banks when wishing to adopt such technologies. Due to the education offered, the agricultural expertise of banks resulting from their longstanding ties with the sector may to a lesser extent be needed as a form of assistance during the implementation process (Grant & MacNamara, 1996), consequently lowering the dependency of the sector on these financial intermediaries when innovating to reduce emissions. As a result, these agricultural enterprises, encouraged by their greater knowledge, may be less reluctant to finance their green innovations with the capital of frequently less informed (read: 'CH_4 aware') equity investors (Allen & Gale, 1999; Saunois *et al*., 2016b).

Lastly, as the adherence to socially responsible investing (SRI) in developing countries is on the lower side (Ataur, 2001; Jamali & Mirshak, 2007), national authorities could set up campaigns in these countries to encourage 'environmental consciousness' among investors. Furthermore, as high-pollution firms in these advancing economies are to a lesser extent scrutinized by (their) shareholders and

[32] Examples are Hook's (2021) article in the Financial Times, David Attenborough's film "*A Life on Our Planet*", and Andersen and Kuhn's documentary "*Cowspiracy: The Sustainability Secret*".

therefore less inclined to bring down their overall emissions, policymakers could (partly) re-incentivize such companies by putting an explicit price on the excessive emittance of GHGs, for example via a tightening of the environmental regulations. Yet, when doing so, they must bear in mind the potential outsourcing of environmentally harmful activities by these companies to countries with laxer environmental standards (Ben-David *et al*., 2019; De Haas & Popov, 2021), as well as the fact that the Environmental Protection index – the proxy that measures the stringency of countries' environmental regulation – only reached statistical significance (for methane) in the robustness tests of this thesis (Table 6).

6.3 Limitations and future research

When interpreting the results of this thesis, a few limitations must be borne in mind. First and foremost, methane data is still in early stages of development. As of today, estimates of methane emissions are subject to a high degree of uncertainty, with different data sources seldom providing completely congruent emissions levels and abatement potentials (IEA, 2021b). Furthermore, numerous criticisms are levelled at the so-called Global Warming Potential (GWP), the metric commonly used to express non-CO_2 greenhouse gasses (GHGs) into their CO_2-equivalents (Balcombe *et al*., 2018)[33]. Therefore, in an effort to reconcile the various and often conflicting data into a coherent set of estimates, the IEA launched its *Methane Tracker* in 2019. This comprehensive set of estimates is continuously updated, with its most recent variant even including large-scale methane leaks that were detected by satellites in 2020 (IEA, 2021b). Hence, future research is encouraged to test the robustness of this thesis's results once the debate around the correct measurement of methane (and other non-CO_2 GHGs) is settled, with the IEA's methane tracker as the recommended source for data on methane emissions.

Second, whereas De Haas and Popov (2021) also conduct analyses at the industry (and firm) level, consequently yielding deeper insights into the two underlying mechanisms that may explain the cleansing effect of deepening stock markets that they find – capital reallocation *between* and technological progress *within* sectors -, the empirical work of this thesis only touches upon the country-level. Yet, as (reliable) methane data is only limitedly available and, in addition, since methane's large side effects and self-reinforcing features make it hard to properly distinguish between the relative contributions of different industries to the gas's overall emissions (Balcombe *et al*., 2018; Neubauer & Megonigal, 2015), the absence of these 'lower-level' analyses is inevitable. Therefore, to enhance the comparability of this study's findings with those of these authors, future studies are suggested to apply the industry (and firm) level analyses of De Haas and Popov to the emissions of methane once the data needed for it become available. When doing so, these inquiries are encouraged to also test (and, if

[33] See subsection 2.4 and Balcombe *et al*. (2018) for more details on the metric's shortcomings. Importantly, as was mentioned in the data section, data on methane emissions from the World Development Indicators that are being used in this thesis also use the GWP metric to convert the gas's emissions into their CO_2-equivalents.

necessary, correct) for the potential outsourcing of methane-intensive activities to other countries by (financially) developed economies.

Thirdly, although De Haas and Popov (2021) state that the mitigating effect of deepening stock markets on CO_2 emissions survives when being controlled for the stringency of countries' environmental regulation, this finance-CO_2 link does no longer reach statistical significance once this additional controlling factor is included in the models of this thesis[34]. Hence, scientific studies to come are recommended to once again check the robustness of the cleansing effect of deepening stock markets as reported by De Haas and Popov (2021) when the state of environmental regulation is held constant. Nevertheless, the reader of this thesis is advised to take this inconsistency into account while going through the results of the second phase of the main analysis (Table 4).

Lastly, to interpret the results of this thesis as causal, two assumptions need to hold. First, financial development (FD) and structure (FS) must be unaffected by current or expected methane and CO_2 emissions per capita. Second, a country's level of emitted GHGs and both its financial system size and structure should not be affected by a common factor. The latter assumption is, however, disputable. For instance, a reduction in income taxes can simultaneously result in higher stock market investments and in an increase in the consumption of methane- and carbon-intensive products, resulting in a potentially biased causal link between FS and the per capita emissions of GHGs. In addition, a change in the global demand for products produced by methane- and carbon-intensive sectors that rely (heavily) on external financing could affect both the emissions variables and the financial proxies, consequently distorting the concomitant estimations. Therefore, to address this potential presence of endogeneity, future research could test the robustness of this thesis's results by inducing exogenous shocks to FD and FS. Following De Haas and Popov (2021), two different policy changes can be used to provoke these shocks, namely Bekaert *et al.*'s (2005) *equity market liberalization events* and Abiad *et al.*'s (2010) measure for the *openness of the domestic banking system*[35].

7. Conclusion

The 2015 Paris Climate Conference (COP21) has put finance firmly at the heart of the debate on climate change. Yet, the rapid growth in green finance initiatives that followed laid bare the scarceness of evidence on the link between conventional finance and environmental degradation. To address this scientific paucity, De Haas and Popov (2021) empirically investigated the relationship between financial development and structure, on the one hand, and CO_2 emissions, on the other hand, subsequently finding that emissions of the gas are reduced as stock markets deepen. Nevertheless, another potent greenhouse

[34] See Appendix Table 1, column (2) in appendix D.
[35] See De Haas and Popov (2021, p.9) for further details on these instruments and how they may influence the size (FD) and structure (FS) of financial systems.

gas (GHG) was no explicit part of their analyses: methane (CH_4). With an overall climate forcing 28 times stronger than that of CO_2 in the 100 years after its emission (Balcombe *et al*., 2018; Saunois *et al*., 2020), and with features that make reducing the atmospheric concentration of the gas an effective means to achieve climate change mitigation rapidly (IEA, 2021b; Shindell *et al*., 2012), a separate inquiry of the finance-methane link is warranted.

To quantify this role, this thesis applies the country-level analysis of De Haas and Popov (2021) to the per capita emissions of methane. Exploiting a large panel of 105 countries over the period 1990-2012, it is found that for a given level of economic development and environmental protection, financial sector size has no impact on CH_4 emissions, but that deeper stock (credit) markets increase (reduce) per capita emissions significantly. To put this finding into perspective, a back-of-the-envelope calculation suggests that shifting the financial structure of all countries in the world to at least 50-percent equity financing would result in an increase in current worldwide per capita CH_4 emissions of about 0.151 metric tons of CO_2-equivalents, which would adversely impact the Paris Agreement's 40% reduction target in overall GHG emissions to achieve by 2030 with 2%. In addition, by re-estimating De Haas and Popov's (2021) finance-carbon link using the more extensive country sample of this thesis, we find that the cleansing effect of increased equity-based financing as reported by these authors either reverses or disappears. Lastly, the analyses of this thesis suggest that if one wants to come up with valid implications regarding the association between conventional finance and environmental degradation in general, both the per capita emissions of CO_2 and CH_4 need to be accumulated.

The results of this thesis can be interpreted in light of the Kuznets-curve argument that a country's pollution level follows an inverse U-shape pattern as it develops economically. When pollution is measured through the per capita emissions of methane, this study's results imply that this pattern of per capita pollution over time may be closely associated with the sequential development of different types of financial markets. As credit markets tend to deepen at earlier stages of development than stock markets (Demirguc-Kunt *et al.*, 2011; Gambacorta *et al.*, 2014), and since the results of this thesis indicate that financial systems that are tilted towards the former (latter) emit less (more) CH_4 per capita, this inquiry's findings show that the evolution of financial structure may weaken the concavity of the relationship between economic development and the per capita emissions of methane as documented in previous studies (e.g. Benavides *et al*., 2017). For the emissions of CO_2 and the accumulated emissions of both GHGs, however, mixed results are documented.

Overall, the findings of this thesis suggest that countries that want to reduce their methane emissions stemming from a financial system that heavily relies on equity-based financing should raise awareness among the general public on the gas's detrimental influence on the world's climate. As (ordinary) shareholders (in developed economies) increasingly incorporate the environmental dimensions of firms into their investment decisions (Ataur, 2001; Galema *et al*., 2008; Jamali & Mirshak, 2007), but, at the same time, their often-scarce knowledge about CH_4's environmentally harmful impact lowers the stimulus for methane-intensive firms to cut their emissions of the gas (Asker *et al*., 2015; Le Fevre, 2017), this amplified awareness among the general public could reduce the methanic emissions that come with deepening stock markets. Furthermore, countries that wish to emit fewer CH_4 emissions could stimulate the establishment of green (credit departments within) banks or educate the agricultural sector – the largest emitter of anthropogenic methane (Karakurt *et al*., 2012; Saunois *et al*., 2020) – on how to successfully implement methane-mitigating technologies, consequently making the sector less dependent on the knowledge and expertise of banks. Lastly, considering the low adherence to socially responsible investment (SRI) principles in developing countries (Ataur, 2001; Jamali & Mirshak, 2007), these countries' policy makers are advised to stimulate the 'environmental consciousness' among (ordinary) equity investors in general.

Nevertheless, it is important to mention that, as of today, methane data is still in early stages of development. The estimations of methane emissions often come with substantial degrees of uncertainty (IEA, 2021b), and the metric used to convert these emissions into their CO_2-equivalents – the Global Warming Potential (GWP) – is increasingly criticized (Balcombe *et al.*, 2018). Therefore, future studies are suggested to test to robustness of this thesis's results once more reliable methane data come available. In addition, when these new data series also enable future research to adequately differentiate between the shares of a country's aggregate CH_4 emissions accounted for by the various industrial sectors, they are also encouraged to apply De Haas and Popov's (2021) industry-level analysis to the emissions of methane. Yet, notwithstanding these limitations on the currently available methane data, this thesis provides some first interesting insights into the link between financial structures and methane emissions.

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Appendix

A. Country lists

i. List of countries included in this thesis

1. Algeria	2. Argentina	3. Armenia
4. Australia	5. Austria	6. Azerbaijan
7. Bahrain	8. Bangladesh	9. Belgium
10. Bolivia	11. Bosnia and Herzegovina	12. Botswana
13. Brazil	14. Bulgaria	15. Canada
16. Chile	17. China	18. Colombia
19. Costa Rica	20. Côte d'Ivoire	21. Croatia
22. Cyprus	23. Czech Republic	24. Denmark
25. Ecuador	26. Egypt, Arab Rep.	27. El Salvador
28. Estonia	29. Finland	30. France
31. Georgia	32. Germany	33. Ghana
34. Greece	35. Guatemala	36. Honduras
37. Hong Kong SAR, China	38. Hungary	39. Iceland
40. India	41. Indonesia	42. Iran, Islamic Rep.
43. Ireland	44. Israel	45. Italy
46. Jamaica	47. Japan	48. Jordan
49. Kazakhstan	50. Kenya	51. Korea, Rep.
52. Kuwait	53. Kyrgyz Republic	54. Latvia
55. Lebanon	56. Lithuania	57. Luxembourg
58. Malaysia	59. Malta	60. Mauritius
61. Mexico	62. Moldova	63. Mongolia
64. Morocco	65. Namibia	66. Nepal
67. Netherlands	68. New Zealand	69. Nigeria
70. North Macedonia	71. Norway	72. Oman
73. Pakistan	74. Panama	75. Paraguay
76. Peru	77. Philippines	78. Poland
79. Portugal	80. Qatar	81. Romania
82. Russian Federation	83. Saudi Arabia	84. Singapore
85. Slovak Republic	86. Slovenia	87. South Africa
88. Spain	89. Sri Lanka	90. Sweden
91. Switzerland	92. Tanzania	93. Thailand
94. Trinidad and Tobago	95. Tunisia	96. Turkey
97. Ukraine	98. United Arab Emirates	99. United Kingdom
100. United States	101. Uruguay	102. Venezuela, RB
103. Vietnam	104. Zambia	105. Zimbabwe

ii. Country sample of De Haas and Popov (2021)

1. Argentina	2. Australia	3. Austria
4. Azerbaijan	5. Belgium	6. Brazil
7. Bulgaria	8. Canada	9. Chile
10. China	11. Colombia	12. Costa Rica
13. Croatia	14. Czech Republic	15. Denmark
16. Estonia	17. Finland	18. France
19. Germany	20. Greece	21. Hungary
22. India	23. Ireland	24. Italy
25. Japan	26. Kazakhstan	27. Lithuania
28. Luxembourg	29. Mexico	30. Morocco
31. Netherlands	32. New Zealand	33. North Macedonia
34. Norway	35. Philippines	36. Poland
37. Portugal	38. Russian Federation	39. Slovenia
40. Spain	41. Sweden	42. Switzerland
43. Thailand	44. Turkey	45. Ukraine
46. United Kingdom	47. United States	48. Zambia

B. Pairwise Correlations

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
(1) CH_4 emissions per capita	1.000								
(2) CO_2 emissions per capita	*0.631*	1.000							
(3) GHG emissions per capita	*0.786*	*0.976*	1.000						
(4) Financial development (FD)	0.004	0.372	0.306	1.000					
(5) Financial structure (FS)	0.108	0.219	0.209	0.346	1.000				
(6) Log GDP per capita	0.268	0.646	0.590	0.552	0.103	1.000			
(7) Population (billions)	-0.088	-0.088	-0.095	0.001	0.036	-0.175	1.000		
(8) Recession	0.004	0.016	0.014	0.034	-0.054	-0.014	-0.059	1.000	
(9) Environmental Protection Index	-0.186	-0.054	-0.097	0.352	0.061	0.598	-0.034	0.100	1.000

Note: variables (1), (2), and (3) are three different outcome variables that are not simultaneously included in the estimations. Hence, their coefficients of pairwise correlation can be neglected.

C. Variance Inflation Factors (VIFs)

i. VIFs excluding the Environmental Protection Index:

	VIF	1/VIF
Financial development (FD)	1.672	0.598
Log GDP per capita	1.563	0.640
Financial structure (FS)	1.156	0.865
Population (billions)	1.075	0.930
Recession	1.010	0.990
Mean VIF	**1.295**	

Outcome variables: methane (CH_4), carbon dioxide (CO_2), and total greenhouse gas (GHG) emissions per capita

ii. VIFs including the Environmental Protection Index:

	VIF	1/VIF
Log GDP per capita	2.614	0.382
Financial development (FD)	2.585	0.387
Environmental Protection Index	1.559	0.642
Financial structure (FS)	1.242	0.805
Population (billions)	1.205	0.830
Recession	1.055	0.947
Mean VIF	**1.710**	

Outcome variables: methane (CH_4), carbon dioxide (CO_2), and total greenhouse gas (GHG) emissions per capita

D. Results table

<u>Appendix Table</u>: Per capita carbon dioxide (CO_2) emissions and financial structures (1990-2012 & 1990-2015)

	CO_2 Emissions per capita	
	Period 1990-2012	Period 1990-2015
	(1)	(2)
Financial Development $(FD)_{t-1}$	0.181	0.282*
	(0.157)	(0.162)
Financial Structure $(FS)_{t-1}$	**0.504**	**0.430**
	(0.476)	**(0.484)**
Log GDP per $capita_t$	2.107*	3.847***
	(1.172)	(1.194)
Log GDP per capita $squared_t$	-0.0563	-0.147**
	(0.0618)	(0.0638)
Population $(billions)_t$	-13.19	-29.02***
	(9.895)	(8.575)
$Recession_t$	-0.0894	-0.137
	(0.130)	(0.130)
Environmental Protection $Index_t$	0.165*	0.119
	(0.0966)	(0.0937)
Country fixed-effects	Yes	Yes
Year fixed-effects	Yes	Yes
No. Observations	571	596
No. Countries	27	27
F-statistic	5.361	6.751
Adj. R-squared	0.962	0.959
Adj. R-squared (within)	0.0634	0.0947

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Note: This table reports estimates from two OLS regressions, both including fixed effects as specified. Column (1) covers this thesis's sample period (1990-2012) and is equivalent to Table 4, column (4). The estimates reported in Column (2) are based on the sample period of De Haas and Popov (2021) (1990-2015). In both columns, the dependent variable is 'CO_2 emissions per capita', which denotes aggregate per capita emissions of carbon dioxide in metric tons (1000kg). 'Financial Development (FD)' is defined as the sum of private credit and stock market capitalization, normalized by GDP. The other financial proxy, 'Financial Structure (FS)', reflects the share of stock market financing out of total financing through credit and stock markets. Robust standard errors are included in parentheses.