Master's thesis

NTNU
Norwegian University of Science and Technology
Faculty of Economics and Management
Dept. of Industrial Economics and Technology Management

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Climate Policy and the Development of Green Venture Capital

A quantitative study investigating the relationship between climate regulations and green VC activity through cross-country comparison.

Master's thesis in Industrial Economics and Technology Management
Supervisor: Arild Aspelund
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Preface

This master's thesis is the concluding work of the Master of Science degree at the Norwegian University of Science and Technology. It is written during the spring of 2022 within the topic of Strategy, Innovation and International Business Development at the Department of Industrial Economics and Technology Management (IØT). The aim of this study is to investigate how financial markets more effectively can contribute to environmental sustainability, and more specifically how climate policy helps achieve this.

The research question of this thesis is based on a state-of-the-art literature review performed during the fall 2021, conducted as a preparatory work. This literature review identified a research gap regarding the relationship between climate policy and green innovation, leading to the direction of this thesis. A quantitative cross-country study investigating the factors impacting clean technology investments and fundraising within green venture capital is performed, with a focus on climate policies.

Writing this thesis has been inspiring and a highly valuable learning process. We have gained experience in identifying both theoretically and practically relevant research questions, designing a suitable study to answer them, obtaining the data required to conduct this study, and contributing to a broader discussion.

The authors hope the findings from this study will have implications for scholars and policy makers, as there is a need to realize the important role of financial markets in achieving environmental sustainability.

We would like to thank professor Arild Aspelund for valuable guidance and support in performing this study.

Trondheim, June 10, 2022

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Abstract

The role of finance in ensuring a sustainable economy is receiving increased attention as its influence is becoming visible. Ventures developing innovative products, services and solutions for long-term commercial and environmental sustainability, often called cleantechs, are viewed as an answer to many environmental challenges, which Venture Capital (VC) plays a crucial role in funding and nurturing. Many studies point to the importance of climate policies in developing the imperative area of green VC activity, but with limited empirical evidence. A quantitative cross-country study utilizing hierarchical multiple regression analysis is therefore performed with investment data from Jan. 2011 to Mar. 2022. This study finds that climate policy has a positive effect on both the share of investments performed in cleantech ventures, and the share of VC raised with a green mandate. The relationship is found to be stronger for cleantech investments than for green fundraising. A nation's preconditions are also found to be of great importance, namely, resources in the form of GDP per capita, incentives in the form of CO2 emissions per capita, and capabilities in the form of regulatory quality. More specifically, the nations with the highest carbon emissions are found to allocate the highest share of their capital to green VC funds, implying climate policy to be an effective mechanism. High regulatory quality, with a stable and predictable regulatory landscape, is further found to be an important enabler of cleantech investments. Accordingly, policymakers and regulators should introduce and/or increase the stringency of climate policy, underlining the importance of utilizing regulation in reaching a sustainable society. More research is required, including *which* forms of policy that are the most effective, whether these investments outperform their traditional peers with time, and measurement of the environmental impact such investments yield.

Keywords: cleantech, climate policy, environmental policy, green finance, green innovation, green investing, green technology, impact investing, sustainable finance, sustainable investing, venture capital

Sammendrag (Norwegian summary)

Finansmarkedenes rolle i det grønne skiftet får stadig mer oppmerksomhet og står høyt på agendaen i EU og lignende institusjoner. Tidligfase-selskaper som utvikler bærekraftige produkter og tjenester innen ren teknologi blir av mange sett på som løsningen på flere miljømessige utfordringer, der venturekapital spiller en viktig rolle i å finansiere og forvalte disse selskapene. Flere studier peker på viktigheten av klimareguleringer for å utvikle markedet for grønn tidligfasekapital, men med begrenset empirisk grunnlag. Derfor er det gjennomført en kvantitativ studie som bruker hierarkisk multippel lineær regresjon basert på investeringsdata fra jan. 2011 til mar. 2022 til å sammenlikne klimareguleringer og grønn investeringsaktivitet på tvers av land. Denne studien finner at klimareguleringer har en positiv effekt på både andel investeringer innen ren teknologi og andel kapitalinnhenting rettet mot tidlig-fase fond med miljømandater. Effekten er funnet å være sterkere for investeringer innen ren teknologi enn for kapitalinnhenting til grønne fond. Studien finner også at et lands forutsetninger har stor betydning for aktivitet innen grønn venturekapital. Dette innebærer et lands ressurser i form av BNP per innbygger, insentiver i form av karbonutslipp per innbygger, og strukturelle forutsetninger i form av høy kvalitet på regulatoriske institusjoner. Mer spesifikt finner studien at nasjoner med høyt karbonutslipp evner å allokere den høyeste andelen av sin kapital til miljømessig bærekraftige fond, som impliserer at klimareguleringer virker effektivt. Høy kvalitet og stabilitet i regulatoriske institusjoner er funnet viktig for å muliggjøre høy andel av investeringer innen ren teknologi. Det er følgelig tydelig at lovgivere og regulerende organer bør prioritere klimareguleringer i sitt arbeid for å bidra til miljømessig bærekraft, da dette bidrar til grønn innovasjon. Det er behov for mer forskning om hvilke spesifikke former for regulering som er mest effektive, hvorvidt avkastningen til grønne investeringer vil endre seg med tiden, og hvordan man kan måle den faktiske miljømessige effekten disse investeringene bidrar til.

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1 Introduction

The human influence on our climate system is pressing, where years of a singular focus on economic growth has resulted in emission of greenhouse gasses (GHG) that are threatening the stability of our planet (IPCC, 2021). This requires strong, rapid and sustained reduction in these emissions. Global climate change is therefore one of the most important scientific and political challenges of our time (Betsill & Bulkeley, 2006; WHO, 2014). There have correspondingly been several climate policy initiatives in recent years, maybe most prominently from the European Commission (HLEG, 2017, p. 2). Governments and regulators are increasingly imposing policies with the objective of allocating capital towards sustainable ventures, but how effective are these actually?

Development of new green technologies and carbon neutral economic activities are crucial in reducing GHG emissions. Innovation and entrepreneurship have therefore been recognized as of great importance, where new ventures are viewed as an answer to many environmental challenges (Hall et al., 2010). In order for these ventures to succeed and have the greatest impact possible, they are reliant on Venture Capital (VC) providing capital, facilitation and nurture. Some even go as far as saying that VC funds are "technological gatekeepers, accelerating the process of technological change" due to the importance of their support (Florida & Kenney, 1988). It is followingly clear that VC has a catalytic role in developing new sustainable businesses (Bürer & Wüstenhagen, 2008).

More overarchingly, finance plays an important role in effectively allocating capital to sustainable corporations, ensuring that our future global economy is sustainable (Schoenmaker & Schramade, 2018). As a part of the transition to a greener economy, there has been an increasing amount of research focusing on efficient capital allocation within sustainable finance. This is a fairly new research area, originating from the official agreement that transforming private finance would be key in achieving sustainable development made in Rio de Janeiro in 1992 (United Nations, 2017). The increasing focus on sustainable finance has also been evident in the capital markets, with the United Nations reporting that the number of sustainable investment funds almost doubled in the period of 2016 to 2020, with total Assets Under Management (AUM) more than quadrupling (United Nations, 2021). Given its importance, sustainable finance has been an central element of the recent developments in economic legislation. The European Commission announced an ambitious action plan for sustainable finance based on the findings of the High-Level Expert Group (HLEG) in 2017, including shaping the regulatory environment with the objective of catalyzing more sustainable investments (HLEG, 2017, p. 2).

A body of literature within sustainable finance in VC has emerged during recent years due to an increasing interest, but it is still a relatively nascent field that has yet to be fully examined in the academic literature (Holtslag et al., 2021; Bocken, 2015; Hall et al., 2010). One of the most prominent discussions across current research is the role of climate policies in the field's development (Aggarwal and Elembilassery, 2018; Antarciuc et al., 2018; Chiu, 2021; Cojoianu et al., 2020; Ermakova and Frolova, 2019; Mawdsley, 2018; Sadiq et al., 2021; Santi and Sennett, 2017; Tian, 2018, Criscuolo and Menon, 2015). These policies are claimed to be important for the development of green VC with limited empirical and quantitative evidence. This, combined with them becoming increasingly prominent in the regulatory landscape, makes it a highly relevant area of research. The paper investigates the following research questions through a quantitative cross-country research study:

1. Do more stringent climate policies positively affect the share of cleantech VC investments?
2. Do more stringent climate policies positively affect the share of capital allocated to green VC funds?
3. Are these elements impacted by a nation's preconditions?

The objective of this study is to quantitatively investigate how climate policies impact the development of green VC activity by cross-country comparison. This knowledge is relevant for policy makers and their motivation to impose climate policies, in addition to other market actors such as entrepreneurs and investors in understanding how regulatory developments affect financial markets.

2 Theoretical background

This chapter will provide an introduction to the main concepts addressed in this study: sustainability, sustainable finance, green finance, VC, green VC, cleantech and climate policy. It will further summarize existing research and ongoing discussions within the topic, introduce frameworks utilized for analysis, and conclude with hypotheses to be tested in this study.

2.1 Definitions and introductions

2.1.1 Sustainability

Sustainability is a term utilized across a large range of disciplines, resulting in differing definitions and meanings depending on the context (Brown et al., 1987; Moore et al., 2017). In its more general format, sustainability has been defined as "... the capability of being maintained at a certain rate or level" (Gruen et al., 2008) and "... being able to carry on, endure, or have a future" (Paschek, 2015). Utilizing this in a broader context, the Brundtland Commission articulated the idea of sustainable development in 1987: "Development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (World Commission on Environment and Development, 1987). This definition combined economic, social and environmental concerns – successfully putting these topics on the world's agenda. Many scholars have followingly defined the foundation of sustainable development through these three "pillars of sustainability" (Purvis et al., 2019). This is also the case for the United Nations Sustainable Development Goals (SDGs), which are 17 goals initiated as a "call to action to end poverty, protect the planet, and ensure that by 2030 all people enjoy peace and prosperity" (United Nations, 2015).

For the purpose of this study, the definition of sustainability is restricted to environmental concerns. Environmental sustainability has in its simplest form been defined as "maintenance of natural capital" (Goodland, 1995), or more specifically "... a method of harvesting or using a resource so that the resource is not depleted or permanently damaged" (Santillo, 2007). This topic has been high on the world agenda since the Paris Agreement at the COP 21 in Paris 2015, representing the first-ever universal and legally binding global climate change agreement. The agreement vows to substantially reduce GHG emissions to limit the global temperature increase this century well below 2 degrees celsius above pre-industrial levels, including pursuing efforts to limit the temperature increase even further to 1.5 degrees celsius (United Nations, 2015). The importance of this topic has since only increased, with large amounts of current both European and international regulatory environments being based on environmental policy (European Commission, 2021c). This, in combination with a large amount of studies examining the topic, makes it clear that there is high both practical and theoretical relevance.

Given this study's purpose of examining the effectiveness of environmental policy on investments in early-stage companies and VC fundraising, the definition of sustainability used in this paper can be stated as: "environmental development that meets the needs of the present without compromising the ability of future generations to meet their own", inspired by the definition from the Brundtland Commission.

2.1.2 Sustainable and green finance

Finance plays a key role in achieving sustainable development, with corresponding international climate and sustainability objectives (European Commission, 2021c). Sustainable finance can be defined as "finance to support sectors or activities that contribute to the achievement of, or the improvement in, at least one of the relevant sustainability dimensions" (Migliorelli, 2021). Other definitions include that of Schoenmaker & Scramade (2018): "how finance (investing or lending) interacts with economic, social, and environmental issues", as well as that of the European Commission: "... the process of taking environmental, social and governance (ESG) considerations into account when making investment decision in the financial sector, leading to more long-term investments in sustainable economic activities and projects" (European Commission, 2021c). Traditionally, financial and sustainable considerations have been viewed to be at odds, where improved sustainability would require financial costs and vice versa. In more recent times this view has been challenged, rather arguing that environmental regulations can result in innovations increasing profitability for businesses and returns for investors (Porter & van der Linde, 1995; Fatemi & Fooladi, 2013).

The central role of the financial sector in re-orienting investments towards sustainable technologies and businesses is evident in recent developments, including the European Green Deal. This is a set of policy initiatives with the objective of making the European Union climate neutral within 2050, published by the European Commission in 2019. These initiatives include the EU-taxonomy, a classification system for sustainable economic activities, helping companies become more climate-friendly and protecting investors from greenwashing (European Commission, 2021b). The same reporting is required from investors through the Sustainable Finance Disclosure Regulation (SFDR), a set of rules for increased comparability of sustainable financial products, and the European green bond standards. Such policies are intended to encourage market participants to invest in sustainable activities, and alleviate potential reservations one might have (European Commission, 2021d).

As the focus of this study is on the environmental dimension of sustainability, sustainable finance is defined as "finance to support sectors or activities that contribute to improvement in environmental sustainability" – inspired by (Migliorelli, 2021). "Green finance" is often used as a synonym to sustainable finance, defined by the UN as "to increase the level of financial flows from the public, private, and not-for-profit sectors to sustainable development priorities" (United Nations Environment Programme, 2021). Others define it more succinctly as financing directed towards the environmental aspect of sustainability (Lindenberg, 2014; Wang & Zhi, 2016). Several scholars also utilize the term "impact investing" with a definition similar to that of sustainable finance: investments made into companies, organization, and funds with the intention to generate social and environmental impact alongside a financial return (Global Impact Investing Network, 2017; Barber et al., 2021; Brest & Born, 2013; Clarkin & Cangioni, 2016). For the purpose of this study both "green finance" and "impact investing" are chosen as synonyms to sustainable finance, and will be used interchangeably.

2.1.3 Venture capital

Venture capital became a professional industry in the second half of the twentieth century, but has existed in one form another since the earliest days (Ante, 2008). At its core, VC offers financing for risky projects in exchange for an equity stake, which has been the case from spice trades in the 1400s to how we know it today. The more modern version can be defined as "independent, professionally managed, dedicated pools of capital that focus on equity or equity-linked investments in privately held, high growth companies" (Gompers & Lerner, 2001). Taking a broader view, VC is a part of the overarching category Private Equity (PE), focusing on start-ups and less mature companies (Gilligan & Wright, 2020), as displayed in Figure 1.

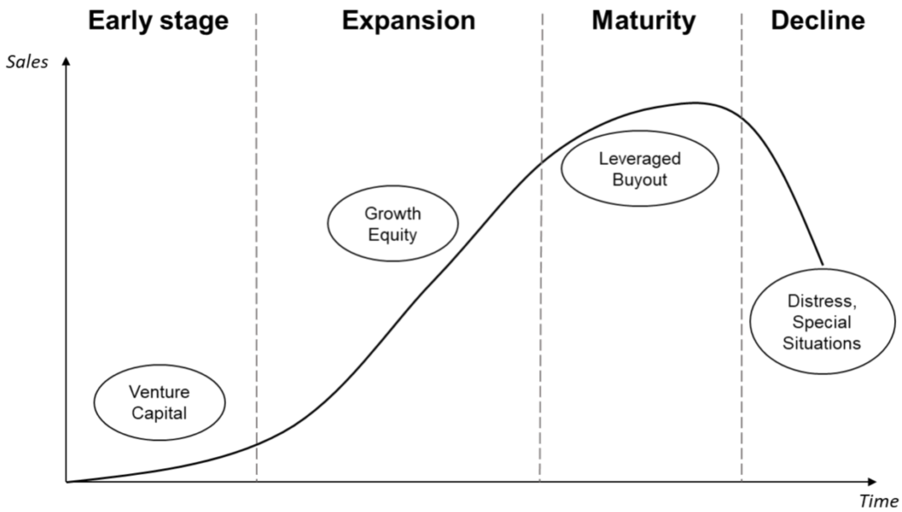

Figure 1: Types of Private Equity relative to company life cycle stage.

Source: Gatti, 2020

2.1.4 Green VC

New ventures developing green technologies and carbon neutral economic activities are reliant on VCs providing capital, facilitation and nurture to have the greatest impact possible (Bürer & Wüstenhagen, 2008). Such ventures are viewed by many as an important element in reducing GHG emissions, where green VC correspondingly is central (Hall et al., 2010). Green VC can be defined as "a high-risk financial capital provision for eco-innovative ventures, which offers the potential for financial returns, as well as contributing to sustainable development" (Randjelovic et al., 2003). This definition has clear similarities with that of sustainable finance established in Section 2.1.2, although with a specification on risk and innovation given the early stages such ventures are located in. Synonyms utilized in the following chapters referring to this definition include "sustainable VC", "green early-phase investments", "sustainable early-phase investments" and "impact VC".

As mentioned, the investments within sustainable finance has increased drastically within recent years, which is the case for green VC as well. Although no concrete figures seem to be available, the largest asset managers in the space are increasingly launching impact funds, including BlackRock, TPG, KKR and Bain Capital (Lenhard & Winterberg, 2021). This can also be seen through the expansion of infrastructure mandates to include energy transition and digitization, with the category as a whole reaching AUM over $1 trillion for the first time in 2021. This was further highlighted as one of the main developments in McKinsey's Private Markets Annual Review of 2021 (McKinsey, 2022).

2.1.5 Cleantech

The technologies and solutions developed by these ventures are often referred to as Clean Technologies, or cleantech for short. More specifically, cleantech can be defined as "innovative products, services and solutions that optimize the use of finite and renewable natural resources for long-term commercial and environmental sustainability" (Davies, 2013). Pernick & Wilder (2007) state that "cleantech refers to any product, service, or process that delivers value using limited or zero nonrenewable resources and/or creates significantly less waste than conventional offerings". The term cleantech is often used to refer to the ventures developing and offering such technologies and solutions, which is what this paper will focus on and refer to when using the term cleantech(s).

2.1.6 Climate policies

To incentivize activities aligned with environmental sustainability, such as those described above, governing bodies can enforce climate policies, also called environmental policies. This can take the form of "stick policies" by "a higher explicit or implicit cost of polluting or environmentally harmful behaviour", or more positively "carrot policies" by "incentives for the development of environmental technologies and processes such as feed-in-tariffs or research and development (R&D) subsidies" (Botta & Koźluk, 2014). More succinctly, environmental policy can be defined as "the official rules and regulations relating to the environment that are adopted, implemented , and enforced by a government agency" (Park & Allaby, 2007). These policies are progressively becoming international with increased focus, such as those included in the European Green Deal (European Commission, 2021a).

2.2 Existings research and discussions

Within the areas introduced above there are ongoing discussions, with corresponding research, which this section will delve deeper into. The three main areas are: the role of climate policy, what effective capital allocation to achieve a sustainable economy is, as well as which additional factors impact the development of cleantechs and green VC.

2.2.1 The role of climate policy

Porter Hypothesis

The traditional view on regulation had been that they reduce profits until Michael Porter in 1995 declared that well-designed regulation actually could enhance competitiveness: "Strict environmental regulations do not inevitably hinder competitive advantage against rivals; indeed, they often enhance it" (Porter & van der Linde, 1995). This notion has since been discussed and researched in detail, becoming known simply as the Porter Hypothesis (PH) (Ambec et al., 2013). Porter, and his co author Claas van der Linde, argued that regulation would be a forcing function for innovation, which again would lead to both environmental and business performance. This is often visualized as in Figure 2.

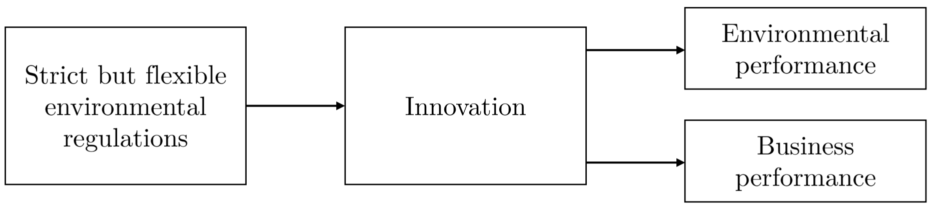

Figure 2: The Porter Hypothesis and its causal links visualized.

Source: Ambec et al., 2013

The mentioned research continues to find conflicting evidence regarding the validity of PH (van Leeuwen & Mohnen, 2017). Taking a sample of studies with a similar focus in Europe, Rubashkina et al. (2015) find evidence supporting PH for the manufacturing sectors of 17 European Countries between 1997 and 2009. On the other hand, Albrizio et al. (2017) find no evidence for PH based on data for the same sector in 11 OECD countries over the time period of 2000 to 2009. Wang et al. (2019) find a more nuanced picture with a similar sample of 24 OECD countries' industrial sectors, where environmental policy has a positive impact up until a certain level of stringency, before the impact turns to adverse due to compliance cost being higher than innovation offset effect. Whereas the majority of these studies investigate innovation within existing companies, a research gap exists regarding the PH for start-ups.

The effect from climate policies on green VC

There has been an increasing amount of research within green VC in recent years, investigating what factors influence green VC activity. Many of these scholars argue that a stable, predictable and sufficiently stringent regulatory environment is one of the most important factors for the development of green VC (Aggarwal & Elembilassery, 2018; Chiu, 2021; Ermakova & Frolova, 2019; Mawdsley, 2018). Despite an increasing amount of research on the topic, there are few studies quantitatively measuring the effect of climate policies, where most are based on qualitative methods such as expert interviews.

Several of these scholars are of the opinion that private actors cannot remake economic behavior alone, but that policies are required to enable the full potential of sustainable finance and green VC (Aggarwal & Elembilassery, 2018; Mawdsley, 2018). They further argue that current regulation should be more stable and predictable over time. In addition to being radical, they should be shaped around measurement of impact, as well as enhancing cooperation with private investors to create the largest flows of capital into sustainable investments possible.

After receiving funding, predictable regulation and environmental policies are also found to be of great importance in increasing the likelihood of success for cleantech ventures (Antarciuc et al., 2018; Cojoianu et al., 2020; Sadiq et al., 2021; Santi & Sennett, 2017; Tian, 2018). In terms of increasing the possibilities for expansion and Total Addressable Market (TAM) both international standards and leveraging elements such as public procurement are found to be of great importance. A predictable regulatory environment is also found to reduce competition by discouraging the establishment of non-clean counterparts, in addition to implementing measures to protect the value creation of environmentally sustainable ventures.

There are thus several arguments for why climate policies should enhance the development of green VC, but this relationship is not obvious, as some will argue that political influence and bureaucracy in general can limit creative innovation (V. A. Thompson, 1965). Desheng et al. (2021) finds that political connections hinder firms' green technology innovations and reduce innovation output. Therefore, there is a need to investigate the actual effect of climate policies on green VC. Even though the majority of the scholars find climate policies to be positive, there exists a research gap in terms of investigating this relationship thoroughly.

Stat of impact and green VC

Despite the increased investments and interest within impact and green VC, current research indicates that it underperforms traditional VC funds by 4.7 percentage points internal rate of return (IRR) (Barber et al., 2021). Investors are although willing to trade off financial returns, accepting up to 3.7 percentage points lower IRR, for funds that invest with a dual objective (Barber et al., 2021). It is from this clear that current performance lies outside of the accepted underperformance, and improvements are required. Such improvements can be influenced by external factors like regulation, and the lack of them might result in stricter expectations from investors in terms of impact measurement – a currently challenging exercise (Kölbel et al., 2020).

2.2.2 Effective capital allocation for a sustainable economy

State of sustainable funds in public capital markets

Despite the inflow of capital to sustainable funds of public equities mentioned in Section 2.1.2, these are currently not found to be effective with regards to progress towards the SDGS and other climate goals. A study commissioned by Greenpace and performed on their behalf in 2021 found that these funds only are effective in terms of divesting from companies that are involved in environmentally harmful activities (Schwegler et al., 2021). This includes finding that such funds do not contribute notably to achieving SDGs or the Paris climate target.

Other studies share these findings, with Kölbel et al. (2020) reviewing the mechanisms of investor impact, where they found that so-called sustainable investing in public equities is unlikely to drive a deeper transformation. They rather find that such vehicles are effective in terms of divestment, mainly based on metrics within ESG performance. Such metrics are static, and do not account for the impact a company can have through its business. For private capital markets, the environmental performance of sustainable funds is not extensively investigated in academic literature.

Tooling for impact measurement

Impact measurement is critical in understanding how companies can support the achievement of SDGs, but such tools are currently lacking (Kölbel et al., 2020; Carroux et al., 2021; Bandini et al., 2022). There are currently no widely recognized or utilized standards, frameworks or tools for measuring the impact an investment can have, hindering the contribution of sustainable investing to societal goals (Kölbel et al., 2020). This is also the case for VC, where ESG indicators are found to have little-to-no impact-generating potential, and impact measurement is thus required (Carroux et al., 2021; Aggarwal & Elembilassery, 2018). Impact reporting within VC is currently inadequate, described as unclear and incomprehensive (Carroux et al., 2021). This has triggered tailor-made approaches, but investors are seldom able to justify the cost of such impact measurement given the immaturity of the topic (Bandini et al., 2022). The need for impact metrics is further recognized by regulators, with the development of the EU-taxonomy and similar initiatives to help companies become more climate-friendly, as well as protect investors from greenwashing (Kölbel et al., 2020; European Commission, 2021b).

The role of start-ups and new ventures

New ventures are viewed as an answer to many environmental challenges, as development of new green technologies and carbon neutral economic activities are crucial in reducing GHG emissions (Hall et al., 2010; Belz, 2013). This is not only through energy improvements at the macro level, but technology-related innovations at the company level are actually found to be of greater importance for “green growth” (Skare & Porada-Rochon, 2022). This directly points towards cleantechs, aiming to develop new products, services and solutions, as introduced in Section 2.1.5. These ventures can further be organized as B Corps, which treat profits as a means to achieve positive societal ends, and impact is the main focus (Stubbs, 2016).

Importance of funding for start-ups

In order to perform such innovations start-ups are dependent on financing, as they in most cases do not have revenues in early stages. This is especially the case for sustainable ventures due to their long-horizon investment needs and high technological risk (Stefani et al., 2019; Owen, 2021). The most common form of such funding comes from VCs, as introduced in Section 2.1.3. In addition to capital, VC plays a central role in facilitating and nurturing start-ups to increase their likelihood of success and having the greatest impact possible, where some even say that they are technological gatekeepers due to the importance of their support (Florida & Kenney, 1988). VC followingly has a catalytic role in developing new businesses, including sustainable ones (Bürer & Wüstenhagen, 2008). For cleantechs specifically, financing is found to be an important barrier for their development across geographies (R. Zhang et al., 2021; Stefani et al., 2019; Owen, 2021).

Incentives and geographical focus on high-emitting nations
There is generally a strong correlation between economic growth and emissions, where the nations with the highest GDP also have the highest level of carbon dioxide (CO2) emissions (Benzerrouk et al., 2021). This has also been the case over time, where there is a rising argument that these nations correspondingly should play their part in reducing carbon emissions, with this being one of the main discussions at COP26 in Glasgow (UN Climate Change Conference UK, 2021). Given the level of emissions these nations have, the potential for impact is high, with an argument to be made for a geographical focus of reductions and investments on high-emitting nations (Parker & Blodgett, 2012). For developed nations, carbon offsets, i.e. purchasing carbon credits to get to carbon-neutral status, have become increasingly popular (World Economic Forum, 2022). This will although not be sufficient for reaching net-zero, and there is a need for nature-positive solutions, which cleantechs and green VC falls within.

2.2.3 Factors impacting cleantech and green VC

Looking at the development of green VC, there are several factors found to be of importance in academic literature – and there are varying findings regarding what factors are most important. Although several scholars point to climate policy as an interesting factor, there are others impacting the development of cleantech and green VC as well. To ensure a nuanced perspective, obtain a broad understanding of which factors affect green VC, and be able to identify the true effect of climate policy, these will be investigated further.

Tangential studies
Looking at the most relevant tangential studies investigating factors impacting green VC, several factors are found to be relevant. Criscuolo & Menon (2015) find that long term environmental policies are associated with higher levels of venture capital, especially in the green sector. Cumming et al. (2016) find that regulatory quality is important for the amount of cleantech investments, while not investigating climate regulations specifically. Increasing economic activity (in terms of GDP) is also found to be associated with an increase in cleantech VC deals, in addition to oil prices, increased stakeholder attention through media and the specific country's culture in the form of uncertainty avoidance (Cumming et al., 2016).

Studying bioenergy innovation, Lundmark and Bäckström (2015) find that R&D funding has a positive and statistically significant effect on green innovation, in addition to climate policies. This is supported by Criscuolo & Menon (2015), finding both these factors to be associated with higher levels of venture capital in the green sector. In addition to R&D funding, other forms of financial support such as grants and loans were found to positively impact the development of green VC, in addition to the country's renewable energy generation. Bürer & Wüstenhagen (2009) find supporting evidence for this through their qualitative study of factors impacting the development of cleantech in Europe and North America, more specifically that renewable energy production and financial support are central. The importance of financing has also displayed itself in China, where it is found to have a substantial impact (Chen, 2010). Lyeonov et al. (2019) confirms the findings of Bürer & Wüstenhagen (2009), finding a positive link between renewable energy consumption and green investments.

Investigating how innovation responds to climate changes, Su & Moaniba (2017) find that high carbon emitting countries develop more climate-related technologies – carbon emissions thus increasing green innovation. On the other hand, Huang et al. (2021) and Shen et al. (2021) find that green innovation leads to reduction in carbon emissions, implying that the green investments fulfills its purpose, and that countries with a high degree of green innovation have lower carbon emissions. This effect would make carbon emissions a less important factor. Line & Zhu (2019) also find that renewable energy technological innovations respond actively to carbon emissions in their study comparing Chinese provinces. Overall, there are thus varying findings in terms of which factors are most important for understanding the development of cleantech and green VC. The factors found to be of importance in tangential studies are summarized in Table 1 (on the next page).

Thematic categories of factors

To obtain a systematic overview of the factors found to be of importance in addition to climate policy, a bespoke framework with three overarching categories was developed. Structuring the factors into categories enables a structured discussion of the interaction between factors, in addition to identifying which categories that are of importance. The thematic categories chosen for this framework are depicted in Figure 3, namely resources, incentives and capabilities – representing a nation's preconditions for green VC activities in addition to climate policies. The intention is to choose variables most applicable to represent the overall categories.

Resources refers to a nation's wealth, where gross domestic product (GDP) is one of the most common indicators for this purpose (International Monetary Fund, 2020). GDP is a variable found to be of importance for cleantech VC investments by Cumming et al. (2016), in addition to being used as a control variable by others, such as Criscuolo & Menon (2015).

Incentives indicate to what extent a nation is in need of changing practices to reach climate change objectives. Factors found relevant in academic literature and utilized in this category are carbon emissions (Su & Maniba, 2017; Lin & Zhu, 2019) and renewable energy generation (Lyeonov et al., 2019; Criscuolo & Menon, 2015).

Capabilities are meant as structural preconditions for green business development and governmental efforts encouraging innovation. Factors found relevant in academic literature and utilized in this category are R&D expenditures (Bürer & Wüstenhagen, 2009; Criscuolo & Menon, 2015) and regulatory quality (Cumming et al., 2016).

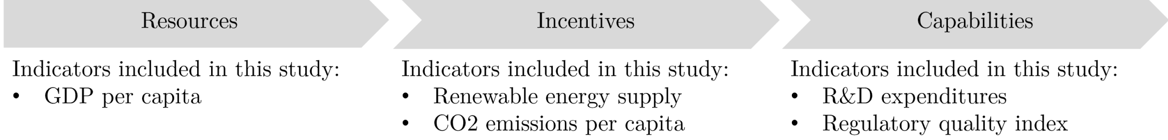

Figure 3: Framework for factors impacting cleantech and green VC in addition to climate policies.

Table 1: Factors found to be important for green VC in tangential studies.

Tangential study	Factors found to be of importance
Lundmark & Bäckström, 2015	• Policy, more specifically feed-in-tariffs (FITs) and tradable green certificates • R&D activities
Criscuolo & Menon, 2015	• Environmental policies with long-term perspective • R&D intensity • Renewable energy generation • Financial support, e.g. grants and loans
Bürer & Wüstenhagen, 2009	• Climate policy, more specifically feed-in-tariffs (FITs) • Government grants • Public R&D
Chen, 2010	• Fiscal policies
Cumming et al., 2016	• Oil prices • Increased stakeholder attention (media) • Uncertainty avoidance • GDP • Governance indicators: governance effectiveness and rule of law
Su & Moniba, 2017	• Carbon emissions
Lyeonov et al., 2019	• Renewable energy generation
Lin & Zhu, 2019	• Carbon emissions

2.3 Hypotheses

As alluded in Section 2.2, several scholars argue climate policies have a decisive role in the development of cleantech and green VC, despite limited empirical and quantitative evidence based on recent data. This paper therefore investigates to what extent climate policy positively affects investment activity in cleantech and fundraising for green VC funds, as stated in hypothesis 1 and 2 (H1 and H2). The choice of variables are elaborated in Section 3.2.1.

Existing literature also has varying findings in terms of other factors being important for the development of cleantech and green VC. Following the framework described in Section 2.2.3, this paper also investigates to what extent a nation's preconditions (in terms of resources, incentives and capabilities) affect the investment activity in cleantech companies and fundraising for green VC funds – stated in hypothesis 3 (H3). The hypotheses are visualized in Figure 4, illustrating which factors are expected to affect cleantech investments and green fundraising.

H1: *More stringent climate policy positively affects investment activity in cleantech companies.*

H2: *More stringent climate policy positively affects fundraising for green VC funds.*

H3: *Each nation's preconditions affect investment activity in cleantech companies and fundraising for green VC funds.*

> **H3.1:** *A nation's resources affects investment activity in cleantech companies and fundraising for green VC funds.*
>
> **H3.2:** *A nation's incentives affects investment activity in cleantech companies and fundraising for green VC funds.*
>
> **H3.3:** *A nation's capabilities affects investment activity in cleantech companies and fundraising for green VC funds.*

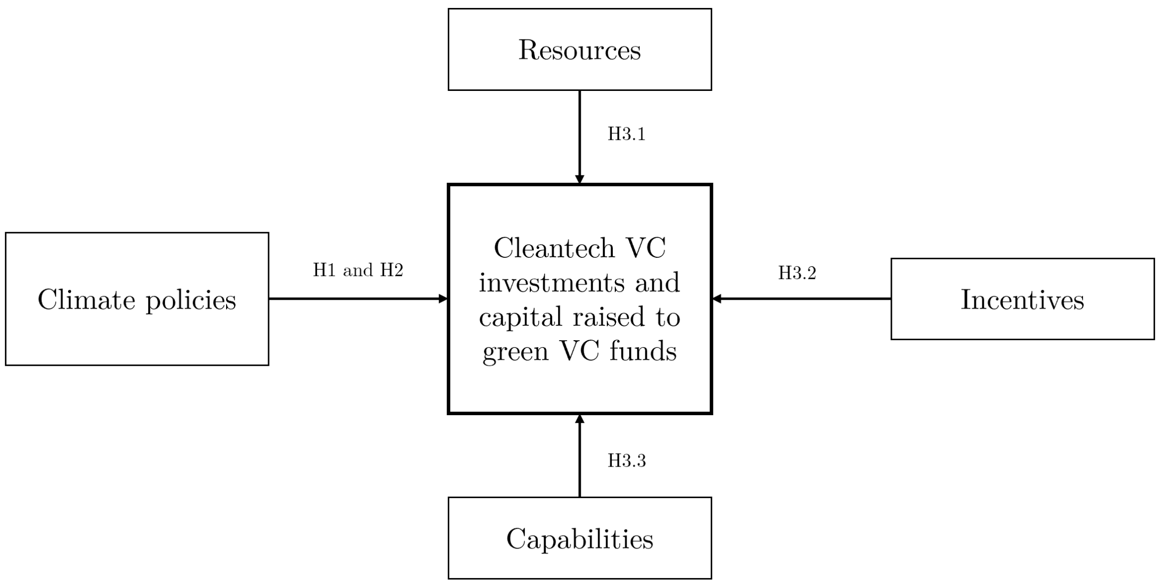

Figure 4: Hypotheses visualized.

3 Methodology

The objective of research can be stated as acquiring knowledge, or to perform a scientific search for information on a specific topic. To acquire this knowledge, the research should be systematic, logical, empirical and replicable. It is thus important that the researcher chooses a research methodology that fulfills these criteria (Kothari, 2004, p. 20). The following chapter will present and explain the research methodology used in this study. Firstly, the choice of research method will be presented. Then, the data sources and data processing techniques will be introduced. Lastly, there will be an explanation of the statistical method applied, followed by a discussion of possible limitations.

3.1 Choice of research method

Selecting a research design involves several decisions relating to how data is collected, analyzed and interpreted. The overall decision involves which design should be used to study a topic, where the two major types of design are qualitative and quantitative methods, in addition to mixed methods combining the two (Creswell, 2009, p. 22). This study uses a quantitative research approach with a macro perspective, performing a multiple regression analysis based on the arguments below.

First, a quantitative approach is suitable for investigating larger samples in a deductive manner. To get a thorough understanding of the relationship between climate policies and the development of cleantechs and green VC, it is beneficial to study as many investments and VC funds as possible, subordinated to differing regulatory landscapes. Quantitative methods are by several scholars argued to be beneficial for investigating larger samples and project findings onto populations, thus making valid generalizations and inferences (Borrego et al., 2009; Hägg & Hedlund, 1979; Polit & Beck, 2010). These methods are therefore a good fit for deductive approaches, in which theories from existing literature justifies the variables, the purpose statement and the direction of the narrowly defined research question (Borrego et al., 2009). Since this paper seeks to get a broader understanding of the effect of climate policies in a deductive manner, a quantitative research design was evaluated to be appropriate.

Second, a quantitative research design enables the use of statistical tools such as regression analyses. Regression techniques are popular tools for the investigation of relationships between variables, and have long been a central field of economics. From this, they have increasingly become important for a range of other applications such as legal policy makers (Sykes, 1993). Gunst & Mason (1980) argues that regression analysis is applicable when the goal is to express a response variable as a function of predictor variables. Such an expression can be used to identify which variables most affect the dependent variable or to verify hypothesized causal models (Gunst & Mason, 1980). Since this paper investigates the causal effect between two variables, namely climate policies and sustainable investment activity, regression analysis was seen to be a natural choice that is easily applicable and appropriate for answering the research questions. Details regarding the regression analysis performed will be elaborated on in Section 3.4.

Third, a macro perspective is evaluated to be appropriate as the nature of the research problem necessitates an overview of various types of investors and climate policies. Understanding the total effect of climate policies requires studying the aggregate performance of various economies in a big-picture view. As legislation often is country-specific, issued by policy makers accountable to governments (Choi et al., 2005), a macro perspective research design comparing countries with various climate policies was seen to be suitable.

Lastly, there is a lack of recent research that quantitatively investigates the effect of climate policies on the development of sustainable investment activity. The most relevant papers, such as Cumming et al. (2016) and Criscuolo & Menon (2015) mentioned in Section 2.2.3, have not included the effect of the many recently implemented policies after the Paris Agreement in 2015, such as the European Green Deal in 2019 (European Commission, 2021a). Cojoianu et al. (2020) is one of the more recent papers on this subject, but uses data from no later than 2013. Since several papers find climate policies to be important for cleantech and green VC development through qualitative research methods, such as Ermakova & Frolova (2019) and Antarcuic et al. (2018), it is evaluated to be highly relevant to perform a quantitative study that investigates this relationship from a macro perspective with recent data.

3.2 Choice of data sources

3.2.1 Explained variables

To perform a quantitative study on the development of green VC activity, market data from a range of countries was required. Due to limited time and resources for data gathering, as well as broad scope of the research questions, it was chosen to use data from a financial database that offers a large amount of data with global reach. Because "any regression analysis is only as good as the data on which it is based" (Montgomery et al., 2021, p. 5), it was important to find a reliable data source that provides data with sufficient quality and quantity to make valid inferences from the analyses.

Refinitiv, one of the world's largest providers of financial markets data and infrastructure, was chosen as one of the data sources for this study. They have 400 000 end users across 190 countries, and can thus be argued to have a global reach (Refinitiv, 2022c). Refinitiv and their software Eikon is seen as the most trustworthy and comprehensive international database of financial and accounting data (Shakil, 2021). The database is also used as a source in many published scientific studies, such as Noja et al. (2020) and Daehler et al. (2021). Since this paper is investigating VC, it was chosen to use Refinitiv Eikon Private Equity, an offering of private equity data covering 50 years of history, over 57 000 private equity and venture capital funds, in addition to 325 000 investments (Refinitiv, 2022a).

To ensure data relevant to the research questions, certain decisions were made during the data gathering process. Within the Refinitiv Eikon software, the search tool was firstly restricted to "Private Equity/VC". The search was further restricted to only include "Venture Capital Deals", to ensure that the dataset only contained information about VC. The database then offers three types of data records, namely investments, fundraising and exits. To investigate the development of green VC, it was chosen to use data about investments and fundraising. With this information, it is possible to evaluate both how much capital that is raised to green VC funds, but also to what extent funds are choosing to invest in cleantechs. Exits were evaluated to be less relevant for the research question, as the focus lies on the capital allocation towards more sustainable ventures.

These choices made it possible to study two datasets with two variables relating to the development of green VC activity. The investments dataset enabled measurement of how many investments that are targeted towards clean technology, while the fundraising dataset made it possible to measure how much capital that is raised to green VC funds. These are the two dependent variables analyzed in this study, and will be described in more detail in 3.3 and 3.4.

Lastly, the search was restricted to a specific time period. It was desirable to only include the most recent data to get an updated overview of the effect from recently imposed climate policies. There have been many changes in the regulatory landscape of climate policies during the years, and it was therefore intended to only include data as new as possible. At the same time, enough data to ensure statistical significance of the findings in the regression analysis was required. Therefore, it was chosen to restrict the search of both investments and fundraising to the last ten years. The investment date and fundraising date was restricted to no earlier than January 1st, 2011, and until March 1st, 2022, when the final data gathering was performed.

3.2.2 Exploratory variables

To investigate the effect of climate policies on green VC development, an exploratory variable that measures climate legislation was required. Policies are not quantitative in nature, and it is thus not obvious how to measure them quantitatively. Similar studies such as Criscuolo & Menon (2015) uses dummy variables on whether a certain policy exists or not in a specific country, which will measure whether efforts are made towards imposing climate policies to a certain extent, but it can be argued that it does not measure the overall effect of the legislative landscape. Cumming et al. (2016) uses indexes measuring regulatory quality and political stability (while not climate policies specifically). In this study, a version of the latter approach is chosen, using an index measuring the overall performance of the climate policy in a country.

It was chosen to use the Climate Change Performance Index (CCPI), which is an independent monitoring tool for tracking countries' climate protection performance. The index has been published annually since 2005, and is designed by Germanwatch, a non-profit organization (CCPI, 2022). A total of 60 countries, in addition to the EU, are evaluated by their climate mitigation efforts across four categories that is weighted into a total score: greenhouse gas emissions (40% of overall score), renewable energy (20% of overall score), energy use (20% of overall score) and climate policies (20% of overall score). Climate policies is a score measuring the country's performance in terms of its national climate policy framework and implementation, as well as international climate diplomacy. The climate policy score is based on a questionnaire answered by climate and energy policy experts from non-governmental organizations, universities and think tanks within the countries that are evaluated. The evaluation method sets zero as a bottom cut off, and 100 points as the maximum that can be achieved (Burck et al., 2021). For the purpose of this study, the CCPI climate policy score published in 2022 is used as a variable to describe the quality of the climate policy in a certain country.

In order to investigate hypothesis 3, it was chosen to include other exploratory variables according to the conceptual framework presented in Section 2.2.3. To include data about various countries' resources, incentives and capabilities to both allocate capital to green ventures and implement environmental regulations, it was intended to use reliable, publicly available databases of country level indicators. Therefore, the International Monetary Fund, Organization for Economic Co-operation and Development (OECD) and the World Bank were chosen as primary data sources. Further details about the variables included in the regression analyses are presented in Section 3.4.

3.3 Data processing

To make sure the data had a relevant format to be used in the analyses, data processing was performed. This was only done on the two datasets with VC data from Refinitiv Eikon. This is due to all the exploratory variables such as CCPI climate policy score already being prepared with a specific value for each country. Data from these sources were therefore used directly in the analyses.

3.3.1 Investments

The investment dataset, with time restriction from January 2011 to March 2022, consisted of 96 199 investments. These investments were aggregated on a country level, i.e. every country was labeled with the total number of investments, in addition to the total number of investments within clean technology. The labeling of cleantech companies was based on Refinitiv Eikon's categorization of "Primary Technology Application" of the investment company, which has a category called "Clean Technology". Further, the percentage of cleantech investments (called "Cleantech") was calculated for each country in the following manner:

$$Cleantech = \frac{Number\ of\ investments\ in\ clean\ technology}{Total\ number\ of\ investments} \cdot 100\% \tag{1}$$

This resulted in a cross-sectional dataset of various countries labeled with a cleantech percentage. To avoid including countries with too few investments, and increase the possibility of inferences being representative, a limit for the minimum number of total investments in a country to be included in the processed dataset was set. It was chosen to only include countries with a total number of investments above 100. The reason for calculating cleantech percentage instead of using the absolute number of cleantech investments was to account for the size of the economy and the high variability in total investments registered in the database.

3.3.2 Fundraising

The fundraising dataset, with the same time restriction, consisted of 7649 fundraisings. Since the database did not offer any information regarding whether a fund is environmentally sustainability focused, it was necessary to perform manual labeling of the dataset. To reduce the time spent on manual labeling, the dataset was scaled-down from 7649 to 2251 rows. Since the dataset was unevenly distributed across countries, it was possible to only delete fundraisings from the two largest, and initially overrepresented, countries; USA which had 4850 fundraisings represented, and China which had 618. Since the deletion of rows only affected two countries in the dataset, which had a large sample represented, it is assumed that this does not affect the validity of the data notably.

The down-scaling was done by using proportionate stratified random sampling, which is a method ensuring that the sample is representative to the original dataset with regards to selected properties (Aoyama, 1954). Using such a method often produces a smaller error of estimation relative to a simple random sample of the same size (Pennsylvania State University, 2022). The properties viewed to be of greatest impact, and thus important to account for in our stratification, were fund size and vintage year. For vintage each specific year was utilized, whereas for fund size we utilized buckets of USD millions [0, 5), [5, 15), [15, 50), [50, 100), [100, 300) and [300, 5000). This resulted in reductions for the USA and China as displayed in Table 2 and Table 3 respectively.

Table 2: Illustration of the stratified random sampling process for USA fundraising data.

		Fund size (USD millions)					
		[0, 5)	[5, 15)	[15, 50)	[50, 100)	[100, 300)	[300, 5000)
Vintage year	2011	37 → 2	20 → 1	60 → 4	26 → 2	36 → 2	19 → 1
	2012	55 → 3	33 → 2	47 → 3	20 → 1	36 → 2	22 → 1
	2013	41 → 3	27 → 2	56 → 3	31 → 2	54 → 3	28 → 2
	2014	68 → 4	43 → 3	66 → 4	49 → 3	54 → 3	45 → 3
	2015	67 → 4	32 → 2	62 → 4	59 → 4	63 → 4	38 → 2
	2016	67 → 4	55 → 3	90 → 6	64 → 4	89 → 6	50 → 3
	2017	73 → 5	62 → 4	103 → 6	63 → 4	70 → 4	25 → 1
	2018	90 → 6	88 → 5	117 → 7	99 → 6	101 → 6	66 → 4
	2019	127 → 9	75 → 5	154 → 10	89 → 6	139 → 9	73 → 5
	2020	164 → 10	79 → 5	129 → 8	85 → 5	108 → 7	77 → 5
	2021	180 → 11	99 → 6	144 → 9	68 → 4	97 → 6	86 → 5
	2022	26 → 2	7 → 0	14 → 1	6 → 0	7 → 0	13 → 1

Table 3: Illustration of the stratified random sampling process for China fundraising data.

		Fund size (USD millions)					
		[0, 5)	[5, 15)	[15, 50)	[50, 100)	[100, 300)	[300, 5000)
Vintage year	2011	5 → 2	29 → 14	57 → 28	36 → 17	37 → 18	27 → 13
	2012	6 → 3	12 → 6	37 → 18	18 → 9	16 → 8	6 → 3
	2013	2 → 1	1 → 0	9 → 4	3 → 1	4 → 2	4 → 2
	2014	1 → 0	1 → 0	3 → 1	4 → 2	10 → 5	6 → 3
	2015	0 → 0	2 → 1	8 → 4	5 → 2	6 → 3	10 → 5
	2016	1 → 0	1 → 0	3 → 1	7 → 3	10 → 5	9 → 4
	2017	0 → 0	1 → 0	2 → 1	1 → 0	13 → 6	8 → 4
	2018	0 → 0	1 → 0	4 → 2	7 → 3	23 → 11	15 → 7
	2019	0 → 0	0 → 0	6 → 3	0 → 0	6 → 3	13 → 6
	2020	1 → 0	2 → 1	8 → 4	4 → 2	16 → 8	19 → 9
	2021	0 → 0	2 → 1	4 → 2	8 → 4	12 → 6	17 → 8
	2022	0 → 0	0 → 0	0 → 0	1 → 0	1 → 0	1 → 0

The manual labeling to categorize funds as green or not was done by searching the website of the VC fund and evaluating whether certain criteria are satisfied. The criteria were inspired by the procedure of Barber et al. (2021), except that this study restricts impact funds to be defined as funds with the objective of achieving environmental impact. Firstly, the fund must state a dual objective in its motivation, by communicating that it seeks to achieve both financial returns and environmental impact. In addition, the portfolio must include minimum one company operating within clean energy or stating an environmental sustainability mission in their business model. The criteria for funds being defined as green are visualized in Figure 5. In some cases, the desired information was not available, e.g. the VC firm not having a website. These funds were thus labeled as non-green, meaning that some funds may have been mislabeled due to missing information (false negatives). Despite this, the method should provide a clean sample of green funds, where few funds were mistakenly labeled green (false positives).

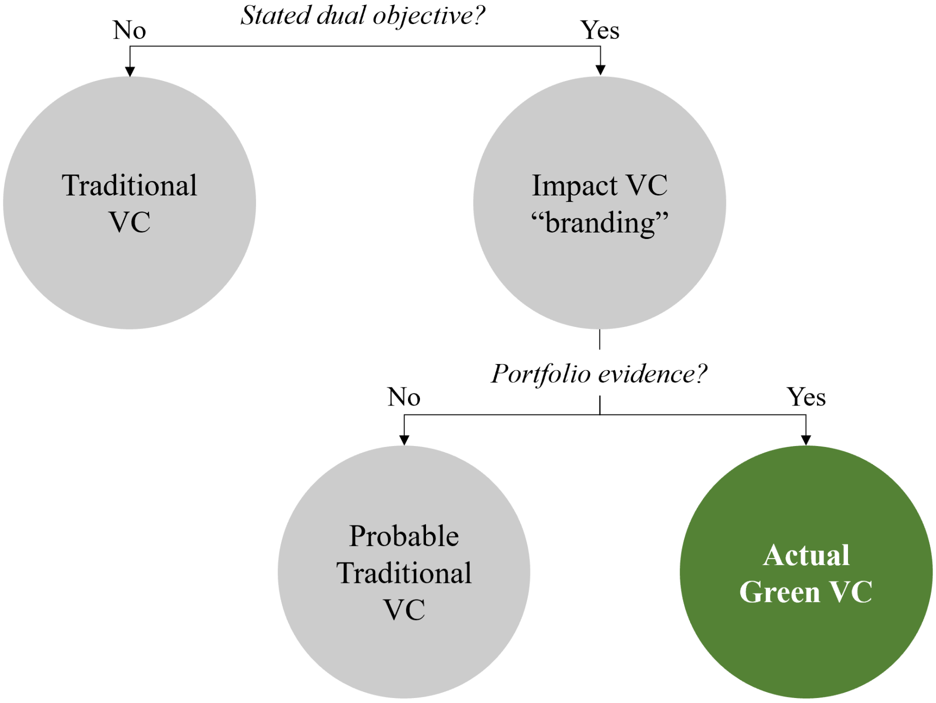

Figure 5: Criteria for funds being defined as green.

Further, the dataset was aggregated on a country level, resulting in every country being labeled with the total amount of capital raised to VC funds, in addition to the total amount of capital raised to green VC funds. Then, the share of fundraising committed to green VC (called "GreenCap") was calculated in the following manner:

$$GreenCap = \frac{Total\ capital\ raised\ to\ green\ VC\ funds}{Total\ capital\ raised\ to\ VC\ funds} \cdot 100\% \tag{2}$$

This resulted in a cross-sectional dataset of various countries labeled with a share of fundraising committed to green VC. The rationale for using share of capital committed to green VC funds instead of total capital committed to green VC funds was also here to account for differing size of economies and high variability in total fundraisings registered in the database. An alternative approach could be to use the number of fundraisings, but for the purpose of the research questions it was evaluated to be more interesting to study the total capital committed. To avoid including countries with too few funds raised, and increase the possibility of the sample being representative, there was a limit for the minimum number of total fundraisings in a country to be included in the dataset. It was chosen to only include countries with a total number of fundraisings above 20, assuming that this will provide a sufficient amount of capital to be analyzed. Finally, both datasets were merged with all the country-level independent variables such as the CCPI climate policy score.

3.4 Multiple regression analysis

As mentioned in Section 3.1, the analysis in this paper is performed as a regression analysis. In order to investigate the research questions thoroughly, it was chosen to use a multiple linear regression analysis that allows for multiple regressor variables.

3.4.1 Regression model building

The CCPI climate policy score is the main explanatory variable of interest, but in order to control for other variables and get a broader understanding of the mechanisms behind the development of green VC activity, several variables were added. To clearly see the effect of adding one more variable to the regression model, a hierarchical multiple regression approach was used by building nested models sequentially. In hierarchical regression, the researcher chooses the order in which variables are entered based on theoretical hypotheses, and the coefficient of interest is the proportion of variance accounted for at a particular step over and above that accounted by the independent variables in the previous step (Wampold & Freund, 1987). The procedure of choosing variables to enter into the regression model is based on CCPI climate policy score being the main independent variable of interest, while the other variables are based on the conceptual framework presented in Section 2.2.3. It was intended to use variables measuring a country's resources, incentives and capabilities, utilizing these to control for the effect of the CCPI climate policy score, while providing broader understanding of what actually affects the development of green VC activity. The two series of regression models that were built sequentially are illustrated in equation (3) and (4) below. "CCPI" refers to the CCPI climate policy score described in Section 3.2.2. The equations illustrate the two explained variables of interest, that CCPI climate policy score is the main explanatory variable which is always included, and that additional variables will be added to build the regression models.

$$Cleantech = \beta_1 \cdot CCPI + ... + \beta_n \cdot variable_n \tag{3}$$

$$GreenCap = \beta_1 \cdot CCPI + ... + \beta_n \cdot variable_n \tag{4}$$

Since the dataset is cross sectional with one observation per country, the sample size will naturally be limited. To ensure sufficient degrees of freedom, it was chosen to include a maximum of one independent variable per 10 observations, which is argued by several scholars as a suitable limit (Peduzzi et al., 1995; Concato et al., 1995; Jackson, 2007). It was also chosen to include a maximum of one variable from each of the categories (resources, incentives and capabilities), to avoid adding too many independent variables and to be able to see categories in combination. This is also assuming that the variables within each category are good measures for their respective category.

Lastly, in order to avoid multicollinearity problems, it was chosen to not combine independent variables that are heavily correlated. There is no widely agreed cutoff for the maximum correlation between independent variables, as what is large in one research domain may be small in another (C. G. Thompson et al., 2017). Some scholars suggest "rules of thumb" that multicollinearity problems are not likely to exist if bivariate correlations are below cut-off values, typically 0.7 or 0.8 (Kalnins, 2018). Therefore, it was chosen to not combine variables with a correlation higher than 0.7.

The three restrictions that formed a basis for choice of combination of variables to include in the hierarchical regression analysis are summarized below in Figure 6.

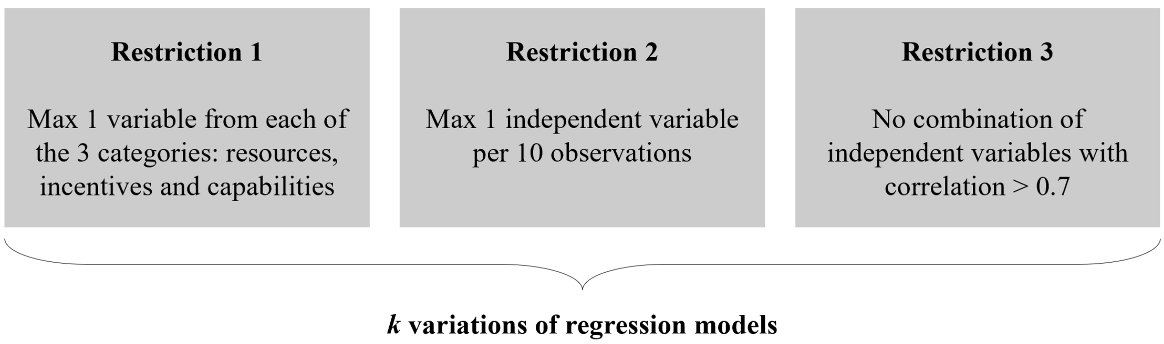

Figure 6: Restrictions for combination of variables in regression models.

Even though high correlation between pairwise predictors indicates multicollinearity, low correlation coefficients cannot be viewed as evidence for a lack of multicollinearity (Belsley et al., 1980). For that reason, it was also performed a variance inflation factor (VIF) analysis to evaluate whether the resulting regression models were affected by multicollinearity problems. Several scholars argue that VIF values greater than 10 indicate problematic multicollinearity (Cohen et al., 2003; C. G. Thompson et al., 2017). To be confident in avoiding multicollinearity problems, typical suggestions for cutoff points are in the range of 5–10 (Craney & Surles, 2002). It was therefore chosen to use the VIF values to evaluate reliability of the regression models. Regression models containing VIF values greater than 10 were considered unreliable for interpretation and thus excluded, while models containing VIF values greater than 5 were included but considered less reliable.

The method applied does have similarities with, and will follow the same structure as, Cumming et al. (2016) and Criscuolo & Menon (2015). The presentation of results will thus follow a standard structure of multiple regressions analyses; firstly descriptive statistics will be presented, followed by a correlation matrix of the variables included, and finally a summary of the regression models (Keith, 2014).

3.4.2 Overview of variables included in the analysis

All the variables used in the multiple regression analysis will be presented below, including variable name and explanation. An overview is depicted in Table 4.

Table 4: Overview of variables used in the multiple regression analysis.

	Variable	Definition	Data source
Dependent variables	Cleantech	Percentage cleantech VC investments of all VC investments registered in the period Jan. 2011 to March 2022.	Refinitiv Eikon
	GreenCap	Percentage capital raised to green VC of all capital raised to VC funds in the period Jan. 2011 to March 2022.	Refinitiv Eikon
Climate policies	CCPI	Climate policy score from Climate Change Performance Index 2022.	Germanwatch
Resources	GDP	Gross domestic product per capita in US dollars, values from 2021 (or newest available).	International Monetary Fund
Incentives	RenEnergy	Renewable energy supply, measured as percentage of total energy supply. 2020 values (or newest available).	OECD
	CO2	CO2 emissions measured in metric tons per capita, 2018 values (or newest available).	The World Bank
Capabilities	R&D	Gross domestic spending on R&D measured as percentage of GDP, 2020 values (or newest available)	OECD
	ReqQual	World Governance Indicators Regluatory Quality Index from 2021.	The World Bank

Cleantech: The percentage of total investments registered in a country which are targeted towards cleantech companies, measured in the period between January 1st, 2011, and March 1st, 2022 (Refinitiv, 2022b).

GreenCap: The percentage of capital committed to green VC funds from all VC fundraisings performed in a country, measured in the period between January 1st, 2011, and March 1st, 2022 (Refinitiv, 2022b).

CCPI: CCPI climate policy score is one of the components of the Climate Change Performance Index, and rates the performance of a country in terms of implementing effective regulations with the objective of reducing greenhouse gas emissions. The index rates 60 countries with a score between 0 and 100, where 100 points is the best climate policy performance that can be achieved (Burck et al., 2021).

GDP: Gross domestic product per capita in US dollars, published by the International Monetary Fund. This indicator represents the total value at current prices of final goods and services produced within a country during a specific time period divided by the average population for the same one year. The variable is logged to make interpretation of coefficients more intuitive. All countries are labeled with the most recent data, which is from 2021, where some exceptions have their newest value from 2020 (International Monetary Fund, 2022).

RenEnergy: Renewable energy percentage is defined as the contribution of renewables as percentage of total energy supply. Renewables include hydro, geothermal, solar, wind, tide and wave energy sources, in addition to bioenergy such as those derived from biofuels, biogasoline, biodiesel and biogases. Biofuels are defined as fuels derived from biomass, which includes food, vegetal waste, ethanol, animal materials and sulphite waste. The renewable fraction of municipal waste is also included. Latest available data is used, where most countries have the newest measure from 2020 and some are labeled with values from 2019 (OECD, 2022b).

CO2: Carbon dioxide (CO2) emissions in a country are measured in metric tons per capita. The emissions are primarily those stemming from the burning of fossil fuels and the manufacture of cement, in addition to carbon dioxide produced during consumption of solid, liquid and gas fuels, as well as gas flaring. Emissions from land use such as deforestation are excluded. The CO2 emissions of a country are only an indicator of one greenhouse gas, and gasses such as methane and nitrous oxide are not considered, but CO2 makes up the largest share of gasses contributing to global warming and climate change. Estimates of CO2 emissions are probably accurate within 10 percent, while some country estimates have larger error bounds. All countries are labeled with the most recent data, which is from 2018 at the World Bank database (World Bank, 2022). Not all countries were included in the World Bank database, and it was therefore chosen to use Our World in Data, which utilizes estimates from 2020, as an additional source for the missing values (Ritche et al., 2020).

R&D: Gross domestic spending on research and development (R&D) measured as a percentage of GDP. R&D expenditures are defined as the total expenditure on R&D carried out by all resident companies, research institutions, university and government laboratories, etc., in a country. It includes R&D funded from abroad, but excludes domestic funds for R&D performed outside the domestic economy. The indicator is measured in USD constant prices using 2015 as base year and Purchasing Power Parities (PPP) and as percentage of GDP. Most recent data available is used, where most countries have values from 2020 and some exceptions are labeled with 2019 data (OECD, 2022a).

RegQual: Worldwide Governance Indicators (WGI) are published by the World Bank, reporting aggregate and individual indicators for six dimensions of governance. Governance consists of the traditions and institutions by which authority in a country is exercised. This includes the process by which governments are selected, monitored and replaced, in addition to the respect of citizens and the state for the institutions that govern economic and social interactions among them. The WGI data sources reflect the perceptions of a diverse group of respondents, where several sources are surveys of individuals or domestic firms with first-hand knowledge of the governance situation in the country (Kaufmann et al., 2010). The WGI Regulatory Quality Index is one of the six dimensions of governance, and the index captures the perceptions of the ability of the government to formulate and implement sound policies and regulations that permit and promote private sector development. The index is quantified as a value between -2 and 2, where 2 corresponds to the highest possible regulatory quality. Newest available data from the 2021 WGI publication is used (Kaufmann & Kraay, 2021).

3.5 Methodological limitations

The quality of quantitative research studies is commonly evaluated in terms of reliability and validity (Bryman, 2016; McNabb, 2010). Methodological limitations of the research design of this study will be discussed in terms of these measures below.

3.5.1 Reliability

Reliability refers to the consistency of a measure of a concept (Bryman, 2008, p. 169). Researchers must pay attention to ensure that they are measuring what they intend to measure, and stability of the measurement procedure is a major concern in longitudinal research designs (McNabb, 2010). As this study uses widely recognized and reliable data sources, the input data used is evaluated to be both consistent and reliable. The regression method applied is further easily replicable and consistent in nature, where the measurement system of this study is expected to produce similar results if repeated.

This study is performed with the research design of a cross-sectional analysis with aggregated data from the last ten years. There is thus no distinction between capital movements registered at the beginning of the time period and those registered at the end, as all these are aggregated to a common value. The result of a similar study may therefore change depending on the choice of time period to be investigated. This method does neither measure the development within the time period. An alternative approach could therefore be to use a panel dataset with one observation per country per year, as done by Cumming et al. (2016). This would increase the total sample size used in the regression analysis, which again may increase the reliability and the confidence level of the findings (Mascha & Vetter, 2018). It was although not an option for this study as several of the variables did not have per year records, especially the CCPI climate policy score which only has numerical registrations from 2017 and after (Burck et al., 2021). Assuming that it takes several years to see the effect of imposed legislation, aggregation of financial data and climate policy scores from the last ten years is still evaluated to be highly relevant.

In terms of measuring green VC activity, Refinitiv Eikon was the only data source used. There exist several financial databases which provide private equity and VC data, such as Preqin and Pitchbook. Using multiple data sources could increase the reliability of the study as it limits the chance of biases or lack of data coverage from one single source. Due to availability and funding restrictions, it was not possible to use other data sources in this study.

3.5.2 Validity

Validity is the degree a variable accurately represents what it is supposed to (Hair et al., 2013). When quantitative measures are used to describe social concepts, it is important that the measure devised for a concept really does reflect the concept that it is supposed to be denoting (Bryman, 2016). This study uses two variables to measure the development of green VC activity, cleantech investments and capital raised to green VC funds. These are variables used by several scholars within the research area and do reflect two main aspects of VC activity: investments and fundraising. Policies can be said to be less quantitative and measurable, where it therefore was chosen to use an aggregated index from a reliable data source. The analysis does thus not provide detailed insight about specific types of climate policies and their isolated effect.

Choosing to perform a cross-country analysis is to a large extent based on data availability, and that many macro variables are measured on a country level, including the CCPI climate policy score. Since financial markets are global, it can be discussed to what extent country borders are describing differences in VC activity. It is assumed that VC actors must obey the regulations imposed by the government in the country they are operating, but it could be that some regulations are more differentiated across industries than countries. Therefore, there may be some nuances which are not detected in a cross-country study.

As explained in Section 3.3.2, there was manual labeling of green VC funds in the fundraising dataset. The labeling was based mainly on how the fund communicates its performance objectives on its website. It is possible that some funds are communicating other objectives than what they are pursuing, raising the possibility of greenwashing issues and false positives in this study. Nevertheless, increased marketing on environmental impact does imply that investors are more aware of environmental concerns. Manual labeling does also enable reliability issues, as the labeling may be influenced by subjective evaluations. To avoid this, objective criteria for the labeling process was used, which are displayed in Figure 5.

4 Results

The following section will present findings from the analysis described in Chapter 3. First, the analysis of share of investments in clean technology will be presented, containing summary statistics of the dataset analyzed and results from the regression analysis. Then, the same procedure will be performed for analysis of the share of fundraising committed to green VC.

4.1 Share of cleantech investments

The procedure of the analysis was performed as described in the method chapter. A total dataset consisting of 96 199 VC investments was aggregated to 41 countries that satisfied the criteria presented in Section 3.3.1. Some of these countries were excluded due to not being a part of the 60 countries listed in the CCPI index. The resulting dataset used in the regression analysis consisted of 33 countries, aggregated by a total of 91 275 VC investments in the time period. The investments are naturally not evenly distributed across the represented nations. A large majority of the investments are registered in the US, represented with 44 474 investments. The second largest contributor is China with 13 656 investments. Canada, France, India and the United Kingdom all have between 4 000 and 5 000 registered investments. The countries with the smallest number of total registered investments are Portugal (131), Vietnam (129) and New Zealand (111). See Appendix A for a full overview of the countries included, with total investments and number of cleantech investments. The 33 countries and their percentage of investments in cleantech are illustrated in Figure 7. Vietnam was the only country found to have zero investments in cleantech, meaning that all other countries on the map with zero percentage of cleantech investments were not included in this study due to insufficient data coverage. Finland and Canada are the countries found to have the highest percentage of cleantech investments, respectively 8.20% and 7.99%, followed by Norway (6.74%), New Zealand (6.31%) and Portugal (6.11%).

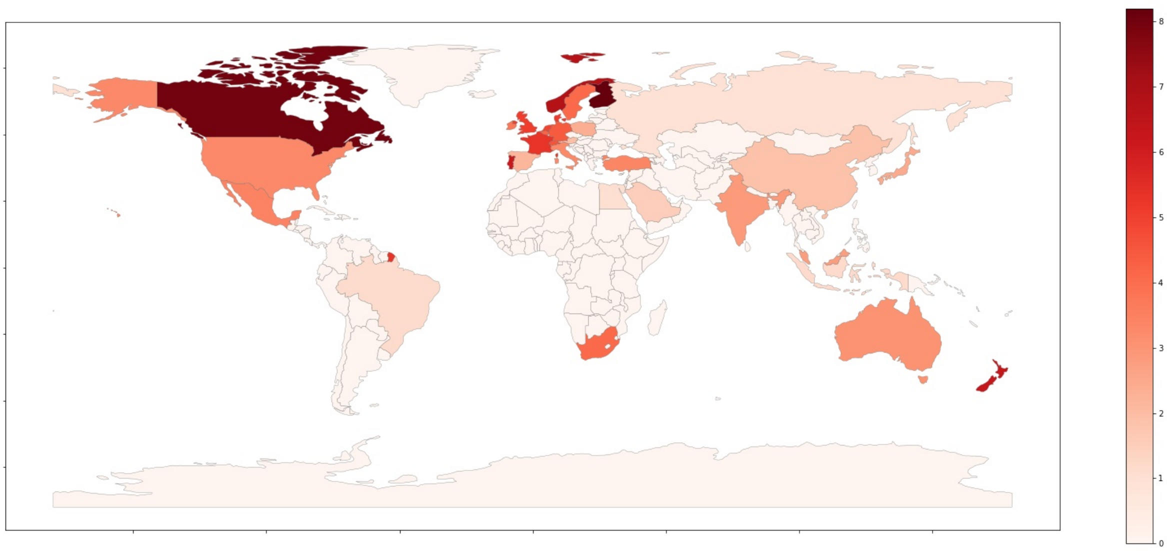

Figure 7: Heatmap illustrating share of cleantech investments per country.

4.1.1 Summary statistics

Summary statistics of the dataset is reported in Table 5. The average percentage of cleantech investments is found to be 3.622% across all 33 countries, while the median (p50) is found to be 3.349%. The min value of 0% is represented by Vietnam, while the max value of 8.200% is Finland. The mean CCPI climate policy score is 9.87 across the included countries. Australia is the country with the lowest score (0.000), while Denmark has the highest (17.870). The GDP per capita variable is logged, which makes a mean of 10.105 corresponding to a geometric mean of USD 24,465. Norway is the country with the highest share of renewable energy of primary energy supply (51.109%), while Saudi Arabia has the lowest (0.021%). Australia has the highest CO2 emissions in terms of tons per capita, (15.5 tons), and India has the lowest (1.8 tons). R&D expenditures as a percentage of GDP is found to be 1.748% on average, where the max value is represented by Sweden (3.388%), and the min value by Indonesia (0.100%). New Zealand is the country with the highest score on regulatory quality (1.880), where Egypt has the lowest score (-0.600).

Table 5: Summary statistics for investments data.

	Variable	mean	sd	p50	min	max	N
Dependent variable	Cleantech	3.622	2.019	3.349	0.000	8.200	33
Climate policies	CCPI	9.87	4.715	9.86	0.000	17.870	33
Resources	GDP	10.105	1.116	10.614	7.658	11.537	33
Incentives	RenEnergy	18.844	13.898	15.817	0.021	51.109	33
	CO2	7.067	3.866	7.000	1.800	15.500	33
Capabilities	R&D	1.748	1.017	1.466	0.100	3.388	33
	RegQual	0.948	0.796	1.340	-0.600	1.880	33

4.1.2 Correlation matrix

The correlation table for the variables in the dataset is reported in Table 6. RegQual is the variable found to have the highest correlation with cleantech percentage (0.684), followed by GDP (0.601). The CCPI climate policy score is found to have a correlation of 0.481 with cleantech percentage. As described in the method section, correlations were used to evaluate which variables that could be combined in a regression model, and variables with correlation higher than 0.7 were not combined in any regression model. Table 6 shows that GDP, R&D and RegQual have a correlation larger than 0.7 in each combination of each other and was therefore not combined in any regression model. GDP and R&D have a correlation of 0.726, indicating that there is coherence between countries being rich and spending the most on R&D. As the R&D variable is measured as percentage of GDP, it does account for the natural difference in absolute numbers spent, but this result shows that there still is high correlation between the variables. GDP is also heavily correlated with RegQual, having a correlation of 0.875. There is thus very large coherence between countries being rich and them being evaluated to have governments with high ability to formulate and implement sound policies and regulations. The only negative correlations are between CO2 and CCPI, in addition to CO2 and RenEnergy. This suggests that countries with high emissions have lower CCPI climate policy score, and that countries with higher share of renewable energy have less CO2 emissions.

Table 6: Correlation matrix for investment data.

	Cleantech	CCPI	GDP	RenEnergy	CO2	R&D	RegQual
Cleantech	1						
CCPI	0.481	1					
GDP	0.601	0.218	1				
RenEnergy	0.382	0.331	0.208	1			
CO2	0.185	-0.291	0.464	-0.400	1		
R&D	0.403	0.418	0.726	0.287	0.193	1	
RegQual	0.684	0.314	0.875	0.304	0.361	0.706	1

4.1.3 Results

The results of the regression analysis are reported in Table 7. As explained in Chapter 3, the regressions analysis was performed as hierarchical multiple regression with CCPI climate policy score as the main independent variable, building nested models with the other independent variables. All regression models include CCPI and maximum one variable from each part of the conceptual framework described in Section 3.4.1. In addition, as depicted in Figure 6, it was chosen to include a maximum of one independent variable per 10 observations and no combination of variables that are heavily correlated. This resulted in the inclusion of maximum 3 independent variables due to the number of nations being 33. These considerations resulted in 10 regression models presented in Table 7.

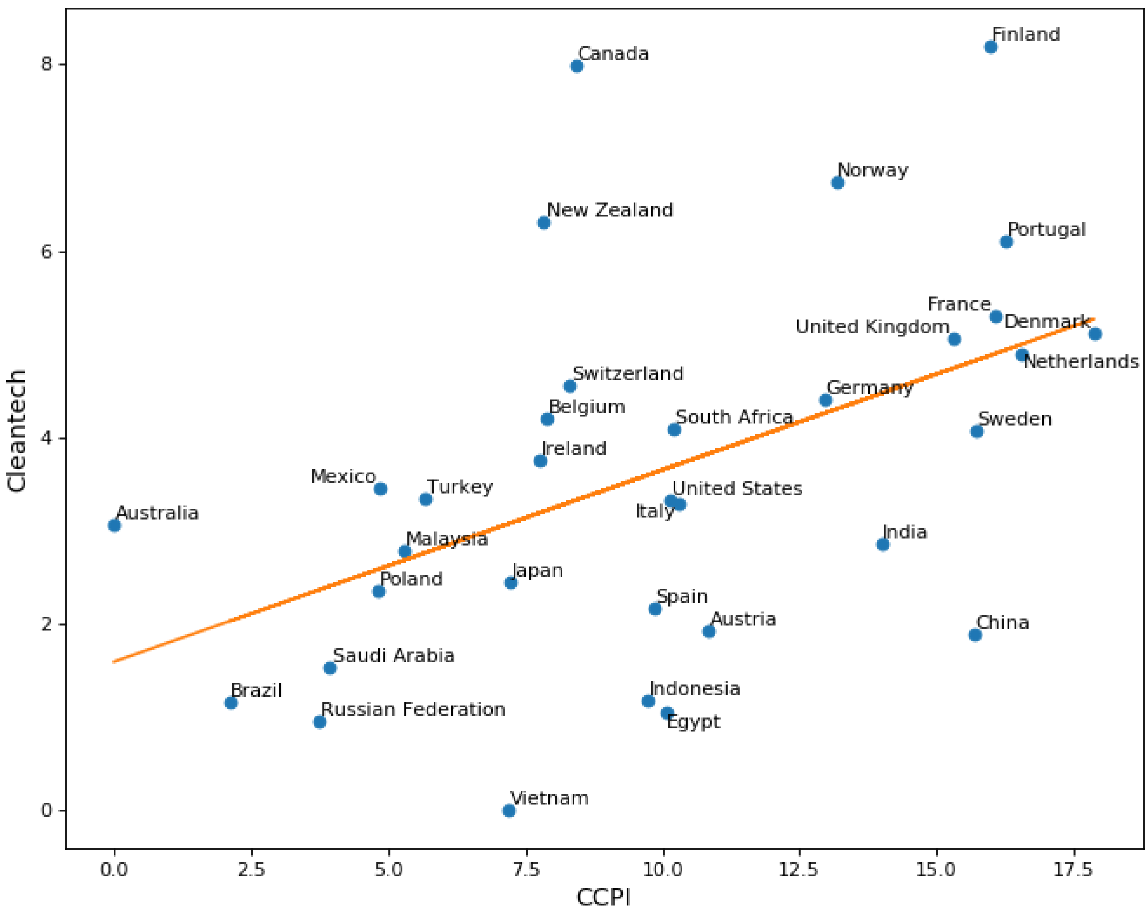

Figure 8: Scatterplot of CCPI climate policy score compared to share of cleantech investments.

Model (1) uses CCPI climate policy score as the only independent variable, and is illustrated in Figure 8. The model suggests that one CCPI score point is associated with 0.2057 percentage points increase in the share of cleantech investments, and has an R-squared of 0.231. The estimated coefficient on CCPI is positive and statistically significant across all regression models performed in this analysis.

Looking at GDP per capita, the coefficient is found to be positive and statistically significant with a p-value lower than 0.01 in all three models where it is included, and the F-statistic change from model (1) to model (2) is 15.151. Since the GDP per capita variable is logged, the result indicates that a one percentage increase in the GDP per capita is associated with approximately 0.006 percentage points increase in the share of cleantech investments.

The analysis does not find RenEnergy to have a significant effect on the share of cleantech investments, either in model (3), (5), (6) or (7). The adjusted R-squared has a small increase from model (2) to model (3), but the F-statistic change is insignificant with a corresponding P-value of 0.220.

Analyzing the effect of CO2 tons per capita on cleantech percentage provides ambiguous results. The coefficient for CO2 is found to be significant in model (8), indicating that a one ton increase of CO2 emission per capita is associated with 0.1855 percentage points increase in the share of cleantech investments. The F-statistic change from model (1) to model (8) is also found to be significant. The coefficient is still significant in combination with the R&D variable, while being slightly lower (0.1629). The coefficient is not found to be significant in model (4) and model (10), in combination with GDP and RegQual respectively, and the F-statistic change is not significant from model (3) to model (4). Therefore, the analysis does not find strong evidence supporting that CO2 emissions in tons per capita has a positive effect on the share of cleantech investments.

R&D expenditures are not found to have a significant effect on the share of cleantech investments in model (6) or model (9). The coefficient is positive in both models, but the adjusted R-squared is actually decreasing from model (8) to model (9). The F-statistic change is not significant neither in model (6) nor model (9).

The effect from RegQual is found to be positive and statistically significant both in model (7), (10) and (12) with a P-value less than 0.01. All models have an F-statistic change that is significant, and inclusion of the variable almost doubles the adjusted R-squared. The coefficient indicates that a one point increase on the WGI Regulatory Quality Index is associated with approximately 1.4 percentage points increase in the share of cleantech investments.

Across all regression models, model (12) has the highest adjusted R-squared, followed by model (7), (10) and (3), thus explaining most of the variance in share of cleantech investments. This indicates that in addition to CCPI climate policy score, WGI Regulatory Quality Index and GDP per capita are the variables having the largest effect on the share of cleantech investments in a country.

Table 7: Regression report for share of cleantech investments.

		(1)	(2)*	(3)*	(4)	(5)	(6)	(7)*	(8)	(9)	(10)*	(11)	(12)*
Climate policies	CCPI	0.2057 [a] (0.067)	0.1571 [b] (0.057)	0.1348 [b] (0.059)	0.1714 [b] (0.065)	0.1703 [b] (0.070)	0.1383 [c] (0.074)	0.1125 [c] (0.058)	0.2499 [a] (0.066)	0.2220 [a] (0.077)	0.1424 [b] (0.063)	0.1619 [b] (0.073)	0.1262 [a] (0.055)
Resources	GDP		0.6527 [a] (0.168)	0.6216 [a] (0.168)	0.5964 [a] (0.206)								
Incentives	RenEnergy			0.0252 (0.020)		0.0363 (0.024)	0.0313 (0.024)	0.0178 (0.019)					
	CO2				0.0424 (0.087)				0.1855 [b] (0.081)	0.1629 [c] (0.087)	0.0439 (0.078)		
Capabilities	R&D						0.4096 (0.340)			0.2498 (0.349)		0.4863 (0.339)	
	ReqQual							1.4298 [a] (0.338)			1.3920 [a] (0.383)		1.4990 [a] (0.329)
	Constant	1.5920 [b] (0.735)	-7.4442 [a] (2.400)	-7.2455 [a] (2.383)	-7.0630 [b] (2.555)	1.2583 (0.752)	0.9522 (0.789)	0.8212 (0.611)	-0.1551 (1.025)	-0.1568 (1.033)	0.5880 (0.888)	1.1742 (0.779)	0.9959 (0.591)
	R^2	0.231	0.489	0.515	0.493	0.287	0.321	0.559	0.347	0.358	0.551	0.281	0.546
	Adjusted R^2	0.206	0.455	0.465	0.441	0.239	0.250	0.513	0.303	0.292	0.504	0.233	0.516
	ΔF-stat	9.319	15.151	1.573	0.235	2.331	1.453	17.883	5.301	0.518	13.185	2.062	20.802
	Prob (ΔF)	<0.005	<0.001	0.220	0.631	0.137	0.238	<0.001	0.029	0.480	0.001	0.163	<0.001
	F-stat	9.319	14.36	10.28	9.409	6.025	4.562	12.24	7.957	5.389	11.85	5.85	18.04
	Prob (F)	<0.005	<0.001	<0.001	<0.001	<0.01	<0.01	<0.001	<0.002	<0.005	<0.001	<0.01	<0.001
	Observations (# of nations)	33	33	33	33	33	33	33	33	33	33	33	33
	# of investments	91 275	91 275	91 275	91 275	91 275	91 275	91 275	91 275	91 275	91 275	91 275	91 275

[a] $p < 0.01$
[b] $p < 0.05$
[c] $p < 0.10$

As mentioned in the Chapter 3, a VIF analysis was performed to evaluate the reliability of the resulting regression models. The VIF values for all coefficients in the regression models are reported in Table 8. All models have VIF values below 10, but model (5) and model (9) do have a VIF value slightly above 5. In model (5), the VIF value for CCPI score is 5.167, which might raise concern for multicollinearity issues, and thus the interpretation of this model. CCPI score is not heavily correlated with RenEnergy or R&D (0.331 and 0.418), but the VIF values are still above the limit of 5. Model (9) has a VIF value of 5.652 for R&D expenditures, which has a correlation of 0.418 and 0.193 with CCPI climate policy score and CO2 tons per capita, respectively. This indicates that the correlation between CCPI and R&D (0.418) causes potential multicollinearity issues, which might explain why the VIF value in model (11) also is above 4. Interpretation of these models are thus given less weight in the further analysis.

Table 8: VIF values from regression analysis on share of cleantech investments.

		(1)	(2)	(3)	(4)	(5)	(6)*	(7)	(8)	(9)*	(10)	(11)	(12)
Climate policies	CCPI	-	2.665	3.790	2.894	2.979	5.167	3.794	2.194	4.274	2.867	4.225	2.578
Resources	GDP		2.665	2.946	3.725								
Incentives	RenEnergy			3.293		2.979	3.198	3.225					
	CO2				3.066				2.194	2.935	2.925		
Capabilities	R&D						4.535			5.652		4.225	
	ReqQual							2.792			3.438		2.578

Summarizing the results of the analysis on share of cleantech investments, there is found support for hypothesis 1, in addition to hypothesis 3.1 and 3.3. CCPI is found to have a significant effect on Cleantech in all models, indicating that more stringent climate policies positively affect the investments activity in cleantech companies. GDP is also found to positively affect Cleantech, indicating that countries with more resources have a higher share of their VC investments within clean technology – thus supporting hypothesis 3.1. Since neither RenEnergy or CO2 are found to have significant effect on Cleantech, there is not found support for hypothesis 3.2. R&D was not found to be a relevant indicator for Cleantech, but RegQual was found to be an important variable. This is indicating that countries with higher regulatory quality are those with the highest share of cleantech investments, thus supporting hypothesis 3.3. The summary of the results from this analysis are visualized in Figure 9.

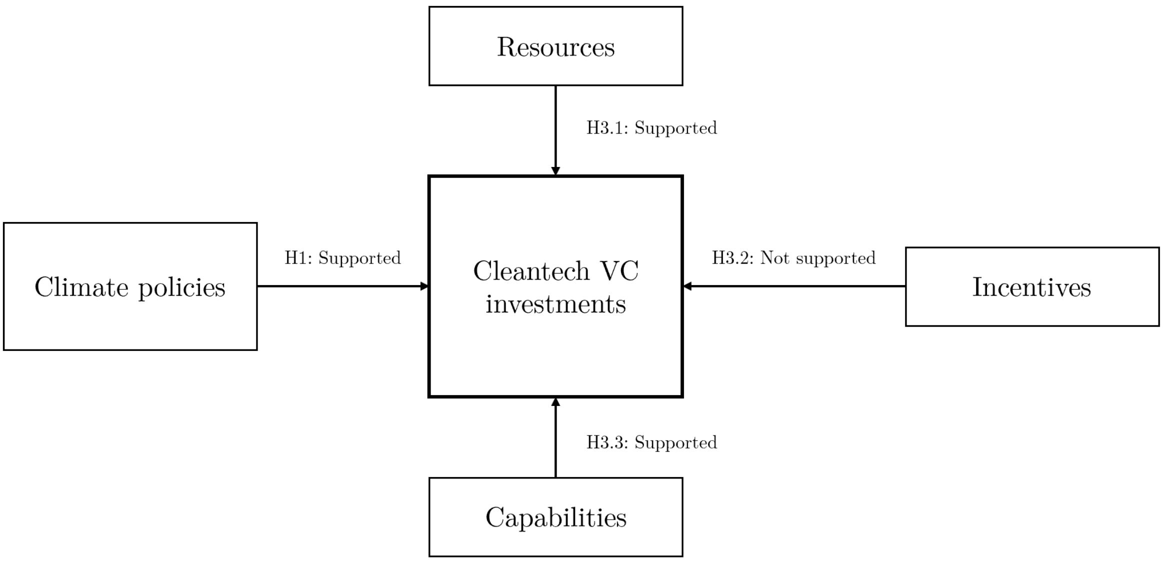

Figure 9: Summary of the results from the cleantech analysis visualized.

4.2 Share of fundraising committed to green VC

The same procedure as above was performed for the second dataset, analyzing the share of fundraising committed to green VC funds. Executing the data processing steps explained in Section 3.3, and merging these countries with the countries listed on the CCPI climate policy score index, resulted in a dataset consisting of 27 countries aggregated from 2 251 fundraisings. See Appendix B for a full overview of the countries including total registered capital and shares committed to green VC funds. The 27 countries and their share of fundraising committed to green VC are illustrated in Figure 10. Egypt, Italy and Indonesia were the only countries found to have no registered capital committed to green VC funds, meaning that all other countries on the map with the lightest color were not a part of the 27 countries in the dataset. The country having the highest share of capital raised to green VC funds is Luxembourg, with 71.67%, far more than the second highest, South Africa with 26.82%, followed by Sweden (20.02%). The large difference between Luxembourg and the other countries explains the lack of dark red colors on the map.

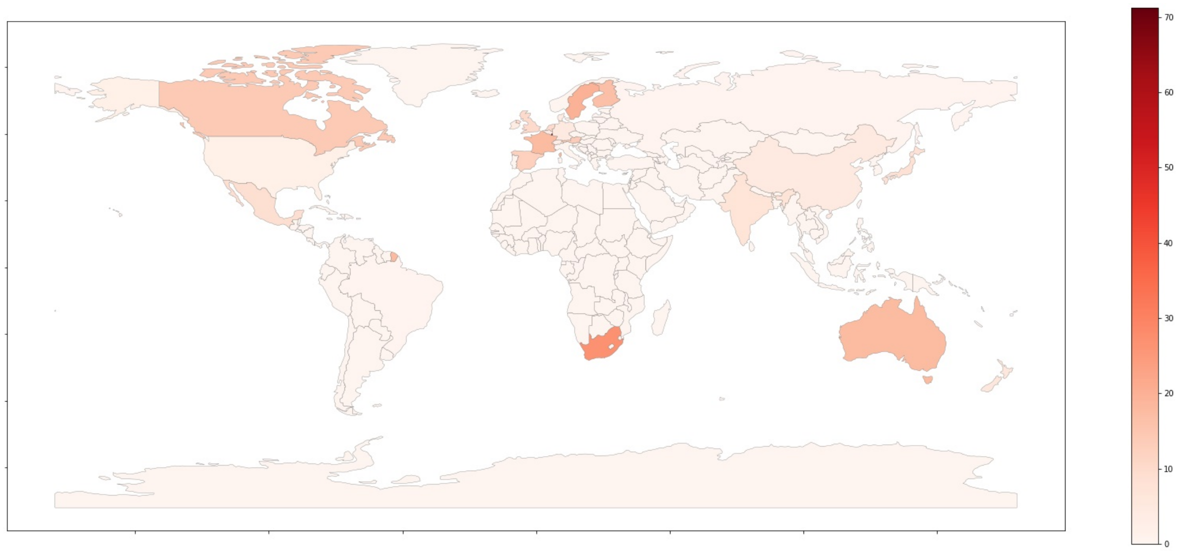

Figure 10: Heatmap illustrating share of fundraising committed to green VC per country.

4.2.1 Summary statistics

Table 9 reports the summary statistics for the dataset. The mean percentage of capital committed to green VC funds is found to be 10.719, while the median is 6.916. All other independent variables are identical as is in the dataset for share of cleantech investments, but this dataset contains only 27 countries (compared to 33). Since another sample of countries are included, there are some variations which are depicted in Table 9.

This sample of countries has a slightly higher mean CCPI climate policy score than the former. The max value is that of Luxembourg, which is ranked as number one in the CCPI climate policy index. The mean GDP per capita is also slightly higher than in the first dataset, while the percentage renewable energy percentage is slightly lower. The max value of renewable energy (47.847%) is the score of Brazil, as Norway was not included in this dataset. The min value is of Russia (2.888%). Both CO2 tons per capita, R&D expenditures and WGI Regulatory Quality Index has a mean that is higher than in the first dataset, but the min and max value of these variables are identical.

Table 9: Summary statistics for fundraising data.

	Variable	mean	sd	p50	min	max	N
Dependent variable	GreenCap	10.719	14.010	6.961	0.000	71.237	27
Climate policies	CCPI	10.646	4.827	10.130	0.000	18.11	27
Resources	GDP	10.270	1.165	10.786	7.658	11.785	27
Incentives	RenEnergy	18.797	13.061	13.910	2.888	47.847	27
	CO2	7.331	4.146	7.100	1.800	15.500	27
Capabilities	R&D	1.897	1.025	1.756	0.100	3.388	27
	ReqQual	1.067	0.820	1.470	-0.600	1.880	27

4.2.2 Correlation matrix

Correlations are reported in Table 10. The variable having highest correlation with share of fundraising committed to green VC is CO2 (0.423), followed by RegQual (0.375). GDP has a correlation of 0.363 with GreenCap, which is almost half of the correlation with Cleantech (0.601). CCPI has a correlation of 0.363 with GreenCap, which also is lower than that of Cleantech (0.481).

RenEnergy and R&D are actually found to have negative, although low, correlation with GreenCap. These variables had a correlation with Cleantech of respectively 0.382 and 0.403. R&D and RegQual were found to be heavily correlated with GDP in Table 6. This is still the case with the sample of countries used in the fundraising dataset. GDP has a correlation of 0.661 with R&D, which is lower than in the former correlation analysis (0.726). RegQual is found to have a correlation of 0.877 with GDP, which is slightly higher than earlier (0.875), and confirms that these two variables are highly correlated.

Table 10: Correlation matrix for fundraising data.

	GreenCap	CCPI	GDP	RenEnergy	CO2	R&D	RegQual
GreenCap	1						
CCPI	0.363	1					
GDP	0.325	0.196	1				
RenEnergy	-0.095	0.133	0.068	1			
CO2	0.423	-0.107	0.539	-0.409	1		
R&D	-0.055	0.279	0.661	0.216	0.225	1	
RegQual	0.375	0.280	0.877	0.199	0.463	0.625	1

4.2.3 Results

Table 11 reports the results of the regression analysis on share of fundraising committed to green VC, consisting of 6 regression models. As mentioned, the inclusion of independent variables was chosen based on the number of observations with maximum one independent variable per 10 observations, shown in Figure 6. Since 27 countries were included after data processing, it was chosen to only include 2 independent variables in all regression models. Therefore, the main independent variable, CCPI climate policy score, is combined with only one of the other independent variables from model (2) to (6). Model (1) is illustrated in Figure 11, with CCPI climate policy score as the only independent variable. The figure illustrates that there is an increasing slope, and that Luxembourg is an outlier with over twice as high percentage capital committed to green VC funds than any other country. Australia and South Africa can also be stated as outliers, having a share of fundraising committed to green VC well above the trend line.

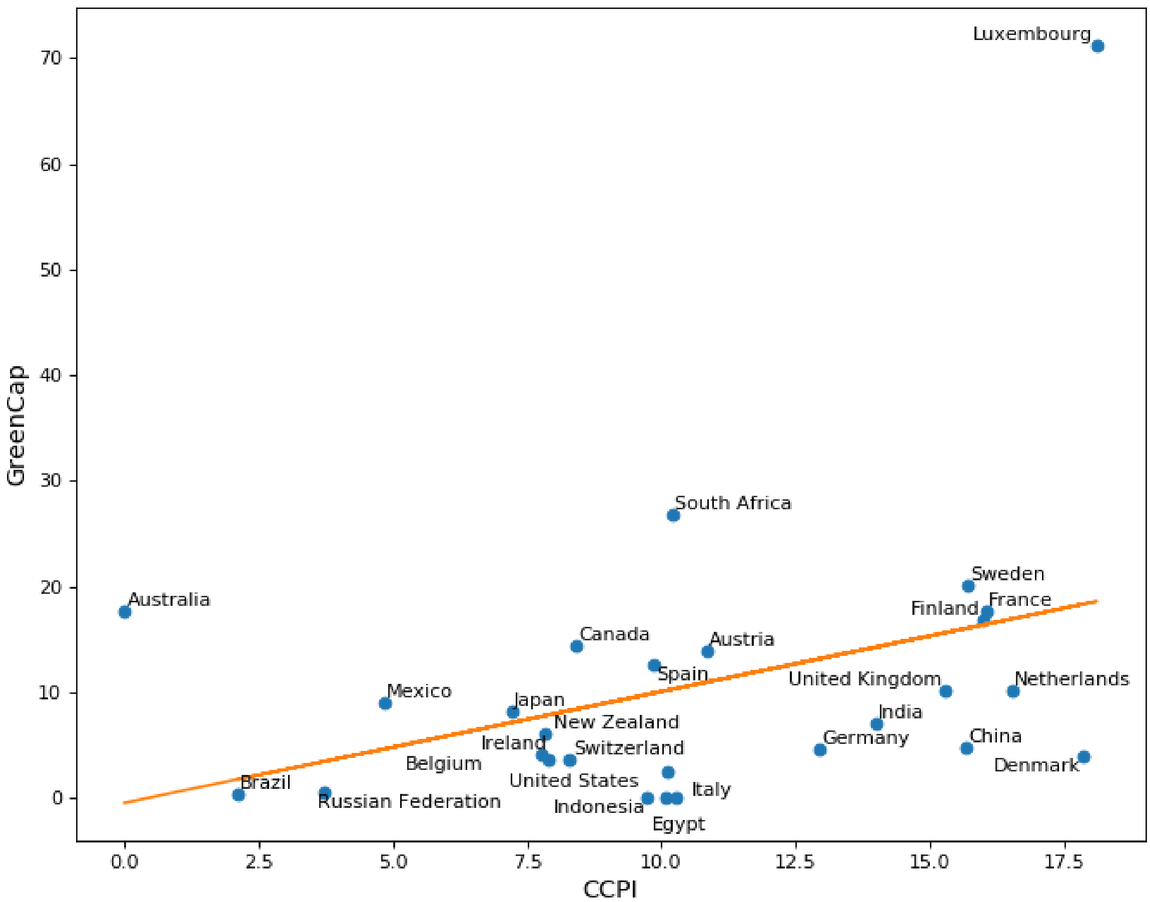

Figure 11: Scatterplot of climate policy score compared to share of fundraising committed to green VC.

The coefficient of CCPI ranges from 0.8121 to 1.1986, indicating that one CCPI climate policy score point increase is associated with approximately one percentage point increase in the share of fundraising committed to green VC. The coefficient is positive across all models, but with varying degrees of statistical significance. In model (1) and (3), the coefficient has a P-value below 0.1, and in model (4) and (5), the P-value is less than 0.05. The coefficient is not found to be statistically significant in model (2) and (6).

Looking at GDP, the effect on GreenCap is not found to be statistically significant. The adjusted R-squared does increase slightly, but the F-statistic change is not significant. This is in contrast to the analysis of Cleantech, where GDP was found to be significant. The coefficient of RenEnergy is found to be negative, but not significant. The adjusted R-squared decreases from model (1) to model (3). The effect of CO2 emissions on GreenCap is found to be statistically significant, with an adjusted R-squared increasing from 0.097 to 0.294 from model (1) to (4). The coefficient has a P-value below 0.01 and indicates that one ton increase in CO2 emissions per capita is associated with 1.15811 percentage points increase in the share of fundraising committed to green VC. The coefficient of R&D expenditures is found to be negative, but not statistically significant (as in the previous regression analysis).

Finally, the effect of RegQual on GreenCap is not found to be statistically significant. The adjusted R-squared is slightly increasing from model (1) to (6), but the F-statistic change is insignificant. This result is in contrast with the analysis of Cleantech, where RegQual was found to be the most important variable.

Across the 6 regression models, model (4) has the highest adjusted R-squared, explaining the most variability in share of fundraising committed to green VC of the regression models. CO2 emissions in tons per capita is the only variable, in addition to CCPI climate policy score, that was found to have a significant positive effect on the share of capital raised to green VC funds.

Table 11: Regression report for share of fundraising committed to green VC.

		(1)	(2)	(3)	(4)*	(5)	(6)
Climate policies	CCPI	1.0528 [c] (0.541)	0.9029 (0.541)	1.1090 [c] (0.550)	1.1986 [b] (0.481)	1.1900 [b] (0.566)	0.8121 (0.547)
Resources	GDP		2.2018 (1.553)				
Incentives	RenEnergy			-0.1564 (0.203)			
	CO2				1.15811 [a] (0.560)		
Capabilities	R&D					-2.3196 (2.666)	
	ReqQual						5.0701 (3.223)
	Constant	-0.4882 (6.303)	-31.5147 (22.743)	1.8501 (7.047)	-13.6316 [c] (7.264)	2.4500 (7.178)	-3.3377 (6.388)
	R^2	0.132	0.199	0.152	0.348	0.158	0.213
	Adjusted R^2	0.097	0.132	0.082	0.294	0.088	0.147
	ΔF-stat	3.787	2.010	0.590	7.964	0.757	2.474
	Prob (ΔF)	0.063	0.169	0.450	0.009	0.393	0.129
	F-statistic	3.787	2.975	2.158	6.403	2.254	3.242
	Prob (F)	0.063	0.070	0.137	0.006	0.127	0.057
[a] $p < 0.01$ [b] $p < 0.05$ [c] $p < 0.10$	Observations (# of nations)	27	27	27	27	27	27
	# of funds	2 251	2 251	2 251	2 251	2 251	2 251

The VIF values for all regression models presented in Table 11 are reported in Table 12. All models have VIF values below 5, and there are thus no concerns for multicollinearity issues. Model (4) has the highest VIF value of 4.241, including R&D expenditures and CCPI climate policy score, which are moderately correlated (0.279). This variable was also found to be a possible source of multicollinearity issues in combination with CCPI in the former regression analysis. Since the VIF value is below the threshold of 5, it will not have any consequences for the further analysis.

Table 12: VIF values from regression analysis on share of fundraising committed to green VC.

		(1)	(2)	(3)	(4)	(5)	(6)
Climate policies	CCPI	-	2.652	2.752	2.308	4.241	2.565
Resources	GDP		2.652				
Incentives	RenEnergy			2.752			
	CO2				2.308		
Capabilities	R&D					4.241	
	ReqQual						2.565

Summarizing the results of the analysis on share of fundraising committed to green VC, there is found support for hypothesis 2, in addition to hypothesis 3.2. CCPI is found to have a positive effect on GreenCap, but not in all models. There is thus found partly support for hypothesis 1, indicating that more stringent climate policies positively affect the share of fundraising committed to green VC. There is not found support for hypothesis 3.1, as the effect from GDP on GreenCap is insignificant. RenEnergy is also found to be insignificant, but CO2 is found to be a strong predictor for GreenCap, indicating that the countries with the highest carbon emissions are those who manage to allocate the highest share of their capital to green VC funds, thus supporting hypothesis 3.2. Neither R&D nor RegQual are found to have significant effect on GreenCap, finding no support for hypothesis 3.3. The summary of the results from this analysis are visualized in Figure 12.

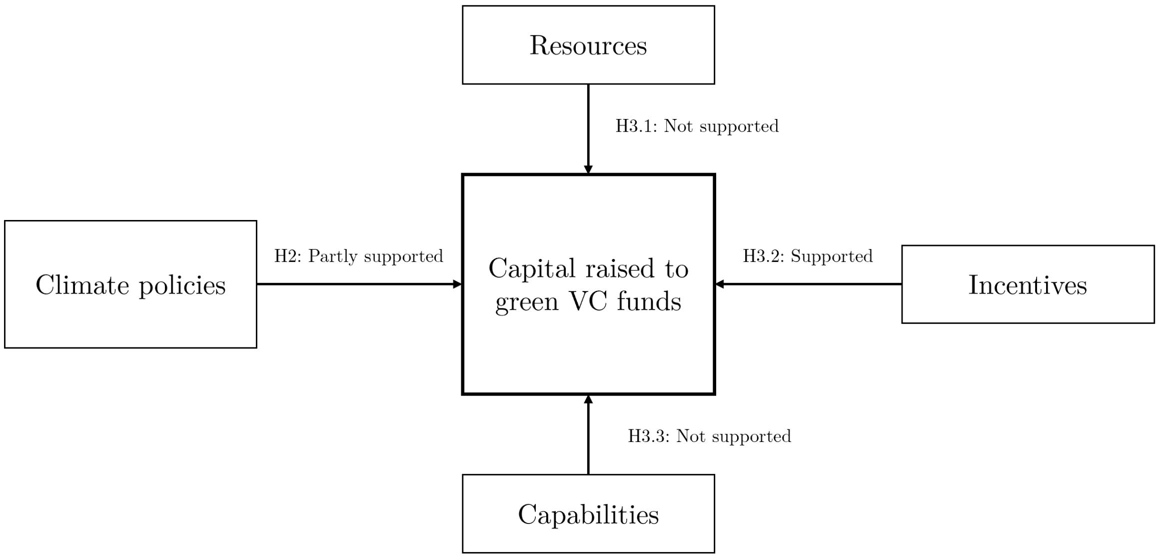

Figure 12: Summary of the results from the green fundraising analysis visualized.

5 Discussion

In this chapter, the results will be discussed with the objective of answering the research questions presented. Firstly, the main findings of this study will be discussed concisely in Section 5.1. Then, three major debates identified will be discussed in Section 5.2, namely the effectiveness of climate policy, capital allocation towards a sustainable economy, and which additional factors are most influential for the development of green VC activity. Further, a research agenda will be suggested, followed by a discussion of practical implications. Lastly, limitations of this study will be discussed.

5.1 Main findings

The results from this study do confirm that climate policies play an important role in the development of green VC activity, finding that climate policies have a positive effect on cleantech investments and capital raised to green VC funds. Overall, the result from this study supports hypothesis 1 and 2. However, this study does find nuances in the relationship between climate policies and green VC in terms of a difference between the effect on cleantech investments and capital raised to green funds. These findings contribute to the discussion of the Porter hypothesis, as climate policies apparently have a positive but nuanced effect on innovation, but how this actually affects both business and environmental performance is debated. A possible explanation for the results observed in this study is the varying time horizon of the two measures applied, which will be discussed further in Section 5.2.1.

This main finding confirming a positive relationship between climate policy and green VC activity is quantitatively and empirically supporting the opinions of several scholars, such as Antarciuc et al. (2018), Ermakova and Frolova (2019) and Tian (2018)), which find climate policy to be an important enabler for green VC. This important finding is underlining what seems to be a prerequisite for successful green innovation in a country; climate policies are effective in catalyzing investment activity and allocating capital towards sustainable ventures. Climate policies are thus facilitating the capital markets to effectively contribute to a more sustainable society, even though the actual effect is debated. This will be discussed further in Section 5.2.2.

In terms of the importance of a nation's preconditions for green innovation, there are varying findings for the two measures and, overall, there is partly support for hypothesis 3. For the share of cleantech investments, resources and capabilities were found important – suggesting that countries need both sufficient wealth and regulatory stability to pursue investments in green ventures. This is in accordance with Cumming et al. (2016), but contradicts Criscuolo and Menon's (2015) claimed importance of R&D expenditures. For share of fundraising committed to green VC, CO2 emissions was found to be the most important variable, suggesting that the high emitters are those who manage to allocate the greatest share of capital to sustainable activities, in accordance with Su and Moaniba (2017) but not Huang et al. (2021) and Shen et al. (2021). There are thus slightly varying findings across the research area, which will be discussed further in Section 5.2.3. The main findings of this study are summarized visually in Figure 13.

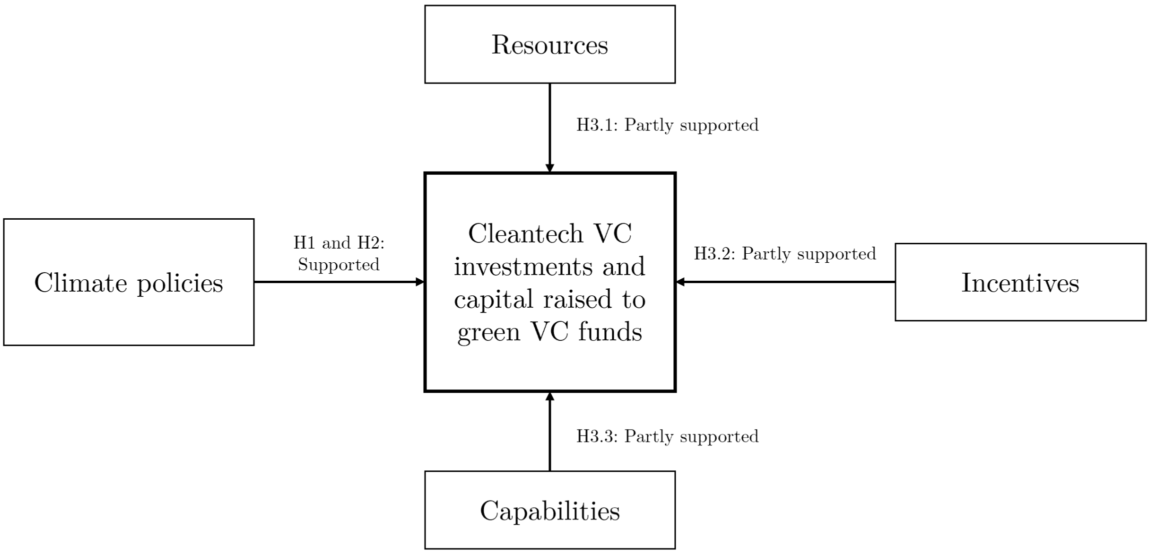

Figure 13: Main findings visualized.

5.2 Theoretical implications

5.2.1 Climate policy is effective for green investment activity

As alluded to by previous studies, this paper quantitatively confirms that environmental policy positively affects investments in cleantech and fundraising within green VC. There is therefore support for PH in terms of regulation increasing innovation. Based upon current research there is although no evidence of these innovations yielding increased business performance, with impact funds earning a 4.7 percentage points lower IRR compared to traditional VC funds Barber et al. (2021). As this study focuses on new ventures/start-ups, and the classification utilized is based on "Primary Technology Application", IRR is viewed to be a good indication of competitiveness. Technology applications are not limited to a vertical industry like manufacturing, but rather serves multiple of these in a narrow form, so-called horizontal industry. Comparing their success to peers within a vertical industry is therefore viewed to provide a skewed perspective.

This could be explained by the field's immaturity and differing time horizons of these indicators. Cleantech investments can be performed by any investment vehicle, as displayed by our findings, and would therefore be the quickest to increase in line with interest. Fundraising represents a larger barrier, often dependent on allocation of capital from Limited Partners (LPs), which single investments are not, as well as being challenging in a fairly new and unproven industry. This could also be exacerbated by the cleantech industry's history, with a crash in '08 due to the financial crisis and corresponding change in focus (Day, 2021). Returns, often measured by IRR, are even further out in time, many times not fully visible until multiple fund cycles later. Funds need to exit well-performing ventures, often with a time horizon of 10+ years since the initial investment, which is only increasing with the advance of multistage/crossover funds (ABS Investment Management, 2020). The ability to evaluate the potential of an idea and early-stage venture may also increase in parallel with the field's maturity, naturally improving likelihood of success and corresponding returns. Similar developments have been seen in other segments of VC, maybe most similarly health technology (healthtech). Investments have here been significant over quite some time, while dedicated fundraising and returns substantially increased in later years with increased evidence of success through acquisitions, IPOs and SPACs, e.g. resulting in 32 new unicorns in 2021 (SVB, 2022).

Given the lag of these indicators, looking to a more live one in public markets could be relevant, where green investments currently outperform the market as a whole. Researchers at The University of Chicago published a study at the end of 2021, finding that the value-weighted return of a portfolio with stocks who perform in the top third in terms of greenness returned a cumulative difference of +174% over the sample period of 8.2 years (Pastor et al., 2021). This represents a 6.5% monthly return alpha. Greenness was in this study based on the "environmental pillar score" of MSCI ESG ratings, including the themes of climate change, natural capital, pollution & waste, and environmental opportunities. MSCI also offers their own "ESG Leaders Index", which in eight of fourteen years through 2021 has outperformed the MSCI All Country World Index (ACWI). This development also holds true for bond markets, although not as strong – green bonds are on average traded at a 63 basis points premium relative to comparable corporate bond issues (Nanayakkara & Colombage, 2019). It is followingly clear that we might see drastically different return profiles of cleantech and green VC investments with time.

Due to lacking tooling for impact measurement, it is difficult to quantify the environmental performance cleantech investments yield. This is a recognized issue within the field, and its improvement is said to be crucial in increasing credibility (Aggarwal & Elembilassery, 2018; Mawdsley, 2018; C. Zhang et al., 2019). There are correspondingly ongoing initiatives like the EU Taxonomy, but the majority of these are tailored towards more mature businesses, rather than start-ups and new ventures. This is the case for the EU Taxonomy, where one's score is based on the share of revenue stemming from taxonomy defined sustainable economic activities (European Commission, 2021b), which start-ups seldomly have much of. Allocation criteria are therefore important, but also lacking, where perceived sustainability mission in most cases takes the place of real emission reduction potential due to lacking measurement (Bento et al., 2019). This further hinders the development of cleantech and green VC as a whole, having to rely more on social capital and partner-networks relative to non-sustainable ventures (R. Zhang et al., 2021).

Increased policy stringency is not necessarily exclusively a positive thing, as it can hinder innovation and other advancements. Porter and van der Linde (1995) described this notion when developing PH, emphasizing that regulations would have to be both strict and flexible in order to drive innovation and competitiveness (Porter & van der Linde, 1995). This has since been supported by research like that of Desheng et al. (2021), finding that political interference hinders innovations within green technology specifically. Drawing upon the experiences of other sectors, Wang et al. (2019) find environmental policy to have a positive effect on innovation and business performance until a specific level of stringency, before the relationship becomes adverse as compliance costs become higher than the innovation offset effect. It is followingly clear that the level of stringency is of great importance, in addition to the specific policies implemented.

5.2.2 Climate policy promotes effective capital allocation for sustainability

Climate policy is found to be an effective mechanism for capital allocation towards impactful vehicles. As mentioned, many of today's sustainability funds consisting of publicly traded equities mainly divest environmentally harmful companies, rather than positively contributing to achieving UN's SDGs and the Paris climate target (Schwegler et al., 2021). This is also becoming increasingly clear to consumers, e.g. with Tesla recently being removed from the S&P 500 ESG Index (Forbes, 2022). Green VC and cleantech on the other hand, are developing sustainable products, services and solutions directly contributing to progress towards these goals. Despite the currently lacking tooling for impact measurement, there is clear anecdotal evidence of cleantechs both having great emission reduction potential and starting to realize it (PwC, 2021). The question should therefore not be whether this changing capital allocation creates positive environmental impact, but rather *how much*.

Initial research on the allocation criteria of green VC shows high alignment with SDGs. Carroux et al. (2021) find that this is the most widely used format of tracking impact performance, with SDG11 sustainable cities and communities and SDG07 affordable and clean energy in the lead. This is supported by Bandini et al. (2022), where Italian impact investors utilize SDGs as impact themes, and based on these track social outcome or social output. This is in the place of social impact, due to the methodological difficulties described. SDGs further serve as the basis for initiatives springing up like the impact management project, a non-profit building and applying consensus for practices in impact management (Impact Management Project, 2022). It is conclusively clear that despite lacking tooling, impact VC investors are working hard on aligning their investments with society's most pressing challenges.

Carbon offsets and increasing renewable energy production is not sufficient in itself, and new technological solutions are required. The World Economic Forum (WEF) refers to this as "carbon insetting", doing more good rather than less bad, and point to it being central in reaching climate goals. Skare & Porada-Rochon (2022) illustrates the potential associated with such solutions well in their study, finding that technology-related innovations at the company level are *more important* for sustainable development than non-technology innovations. Innovation and cleantech is therefore a necessary prerequisite for long-term sustainability, but not sufficient on its own. It is followingly clear that new ventures and their funding is central in achieving a sustainable economy and society, best doing so in collaboration with other impactful initiatives.

The mechanism of environmental policy is also found to be effective in a geographical lense, where activity is greatest in the nations with the largest incentives. The factor utilized in this study was CO2 emissions per capita, and tangential studies have found the same for renewable energy production (Criscuolo & Menon, 2015; Bürer & Wüstenhagen, 2009). As these perspectives mature there are many elements outside of energy production that are crucial for sustainability, e.g. extending the lifespan of products and recirculating them in a proper way. This speaks to emissions being a more overarching indicator, especially as life cycle analyses and similar methods accounting for the entire lifespan of a product become more prevalent. The two might also become more correlated with time, as carbon taxes and feed-in-tariffs are pointed to as some of the most effective more specific forms of environmental policies (Ermakova & Frolova, 2019; Sadiq et al., 2021).

5.2.3 Other factors impacting cleantech and green VC

In terms of how a countries' resources, incentives and capabilities affect the development of green VC, the results both confirm and contradict the findings of other scholars on the subject. As expected, countries with more resources have more VC activity and also a higher percentage of cleantech investments and green capital. Although the coefficient of GDP on GreenCap was not found to be statistically significant, the effect on Cleantech was found to be significant on all occasions. This is in accordance with the findings of Cumming et al. (2016), which finds that GDP is associated with an increase in the number of cleantech VC deals. More resources enable spending more on investments focusing on environmental objectives, especially when these investments are found to provide lower returns (Barber et al., 2021). The effect from GDP is not found to be significant for the share of fundraising committed to green funds, which might imply that this relationship is not as strong as Cumming et al. (2016) suggests. Richer countries do have a higher share of clean investments, but when looking at how much capital is actually being allocated to green VC funds, the relationship is weaker.

Countries' incentives for pursuing green early phase investments are partly found to have an effect on green VC activity. Renewable energy supply is not found to have a significant effect on either cleantech investments or capital raised to green funds. This is contradicting the findings of Lyeonov et al. (2019) and Criscuolo and Menon (2015) which finds a positive relationship between share of renewable energy and green investments, although not investigating VC investments especially. The causality between these variables is unclear as countries with large amounts of cleantech investments will be expected to get a larger share of renewable energy, while it could also be expected that countries already having a high degree of renewable energy have less incentive of pursuing green investments – which may explain contrasting findings. This study suggests that the latter effect may be dominant, finding a negative (although not statistically significant) relationship between renewable energy supply and share of fundraising committed to green VC.

Regarding CO2 emissions, the results indicate a positive and significant relationship with the share of fundraising committed to green VC, while there is a weak relationship with cleantech investments. It is expected that countries with high emissions also have a higher incentive for green investments, in addition to a higher potential of carbon emission decrease, as found by Su & Moaniba (2017). The result of this study indicates that this effect is greater for moving shares of capital to funds with environmental mandates than increasing the number of cleantech investments. Other studies, such as Huang et al. (2021) and Shen et al. (2021), find that green investments are associated with a decrease in CO2 emission, while economic activity in general leads to increasing emissions. Since this study finds economic activity to increase green investments, the effect on CO2 might be influenced by forces pulling in opposite directions. That is, CO2 emissions being increased by GDP, which both leads to more green investments – which again reduces CO2 emissions. The underlying effect explaining this result is thus unclear. The fact that shares of capital raised to green VC funds are found to have a strong relationship with CO2 emissions, might indicate that the incentive-effect is decisive, supporting Su & Moaniba (2017). The countries with highest CO2 emissions are those most incentivized to prioritize capital to green VC funds.

Capabilities, in terms of R&D expenditures and regulatory quality, are found to be an important factor for green VC activity in the latter case. R&D expenditures are not found to have an effect on either cleantech investments or share of fundraising committed to green VC. This is contradicting the findings of Criscuolo & Menon (2015), which finds increased R&D expenditures to be associated with increased number of VC deals and total funding in environmental technology. It is expected that R&D expenditures enhance innovation and VC activity, and as green innovation is high on the agenda, it would be expected to see an increase here as well. It might be that the positive effects found by Criscuolo & Menon (2015) are not as strong on green ventures. If R&D expenditures lead to a proportionate increase in both green and non-green VC activity, it will not lead to a change in the share of green VC. However, this study does find that R&D expenditures do not lead to an overall increase in the share of cleantech investments or green VC funding, possibly implying that these R&D expenditures are not sufficiently targeted towards green innovations. It can also be mentioned that R&D was found to be a potential source for multicollinearity issues, and the interpretation of these variables may be less valid.

The WGI Regulatory Quality Index is found to have a strong relationship with share of cleantech investments and found to be positive but not significant with share of green VC fundraising. Regulatory quality being an important factor is in accordance with the findings of Cumming et al. (2016), finding regulatory quality to positively affect the number of cleantech VC deals. This study thus confirms that factors such as a stable regulatory environment with strong and trustful formal institutions are crucial for the development of green VC activity. This can also be seen as confirming the findings of Ermakova & Frolova (2019), which argue that lack of regulatory stability and uncertainty of government policies are one of the main barriers for the development of green VC. It is thus not necessarily sufficient that policy makers focus on climate policies if the fundamental frames of the regulatory landscape do not have adequate quality. This does not explain why this variable is not found important for explaining the share of fundraising committed to green VC. As discussed in Section 5.2.1, the field's maturity may explain some of the results observed in this paper. A possible explanation can be that the majority of countries with high regulatory quality have large amounts of cleantech investments, while in most countries the green VC market is not sufficiently developed to have a high share of funds with environmental mandates.

5.3 Research agenda

Given the effectiveness of environmental policy found in this paper, a natural line of further research could be to investigate exactly *which* forms of policy that are the most effective. As mentioned, multiple studies seem to be especially positive towards carbon taxes and/or FITs, although this has not been investigated with regards to new sustainable ventures specifically (Botta & Koźluk, 2014; Ermakova & Frolova, 2019; Sadiq et al., 2021). This can be performed through case studies of the best performing nations. It could also be interesting to look at the more quantitative impact such policies have had, comparing nations who score similarly on the preconditions found to be of impact in this study, and investigating the difference in activity based on more stringent environmental policy. Another avenue of research could be the most effective level of stringency for climate policies as a whole, and/or for the specific policies implemented. Wang et al. (2019) find that the relationship between performance and regulation become adverse after a certain level, supported by Desheng et al.'s (2021) findings of policies potentially hindering innovation.

Being an emerging field, another proposed area of further research is whether fundraising of green VC funds and/or their returns increase as the industry matures. Both of these indicators are severely lagging, often by many years, compared to cleantech investments. As described, similar dynamics can be seen in adjacent markets such as healthtech, and the authors' hypothesis is that cleantech will see resembling developments in the coming years. This is further supported by the performance of green equities in public markets, currently outperforming the wider markets as a whole.

The development of impact tooling will be crucial for the development of cleantech and green VC, but is currently lacking. This is thus a highly valuable avenue of further research as well. This will not only be important in terms of quantifying the environmental impact of investment over time, but also for evaluating investment opportunities initially, so-called allocation criteria. There are ongoing initiatives within the topic, but further research and the development of widely recognized tooling is central in providing the field with credibility.

5.4 Practical implications

5.4.1 Increased climate policy and Luxembourg as inspiration

It is clear that policymakers and regulators should introduce and/or increase the stringency of environmental policy to incentivize investment activity in green ventures. Policies the CCPI indicator utilized for this study include measures for electricity and heat production, manufacturing and construction, transport and residential, as well as biological protection. For more specific inspiration, countries performing well can be investigated, although more research is required to determine the most effective single policies. An example of such a nation is Luxembourg, with over twice as high a percentage of capital committed to green VC funds than any other country, described in Section 4.2.

Luxembourg scores highly on environmental policies, but has also taken other measures to accelerate the transition to a sustainable economy. Overarchingly, they have developed a National Plan for Sustainable Development, and are well on the way to decoupling economic growth and emissions (SGI, 2022). This plan includes efforts such as a CO2 tax, incentives for electrification of automobile traffic, introduction of higher energy-efficiency standards for new residential buildings, in addition to developments within policy.

What truly separates Luxembourg from the rest of the nations included in this study, is their initiatives within green finance and eco-innovation/cleantech. Multiple innovation programs with public financial support focusing on cleantech and circular economy have been launched (OECD, 2020). They have also managed to stimulate demand for cleaner products and technology through programs such as PRIMe House supporting residential houses, Clever akafen for transparency in the footprint of products, and the Climate Pact to incentivize municipalities in taking actions towards sustainability. In terms of green finance, Luxembourg started their journey with the first-ever green bond listed on the Luxembourg Stock Exchange in 2007, a position which only solicited itself with the Luxembourg Green Exchange in 2016 – the first platform dedicated exclusively to green, social and sustainable securities. As of today, it lists approximately half of the world's market of these bonds (OECD, 2020). Despite these developments, regular evaluations are performed, with one of the latest recommendations and initiatives being establishing a green finance strategy. It is clear that Luxembourg really is at the forefront of environmental policy, cleantech and green finance, while not resting on its laurels to maintain this position.

5.4.2 Regulatory quality and stability

To ensure the highest impact possible of such policies, regulatory quality is of great importance, including stability. Regulation needs to be stringent while maintaining flexibility, both permitting and promoting private sector development. This is emphasized in the foundational work of both Porter and the World Bank Development Research Group (Porter & van der Linde, 1995; Kaufmann et al., 2010). A more specific element highlighted to be of great importance by many related studies in this regard is stability, providing predictability and visibility of the field's development for new actors. This has correspondingly been described as both a main enabler and barrier for green VC and the success of cleantech.

5.5 Limitations

The quantitative analysis performed in this paper does naturally have some limitations one should be aware of. Complementing the discussion of methodological limitations in Section 3.5, the following limitations are evaluated to be of importance for this study.

Firstly, the sample of cases included are mainly based on the data coverage of the Eikon Refinitiv database, in addition to the CCPI data coverage. Refinitiv was found to have the majority of their data records from the US. This uneven distribution of samples could partly be explained by natural differences in economic activity, but it could also be caused by a skewed data source focusing on American and European markets. As described, Refinitiv was the only source applied for investment data, where leveraging several sources possibly could have provided a more balanced and robust sample. Despite efforts to ensure a balanced dataset with random stratified sampling, the sample included in this study may not be perfectly random – possibly influencing external validity (Bryman, 2016, p. 61). The CCPI data was also restricted to 60 countries, mostly European, and a majority well-functioning and wealthy economies. The geographical selection included in this study may therefore be biased, excluding many developing economies. GDP was found to be an important factor for green VC activity in this study, but there could be information regarding the differences between developing and developed countries which are not sufficiently covered in this study.

Second, the CCPI climate policy score is a simplification of the performance of a complex regulatory system within a country. Leveraging an aggregated quantitative measure of climate policies is practical when performing a regression analysis, but has its limitations. The quantification process performed by Germanwatch is essential for the outcome of this study, thus being a possible source of bias. Using an index also provides no insights into the specifics of the climate policies within a country, thus not making it possible to investigate which concrete climate policies that are most effective. Therefore, this is a suggested area of further research proposed in Section 5.3.

Third, this analysis does not investigate the development over time, therefore not providing insight of green VC market changes between 2011 and 2022. As mentioned in Section 3.5, using a panel-dataset would make it possible to investigate temporal changes. This analysis was although not possible to conduct in this study due to lack of sufficient data. Investigating the temporal changes in both cleantech investments and green VC fundraising could have contributed to the discussion in Section 5.2.1 regarding maturity of the green VC market. If the difference between investments and fundraising observed in this study mainly is due to the field's immaturity, one would expect a larger difference between the two in 2011 than in 2022.

Fourth, this paper's contribution to the discussion of the Porter hypothesis is not fully complete. The study performed is mainly analyzing the first step of Figure 2, how environmental regulations affect innovation, and green innovation especially. For discussion purposes it does not investigate competitiveness as a whole, but rather uses IRR as an indicator. Other scholars find green VC funds to underperform relative to their traditional peers, and this is assumed to be a valid indicator for green corporation's competitiveness.

Lastly, investigating the VC market in a cross-country study can be argued to be a simplification, as many VC actors have global footprints with international portfolios. As mentioned in Section 3.5, there could be regulations which are targeted towards specific industries, and an aggregated cross-country study does not illuminate these nuances. Other studies on climate policy modeling, such as van der Werf (2008) and Albrizio et al. (2014), use variables for each country-industry combination. Investigating how climate policies affect the green VC development across different vertical industries could have provided interesting insight, and possibly impacted the conclusions made in this paper.

6 Conclusion

The objective of this study was to quantitatively investigate how climate policies impact the development of green VC activity by cross-country comparison. Many researchers have pointed to the importance of such policies, but its impact on this area specifically has limited quantitative evidence in academic literature. This study addresses this knowledge gap, and finds that climate policy positively affects both the share of investments performed in cleantech ventures, and the share of capital raised to VC funds with a green mandate. These findings contribute to the overarching discussion of how financial markets effectively can allocate capital in a form that contributes to a sustainable society.

The relationship is found to be stronger for cleantech investments than for green fundraising. This could be due to the lag of the latter indicator in combination with the field's immaturity, where one has seen similar developments in tangential VC industries, such as that of HealthTech. This could also help explain the current underperformance of impact VC funds compared to traditional ones. In combination, there is found support for the Porter hypothesis in terms of environmental policy leading to green innovation, but currently not for business performance. Regarding environmental performance, tools for measuring environmental impact is lacking, and an important element in ensuring the further development and credibility of green VC as a whole.

In addition to climate policy, a nation's preconditions are found to be of great importance for the development of green VC activity. This includes resources, most clearly in the form of GDP per capita, incentives in terms of CO2 emissions per capita and capabilities with regards to regulatory quality. The nations with the highest carbon emissions are found to allocate the highest share of their capital to green VC funds, implying climate policy to be an effective mechanism. High regulatory quality, with a stable and predictable regulatory landscape, is found to be an important enabler of cleantech investments.

Based on the effectiveness of climate policies found, it is clear that policymakers should introduce and/or increase the stringency of environmental policy to incentivize investment activity in green ventures. For concrete inspiration, Luxembourg could be looked to, with more than twice as high percentage of capital committed to green VC funds than any other nations, utilizing initiatives within both green finance and eco-innovation/cleantech. Further research is needed to investigate which forms of policy that are the most effective, the impact of maturity on fundraising and returns, as well as the development of impact tooling to enable quantification of the increased environmental performance.

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Appendix

A Cleantech investment data overview

The final dataset for the analysis on share of cleantech investments after the data processing steps are illustrated in Table 13. The investment data are aggregated for the 33 countries included in this analysis. The "Total Investments" column shows the total number of VC investments registered in the Eikon Refinitiv database in the period from January 2011 to March 2022. The "Cleantech Investments" columns shows the number of cleantech VC investments registered in the same period. These two columns are uilized to calculate the share of cleantech investments ("Cleantech %"), which is the dependent variable in this regression analysis. Table 13 illustrates that the dataset is skewed, in therms of United States having a large majority of all registered investments. Most of the other countries have a total number of registered investments between 100 and 1000.

Table 13: Cleantech investment data.

	Country	Total investments	Cleantech investments	Cleantech %	CCPI	GDP	RenEnergy	CO2	R&D	RegQual
1	Australia	847	26	3.07	0.0	62618.59	8.47	15.5	1.79	1.82
2	Austria	208	4	1.92	10.85	53793.37	32.38	7.1	3.22	1.57
3	Belgium	309	13	4.21	7.9	50412.71	9.41	8.2	3.17	1.35
4	Brazil	608	7	1.15	2.11	7741.15	47.85	2.0	1.16	-0.16
5	Canada	4818	385	7.99	8.42	52791.23	17.26	15.5	1.70	1.56
6	China	13656	257	1.88	15.68	11891.20	9.67	7.4	2.24	-0.08
7	Denmark	352	18	5.11	17.87	67919.59	39.03	5.8	2.91	1.79
8	Egypt	190	2	1.05	10.07	3851.75	5.14	2.5	0.61	-0.6
9	Finland	500	41	8.20	15.98	53522.57	36.63	8.0	2.80	1.85
10	France	4326	229	5.29	16.06	45028.27	11.82	4.6	2.20	1.2
11	Germany	3130	138	4.41	12.95	50787.86	16.38	8.6	3.19	1.53
12	India	4335	124	2.86	14.0	2116.44	23.14	1.8	0.7	-0.14
13	Indonesia	341	4	1.17	9.74	2116.44	23.88	2.2	0.1	0.08
14	Ireland	427	16	3.75	7.76	102394.02	13.12	7.6	1.23	1.47
15	Italy	517	17	3.29	10.29	35584.88	19.42	5.4	1.47	0.5
16	Japan	2247	55	2.45	7.21	40704.30	6.77	8.7	3.20	1.35
17	Malaysia	108	3	2.78	5.29	11124.67	3.50	7.6	1.04	0.77
18	Mexico	145	5	3.45	4.85	9967.39	9.63	3.7	0.3	0.08
19	Netherlands	653	32	4.90	16.53	57714.88	9.19	8.8	2.18	1.75
20	New Zealand	111	7	6.31	7.84	48348.99	40.04	6.6	1.41	1.88
21	Norway	193	13	6.74	13.17	82244.23	51.11	7.0	2.13	1.7
22	Poland	212	5	2.36	4.81	17318.50	10.13	8.2	1.32	0.89
23	Portugal	131	8	6.11	16.27	24457.14	28.24	4.8	1.40	0.83
24	Russia	317	3	0.95	3.72	11273.24	2.89	11.1	1.04	-0.44
25	South Africa	147	6	4.08	10.2	6861.17	6.56	7.5	0.83	0.8
26	Spain	695	15	2.16	9.86	30536.86	16.96	5.5	1.25	1.34
27	Sweden	761	31	4.07	15.72	58639.19	44.92	3.5	3.39	1.68
28	Switzerland	723	33	4.56	8.29	93515.48	23.83	4.4	3.18	1.72
29	Turkey	209	7	3.35	5.68	9406.58	16.24	5.0	1.06	-0.01
30	United Kingdom	4933	250	5.07	15.3	46200.26	13.91	5.4	1.76	1.48
31	United States	44474	1477	3.32	10.13	69375.38	8.50	15.2	3.07	1.6
32	Vietnam	129	0	0.0	7.2	3742.86	15.82	2.7	0.53	-0.15
33	Saudi Arabia	523	8	1.53	3.94	23762.42	0.02	15.3	0.13	0.26

B Green fundraising data overview

The final dataset for the analysis on share of fundraising committed to green VC funds after the data processing steps are illustrated in Table 14. The fundraising data are aggregated for the 27 countries included in this analysis. The "Total raised" column shows the total amount of capital raised to VC funds, registered in Eikon Refinitiv database in the period January 2011 to March 2022. The amount is reported in USD millions. The "Raised to green funds" columns shows the amount of capital raised to green VC funds, registered in the same period. This is the total amount of capital raised to the green VC funds found through the manual labeling process. "Total raised" and "Raised to green funds" are utilized to calculate the share of fundraising committed to green VC ("Green Capital %"), which is the dependent variable in this regression analysis. Since this dataset was processed with random stratified sampling for China and United States, these numbers in terms of both "Total Raised" and "Raised to green funds" does not represent the total amounts registered in the Refinitiv Eikon database, but only the total capital aggregated from the final sample included.

Table 14: Green fundraising data.

	Country	Total raised	Raised to green funds	Green capital %	CCPI	GDP	RenEnergy	CO2	R&D	RegQual
1	Australia	7351.60	1293.43	17.59	0.0	62618.59	8.47	15.5	1.79	1.82
2	Austria	653.27	90.69	13.88	10.85	53793.37	32.38	7.1	3.22	1.57
3	Belgium	1579.32	56.93	3.61	7.9	50412.71	9.45	8.2	3.17	1.35
4	Brazil	3218.98	10.00	0.31	2.11	7741.15	47.85	2.0	1.16	-0.16
5	Canada	20135.99	2895.35	14.38	8.42	52791.23	17.26	15.5	1.70	1.56
6	China	63184.12	3031.23	4.80	15.68	11891.20	9.67	7.4	2.24	-0.08
7	Denmark	1298.54	50.00	3.85	17.87	67919.59	39.03	5.8	2.91	1.79
8	Egypt	887.19	0.00	0.00	10.07	3851.75	5.14	2.5	0.61	-0.6
9	Finland	1249167	210.16	16.83	15.98	53522.57	36.63	8.0	2.80	1.85
10	France	19830.49	3503.07	17.67	16.06	45028.27	11.82	4.6	2.20	1.2
11	Germany	13429.01	614.03	4.57	12.95	50787.86	16.38	8.6	3.19	1.53
12	India	18882.65	1314.43	6.96	14.0	2116.44	23.14	1.8	0.7	-0.14
13	Indonesia	1315.69	0.00	0.00	9.74	2116.44	23.88	2.2	0.1	0.08
14	Ireland	1435.94	58.98	4.11	7.76	102394.02	13.12	7.6	1.23	1.47
15	Italy	1496.86	0.00	0.00	10.29	35584.88	19.42	5.4	1.47	0.5
16	Japan	13327.18	1085.58	8.15	7.21	40704.30	6.77	8.7	3.20	1.35
17	Luxembourg	5208.80	3710.60	71.24	18.11	131301.60	10.71	15.33	1.13	1.84
18	Mexico	697.84	63.11	9.04	4.85	9967.39	9.63	3.7	0.3	0.08
19	Netherlands	7073.94	718.62	10.16	16.53	57714.88	9.19	8.8	2.18	1.75
20	New Zealand	824.79	50.21	6.09	7.84	48348.99	40.04	6.6	1.41	1.88
21	Russian Feder	2077.58	11.00	0.53	3.72	11273.24	2.89	11.1	1.04	-0.44
22	South Africa	1050.49	281.80	26.83	10.2	6861.17	6.56	7.5	0.83	0.8
23	Spain	4545.52	572.32	12.59	9.86	30536.86	16.96	5.5	1.25	1.34
24	Sweden	3696.53	740.05	20.02	15.72	58639.19	44.92	3.5	3.40	1.68
25	Switzerland	6487.44	237.44	3.66	8.29	93515.48	23.83	4.4	3.18	1.72
26	United Kingdo	38898.43	3947.48	10.15	15.3	46200.26	13.91	5.4	1.76	1.48
27	United States	39278.06	954.28	2.43	10.13	69375.38	8.50	15.2	3.07	1.6

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