POLITECNICO DI MILANO

School of Industrial and Information Engineering

Master of Science in Management Engineering

AN EMPIRICAL ANALYSIS ABOUT VENTURE CAPITAL IMPACT ON EUROPEAN PORTFOLIO COMPANIES PERFORMANCES IN CLEANTECH

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Abstract

Environment health is the topic at stake today. Governments, supra-national institutions along with local communities are calling for the transition to a low-carbon economy and mobilizing to work it out. Nonetheless, a pivotal contribution would be given by the massive introduction of sustainable business models through which companies deliver their value proposition.

Cleantech is one main emerging category in this scenario and it encompasses those technologies capable of generating yield for investors and, at the same time, reducing the negative impact on the environment. As the goodness of these business models is often not proven in the market, the capital provision from risk prone investors is necessary. In the current academic literature, the extent to which venture capital can be the main ambassador in sustaining with capital and expertise the environmental revolution is an open question.

This work is exclusive in its purpose. It investigates the relationship between venture capital and portfolio companies' performance in cleantech in the European landscape, and it is supported by an econometric analysis. To carry out the empirical study, we resort to the VICO database and single out cleantech companies, while the control group is extracted from Orbis. Firms included were born between 1989-2014 and invested between 2005-2014. The econometric analysis is divided in two parts: the first model relates the probability to grow after the investment to VC and its characteristics, and it aims at studying the monitoring and value adding capabilities of such investors; the second model relates the probability to get invested to the operating performance before the investment, and it aims at detecting the screening capabilities. The results are noteworthy: we find that VC-backed companies are more likely to grow in terms of intangible assets after the investment, while there is no significant impact on the growth of sales and headcount. It seems that VC does intensive R&D activity but that it lacks technical expertise. Concerning the screening process, VC invests in less profitable and smaller companies, while patents do not act as a signal. On the whole, there is no empirical evidence that VC is about to spur the development of cleantech.

Sommario (Italian version)

Oggi la salute ambientale è diventata un tema di discussione quotidiano. Governi, organizzazioni internazionali e comunità locali di tutto il mondo si appellano ad una nuova economia a basse emissioni ed esortano a trovare quanto prima una soluzione. Nondimeno, l'introduzione di *business model* sostenibili, attraverso cui le aziende trasmettono la loro *value proposition*, costituirà un contributo di primaria importanza.

Su questo sfondo si erge il cleantech, un settore emergente che comprende tutte quelle tecnologie in grado di generare un profitto per gli investitori e al contempo ridurre l'impatto negativo sull'ambiente. Dato che l'efficacia di questi *business model* non è ancora testata sul mercato, sono necessari investimenti che finanzino progetti ad alto rischio. Nella letteratura scientifica, rimane una questione irrisolta fino a che punto il venture capital potrà essere l'ambasciatore di questa rivoluzione ambientale, tramite l'apporto di capitale e delle competenze tecniche e manageriali in suo possesso.

Questo lavoro è unico nella sua finalità: nel contesto europeo, si indagano le correlazioni tra il venture capital e le performance delle società nel portafoglio, attraverso il supporto di uno studio econometrico. Per svolgere l'analisi empirica, abbiamo attinto al database VICO Updated e selezionato le aziende con un modello di business cleantech, mentre il campione di controllo è stato estratto da Orbis. Le imprese del campione sono state fondate tra 1989-2014 e investite da fondi di venture capital tra 2005-2014. L'analisi econometrica approfondisce due aspetti: il primo è la verifica delle capacità di *monitoring* e di *value adding* dell'investitore, analizzando la probabilità di crescere una volta ricevuto l'investimento del venture capital e le sue caratteristiche; il secondo invece, studia la probabilità di essere investite legata alle performance operative antecedenti l'investimento, con l'obiettivo di individuare eventuali capacità di *screening*.

I risultati ottenuti sono degni di nota: troviamo che è più probabile che le aziende investite dal venture capital accrescano i beni intangibili (cioè gli *intangible assets*) dopo l'investimento, mentre non è visibile un impatto significativo sulla crescita delle vendite e

dell'organico. Sembra che il venture capital svolga un' intensa attività di ricerca e sviluppo ma manchi di conoscenza tecnica. Nel processo di *screening*, il venture capital preferisce finanziare imprese più piccole e meno profittevoli, mentre i *patents* non riescono ad attrarre ulteriori investimenti.

Alla luce dei risultati, non troviamo evidenza empirica del fatto che il venture capital possa dare un contributo importante alla fioritura del cleantech.

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In this section we would like to sincerely thank all the actors that have made a contribution to our thesis.

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Finally, we thank our families and friends, for the support and the love during the most difficult periods of these years.

Executive summary

This work can be a little contribution to the global environmental cause. It is a study about the impact of venture capital on portfolio companies' performances in cleantech, that is a "*new technology and related business models that offer competitive returns for investors and customer*s", while "*greatly reducing or eliminating negative ecological impact, at the same time as improving the productive and responsible use of natural resources*." (The Cleantech Group). As this category encompasses a broad range of technologies and usages, from the public utilities' production of renewable energy to the optimization of households-level gas and power consumptions, cleantech's flourishing is likely to be pivotal for the transition of the whole system to a low-carbon economy (LCE). Nonetheless, to spawn a canvas of cleantech technologies, both capital injection and expertise must be channelled to ideas and early-stage projects, because the success will depend on the capability of such ventures to be profitable. This analysis is exclusive and relevant in inquiring the impact of a private investor category (i.e. venture capital) on investee companies' performances, through a quantitative method, since the ultimate purpose for investors (and for society in this case) is to sell these companies' shares through IPOs or M&As.

While incumbents are good at bringing about incremental innovation, entrepreneurial ventures are necessary for the introduction of quantum leap technology. Big corporations can count on internal financial resources and often on external ones. Differently, start-ups, that generate almost zero or no cash and deliver new value propositions, depend upon the financial provision of risk-prone investors. Among these ones, venture capital (VC, hereafter) is a main actor. Kortum & Lerner (2000) find that VC abilities in spurring innovation is three to four times more successful than corporate R&D. Radical innovation is core for that process that Shumpeter calls "*creative destruction*" (Schumpeter, 1942) and that is a force making markets working efficiently (i.e. dynamic efficiency). Indeed, VC's investment targets are emerging sectors, such as software/IT and biotech (for instance, in 2014, in US, the biggest VC market, almost 90% of capital is invested in high-tech sectors, according to Teker, Teker, & Teraman (2016)). Cleantech represents a new target sector; the share of VC investments in cleantech has grown from 2% to more than 10% in the last decade (Usher, 2008).

O'Rourke (2009) divides the evolution of the definition of cleantech into three distinctive phases: at the onset in 90s, cleantech concept appears in *discourses* but is not a legitimated and recognised category among environmental technologies; in the second phase, from 2002 to 2004, the two major organizations sponsoring cleantech, the Cleantech Group and Clean Edge, introduce this technology to the North America's VC community, sponsoring it as a new investment category; the last phase is marked by the entrance in the mainstream media in 2006 and a peak of investments in 2008. Is it worth noting that the definition modelling was mated by increasing capital flows and greater interest to the sector. Given the broad spectre of the industries in which cleantech business models compete, as well as the public good nature of their value proposition, there are several stakeholders playing a primary role in their development: incumbents of traditional Oil&Gas industry, that face the double nature of opportunity (for new market shares) and threat (of substitution, according to Porter's five forces model (Porter,1989)); VC and financial institutions, as capital providers; governments and sovra-national entities that engage to tackle the negative externalities of pollution and global warming, and promote the transition to a low-carbon economy.

Some studies aim at inquiring which are the determinants of VC investments in cleantech sector. Those are regulatory environment, energy price & stock returns, media coverage, Hofstede cultural dimensions (Hofstede, 1984).

Public policy is a driver in shaping the regulatory context. According to Giudici, Guerini, & Rossi-Lamastra (2017), the need for governmental intervention is rooted in the peculiar nature of cleantech business, which makes tailored incentives and regulations a fundamental pre-requisite for the success of the industry. There are two main categories of public policies: technology push and market pull. Technology push policies contribute to the supply of technology and concern public grants, loans, R&D financial aid for early stage investments, training programs and governmental VC. Market pull policies contribute to the demand of technology and concern public procurement, feed-in tariffs, renewable portfolio standards and measures that incentivize the adoption of firms and consumers. Many experts agree that the two approaches are complementary and a case study by Klaassen et al. (2005) on Denmark, Germany and UK validate this thesis. For instance, Denmark between 1979-1989 implemented jointly a system of subsidies for installation of wind turbines and an R&D program, while UK in the early 90s suffered a shortage of R&D expenditure despite it was able to drive down market prices. The most favourable environment would include "*a stable, long-term, transparent and predictable regulatory environment.*" (European Commission, 2016). Indeed, long term policies such as feed-in tariffs and quantity renewable standards (rather than fiscal incentives, for instance, that are perceived as short term measures) are among most preferred policies when surveying VC (Bürer & Wüstenhagen, 2009) and most determinant when observing correlation with VC deals (Menon and Criscuolo, 2015).

Stock market and commodity prices may be drivers for the VC investments in cleantech. Colombo et al. (2016) and also Kumar et al. (2012) find that increasing oil prices poses an incentive to invest in alternative sources of power. Colombo et al. (2016) find also a positive correlation of media coverage with VC cleantech deals. Doing advertising, informing stakeholders and potential shareholders about benefits, along with making the products fashion, help in building image and reputation of the sector. From a cultural point of view, referring to the Hofstede model (Hofstede, 1984), uncertainty avoidance is negatively correlated with the number of deals (Colombo et al., 2016).

However, there are some tricky aspects in the relationship between VC and cleantech. These are related to the *Cash Flow Valley of Death*, *Managerial Valley of Death*, and exit mechanisms for start-ups along with the commodity nature of energy.

Under certain circumstances, VC is not able to provide capital to cleantech due to structural problems. The proper mode of funding for a general project depends upon the level of risk associated to the technology and the level of capital intensity. Projects characterized by low level of risk get funds from traditional institutions such as banks, while VC build high-risk portfolios financing several technologies (to diversify risk) characterized by low capital intensity. The *Cash Flow Valley of Death* concerns those cleantech projects highly risky and capital intensive, such as offshore wind farms or advanced biofuel refineries. The order of magnitude for capital intensity can dwarf VC size. For instance, Solyndra, a former producer of photovoltaic systems, had to raise about $970M in equity and $500M in debt before going to IPO, while Google just $40M (considering a typical $300M VC fund).

Concerning the *Managerial Valley of Death*, managers approaching cleantech that come from Oil&Gas incumbents, fail in leading entrepreneurial firms where competition is high and cash flow is limited, while VC-based entrepreneurs may have not the capability to manage commodity pricing and regulatory uncertainties (Ghosh & Nanda, 2010). Randjelovic et al. (2003) also point out a lack of managerial skills in green sector.

Exit mechanisms can be critical for cleantech. It is observed that, while for IT and biotech industries incumbents are prone to buy start-up, Oil&Gas giants intentions are ambiguous. Zhong & Bazilian (2018), focusing on the role of Oil&Gas established companies concerning the current energy transition, look at their budget share pledged for renewable energy CAPEX. For instance, Shell, the biggest player in the industry, in 2016 reported a CAPEX of $200m on renewable. It is a very small percentage on $80bn revenues (*2016 Shell Annual Report*, 2016). It is possible that established traditional energy firms see themselves in the same situation as Laio, father of Edipo, when he was told by the oracle that the son will grow and kill him. Not willing to end up as Laio, they give up on feeding these start-ups. A visible lack of trust of established giants towards cleantech companies may further freeze-up funding upstream the innovation chain, with VC not envisaging exit opportunities.

Finally, the commodity nature of the final product is another important issue. In biotech and IT, companies try to offer cutting edge products that meet the always fickler customers and their needs, and this leads incumbents to compete in acquiring start-ups to spot opportunities. Being energy a commodity, except for few ideological green people, it is the same whatever the source of production. An end-user cannot tell the source of production.

Although there is widespread interest in understanding the current context in cleantech, inquiring which policies are most preferred by VC or which variables are positively correlated with VC deals, no extant literature has tested the operating impact of VC on portfolio companies' performance in cleantech. This is likely to be relevant for the deployment of cleantech as well.

Academic research on the impact of VC on investee companies divides into two big families of research questions: the survival probability (and types of exit) and the economic, financial and operating performances.

VC can show monitoring capabilities, improving the performance of investee companies and/or leading them to positive exits, and screening capabilities, in detecting the most promising business models.

Berger & Udell (1998) argue that a VC company is welcome by entrepreneurs as it provides not just capital, but also post-investments monitoring and value adding services such as networking with customers and suppliers, knowledge and moral support. Performing well such activities brings about benefits both to the investor (through higher return) and to the entrepreneur (through improvement of performance). Alemany & Martí (2005), among others, find that VC backed firms grow more than non-VC backed after the investment. Given the heralded managerial valley of death in the sector, it is worth testing whether their results hold in cleantech.

H1. VC-backed cleantech companies are more likely to grow than non-backed cleantech ones after the investment.

However, VC investments can differ along many dimensions, both investors-specific (e.g. private venture capital vs governmental venture capital) and investment-specific (e.g. syndicated investments vs non-syndicated ones). D. J. Cumming & MacIntosh (2007) state that the difference in performances can originate from the different governance. Alperovych et al. (2015) underline a different contribution to efficiency improvement within the VC categories, pointing out that GVC investments can cause a degradation in efficiency. It is worth to inquire the difference among VC types.

H2. IVC-backed cleantech companies are more likely to grow than non IVC-backed ones.

Syndication is another alternative to explore. The participation of more than one investor can be a potential source of augmented capability both in the screening process thanks to double control (Gompers & Lerner, 2004), and in the monitoring and controlling process, enjoying synergies in advising. The downside can be the emergence of communication costs (Cumming et al., 2007).

H3. Syndication of VC investments (i.e. the presence of more than one investor) in cleantech increases the odds of growth for investee companies.

Demographics characteristics of investors can be relevant as well in the outcome. Alemany & Martí (2005)'s study shows that VC experience results determinant in the outcome. The participation to company's boards let VC share its expertise and knowledge (MacMillan et al. 1989; Hellmann and Puri, 2000; 2002). Moreover, the provenience of investors can be another relevant variable. Cumming et al. (2017) posit positive correlation of the geographic distance between investors and entrepreneurs and the exit outcome.

H4. Experience of VC investors in cleantech increase the odds of growth for investee companies.

H5. Cross border investments of VC in cleantech increase the odds of growth for investee companies.

VC's investments are not randomly targeted: they often show pre-investment screening capabilities, acting as a 'scout' in the selection of better performing firms (Baum & Silverman, 2004; Chemmanur et al., 2011; Chemmanur et al., 2011). Along with superior operating performance, VC-backed firms are likely to be more innovative than non-backed ones, and patents can be a signal, to overcome information asymmetries and attracting VC (Lahr & Mina, 2016).

H6. VC-backed cleantech companies show higher performances than non-backed ones before the investment.

H7. VC-backed cleantech companies show a higher innovation rate than not backed ones before the investment (i.e. patents act as a signal).

The hypotheses get tested through an econometric analysis. Data for invested firms and rounds characteristics are from VICO Updated, the database on entrepreneurial VC-backed ventures in the European landscape. The control group comes from Orbis. For each invested firm, it gives 10 non invested similar companies in terms of age, industry and country. Once the database is built, cleantech companies are identified through a text analysis on the items describing the business activity. The dictionary for the text analysis resembles that one used (with similar goals) by Douglas J. Cumming et al. (2017). For English and Italian companies already present in the old version of VICO, a manual check on websites is carried out to detect the cleantech nature. Additional cleantech companies are identified in the historical annual rankings published by the Cleantech Group, considering just European ones.

After dropping the observations without sufficient variables to observe, we get the screening sample, made of 138 VC backed firms observed only in the year of the first investment, and 1349 non-VC-backed companies. On this sample, we perform a propensity score matching to control for selection and we get the monitoring sample, made of 684 companies, of which 135 invested.

A Probit model is used to test the hypotheses. For monitoring (H1-H5), growth is the dependent variable. Performances observed for growth are sales and employment (as most studies), total assets and intangible assets (as Alemany & Martí 2005) and fixed assets. For screening (H6-H7), the investment is the dependent variable. Regressors are control variables along with ad-hoc built dummies to test the hypotheses.

The results are unexpected. In general, VC backing has positive and statistically significant impact on the growth of intangible assets. We find also that more aged VC has a bigger statically significant impact than younger VC on the growth of sales, but neither of them is significant for the whole model. Concerning the other VC characteristics, the differences between the coefficients are not statistically significant.

The lack of capability to increase performances as sales and employment entails that cleantech firms may need more time to scale-up and have a relevant impact on local area. As Ghosh & Nanda (2010) argue, the required timespan of VC holding can be longer than the usual 3-5 years in alternative sectors as IT. Moreover, the results can be read as a partial evidence of the Managerial Valley of Death. Concerning screening capabilities, VC selects less profitable and smaller cleantech companies, and this is in line with literature on VC screening, but there is no evidence that most growing firms get the attention of investors. Furthermore, we do not find evidence that patents act as a signal to attract VC.

There are margins to improve our work in developing a more sophisticated model to detect cleantech companies in the initial database, considering a larger sample beyond European ventures, accounting for differences across cleantech sectors, along with testing the hypotheses with other econometric models (also accounting for short term and long-term impacts).

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Introduction

The last 15th March 2019, the global community was called by a sixteen Swedish girl, Greta Thunberg, to take to the streets and demonstrate against climate change. There is an urgent necessity to deal with issues regarding the mitigation of climate change and the relative effects, as warming temperatures, changes in precipitation and sea level which, in turn, will affect water supply and quality, habitat, and food production. Harmful effects of the human activity cannot be neglected anymore and compel the whole world to figure out a new technological and economic paradigm, based on cleaner and sustainable technologies.

Clean technologies started to arise in early 90s, as a subset of environmental ones, and entered into the mass market in the middle of ‘00s. Nonetheless, during the last 20 years, their adoption did not gain a foothold in the market, remaining stagnant and bogged down at an embryonal status. But now things seem to have turned around. People are asking more attention to the environment, more respect, along with sovra-national organizations that are goading single governments to give a momentum to cleantech innovations adoption. The time strikes as being ripe for change.

Since its dawn, venture capital firms have devoted a consistent amount of capital flow to finance cleantech high-growth potential ventures, identified as risky investments delivering highly profitable yields. In combination with governmental R&D and appealing policy schemes, venture capital looks like one of the crucial actors in charge of driving the transition.

The scope of this study is to assess to what extent VC’s engagement in cleantech equities will lead positive impact on performances. The focus is on a sample of 684 European cleantech firms, being VC-backed along the time period between 2005 and 2014.

The current state of research highlights some challenges peculiar to the sector that would dampen cleantech firms’ performance: the lack of managerial skills and undefined exit mechanisms, together with capital intensive projects, turn VC’s preferences towards other choices, as biotech and IT sectors. Also, the commodity nature of energy put VC under ambiguous conditions prejudiced by political regulations. Academics agree on performances that VC brings value adding and monitoring services during the holding period, ensuring more efficient outcomes to investee companies. Instead, there is a mixed evidence on the capabilities of VC to screen the most promising enterprises, given the high number of failures.

The present work aims at bridging a gap in the literature, covering the VC impact on cleantech ventures performances both in the pre- and post-investment stages. The analysis is undertaken through an econometric approach: two models are developed to distinguish between the selection and the monitoring analysis, and test what accounting variables are more affected by VC's intervention.

Overall, the work is developed as follows: in the literature review, the features bonding cleantech to venture capital are deeply discerned, with references to the major academic results. In section 2, we conceive the research question standing our study and afterwards, the econometric analysis on VC's impact on performance is drafted. Once reported the results, they are discussed and compared to the literature. At the end of the work, conclusions are drawn together with some insights for further research.

1 Literature Review

1.1 Venture capital in a new emerging sector

1.1.1 Venture capital for innovation

The social sphere needs innovation, because new issues, such the environmental one, can be tackled with anything but new solutions. Schumpeter called for creative destruction for the market to work efficiently (Schumpeter, 1942). Radical innovation in general comes from Start-ups, ventures that deliver their value proposition with a new, unproven business model. Hockerts & Wüstenhagen (2010) state that incumbents are better at introducing incremental innovation, while start-ups are more suitable to introduce quantum-leap solutions. They are engine for innovation.

Venture capital (VC, hereafter) is a financial actor that helps new business models' development across the different phases of the lifecycle (P. A. Gompers & Lerner, 2004). Therefore, VC plays a crucial role in the introduction of new technology, better than other alternatives. For instance, Kortum & Lerner (2000) find that venture capital is three to four times more powerful than corporate R&D in spurring innovation. Florida & Smith Jr (1990) and Kortum & Lerner (2001) state that experience and business cases across different industries demonstrated that VC and private equity investments can significantly accelerate the market diffusion of new technologies. Hall et al. (2005) argue that VC is the appropriate form of external capital to support innovative small-medium enterprises because specialized and knowledgeable VC investors can overcome information asymmetries. Moreover, since the firm (the entrepreneur provides technical expertise) needs also advising and strategic management capabilities, the expected value added that the investor brings in terms of business experience and network of contacts is valuable (Hellmann & Puri, 2000; Hsu, 2004; Zook, 2004).

Unfortunately, VC is both still underdeveloped at the aggregate level and unevenly distributed geographically. The biggest VC market are US, Canada and UK, while the European Union is striving to spur entrepreneurial finance. As Balboa et al. (2017) argue, VC markets did not evolve in Europe as they did in US due to the lack of some necessary conditions in the environment. The differences of culture and language between European countries are likely to raise important barriers, and information asymmetries. But also, as Teker et al. (2016) argue, country-specific factors for the development of VC are its cultural look over entrepreneurship, intellectual property protection, efficiency of capital markets, tolerance for failure and infrastructure for services. In Europe there is shortage of them.

VC funds show several varieties of governance, they can be both public and private. In Europe, to counterbalance the lack of private investors, policymakers have been promoting the establishment of governmental VC (Colombo et al., 2016). As the graph below shoes, US is the biggest market for VC finance (Figure 1).

Concerning the industrial distribution, in US in 2014 $35,7bn were invested in software/IT (70% of total investments), $8,8bn in biotech/medial (17%), while just $5bn in non-high-tech sectors. Conversely, in Europe the most attractive sector is the consumer products one.

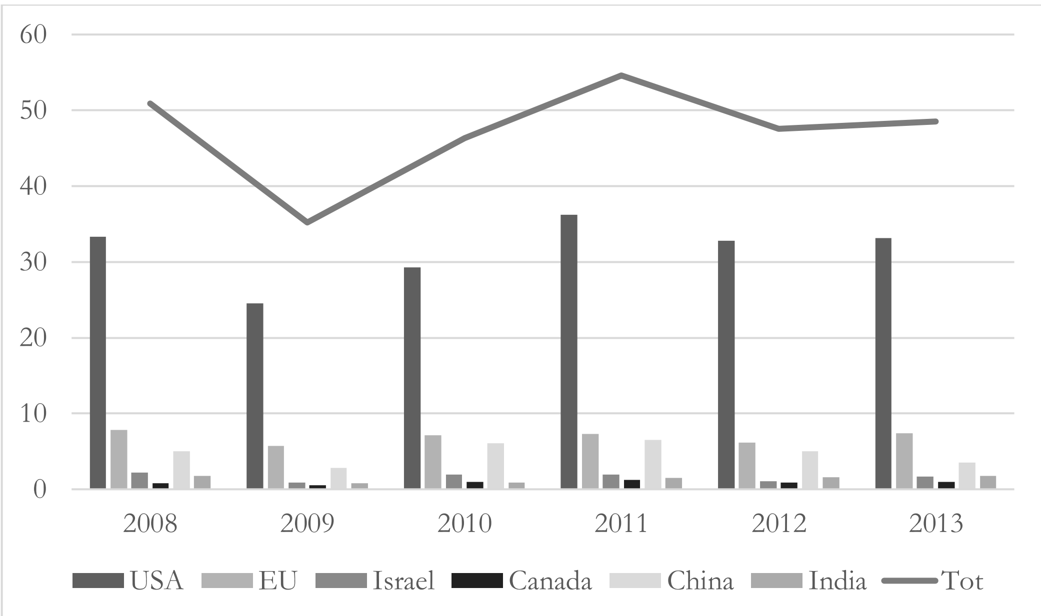

Figure 1 VC $bn investments around the world. Source: (Teker et al., 2016).

A new category of investments, transversal to traditional sectors, toward which VC has been channelling a relevant amount of capital in the last years, is cleantech. Pernick and Wilder define "clean tech" as "*any product, service, or process that delivers value using limited or zero non-renewable resources and/or creates significantly less waste than conventional offerings*" (Pernick R. & Wilder C., 2007). Since 2004, the share of VC investments in cleantech in US has soared from less than 5% to more than 20% in 2010 (Figure 2), while globally it has soared from 2% to more than 10% (Usher, 2008).

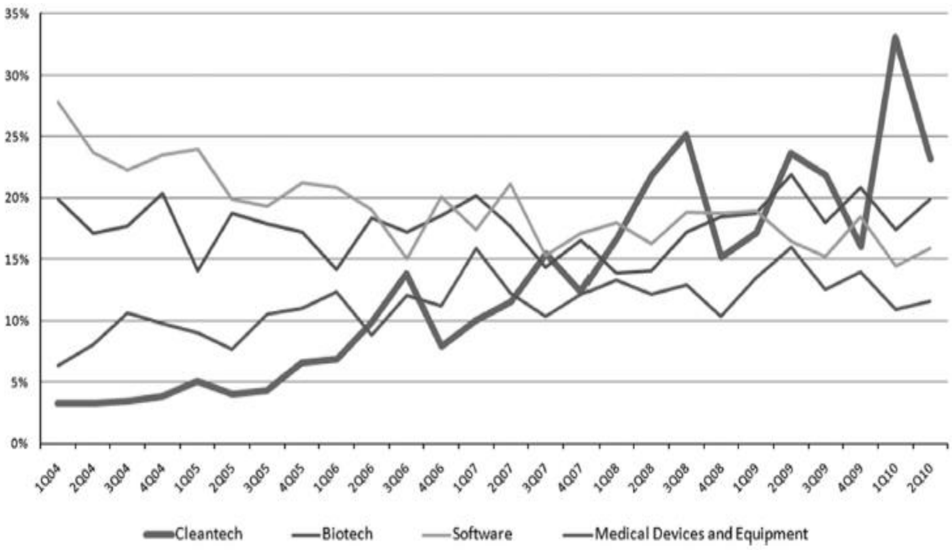

Figure 2 VC investments share in US for main sectors. Source: The Cleantech Group.

1.1.2 Brief historical account of the rise of cleantech

The concept of cleantech is relatively new, the limited timespan through which the concept of cleantech has taken form counts barely 20 years, since the beginning of 90's to the first decade of the new millennium. O'Rourke (2009) portioned the evolution of the definition of cleantech into three distinctive phases (Table 1). Below, each single step is described.

At the beginning, cleantech innovations were categorized as other type of technologies because the category did not have a singular identity. But, before receiving substantial financial flows, cleantech waited to be introduced to the venture capital community by the Cleantech Group (CG) and Clean Edge (CE). They showcased the new environmentally-friendly and economically worth technologies to funding providers and gave legitimacy to cleantech as a technology and an organizational field. The last phase of cleantech highlights an essential change: it was approached to environmental issues and so became an applicable solution to tackle global threats.

Phase	Description
Phase 1 1995-2000	At the very early stages, clean technologies did not constitute per se a legitimated and recognized category, but were part of a wider set of technologies, as environmental technologies, or indeed included in other investment categories, that, however, did not attract vast amounts of capital. Cleantech was a niche investment category.
Phase 2 2002-2004	From 2002 onwards, the concept took a breath outside technological contexts and was presented to the venture capital circle in North America, that made it a novel favourable financial area. In addition, the Cleantech Group and the Clean Edge linked it to other legitimate technology and organizational fields.
Phase 3 2005-2006	Cleantech attracted investors and a wider audience, cleantech was more actively linked to salient macro-issues and current events such as energy security, climate change, oil prices and job creation.

Table 1 Cleantech phases (O'Rourke, 2009).

The first time the word "cleantech" appeared in a press article was in 1990, in the annual report of the United Nations Economic and Social Commission for Asia and the Pacific (UNESCAP). The publication referred to the CLEANTECH 1990 Exhibition, an event held in Bangkok aimed to sensitize about contemporary developments in "clean, low-waste and pollution control technologies" (UNESCAP, 1990). After an event worth on international scale, the deployment of cleantech concept remained constrained to engineering and material science fields, with a very specific meaning. At that time, the financial landscape was hostile: the IT investing boom and the dot.com crisis, together with the seemed preconditions to enter the sector (i.e. specialized skills and a more patient capital) deflected the attention to other investment opportunities. During 90s' Cleantech was a niche investment category.

The new millennium signed the emergence of cleantech as a novel investment category. By the end of 1990s it spread outside the scientific circles and reached business and economic contexts. In Figure 3 it is tracked the use of cleantech as a term in science, business and economics, medicine and pharmacology. As the brown line suggests, the term adoption in business slowly continued to increase from ‘90s to 2010, with 2002 as turning point. In those years, discourses[1] about the new category spread through conferences and publications, and the establishment of cleantech as an investment category flew into discursive arenas[2], where its identity have been shaped. Cleantech narratives can thus be seen as “central in shaping the material reality of the sector” (Georgeson, Caprotti, & Bailey, 2014).

In fact, in 2002 the concept was introduced to the VC’s community in North America. The two major cleantech groups, Clean Venture Network (CVN) and CE, had the intuition to gather together technical expertise on clean technologies and venture capital. To give a chance to the novel idea to soar, it had to mark the difference between environmental technologies and cleantech ones, being the former just a regulatory driven market and the latter an opportunity for profits. In the subsequent years, several conferences and reports were promoted by CE and CVN to monitor venture capital deals; patterns, topics and standards adopted to measure profitability and progresses tended to imitate already existing VC’s categories.

O’Rourke (2009) argues that from 2002 onwards, cleantech was intentionally constructed and promoted as a new venture capital target category by the CTG and CE: they drew on a nebulous group of technologies and companies, renamed and promoted them by replicating existing VC norms. It was the mimicking of venture capital norms and conventions already existing for biotech and nanotech (names, routines, categories, presentation of data) to confer legitimacy to the new sector and make it larger and established. (Caprotti, 2012, 2016; O’Rourke, 2009)

[1] *“A discourse is an ensemble of ideas, concepts and categories through which meaning is given to phenomena” (Hajer, M. A., 1995)*

[2] *A discursive arena “is composed of political institutions, established and emergent markets, informal networks, media and public spaces where discourse is mediated, debated and appropriated” (Caprotti, 2016).*

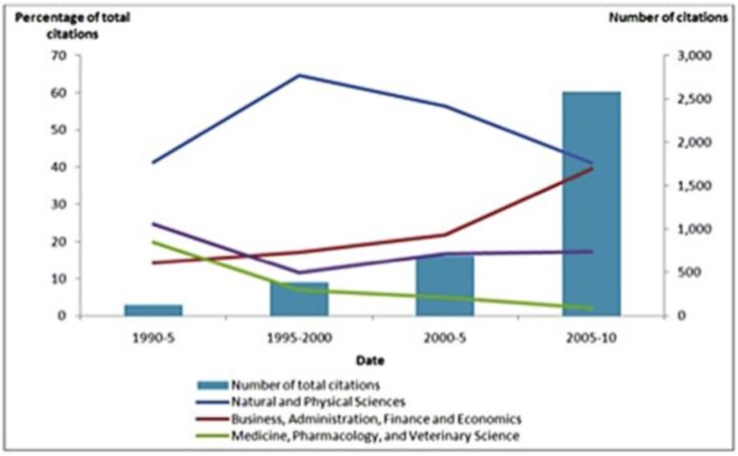

Figure 3 The adoption of 'cleantech' term in scientific, business and medicine researches (Caprotti, 2016).

In 2005, very notable newspapers started publishing articles concerning cleantech arguments: the New York Time, The Wall Street Journal and The Economist paved the way to become confident to an even wider public. As well as news media, "clean goals" were launched by large and famous companies (e.g.: GE and Walmart).

The great entrance of cleantech into the mainstream media dates back to 2006 (Figure 4) and then continues throughout the following period.

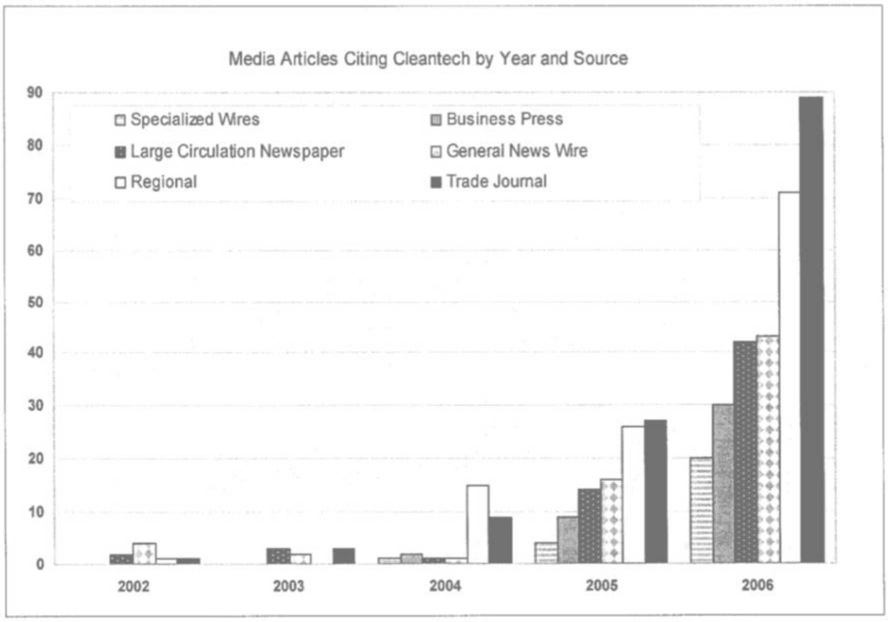

Figure 4 Number of printed media articles reporting cleantech from 2002 to 2006. Source: O'Rourke (2009)

In 2007, the founders of CE, Ron Pernick and Clint Wilder, endeavoured to define the category: "cleantech refers to any product, service, or process that delivers value using limited or zero non-renewable resources and/or creates significantly less waste than conventional offerings" (Pernick R. & Wilder C., 2007). They also introduced the ideas of "cleantech revolution", as the increased interest in cleantech mated by a rise in capital flows.

Figure 5 shows the increased term adoption in business disciplines: in 2007 the share of total usage of the term jumped to 42%, then to 50% in 2008, and to 52% in 2009. For what concerns investments, they peaked in 2008: it is worth noting that capital amounts into the new sector and the increasing use of the concept point to the *co-constitution* of an emergent sector by both capital and discursive mechanisms (Caprotti, 2012). De facto, the rapid development was exhorted by three determinants. First, the augmenting amount of capital spent in sectorial technologies. The amounts of capital invested in cleantech at the VC level increased from $590.1 million in 2000 to a peak of $8.4 billion in 2008 (Caprotti, 2012). Second, the greater number of utilities projects promoted by finance firms and corporations, outlining an enduring interest in cleantech as an established, mature and defined sector. Third, an increasing involvement of established investment firms in the sector remarks the passage of cleantech from a niche investment area to a more widely available targeted one (Caprotti, 2012). In other words, it can be said that the emergence of cleantech is nothing but a progressive increase in financial flows active in the sector, intertwined with discursive strategies.

As Figure 5 illustrates, the recessionary pressure of the global financial crisis was a standstill even for cleantech. Despite this, the novel industry reacted better than most with a fall in investment of just 6.6%, compared to 19% for the oil and gas industry (Caprotti, 2016).

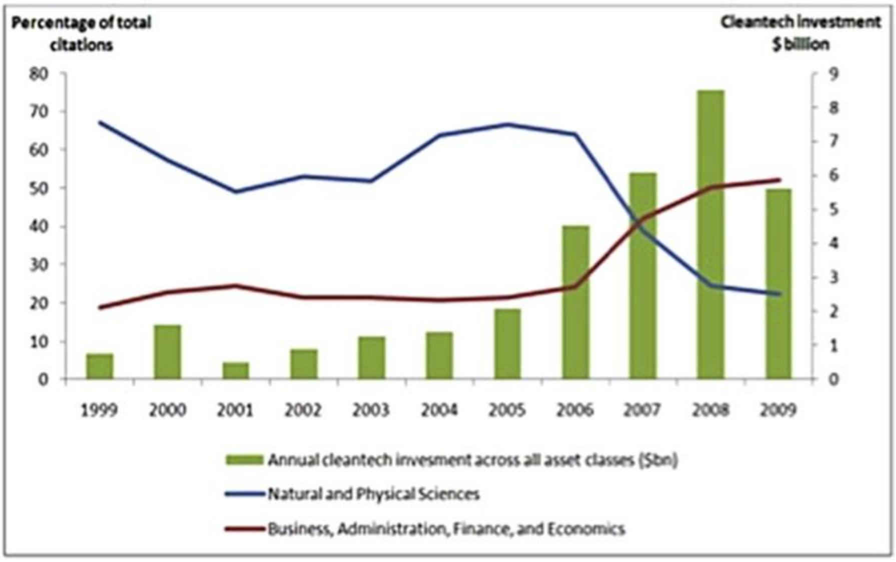

Figure 5 Use of 'cleantech' in scientific and business disciplines, compared with capital flows trends, 1990-2009. Source: Caprotti (2016).

By tracing the major events through which the history of cleantech twisted and turned, it is straightforward the contingency on a dense and extensive network that gleaned a pool of actors from distinct areas. First, the breadth of the definition has involved many actors in shaping definitional boundaries; second, the nature of technologies, not targeting same markets but transversal to a plurality of industries, has engaged technological specialists from several fields to take part into the process. Third, the venture capital community, the promoter of cleantech development. In Table 2, the actors involved in cleantech network are discussed.

Actor	Description
Cleantech Group and Clean Edge	The actors in charge of promoting clean technologies to venture capital and continuously reframed cleantech sub-sectors.
Governments	Governments have the cumbersome role of enacting policies appealing to private investors and pushing the worldwide population to shift to a new economy. The definition of the most suitable regulation scheme is an iterative process, just a collection of past successful implementations. Without their prompt intervention cleantech could not reach the maturity needed to enable a clean energy economy.
Venture capital	There is no uncertainty around the help that investment will provide to new technologies, in improving resource use in parallel with reducing social and environmental negative impacts, in this context the private sector appears as the most desirable entity in offering such assistance. (Milunovich, S. & Rasco, J., 2008).
Technology experts	Technologists and researchers are cleantech specialists whose challenge is to find always environmentally-friendly and money-making technologies.
Incumbents	There are no cleantech incumbents, so they are replaced by oil and gas giants, the supporters of a fossil fuel-based economy, unlikely biotech, incumbents avoid buying cleantech start-ups once they reached the almost maturity status. Afraid by their power, incumbents are not financing the new economy
Service providers	Service providers as law firms, consultancies, need to be instructed in cleantech matters to follow their client investments.
Sopra-national organizations	International organization have to align governments interventions towards a unique direction, the low carbon economy[3].

Table 2 Main actors participating to the cleantech definition.

1.2 Forces pushing VC to cleantech

This section reviews which are the most common determinants of VC deals in cleantech according to current academic literature. Public policy is considered a main variable in shaping a favourable environment, given the public good nature of the product. Along with government intervention, other variables are stock-market prices of energy commodities, media coverage, social awareness of sustainability and Hofstede cultural traits.

[3] *We explain the concept of low carbon economy in the A.1 Transition to a Low carbon economy.*

1.2.1 Public policy

Public intervention is recognized as the most commonly cited cleantech driver, especially policies and regulation designed to enhance firms' competitiveness. The need for governmental intervention is rooted in the peculiar nature of cleantech business, which makes tailored incentives and regulations a fundamental pre-requisite for the success of the industry (Giudici et al., 2017). At the same time, public policy may play a determining role for VC both in shaping perceptions of prices (through fiscal intervention) and expectations for regulation.

The challenge for governments is to design the best fitting intervention, that should foster activity innovation and entrepreneurship by leveraging the private funding sector (e.g.: venture capital and private equity). "Technology push" and "market pull" are both necessary actions to stimulate technological advancement[4]. Supply side policies push technology supply, while demand side policies pull the demand of technology. An upstream action entails grants, loans, prized and R&D financial aid for very early stage investments via special programs. A downstream action concerns policies, regulations and tax or VAT reduction mechanisms to prompt demand. A suitable market would include "a stable, long-term, transparent and predictable regulatory environment" (European Commission, 2016).

A case study by Klaassen et al. (2005) on public R&D support aimed at reducing cost of innovation for wind energy turbines compares solutions enacted by Denmark, Germany and UK. They point out the fact that doing R&D is a necessary, but not sufficient, condition for the development of cleantech business models.

Between 1979-1989 Denmark resorted to a system of subsidies, that entail a 30% discount on installation costs, to achieve a rapid expansion of wind turbines. Since 1985 it imposed a partial refund for energy and environmental taxes levied on electricity

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[4] *Bloomberg New Energy Finance (2010) provides a wide description of the different supply and demand side policies.*

consumption. Parallel with subsidies it started an R&D development program that invested 10% of total energy research in renewables. The R&D scheme was the most successful in stimulating innovative solutions.

On the other side, Germany adopted a paralleled system comprised of feed in law, to regulate the purchase by public energy companies, tax breaks and low interest loans for renewable energy companies (1-2% below the market shares). The feed in law worked as an incentive to use efficient wind turbines in areas with favourable wind conditions. Unfortunately, the first attempt to invest in wind energy failed, so the program was recovered a second time. This time the wind turbines reached a successful result thanks to engineering and shipbuilding knowledge, together with technological Spillovers coming from Denmark. Overall, German and Danish subsidies for promoting capacity were effective solutions in supporting national innovation.

In the early 90s, UK started a two-tier strategy to expand renewable energy use in the country. The strategy consisted of promoting renewable energy through R&D and demonstration projects, and, with electricity sector privatization, guarantee a premium price of kWh for projects receiving the non-fossil fuel obligation (NFFO) subsidy. The NFFO obliged public electricity suppliers and regional companies to buy a certain amount of renewable energy. Even though the English scheme was helpful to drive down prices, it failed in improving the capacity of renewable energy because of the lack of public acceptance and R&D expenditures.

Concerning market pull policies, literature argues that markets can be established also by modelling market properties (Doganova & Karnøe, 2015). The architectures of already existing markets can be transformed and, in the case of cleantech, value metrics extended to include environmental performances. The case of Danish ammonia emissions shed light on regulations' pivotal role in setting up a market space. From the Integrated Pollution Prevention and Control directive (IPPC) a new market arose in Denmark, with the aim to create demand for pollution-reducing solutions and encourage local farmers to invest in the "best available techniques[5]". In the stricter ammonia emissions regulations, CleanFarm[6] entrepreneurs envisaged a market opportunity. By mobilizing Danish policy makers, to ensure the application of stricter measures, and scientists, to show the indisputable evidences of reduced ammonias emissions produced by its products, CleanFarm aimed at being installed in the ten biggest pig farmers in Denmark, to let farmers see the possibility to expand their pig breeding without harming the environment.

We review several papers that agree on the need for public intervention in cleantech investments on the light of empirical results. Menon and Criscuolo (2015) look at 29 countries (almost half of the deals concern US-based companies, UK and Canada following) in the period 2005-2010 and study the effect of different type of public policies on the number of VC deals in cleantech sector. They classify policies in supply and demand side ones, as we mentioned before, but also, according to timeframes, in long and short-term ones. In the analysis they consider regulation price policies (Feed-in tariffs), regulation quantity policies (renewable portfolio standards, tradable renewable certificates, public competitive bidding), sales tax reductions and fiscal incentives. In general, the results of the analysis show that long-term policies such as renewable portfolio standards and Feed-in Tariffs are preferred to short term-oriented policies as fiscal incentives. Fixing the price for energy and obliging to make up the portfolio of utilities with shares of renewable energy are perceived as stable policies. FITs are considered one among best solutions in other results as well. A study by the European Commission (2005) concludes that the most effective systems in wind energy are in Germany, Spain and Denmark with FITs systems. On the contrary, fiscal incentives, especially when renewed every short lapse of time, suggest instability and may deter investments. Finally, very generous incentives, for instance for FITs, are perceived in a negative way, raising concerns about sustainability.

[5] *defined as "as techniques that ensure the highest level of environmental protection without entailing excessive cost" (Doganova & Karnøe, 2015).*

[6] *fictitious name for a new venture commercializing innovative technology that reduces ammonia emissions from farm animals*

Nonetheless, evidence is mixed about the degree of appreciation of actors. For instance, Bürer & Wüstenhagen (2009) surveyed 60 European and North American VC and private equity professionals to understand which are (or at least perceived) the best policies to attract private investors in backing cleantech firms. Their results concerning technology push policies show that investors dislike government VC and programs of mentoring for entrepreneurs. “Government should not pick winners” is a sentence that perfectly evocates the bad feeling for intrusive public actors in market dynamics. Positive feedbacks were for government grants for demonstration plans (is considered to help through the technology Valley of Death along the innovation chain) as well as public R&D and grants for SMEs and communities (we show later that communities are a new dimension to consider when talking about the environmental transformation). Concerning market pull policies, FITs were considered the best, followed by the Technology Performance Standards and the reduction of subsidies for fossil fuel.

Many investors believe that a mix of technology push and demand-pull policies is necessary. But, when analysing surveys, it is important to highlight the danger in drawing conclusions on the light of the results quickly. Some factors account for a biased outcome of survey and were conditioning responses of investors (Bürer & Wüstenhagen (2009)). These are the clean energy exposure (more preference for FIT the more the investment level in cleantech), fund type, geographical provenience (in Germany, Spain and other countries that have an already running and developed public policy pattern the sensitiveness and the awareness of some incentives are surely different from other inexperienced countries) and stage of technology development. We add also that, given the broad spectre of cleantech technologies, the differences may be not just vertical (along stages of innovation chain) but also horizontal (a wind turbine is far different from a software for power usage optimization). The low appreciation level emerging for some policies (e.g. Wustenhagen and Teppo, 2006, quote a response from a VC telling that government would have better stay out of business) should warn for perils: targeting a segment with the wrong policy may be, not just useless and a waste of money, but also harmful, as it may also crowd out potential investments.

The shared conclusions of the papers are that public institution should intervene to tackle the externalities in cleantech sector, but how to do it and what are the best solutions have still to be defined. Moreover, along with cultural entrepreneurial disposition and appealing policy scheme boosting interactions, facilitating market and resource access and yielding capital (e.g. taxation discount, housing subsidies), a forceful legal institution that ensure intellectual property protection for innovative solutions is considered a driver to mobilize cleantech firms to relocate in low carbon cities (Kapsalyamova, Mezher, Al Hosany, & Tsai, 2014).

Another questionable thing about public policy and innovation, is to what extent foreign public policy affects domestic innovation effort. In other words, what are the boundaries of impact of a policy promoted by a country? One early signal in this direction is an eye-catching result of a report published by the World Intellectual Property Organization, according to which 44% of applications for patents filed in 2008 were filed by non-residents. Foreign market context does have an impact on innovators. Other studies have tried to explain dependence between strict foreign environmental regulation and domestic innovation. Moreover, results were conflicting. Lanjouw & Mody (1996) find positive correlation between regulation in US and innovation in Japan and Germany, while Pop (2006) does not find correlation between domestic innovation and foreign environmental regulation. Also, what are the feelings of entrepreneurs toward such issue? Was the policy supposed to benefit foreign competitors as well, domestic investors may dislike the increase of competition. Dechezleprêtre et al. (2013) answer this question looking at the wind industry. Their study focuses on patenting data in the period 1994-2005 for OECD countries. The question research, precisely, is how much public policies, both technology push and demand pull, affect innovation effort at home and abroad. The number of patents filed is a proxy for innovation effort of investors, while the annually added capacity of wind power is a proxy for the effort of public intervention. The approach resembles the PACE (Pollution Abatement and Control Expenditure) method, according to which the level of expenditures in devices to cut pollution should reflect policy effort. The authors argue that, given that the cost of generating power with traditional polluting sources is far lower (Bloomberg New Energy Finance, 2010, does the comparison between several sources across time) than the one related to the production of electricity from wind power, the magnitude of added capacity should reflect the magnitude of public policies. The policies considered of demand-pull nature are FITs and renewable portfolio standards, while public support to R&D represents technology push policies.

Concerning patents, other studies have used them as a proxy for innovation effort. OECD (2009) provides an overview of upsides (availability of data and information on technology type) and downsides (there are other options to protect innovation) of this proxy. Besides, in OECD countries the enforcement of intellectual property rights should be strong, and this makes the analysis quite reliable. To give an idea of magnitudes, in 1994 360MW capacity were installed, while 9,700MW in 2005. The number of inventions grew accordingly. Public R&D in wind power grew by 70% between 1994 and 2005 (from USD108m to USD182m). The results infer that public policy does have an impact both on domestic innovation and foreign one. The marginal effect of installations at home is 28 times more effective than marginal effect of foreign installations. Demand pull polices look more effective, while public support to R&D does not have effect on foreign investors. The conclusions suggest there are barriers to technology diffusion across countries and that understanding and managing these barriers can help in the environmental transformation. Thus, public policy, both domestic and foreign, is acknowledged as a determinant in cleantech VC deals.

Before going on, we want also to make a point on how much pervasive public policy and regulation have been so far in cleantech. Regulatory risk management has become a business process within the firms of the sector. Bürer & Wüstenhagen (2009) surveyed a sample of investors to draw a framework that depicts the strategies developed to tackle and manage dynamically regulation risks. They show that managers opt for managing risk either/both in an active (inbound and outbound) or/and in a passive way (at firm level). Active approach means hiring experts with inherent competence (inbound) or influencing the policy makers (outbound). Passive approach is about diversifying across technologies and countries both at the firm and at the fund level. The conclusion is that rather than just market and technology risks, literature should focus also on the regulatory risk, to get a deeper understanding of the scenario.

1.2.2 Other economic, social and cultural forces

Energy price & stock returns

Stock market and commodity prices may be drivers for the investments in cleantech. Colombo et al. (2016) carry out an analysis of VC deals in cleantech in 31 countries for the period 1996-2010, trying to single out the determinants. A hypothesis validated by the analysis is that oil price and cleantech deals have a U-shaped correlation. Increasing oil price poses an incentive to invest in alternative sources of power. A particularly steep increase would otherwise make energy companies focus in their core business rather than in alternative (potentially cannibalizing) business models. The cleantech companies involved are the ones from energy production sector (as mentioned in the introduction, almost 70% of the whole cleantech, PWC, 2015). The picture (Figure 6) shows graphically the correlation between oil prices and cleantech VC deals for the period 2004-2010.

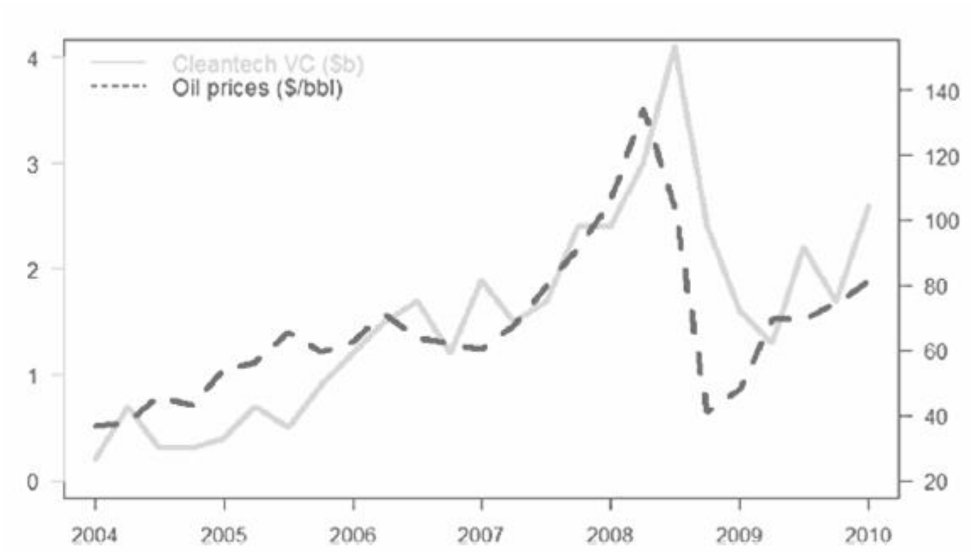

Figure 6 Correlation between oil price and cleantech investments. Source: Bloomberg, New Energy Finance (2012).

A complementary picture is provided by Kumar et al. (2012). They investigate the relationship between oil and carbon prices and alternative energy stock price. Had the oil price an effect on the stock price of clean energy firms (their result shows indeed that increasing in oil price and triggers a switching toward alternative energy, while there is no correlation between carbon stock price and clean energy firms stock price), it would be reasonable to make a connection between VC deals and stock prices of clean energy firms.

Media coverage & cultural dimensions

Colombo et al. (2016) validate also the hypothesis that media coverage has a positive correlation with VC cleantech deals. Doing advertising and informing stakeholders and potential shareholders about benefits (but also to make the product fashion) help in building image and reputation of the sector. This dimension deals with basic marketing theories on any product and can be classified as a communication phase. From a cultural point of view, referring to the Hofstede model, uncertainty avoidance is negatively correlated with the number of deals. Clearly, it fits with the high risk associated to the technology and the inability to have a clean vision on future. Concerning public institution, a stronger rule of law is positively correlated with the number of deals. As mentioned before, the environmental regulation, to be effective, should be credible and sustainable in the medium-long term. Government may also play a role committing itself in the market, that is promoting private and public partnership.

Another attempt to understand which variables affect cleantech investments decisions is done by Masini & Menichetti (2012). For the field of behavioural finance, they draw a pattern of decision making of investors. They call for the necessity of addressing carefully the need of such investors. Because there is no lack of capital, but rather lack of understanding what are the appropriate policy packages to attract capital (Usher, 2008). This study belongs to the same front of Mazzuccato and Semeniuk (2016) work, in the scope of customizing policies to customers (investors), but with a different (and deeper) approach. The authors declare their awareness of the fact that in economics decision making does not always maximize utility in a rational way, because cognitive and irrational factors intervene. Leveraging smartly these soft variables can be a tool to promote investments that are considered too risky by rational decision-makers. Also Wüstenhagen et al. (2007) point out the increasing importance, to understand the effectiveness of public policy, of factors that influence socio-political and community acceptance. The analysis is carried out surveying a sample of European investors, made of private equity and VC, commercial banks and corporations. These investors had a portion of cleantech investments in their portfolio. The framework developed assumes that the decision to invest in renewable energy depends upon three categories of behavioural factors: a priori beliefs (that are the result of personal previous experiences and background of the investor), a preference for some policies (depending on perceived stability and credibility) and the attitude to technological risk. Then, the share of renewable energy in the portfolio is supposed to improve the performance of the portfolio. An interesting point is that the business context resulted highly informed and rational in the decision making. A direct consequent is the preference on average for mature and less risky technologies. The proven reliability of a technology is far more influent than the design of public policies. It stands out also that the sample surveyed prefer short term-oriented incentives. This result conflicts with previous mentioned studies. Finally, a higher share of RE in the portfolio is associated with higher investment performance, and this may suggest a virtuous cycle after having entered the sector as a shareholder.

1.3 VC funding in cleantech

This section reviews in general the reasons that make VC, to some extent, still an underdeveloped mechanism of finance. Then, it digs deeper in describing the tricky aspects of VC financing in cleantech: the cash valley of death, the managerial valley of death, the uncertain exit mechanisms, along with the commodity nature of energy, are the recurrent problems in literature.

1.3.1 Inefficiencies in the market for VC capital

There are challenges to address that are VC-specific at a general level. The U.S. Small Business Administration (2012) find that 50% of the entrepreneurial IPOs in recent years are venture-backed despite only 0,2% of all firms receives venture funding. VC proved effective, but it still plays a marginal role at the aggregate level. If we envisage cash flowing through the chain made of investors backing VC (pension funds, insurance companies, endowments and wealthy private investors are typical sources of venture capital, e.g. Limited Partners), VC and companies (that get capital from VC), we can single out several issues at the interfaces and bridges to mend.

One problem, stemming from corporate decisions, generally driven by cost and risks assessments, is the sceptical approach that business organizations have toward external sources of finance. The Pecking Order Theory discusses the firm's demand for and use of finance (Myers & Majluf, 1984). The theory states that firms prefer to use internal sources first and then to fall into debt. Only if necessary, as a last resort, they consider equity-based finance. Looking at the UK landscape, Revest & Sapio (2012) comment that in UK, VC is hardly accessible to technology based small firms. According to Mason & Harrison (2004) most young ventures in the UK are not ready for investment. They lack solid plans. Nightingale et al. (2009) say that in UK entrepreneurs and VC find difficult to find each other. This is impressive if we think that UK is the country in Europe where VC is most developed.

Another known deadlock, when looking at VC, is the lack of information for stakeholders. Being private entities, they are not prone to doing disclosure. Kaplan & Lerner (2016) highlight also which are the challenges for VC given the lack of information about performances and quote databases and platforms to get data. They also conclude that VC is getting interest from policymakers and investors, but that the lack of data may be a problem.

The sub optimal exploitation of VC can have a double opportunity cost, because there is also a positive indirect effect of venture capital over innovation. Wüstenhagen et al. (2007) point out their importance in the commercialization of innovation, given the ability of VC to influence the expectation dynamics of other, less than fully rational investors. Messica (2008) tells that gut feeling plays a crucial role in the selection of the investments. Thus, VC is both a direct leverage to foster innovation and an indirect one in shaping a favourable environment by triggering additional investments.

1.3.2 The cash valley of death

The proper funding mode, according to literature, hinges upon the capital intensity of the assets and the risk associated with the technology. Figure 7 shows a matrix related to the issue.

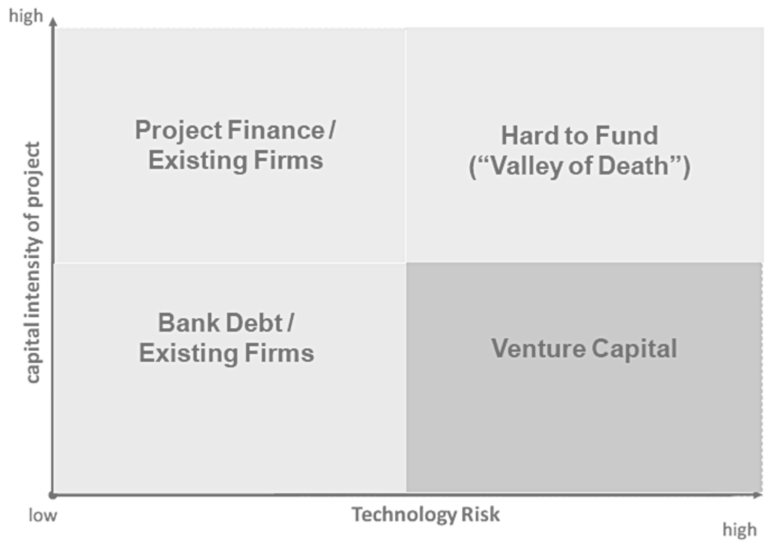

Figure 7 The matrix ranks at high level the relation between type of technology and financial actor. Source: Gosh and Nanda (2010).

To better define the concept of *technology risk*, we report the lifecycle of a general technology and main funding actors. In general, banks should be solid (to guarantee equilibrium of market incumbents) and their governance should prevent them from bearing important risks, so that they just lend capital where there is a guaranteed yield. Other actors, whose governance is designed to bear high risk and manage it through a diversification of investments portfolio, are more appropriate although the yield of the single investment is not guaranteed. A given risk is associated with a given stage of the chain. The lifecycle for a general technology is shown in Figure 8.

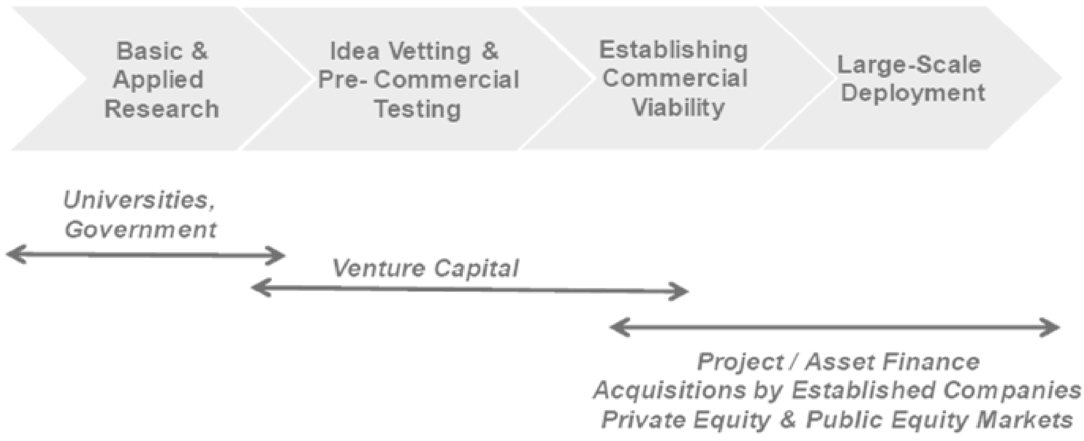

Figure 8 Innovation Chain for a general technology and financial actors. From early stages through later ones, the financial actors involved are designed to bear decreasing risk levels. Source: Gosh and Nanda (2010).

From the theoretical research in laboratories, going through early commercialization and scale-up, the risk is decreasing, because the odds of not selling the product are decreasing. Public actors intervene whenever the risk to bear is too high for any private investor (upstream stages), while, when the risk to bear is acceptable, the projects get funded through external debt finance, because the probability to repay it is high. VC is designed to fall exactly in between. This financial actor proves able to bear substantial risk, as long as the size of fund is not massive.

VC backing focuses on a high technology risk and low capital intensity projects. As a matter of fact, they are key capital flow providers in software and biotech sectors, by financing projects with low capital intensity and a commercial viability of 3-5 years, and that can be sold within the life of a fund (about 10 years). In IT sector, an example is Google, that got 40M$ from VC and went to IPO just 5 years after the first round of VC investment.

Early stage investors as venture capital should provide aid in the most hazardous phase (among other phases in the middle of the technology development) of the innovation chain, the so called “Technology Valley Of Death” (Grubb, 2004) or the “Cash Flow Valley Of Death” (Murphy et al., 2003). Ghosh & Nanda (2010) argue that some technologies for energy production face double risk during the innovation chain. If the technology works in the lab (it may work or not, but this risk exists for start-ups in any sector) it is still not granted that it will have success in the scale phase. It depends on the reliability of first commercial and demonstration plants, along with the infrastructure of the environment. For instance, producing energy with solar panels in the desert requires an effective and efficient infrastructure to carry it to households living downtown. Bloomberg New Energy Finance League (2010) describes accurately these two "Valleys of Death". The commercialization is the middle stage along the innovation chain where most promising prototypes face the tough challenge to succeed in it, standing in the middle between government-funded R&D and funding from customers' purchases. At the same time, this is also the area where venture capital and private equity investors concentrate their deals. We report it in Figure 9 the innovation chain for a cleantech technology.

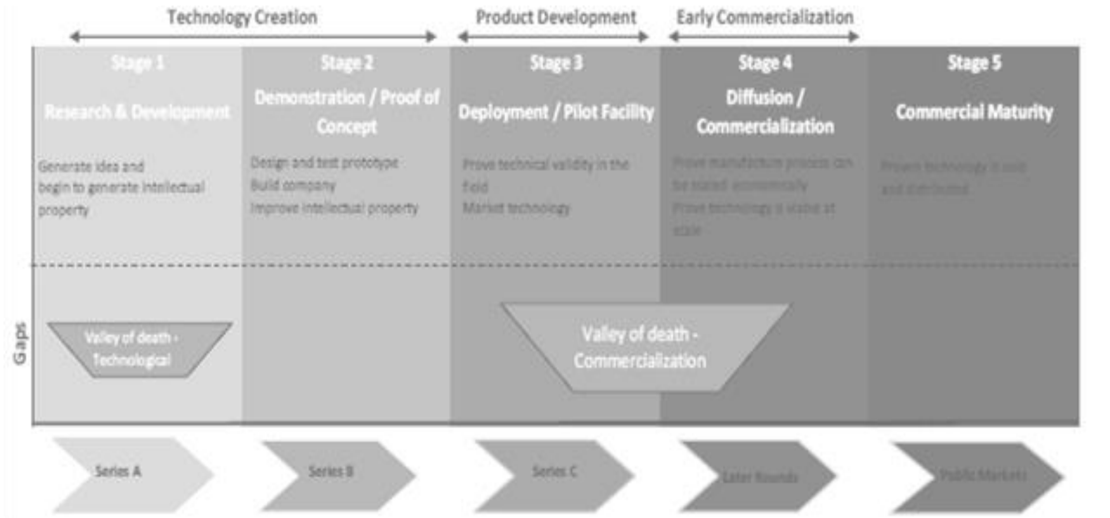

Figure 9 Innovation chain for a cleantech technology. It provides information about the two phases of shortage of funding for these types of technologies. Source: Bloomberg, New Energy Finance, 2010.

The picture provides a comprehensive description of the issue. While the first shortage of funding is not critical as research is generally filled by universities and national laboratories, the second one poses a more serious challenge. Bloomberg New Energy Finance League (2010) report argues that no private investor is designed to fund these types of technologies, far from the commercial maturity and often with size outweighing VC possibilities.

To reinforce the concept, if we compare Figure 8 and Figure 9 we see that there is overlapping between the phases in which VC is supposed to provide funding in a general technology lifecycle and the phases which suffer shortage of funds for cleantech technologies.

A contribute to understand deeper the financing process during the development lifecycle of renewable energy technologies is given by Lam & Law (2018). They provide an even more detailed and customized model of innovation chain for cleantech technologies.

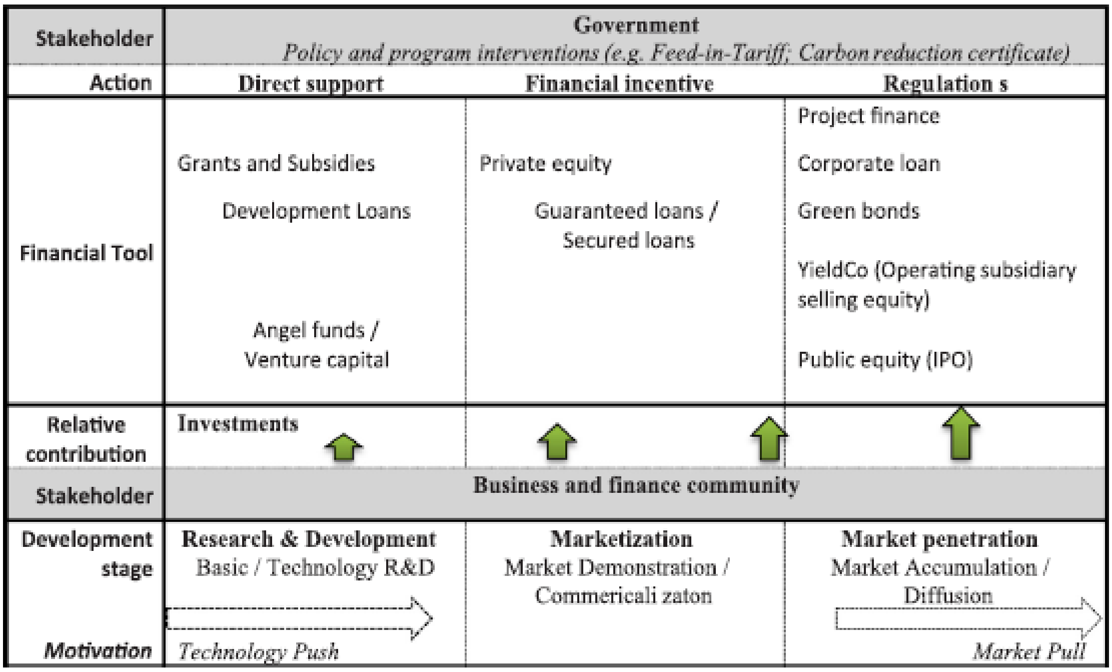

Figure 10 Diagrammatic model of the relations between stakeholders, cleantech projects stages and financial tools. Source: Law and Lam (2018)

With a multifaceted case study approach, they look at the different stages on the innovation chain and the relationships between the entrepreneur, the financial actors and the other stakeholders that shape the context, for different projects. Technologies included are onshore and offshore wind and solar power generation (the variety is covered also in terms of capital intensity and risk level). The authors argue in fact that the sample selection is based on variety in terms of technology coverage (mature and emerging technologies), diversity of funding types and regulatory policies (different financial tools, public interventions types and countries) and stage of completion (construction or operation phase of the project). The result of the study provides a diagrammatic model (Figure 10) depicting a canvas of project stage, financial tools and stakeholders' role. It highlights that the path of the project along the development cycle hinges upon availability of resources, technical maturity, financial viability and the support of government and regulation pattern.

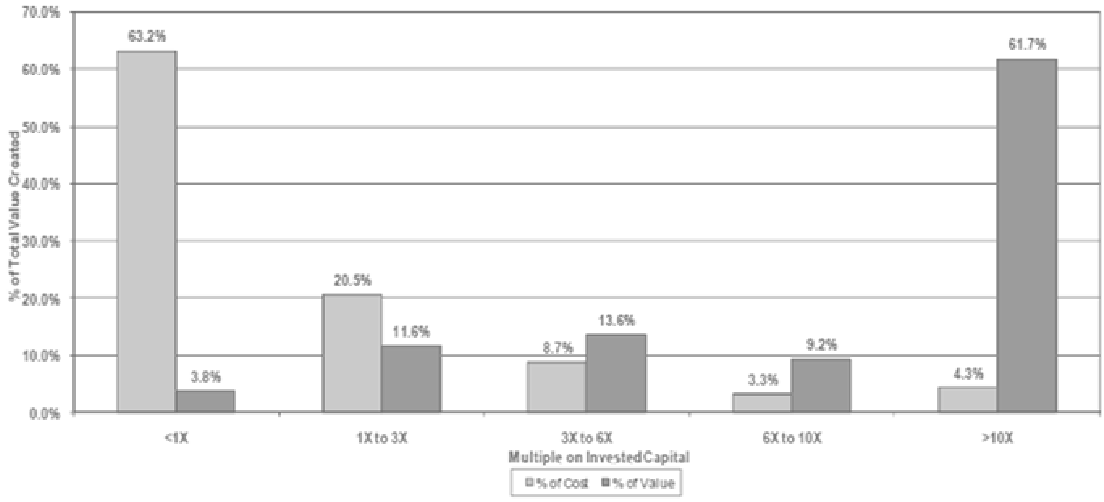

Figure 11 Breakdown of VC portfolio. This analysis is carried out by William Sahlman, based on 468 investments for the fund from 1990-2006. Source: Gosh and Nanda (2010).

The *capital intensity* is the other dimension. To explain why VC may not provide more than a given amount of funding, we introduce an example. Figure 11 and Figure 12 exhibit the distribution of returns for a VC portfolio to show how it does mitigation of risks.

The graph in Figure 11 tells that, given a VC portfolio, the 70% of returns are generated by 8% of money invested. On the other hand, 60% of money invested do not break even. Assuming, obviously, that a priori a VC cannot tell the winner from the loser projects, it needs to spread the resources across several projects to have the returns desired guaranteed. Had it put all the money in one project, the risk to end up with no break-even would be very high. For a VC fund that amounts to some hundreds of millions $, the amount of a single investment cannot be more than $50M.

In Figure 12 a simulation of funding portfolio provides an idea of the order of magnitude of capital invested and returns for a $300M VC fund.

Category of Outcome	Projected Value at Exit	Dollar invested per company	Share owned at Exit	Expected # investments	Total $ invested	Total $ Return
Early Failure	-	$ 5 M	n/a	5	$ 25 M	0
Complete write off	-	$ 8-15 M	n/a	5	$ 55 M	0
Money back	$ 50 M	$ 8-15 M	20%	5	$ 55 M	$ 50 M
Successful exit (low)	$ 200 M	$ 8-15 M	20%	5	$ 55 M	$ 200 M
Successful exit (medium)	$ 350 M	$ 8-15 M	20%	5	$ 55 M	$ 350 M
Successful exit (high)	$ 500 M	$ 8-15 M	20%	5	$ 55 M	$ 500 M
Total					$ 300 M	$ 1,100 M

Figure 12 Portfolio example for a $300M VC fund. Source: Gosh and Nanda (2010).

Some categories of cleantech projects are characterized by high capital intensity and this prevents them from getting VC funding. Gaddy et al. (2017) bundle cleantech sub-sectors, based on the capital requirements and the time of development of the innovation (there is positive correlation between the length of development phase of technology and the risk associated to that technology) and rank five categories, with decreasing capital intensity and length of development phase: *Materials, chemicals and manufacturing processes* include companies that generate new materials or adopt new chemical or biological engineering to either spawn or store or convert energy. Materials for energy generation include new collector materials for solar photovoltaics (copper, indium, gallium, selenide). Materials for storage include nickel, manganese, cobaltoxide to make up batteries. New manufacturing processes are engineered by firms to create known-compounds with new inputs. *Hardware integration* includes companies that sold tangible products, with known technology of parts but original combinations. Companies from this category are producers of electric automobiles and charge stations and other transportation equipment. They do not count on established supply chains and cannot outsource manufacturing capacity. *Software* includes companies selling software to electricity consumers enabling savings and a smart consumption of power. *Finance and deployment* include companies that acted as project developers for well tested technologies such as wind energy or solar photovoltaic. *Other services, consulting and recycling* include companies offering consulting for saving energy or gave access to recycling infrastructure.

Furthermore, Figure 13 classifies the main cleantech technologies according to the dimensions described. The top right quarter of the matrix includes technologies that faces a gap in funding, because they are unsuitable both for traditional entrepreneurial sources of funding and debt finance.

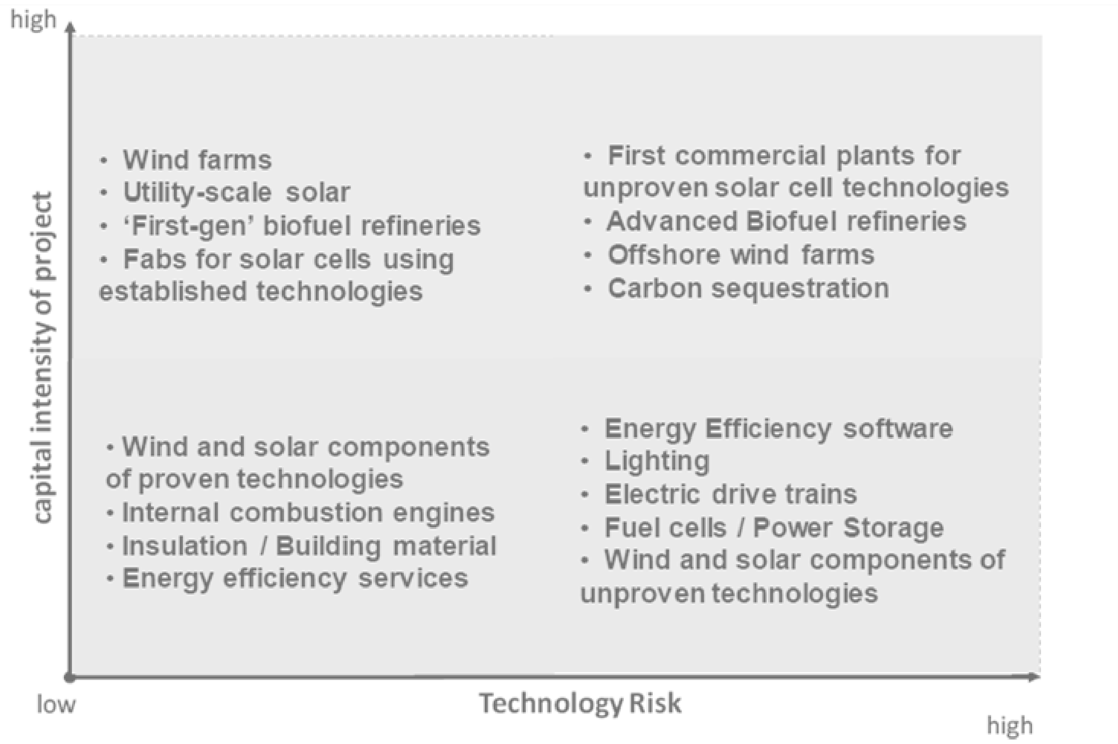

Figure 13 The matrix classifies cleantech technologies according to level of technology risk and capital intensity. Source: Gosh and Nanda (2010)

On the other hand, there are investments that show low risk and would not need VC. Cleantech projects with well-proven technology such as wind farms get funded through project finance and belong to established firms, not start-ups. For instance, Solyndra, a producer of photovoltaic systems with thin-film technology, had to raise $970M in equity and about $500M in debt (from a public entity), before going to IPO in 2010. This is a different order of magnitude from the one of Google's previous example or of the one we see on the figure above, assuming a portfolio is made of 20 start-ups on average. This is one of the reasons why many projects end up not being funded, despite being promising. Establishing larger funds may be one solution for the problem of capital intensity.

1.3.3 The managerial valley of death, exit opportunities, commodity nature of energy

Gosh and Nanda (2010) tell about additional issues for cleantech companies, more than just finance gaps. They talk about a lack of managerial skills, poor exit opportunities and problems related to the commodity nature of energy.

First, they define a “Managerial Valley of Death”. As managers from Oil&Gas usually work for big incumbents with relative low competition and massive available cash flow, they fail in leading entrepreneurial firms where competition is high and cash flow is limited. Other VC-based entrepreneurs may have not the capability to manage commodity pricing and regulatory uncertainties. If this is the case, we should note no performance improvement related to capabilities (e.g. monitoring) after the entrance of VC funds in cleantech firms. Also Randjelovic, O’Rourke, & Orsato (2003) point out a lack of managerial skills in the sector.

Second, exit mechanisms are for cleantech more critical. It is observed that, while for IT and biotech industries incumbents are prone to buy start-up, this does not hold for cleantech one. Oil&Gas giants are not willing to acquire new ventures. Or at least evidence is mixed. It seems that they have done some investments in renewable energies for marketing reasons rather than for real interest in shifting to a more sustainable business model. Pinkse & van den Buuse (2012) in a comparable cases study paper, observe how three giants of Oil&Gas such as Royal Dutch/Shell, Total and BP have approached to PV technology investments and describe their difficulties in integrating this renewable energy technology in their supply chain. Besides, they observe a “re-carbonization” trend given the investments of BP and Shell in tar sands. This schizophrenic behaviour suggests the state of confusion that such incumbents are facing: whether to promote and speed-up the energy transition (feeding the development of the new renewable business models) that is likely to phase out the incumbents themselves or to let these start-ups die and postpone as soon as possible this event (withstanding pressures from media, public actors, shareholders, etc.). A visible lack of trust of established giants towards cleantech companies may further freeze-up funding upstream the innovation chain, with VC not envisaging exit opportunities. It is possible that established traditional energy firms see themselves in the same situation as Laio, father of Edipo, when he was told by the oracle that the son will grow and kill him. Not willing to end up as Laio, they give up on feeding these start-ups. Neither, there is evidence that the market trusts the pattern according to which traditional energy companies should be the acquirers of renewable energy start-ups. Conversely, an event study approach by Palmquist & Bask (2016) on buyout acquisitions in cleantech in the period 1997-2014 for 273 announced and completed deals, concludes that the market trusts more a deal in which a traditional energy or mining company buys a homogenous firm rather than a renewable energy firm. Abnormal returns occur to be higher for homogeneous deals.

Moore & Wüstenhagen (2004) show the opaque experience of companies that have gone through IPO and traded their shares after IPO at lower prices. Zhong & Bazilian (2018), among the most recent literature, focus on the role of Oil&Gas established companies concerning the current energy transition, looking at their budget share pledged for renewable energy CAPEX. Although the best proposals to commit, the level of actual effort is still not engrossing. For instance, Shell, the biggest player in the industry, in 2016 reported a CAPEX of $200m on renewable. It is a very small percentage on $80bn revenues (*2016 Shell Annual Report*, 2016). Nonetheless, the authors mention also the pressures over such incumbents coming from both shareholders and stakeholders. For instance, the World Bank has decided to stop funding O&G projects after 2019 (World Bank, 2014), while Garcia, Cabeza, Rahbek, & Araujo (2014) state that in the next future the petroleum industry will be rated based on its ability to embrace the environmental issue, by diversifying sources of energy, integrate with local value chains and implement innovative technology. A model that O&G companies are experimenting is the corporate venture capital funding. Finding it difficult to integrate the operations of innovative and traditional companies and extending core capabilities, they turn to mentoring and funding with minority stakes such start-ups. This is a second-best solution compared to acquisition, that otherwise would be the riskiest solution, given investments necessary to acquire technical expertise, infrastructure, project management skills and distribution channels to operate renewable power plants.

The conclusion of the paper is once again a visible mixed success in the effort to embrace energy transition and integrating the new business models in the business strategy.

A solution (to the dualism incumbents and new ventures) may be firms that operate through proven business models in cleantech, such as some wind or solar energy producers, becoming “incumbents” that acquire cleantech start-ups.

Finally, the nature of the final product is another important issue. In biotech and IT, companies try to offer cutting edge products that meet the always fickler customers and their needs. Being energy a commodity, except for few ideological green people, it is the same whatever the source of production. An end-user cannot tell the source of production. And there is not grid parity yet. Decisions are driven accordingly.

1.4 VC impact on portfolio companies’ performance

This section reviews the main results in that branch of literature that studies the impact of VC on investee companies’ performance. It helps in understanding which are the main variables (related to investors and firms) to look at when inquiring this kind of question. Historically, the analyses carried out to outline the impact of VC funds on invested companies consider several dimensions.

Two big families of research questions concern the survival probability (and types of exit) and the economic, financial and operating performances. It is reasonable to believe that these two issues are interconnected. For instance, if we take two companies A and B not listed, and A is performing better than B over time, we expect higher odds for A to get a successful exit than for B. Types of exit considered as successful are in general acquisitions and IPOs, while performances can be measured looking to growth for number of employees, sales, total assets, for instance.

In general, it is possible to observe differences of performances between VC-backed and non-backed companies both before and after the investment. Pre-investments screening leads to the selection of most promising projects. In these cases, companies that receive the attention of investors are better than others per se, due to the goodness of the business model. VC then brings about funding and other value adding activities in the holding phase. Chemmanur et al. (2011), using the Longitudinal Research Database of the US Census Bureau (dataset of manufacturing private and public firms, investments for the period 1972-2000), inquire into the productivity gains from VC-backing for enterprises. Moreover, the analysis provides evidence about the correlation between VC-backing and productivity improvement and the success of the exit strategy. The firm efficiency is measured by the Total Factor Productivity (TFP), that is an indicator to account for productivity growth regardless the scale growth of the operations. When the TFP increases, the firm can produce more output with the same input. Their results tell that VC-backed companies considered are at any time more efficient than non-VC ones. This implies the goodness of VC both in screening and monitoring activities.

The ability of VC investments to impact positively on portfolio companies is to bring about networking and expertise contribution. VC investments in small enterprises can affect their performance also by reducing their financial constraints (impacting on investment-cash flow sensitivity). Firms, after to the investment round, are unburdened from the lack of funding and can better tackle growth opportunities. As a matter of fact, Bertoni et al. (2013), studying a sample of Spanish SMEs invested in 1995-2004 by VC, verify the correlation between the reduction of shortage of funds and growth and efficiency. But a VC company does not provide just capital, but also post-investments monitoring and value adding services. Performing well such activities would lead benefits both to the investor (through higher return) and to the entrepreneur (through improvement of performance).

It is worth noting that some studies about performances can be biased because of the survival issue. For instance, Al-Suwailem (1995) tells that surviving VC-backed companies show higher growth rates for assets, sales, revenues, R&D expenses and employees. Megginson & Weiss (1991) argue that the ventures going through IPO are in general larger and less prone to under-pricing than non-VC-backed ones. Can we say that VC-backed perform better than non-backed ones? As few firms survive, just a little portion of VC-backed companies (the virtuous ones) enters the analyses. There is another issue. Given that the VC portfolio is diversified and that it expects higher returns from a minority of firms invested, most of ventures are likely to die. Indeed, when the scenario for a company turns unfavourable (allegedly a living-dead company), VC attention and commitment dwindle (Gorman & Sahlman, 1989). For these doomed VC-backed companies one should observe degradation of performance and a negative exit. Thus, the sample selection and the definition of variables to observe are tricky phases. Manigart et al. (2002) carry out an analysis in Belgian VC market with a sample of VC-backed companies between 1987-1997 and 565 comparable non-VC-backed companies, to understand the impact of VC investments on the survival of invested companies. They find that VC-backed companies have a lower probability to survive than non-ones. This can suggest that VC managers manage risk at portfolio level, rather than at individual company level (they expect from the very beginning most of invested companies to die). More in detail, the results tell that public VC are better than private VC for the odds of survival rate. Among VC types, more aged governmental VC are more virtuous. Experience and learning curve as well as the vocation for less risky ventures can be the determinants. The study suggests also that the type of VC is as much (even more) important as receiving or not capital (Bygrave & Timmons, 1992).

Digging deeper to a second level of analysis on the impact of VC to ventures performances, several authors disentangle the type of VC, to give a broader scope. In general, VC funds can be private, corporate, public, or syndicated, when there is institutional heterogeneity. Other variables considered are demographic characteristics (as age and nationality of VC), the timing of investments (during financial crisis or prosperous economic cycles), the characteristics of Boards (level of expertise and experience of members, number of members). A wide variety of results emerge from the combination of the mentioned dimensions. Unfortunately, most of studies focus on single countries, and it lacks cross countries evidence.

Alperovych et al. (2015) study the correlation between Private VC and Governmental VC and efficiency of recipient firms. Analysing a dataset of 515 Belgian firms invested between 1998 and 2007, they argue that VC investments contribute to efficiency improvement of investee firms but highlight a difference within the categories of VC. Differently from PVCs, GVCs determine a degradation of efficiency. This raises doubts about the negative impact of public funds on the economic landscape. The literature suggests that GVC, being less prone to risk, selects companies from industries not characterised by high growth (Leleux & Surlemont, 2003), but from more stable and with easily forecastable cash-flows. Less need for attention may translate in less actual attention, thus consequent poor monitoring and control. The difference in performances can originate also from the different governance (Cumming and MacIntosh, 2007) and less efficient compensation terms for GVCs (more fixed than performance based, Cumming & Johan, 2013). GVC can be not fully independent in the decision making and this latter can lead to sub-optimal decisions. A study of Croce et al. (2018, Forthcoming) on the impact of GVC and PVC on invested companies' employment growth, reveals that GVCs-backed firms experience employment growth better than PVC in period of normal economic activity (this is unexpected but confirm the thesis that GVCs have screening capabilities), while Companies funded during the years around the financial crisis by PVCs experienced higher employment growth than those ones funded previous the crisis. The idea is that a fund lasts 3-5 years and when investment is done, it goes through the crisis anyway, because the limited partners (i.e. public pension funds, corporate funds, insurance companies, etc.) want their capital to be invested (Balboa et al., 2017; Marti' and Balboa, 2007). PVCs increases their commitment and put extra-effort because they must gain the returns anyway. During crisis, financial constraints are severe for non-invested companies, so differences in performances should be remarkable: GVC is expected to perform worse in terms of employment growth, because of the lack of performance-based retribution and pressures from public to invest in depressed companies.

Though public funds have a dubius impact on performance on ventures, syndicated investments from both PVC and GVC have been collecting public approval. Syndication can be a potential source of augmented capability in the screening process thanks to double control (P. A. Gompers & Lerner, 2004), and in the monitoring and controlling process, enjoying synergies in advising. Besides, it is guaranteed the access to governmental network and contacts to facilitate the entrepreneurial firm. On the other hand, differences lead communication costs (D. J. Cumming & MacIntosh, 2007) that must not outweigh benefits. Free riding can also be a problem whenever there is heterogeneity and it cannot tell the performance contribution of actors. Cumming & Johan (2013) study the impact of VC backing and the type of it on the successful exit of investee companies. They account for GVC, PVC and syndicated investments. The analysis looks at the VICO database, with a good geographical coverage, different from previous mentioned studies that look to one country. The results tell that IVC have higher probability of a successful exit than GVC. Confirming the premises, syndicated VC lead to higher probability of successful exit than PVC. However, there is no evidence to attribute the better performance to institutional heterogeneity or size.

We are about to consider these results to set up the research question.

2 Research Question & Methodology

This chapter introduces the research question of the study, aiming at partially filling in the gap not covered yet in literature. It is then explained the methodology of the empirical analysis: the processes to build the database, to identify cleantech companies and to get the final sample along with the econometric model.

2.1 Theory & Hypotheses development

We have seen that the cleantech's dawn and development is a challenge involving physically and emotionally social and economic actors, being the environmental topic at stake. Nonetheless, what is going to be the engine (and who will be in charge) of the energy transition is not clear yet. Entrepreneurs and their ideas will play a crucial role. But more crucial will be the role of the financial actors in charge of providing capital to these projects, both in early and in later stages of their lifecycle. When the technology is in early stages along the innovation chain, there is no even cash flow generated in the market. VC has not proven as much risk prone as one might envisage.

In the literature of the history of VC and cleantech, some results tell that other sectors such as IT and biotech have been preferred because of operating reasons, exit opportunities and return rates. But capital flow (i.e. investments) depends essentially on the dualism risks and returns (Markowitz, 1952). These two dimensions are not absolute, but perceived, and public institutions can distort their perception. This is what they do when increasing environmental regulation. More information will drive a more aware and virtuous decision-making process, also for public actors that can address market imperfections with more effective results.

Given the ambiguous anecdotal evidence, emerging from the boom and bust cycles of investments across the last 20 years and the heralded lack of management skills in the sector, we call for a deeper understanding of the relationship between VC and cleantech firms. Our thesis is that, shedding a light on how VC finance affects the growth performance of the invested cleantech firms, would enable public actors, among other things, to decide to insist more (and to target better) on incentivizing VC investments in the sector by shaping risks and returns perception (hedging risks and pricing social, rather than economical, returns). We argue that the research providing objective results by leveraging quantitative approaches will help to unfreeze the deadlock.

Triggering VC investments may have a multiplicator effect as well. Manigart and Sapienza (1999) describe the role of signaling that a VC company exerts when investing in a company, catching the attention of additional (bigger and more risk adverse) investors. Was the hypothesis that clean energy sectors show the network economics dynamics validated, the triggering effect would be even louder. Had not VC positive impact on performance of invested companies, public actors would opt to both/either understanding better the reasons and the pitfalls (promoting solutions as education and mentoring) and/or turn the attention to other formal or informal financial providers, such as crowdfunding (D.J. Cumming et al., 2017).

To the best of our knowledge, no one has studied the impact of VC on growth performance likelihood of cleantech invested companies before. Though our topic would be exclusive for cleantech, literature on how venture capital investments affect the characteristic and the life of portfolio companies is massive.

The correlation between VC investments and target companies' performances is studied in two phases of the ventures' lifecycle: before the investment and after it. Indeed, VC can play a role both in the pre-investment process (i.e. screening), and in the post-investment monitoring phase of backed firms. Once entered in the firms' management, some value adding services are brought by VC (Sapienza et al., 1996), as coaching and mentoring, furthermore, reputable VC funds can also provide contacts' network to VC backed firms (Hsu, 2006).

Several studies assess the VC impact on firm performances through different measures of firm growth, such as sales and employment growth (Alemany & Martí, 2005;

P. Gompers & Lerner, 2001), TFP productivity (Chemmanur et al., 2011). Nonetheless, as Gompers and Lerner (2001) identified, the economic impact represents an open issue in the VC academic literature. Marti' et al. (2011), studying a sample of Spanish SMEs invested in 1995-2004 by VC and characterized by low-medium technology level, verify the correlation between the reduction of shortage of funds and growth and efficiency. Their results tell that VC-backed companies considered are at any time more efficient than non-VC backed ones. In fact, the superior performances of financed firms are due both to VC commitment and to their greater business opportunities. The superiority of backed firms could be linked to the screening abilities of VC.

The next section introduces our hypotheses through which we test the relation between VC investments and cleantech companies. Our main interest is to understand whether VC investments bring about performance improvement to the investee cleantech companies. Thus, it is divided in two parts: firstly, we set-up the hypotheses for testing monitoring and value-adding capabilities of VC; secondly, to investigate the possibility that our results are driven by selection bias, we test whether VC-backed companies are better than non-ones before the investments (this would let us detect the screening capabilities of investors in this sector as well).

Monitoring

According to Jensen & Mackling (1976), monitoring activities on invested portfolio firms (Admati & Pfleiderer, 1994; Lerner 1995) support VC managers in reducing agency costs and increasing portfolio firm performance. But agency costs theory disregards the coaching function played by VC (Colombo & Grilli, 2010). VC is welcome by entrepreneurs as it delivers not just capital, but provides post-investments monitoring and value adding services (Croce et al., 2013), such as networking with customers, suppliers and banks, knowledge and moral support (Berger & Udell, 1998), expertise in operational planning (P. Gompers & Lerner ,1999). Performing well such activities would bring positive results both to the investor, through higher return, and to the entrepreneur. Early stage firms and high-tech industries in particular benefit from such value adding activities (Aspelund, Berg-Utby, & Skjevdal, 2005; Colombo & Grilli 2005). Alemany & Martí (2005) study the economic impact of VC on invested firms in Spain. They find that VC determines a higher growth for employment, sales, total and intangible assets and that there is positive correlation between the growth of these dimensions over time with the cumulative VC investments. It is questionable whether for cleantech companies there is a contribution from VC in terms of knowledge and networking. According to the Managerial Valley of Death, the lack of managerial skills in the sector (Ghosh & Nanda, 2010; Randjelovic, O'Rourke, & Orsato, 2003) and the problems inherent in the commodity nature of energy, keep us from taking for granted positive conclusions. Therefore, we posit the following hypothesis.

H1. VC-backed cleantech companies are more likely to grow than non-backed cleantech ones after the investment.

For the next level of analysis, it is worth to consider venture capital fund related variables as the institutional typology and heterogeneity, demographic and cultural characteristics, the timing of investments (during financial crisis or prosperous economic cycles), and the characteristics of Boards.

Several authors clear up the type of VC to give a broader scope. Alperovych et al. (2015) underline a different contribution to efficiency improvement within the VC categories, inter alia, GVC investments would cause a degradation in efficiency. This raises doubts about the negative impact of public funds on the economic landscape. The literature suggests that GVCs, being less prone to risk, select companies from industries not characterized by high growth (Leleux & Surlemont, 2003), but from more stable and with easily forecastable cash-flows. Less need for attention may translate in less actual attention, thus consequent poor monitoring and control. Indeed, the difference in performances can originate from the different governance (D. J. Cumming & MacIntosh, 2007) and less efficient compensation terms for GVCs (more fixed than performance based (Cumming & Johan, 2013)). GVC can be not fully independent in the decision making and this latter can lead to sub-optimal decisions. Our second hypothesis aims to understand if there is a different impact on performance based on the institutional typology of the investor.

H2. IVC-backed cleantech companies are more likely to grow than non IVC-backed ones.

Even though the impact of GVC proves to be not so worthy, syndicated investments from both PVC and GVC have been collecting public approval.

Double control guarantees superior capabilities in the screening process (Gompers & Lerner, 2004), while in the monitoring and controlling process, enjoying synergies in advising. More in detail, it improves decision making through complementary expertise, pooling experience that mitigates adverse selection, signalling quality of the business model to the market and potential acquirers, sharing the risks of the investment (enabling to take decisions that would be too risky without pooling of risk), mitigating hold up threat from the entrepreneur (given the lower investor commitment, she behave to maximise exit opportunities).

On the other hand, communication costs (Cumming et al., 2007) and free riding are major issues. Confirming the premises, syndicated VC lead to higher probability of successful exit than PVC. However, there is no evidence to attribute the better performance to institutional heterogeneity or size. Our third hypothesis aims at testing the benefits of syndication.

H3.Syndication of VC investments (i.e. the presence of more than one investor) in cleantech increase the odds of growth for investee companies.

An alternative approach focuses on how to ensure monitoring through corporate governance demographic and cultural characteristics. Participation to company's boards makes VCs bringing value to the firm, sharing their expertise and knowledge (MacMillan et al. 1989; Hellmann and Puri, 2000; Hellmann and Puri, 2002). Therefore, the presumed superior impact is due to the VCs efforts to ensure that the portfolio company is well-managed, participating in strategy or recruiting when needed. Alemany & Martí (2005)'s study shows that VC experience result determinant in the outcome. In light of this results, our fourth hypothesis states:

H4.Experience of VC investors in cleantech increase the odds of growth for investee companies.

Lastly, as it emerges from previous academic results, we consider that the distance between investors and investee companies affect the impact on performance. When investors and entrepreneurs have the same cultural background and/or speak the same language, it is reasonable to assume that information asymmetries dwindle, and networking and value adding activities have better outcome. Moreover, Cumming et al. (2017) posit positive correlation of the geographic distance between investors and entrepreneurs and the exit outcome. Similarly, we want to test whether it holds for cleantech investee companies as well.

H5. Cross border investments of VC in cleantech increase the odds of growth for investee companies.

Screening

VCs' investments are not randomly targeted. VCs often show pre-investment screening capabilities, acting as a 'scout' in the selection of better performing firms (Baum & Silverman, 2004; Chemmanur et al., 2011). This statement assumes an underpinning capability of identifying future potential and does not consider the consequences in future development determined by selection criteria (Shepherd & Zacharakis, 2002). As a consequence, the superior performance of VC-backed firms might be determined by VC ability to select companies (Gompers and Lerner, 2001). Companies that receive the attention of investors cannot be defined as better than others per se, because VC cannot spot all the firms looking for financing. As proof of this, the number of failures is far from derisiveness (Gorman & Sahlman, 1989; Manigart et al., 2002), which might point out some imperfections in the selection process.

Even though a study by Baum & Silverman (2004) suggests that VC-backed start-ups outperform non-VC-backed ones, the question of causality remains unsolved. Furthermore, Chemmanur et al. (2011) find that the efficiency of VC-backed firms, before the first VC round, is higher than that of non-VC-backed counterparts.

On the other hand, some authors have not found evidences of a positive screening effect, looking to the correlation between higher growth of VC-backed firms and the likelihood of getting VC financing (Bertoni et al., 2011; Balboa et al., 2006). For our purpose, we want to test whether in cleantech, VCs select the ones that show better performances before the investment. Answering this question would allow us both to read better results for monitoring and value-adding capabilities (in case there is selection bias) and to understand whether VC are able to detect better business models.

H6. VC-backed cleantech companies show higher performances than non-backed ones before the investment.

VCs' economic impact has been studied relative to innovation and job creation. Academic research shows a positive correlation between venture capital and innovation (Hellmann & Puri, 2000; Kortum & Lerner, 2000), where innovation has been proxied by the number of patents. In the literature, patents act as a signal: an economic tool to overcome information asymmetries (Lahr & Mina, 2016). In a sector as cleantech, where information asymmetry is a prominent issue, we believe that there is need for signaling. It is worth to test whether in cleantech this holds. For this reason, our seventh hypothesis states:

H7. VC-backed companies show a higher innovation rate than not backed ones before the investment (i.e. patents act as a signal).

2.2 Methodology and data

In this section, the methodology to build the final database, the identification process of cleantech companies as well as the model through which we test the hypotheses of research are reported. The final sample to test the hypotheses is made of cleantech companies exclusively.

2.2.1 Overview of the cleantech market

Over time, the whole investments in cleantech have been growing at a notable pace. It passed from $88bn in 2005 to $332.1 bn in 2018 (Bloomberg New Energy Finance, 2018).

In 2018 it was reported an investment fall down 8% against 2017: solar deals dropped 24% to 130.8 billion due to declining capital costs, while offshore wind projects featured strongly, attracting $25.7 bn. Specifically, Europe saw clean energy investments jumped 27% to $74.5 bn (Figure 14).

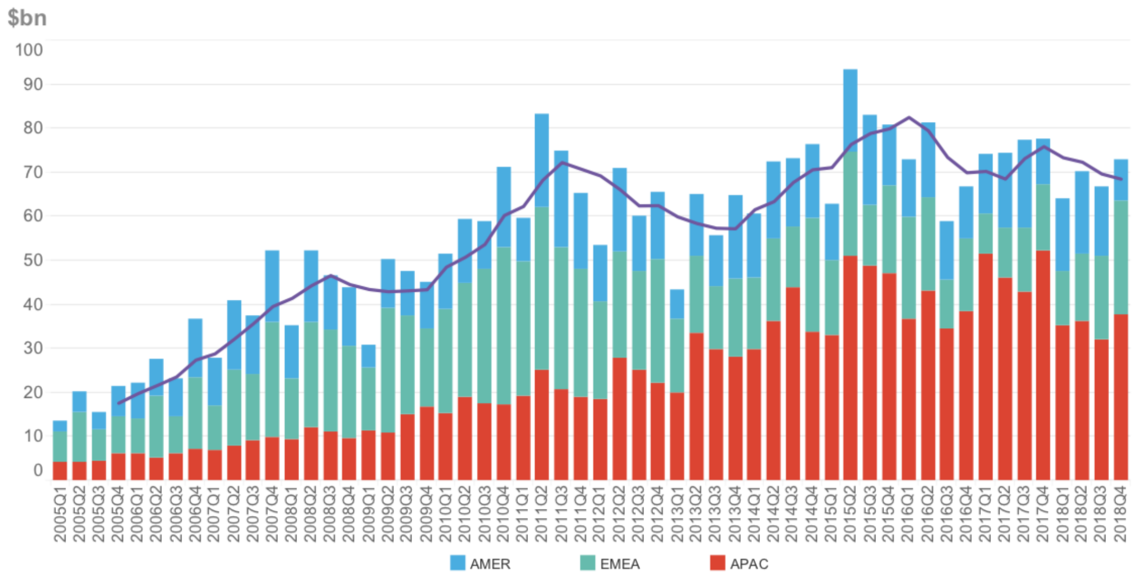

Figure 14 Global investment in Clean Energy by region. Source: Bloomberg New Energy Finance (2018).

The wide spectre of cleantech technologies implies that the aggregate data of the sector may be just an average that does not reflect precisely each individual case. When variety is high, the arithmetic average does not give precise information. Thus, it is required to treat each category within the sector separately. In Figure 15 EMEA data are reported according to three sectors categorization: solar, wind and other (i.e. biofuels, hydro, biomass, waste, geothermal and marine).

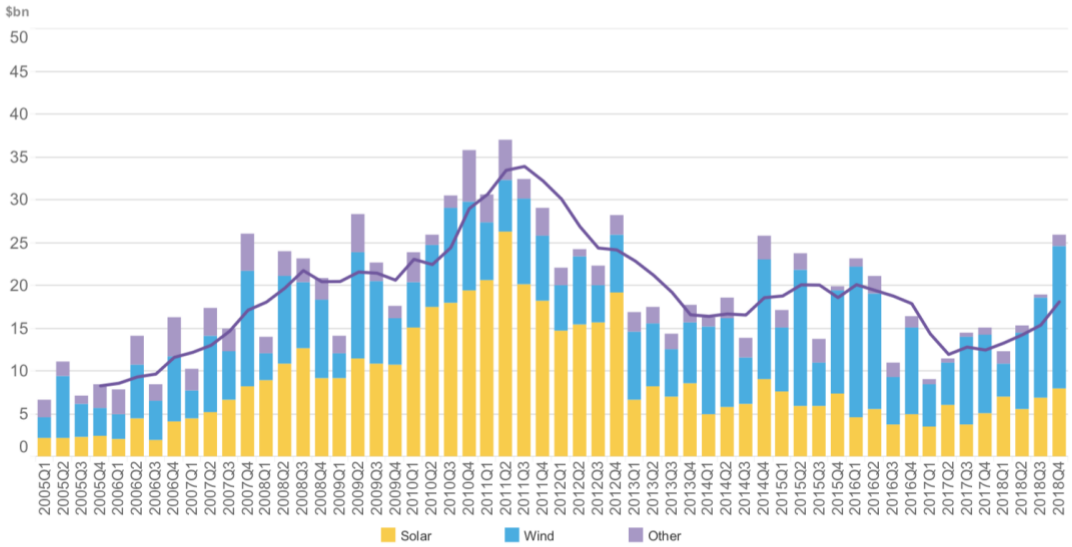

Figure 15 Investments in Clean Energy in EMEA by sectors. Source: Bloomberg New Energy Finance (2018).

Looking at financial flows' providers (in Figure 16), they are categorized into asset finance, public market, small scale solar and VC and private equity (PE).

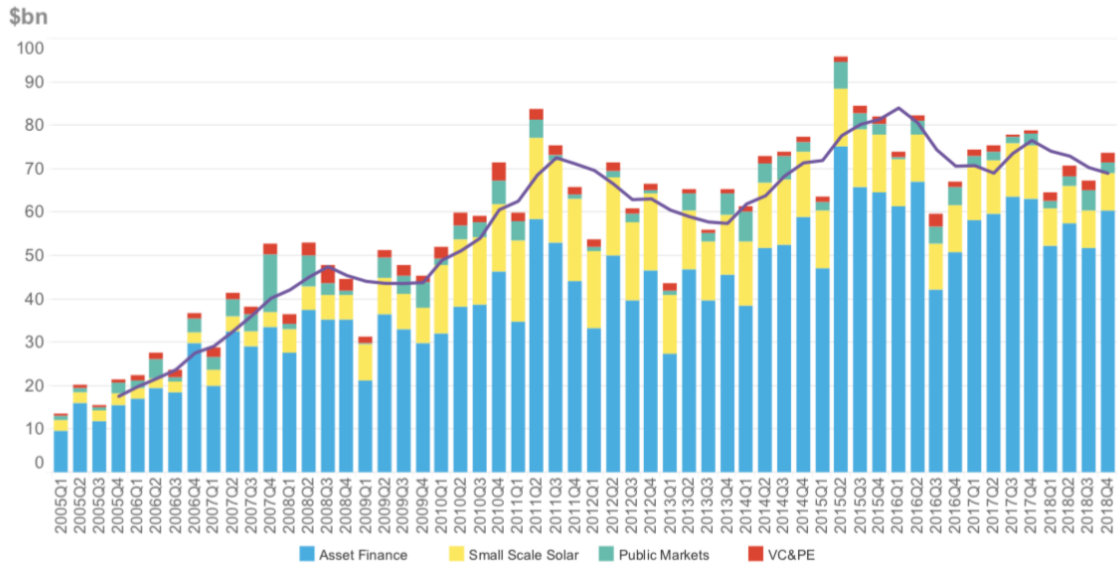

Figure 16 Global Clean Energy investors. Source: Bloomberg New Energy Finance (2018).

We see a positive result concerning global VC and PE: deals leap 127% to $9.2 billion, the highest since 2010. OECD (2017) reports in the Entrepreneur at Glance report an overall European VC investments accounting for less than $1bn in 2017 in cleantech, against almost $2bn in biotech and $2.5bn ICT sectors. As Figure 17 shows, the European VC market is remarkably underdeveloped if compared to the US one.

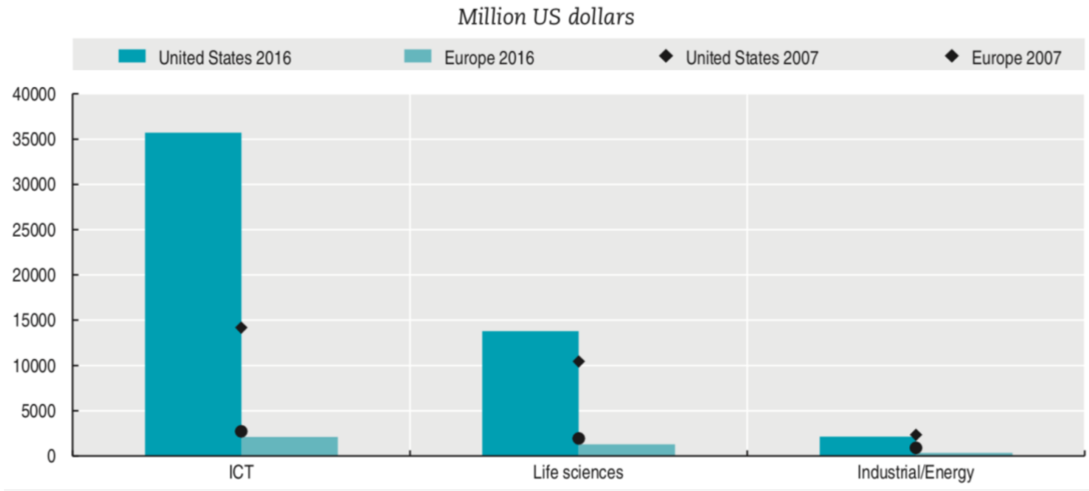

Figure 17 Venture capital investments by sector. Source: OECD (2017).

2.2.2 Sample construction

The process to set-up the final dataset is made of three steps. First, we get data on firms invested by VC and on non-invested firms, as these latter are useful as a control group. Second, we identify in the dataset the companies classified as cleantech. Third, we drop all the non-cleantech companies and the companies for which we do not observe necessary accounting data.

VICO updated companies and control group

The perimeter of analysis is the European landscape. We source investment and investors data from the VICO Updated database, the latest version of the VICO project[7]. The aim of the project was to investigate the European impact of venture capital, in terms of VCs' capability to screen high quality companies and to determine an increase in their

[7] *A complete description of the VICO database and included variables is provided in Bertoni & Martí (2011)*

performances. The VICO Updated version is the application of project “RISIS- Research Infrastructure for Research and Innovation Policy Studies“ funded by the 7th Framework Programme of the European Commission with to aim to enlarge the old VICO database (see Bertoni & Martí (2011)). Companies collected in the database share these common features: i) their birth occurred after 1/1/1988[8]; ii) have received the first venture capital or angel investment at least in 1/1/1998; iii) are located in seven European countries (Belgium, Finland, France, Germany, Italy, Spain, United Kingdom) or Israel. The invested listed companies have been retrieved by merging two commercial databases (Thompson One and Zephyr) and the free online database CrunchBase (www.crunchbase.com). The main source of data was Thompson One, followed by Zephyr and then CrunchBase. The database was enlarged of additional accounting information through Orbis. Accounting data are available for 14,425 companies (80.75% of the sample) from 2005 to 2014 where available.

Overall, the VICO database is considered unique in the largeness of companies reported (17,863), the country coverage, and the extent of information gathered (thanks to the combination of data provided by different proprietary datasets, i.e. Thompson One Private Equity, Zephyr, CrunchBase and Orbis).

The Control Group, defined as a sample of similar non-invested companies, was constructed by searching on Orbis. For each invested company, we asked a sample of 10 non-invested companies similar in terms of age, industry and country. The largeness of the control group gives the possibility to develop econometric studies and select the non-invested companies more similar to the invested group. Companies presented simultaneously in the VICO Updated and the Control group were removed from the database.

[8] *The database also contains information on companies for which the foundation year is not available (5,475 companies).*

Cleantech companies' identification

In a second moment, we had to identify the sub-group of cleantech companies within the total sample, in order to test our research hypotheses. The lack of a sharp definition and the cross-industry aspect of clean technologies made the cleantech business model recognition phase somewhat entangled. A mixed methodology has been implemented.

One method consists of two exogeneous selections outside the VICO database. We drew on the reports annually published by the Cleantech Group, the so called "Global Cleantech 100": since 2009, CTG yearly presents a list of most innovative global companies that will provide cleantech solutions to solve tomorrow technology challenges. Appointed companies are voted by a panel of experts in term of innovation market and feasibility. Those highly scored are included in the Global Cleantech 100. We select from the ranking just the European still working companies and we mark them as cleantech in the database.

The second exogenous methodology consists of a personal check on the websites of Italian and English companies reported in the old VICO.

Additional cleantech companies are identified through a text analysis. In the VICO Updated database and in the CG, companies are labelled as "cleantech" by counting how many times appear words related to a dictionary beneath the items "Primary Business Line", "Full Overview", "Trade Description". Companies for which the number of meaningful words is bigger than 1 are marked as cleantech. The dictionary is reported here ([9]). Douglas J. Cumming, Leboeuf, & Schwienbacher (2017) also use a text analysis to identify cleantech projects with a dictionary that resembles our one. This enforces the goodness of our approach.

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[9]*Selected words are: cleantech, clean, green, renewable, sustainable, hydropower, PV, solar, wind, biomass, geothermal, biofuel, biomaterial, biodiesel, water, emission, carbon, recycling, waste, efficiency, hybrid.*

We get 420 cleantech companies from the "exogenous" process, 307 invested firms and 1537 non-VC-backed from the text analysis. Overall, we got 2204 cleantech companies (the intersection of groups is not nil).

Matched cross section sample

Once identified cleantech companies, we drop all other ones from our dataset. We have 2194 cleantech companies, 666 VC invested and 1528 from control group. Concerning VC invested companies, we keep the ones for which we observe accounting data in the year of the first investment received. We drop also from the whole sample companies for which we do not observe at least one of the items "Fixed Assets", "Age", "Turnover". The reason is that these are the performances adopted in literature to infer on companies' growth. The screening sample is comprised of 138 VC backed companies and a control group made of 1'349 companies, for a total of 1'487 companies. For VC backed companies we have a unique observation per company related to the first investment year, while for the control group we have in general more than one observation per company.

To control for the selection on observables and get the sample for the monitoring analysis, we resort the propensity-score matching function (PSM) to extract a matched sample. The method finds for each VC-backed firm a group of 10 control group companies, that had the most similar probability to receive financing. Matching is performed using nearest neighbour PSM (see Croce et al. (2018, Forthcoming); Croce & Martí (2016)). Propensity scores were computed by estimating a probit model in which the dependent variable is the probability of receiving VC and the independent variables include age in logarithm, size (measured by the log of sales and fixed assets), as well as year, country and industry dummies[10]. We are able to find a suitable matched cross section sample for the monitoring analysis, made of 684 companies, 135 VC-backed between 2005 to 2014 and 549 not VC-backed.

[10] *As a robustness check, we also include sales growth (measured as the difference between the average of five years after the first investment and five years prior that time in logarithm).*

2.2.3 Model specification

We want to study how much access to VC and different typologies of such investors affect portfolio companies' performances, in cleantech. Thus, a general model, that takes into account also other control variables, is defined as:

$$Growth = f(VC\ backing, VC\ diversity^{11}, Controls) \quad (1)$$

To draw the model, we take inspiration from Brown & Earle (2017) that study how much financial access affects the employment growth of portfolio companies,

$$\Delta \mathrm{employment_i} = \alpha_0 + \alpha_1 \mathrm{lnAge_i} + \beta_1 \mathrm{VC_i} + \beta_2 \mathrm{EquityInvested_i} + \mathrm{R_i} + \mathrm{S_i} + \mathrm{T_i} + \varepsilon_{\mathrm{it}} \quad (2)$$

Where, observing m companies, $\Delta \mathrm{employment_i}$ is the difference between the average number of employees in the three years after the investments and the average number of employees in the three years before it, for company i. $\mathrm{VC_i}$ is a dummy variable that takes 1 if the company i receives VC funding, 0 otherwise. According to Grilli & Murtinu (2014), the funding provided to financially constrained companies should affect employment growth, and $\mathrm{EquityInvested_i}$ accounts for it, while $\mathrm{lnAge_i}$ takes the natural logarithm of the age of the company at the time of the investment. Other variables to include are dummies related to the sector, the year and the country, to account for cross sectional differences related to them.

We slightly modify equation (2) for our purposes, in order to encompass other performances that determine the growth of companies, along with digging down into the characteristics of investors. We opt for a Probit model:

$$Pr\ (Growth = 1) = \Phi\ (x'\beta) = \int_{-\infty}^{\frac{(x'\beta)}{\sigma}} \frac{1}{2\pi}\ e^{\frac{-z^2}{2}} dz$$

[11] *$VC\ diversity$ is a vector of variables looking at VC institutional nature (e.g. GVC, PVC,…) as in (Douglas J. Cumming, Grilli, & Murtinu, 2017), and other demo cultural features.*

$$Growth_i = \begin{cases} 1 \;\; if \;\; \Delta performance_i > 0 \\ 0 \;\; if \;\; \Delta performance_i \leq 0 \end{cases}$$

$Growth_i$ is a dummy variable for company i, that takes 1 if the difference between the average performance of the company in the five years after the investment and the average performance of the company in the five years before it, is positive, and 0 otherwise. Along with Employees and Sales, that are the two main observed variables in literature when studying the growth of entrepreneurial ventures, we observe Total Assets, Intangible Assets as Alemany & Martí (2005), and Fixed Assets.

To test H1 (i.e. monitoring capabilities of VCs on cleantech firms), the equation is

$$x'\beta = \beta_0 + \beta_{VC} * VC_{backed} + \sum_k C'\beta_k$$

Where the vector of control variables is

$$C = [Age \;\; EquityInvested \;\; Sector \;\; Year \;\; Country]$$

VC_{backed} takes 1 if the company is invested, 0 otherwise. To understand whether VC-backed companies increase the probability to grow more than non-invested ones, we need to test $\beta_1 > 0$ at some levels of significance. Concerning control variables, we include country dummies, industry dummies and year dummies which allow us to control for cross-sectional differences among countries, industries and across time, respectively. For Age and $EquityInvested$ we take the natural logarithms.

The equation of H2 is

$$x'\beta = \beta_0 + \beta_{IVC} * IVC + \beta_{captive} * captive + \sum_k C'\beta_k$$

H2 aims at testing the value adding provided by private venture capital in respect to other forms of funding. For this purpose, we disentangle the VC typology into private venture capital (IVC) and not independent venture capital firms (captive). If there is at least

1 independent venture capital investor, the IVC dummy takes 1, 0 otherwise. On the other side, the $captive$ dummy takes 1 if there are no IVC investors in the round.

To test H2 we need to perform the following Wald test for

$$\beta_{IVC} - \beta_{captive} > 0$$

To test H3, the equation is

$$x'\beta = \beta_0 + \beta_{mono} * mono + \beta_{synd} * synd + \sum_k C'\beta_k$$

H3 aims at assessing the superior value adding services provided by investments, when those are carried out by more than one investor. For this purpose, we distinguish among $mono$ investments, and $synd$. Among invested companies, each observation takes dummy $mono$ equal to 1 when the investment is made by just one investor, 0 otherwise. Each observation takes dummy $synd$ equal to 1 when the investment is made by more than one investor, 0 otherwise.

We resort to the Wald test to verify the inequation

$$\beta_{synd} - \beta_{mono} > 0$$

In H4 we want to assess if the experience of venture capital can increase the performance of VC backed firms. It is reasonable to assume that experience can be given either/both by being elder (in terms of age) or/and by managing more funds (piling up experience by diversifying the activities). For this reason, we divide H4 in two parts.

To test H4.1, the equation is

$$x'\beta = \beta_0 + \beta_{mat} * maturity + \beta_{not\_mat} * not\_maturity + \sum_k C'\beta_k$$

With $maturity$ being a dummy variable that takes 1 when average age of the VC is higher than the median age of all the VC of the sample, 0 otherwise (and in this case, $not\_maturity$ takes 1).

To test H4.2, the equation is

$$x'\beta = \beta_0 + \beta_{larg} * largeness + \beta_{not\_larg} * not\_largeness + \sum_k C'\beta_k$$

With $largeness$ being a dummy variable that takes 1 when the maximum number of funds managed by the VC undertaking the investment is bigger than the median number of all the VC of the sample, 0 otherwise (and in this case, $not\_largeness$ takes 1).

We resort to the Wald test to verify the inequations for H4.1 and H4.2

$$\beta_{larg} - \beta_{not_{larg}} > 0$$

$$\beta_{mat} - \beta_{not\_mat} > 0$$

To test H5, the equation is

$$x'\beta = \beta_0 + \beta_{cross} * cross\_border + \beta_{not\_cross} * not\_cross\_border + \sum_k C'\beta_k$$

H5 discovers the performance brought by cross border investments. If there is at least one investor resident in a foreign country, the dummy $cross\_border$ takes 1, 0 otherwise; while the other dummy not_cross_border takes 1 if all investors belong to the invested country, 0 otherwise.

To test the difference, we need to perform the Wald test on the following:

$$\beta_{cross} - \beta_{not\_cross} > 0$$

Complementary to our analysis, we must do the check for the selection process. To study H6 and H7, we introduce another model. We keep using a Probit model to circumvent linearity assumptions.

The general model to test whether some operating characteristics affect the probability for entrepreneurial firms of getting invested by VC is the following

$$VC\_backing = f(Performance\ before, Size\ before, Growth, Controls)$$

$$Pr\ (VC = 1) = \Phi\ (x'\beta) = \int_{-\infty}^{\frac{(x'\beta)}{\sigma}} \frac{1}{2\pi}\ e^{\frac{-z^2}{2}} dz$$

$$VC_i = \begin{cases} 1\ if\ \ y_i^* > 0 \\ 0\ if\ \ y_i^* \leq 0 \end{cases}$$

Where y_i^* is the unobserved variable that makes the firm to get VC backing. VC_i is a dummy variable that takes 1 if the company is invested by VC, 0 otherwise.

To test H6 and H7, the equation is

$$x'\beta = \beta_0 + \beta_{TotAss} * lnTotalAssets + \beta_{Prof} * lnProfitability + \beta_{Growth} lnSalesGrowth + \beta_{Opp} * lnOpportunity + \sum_k C'\beta_k$$

Where the vector of control variables is

$$C = [Age\ \ Sector\ Year\ Country]$$

and $lnTotalAssets$ is the natural logarithm of average value of Total Assets in the five years before the investment, and it is a proxy for the size; $lnProfitability$ and $lnSalesGrowth$ are respectively the natural logarithm of average value of EBITDA over Total Assets and the natural logarithm of average value of Sales growth rate in the five years before the investment, and are both proxies for the performance before; $lnOpportunity$ is the natural logarithm of intangible assets over total assets in the five years before the investment and it is a proxy for opportunity for growth.

To test H6 and H7, we run the same equation in the Probit. When testing H6, we omit $lnOpportunity$.

To test whether more performing companies get the attention of VC (H6), we should perform the Wald test

$$\beta_{TotAss} > 0$$

$$\beta_{Prof} > 0$$

$$\beta_{Growth} > 0$$

To test whether patents act as a signal for VC (H7), we should perform the Wald test

$$\beta_{Opp} > 0$$

2.2.4 Descriptive statistics

The sample for the empirical analysis is drawn from the matched cross section sample described above and includes all the cleantech ventures with available accounting data. We have data on 387 firms, 84 of which are VC-backed and 303 can be considered as potential targets for VC investors.

Beneath, it is shown that VC investments of our sample occurr between 2006 and 2013[12] (Table 8). The number of first rounds investments increases until 2008, year in which it starts a floating period that peaks in 2011 (19 investments out of the overall 84). In 2012 the number of VC investments dramatically falls and furtherly decreases in 2013, when just 2 deals are signed.

	Year of first VC round							
	2006	2007	2008	2009	2010	2011	2012	2013
N. of VC-backed firms	5	10	16	11	16	19	5	2
%	5.95	11.9	19.05	13.1	19.05	22.62	5.95	2.38

Table 3 Descriptive statistics on the first VC round.

[12] In the VICO database the investment period is 2005-2014. Unfortunately, the lack of accounting data on the sidelines leads to loose observations about 2005 and 2014.

Cleantech firms in the matched sample are located in seventeen European countries, while empirical sample ones are established in just thirteen of them; both were founded between 1988 and 2014. Sample firms' sectors follow the NACE Rev. 2 classification. We exhibit the distribution in terms of country, industry and foundation period of the matched cross section sample against the empirical sample in Table 4.

We perform χ^2 test to verify that VC-backed companies of the matched sample are distributed similarly to not VC-backed ones. χ^2 [16] = 20.8982, χ^2 [10] = 5.9280, χ^2 [5] =8.1922 are the tests for country, industry and foundation period respectively. The results are in line with our expectations, given the process we perform in doing the propensity score matching, where we include country dummies, industry dummies and year dummies.

Concerning the empirical sample, we run χ^2 test and verify that VC-backed companies have the same distribution of not VC-backed ones in terms of industry and foundation period. In fact, χ^2 [5] = 4.6529 by company foundation period, χ^2 [9] = 8.9009 by industry. However, the test reveals a difference of distribution when performed on the country distribution (χ^2 [12] = 34.0329). This is the result of the identification process of cleantech companies, in which we checked manually the websites of cleantech companies based on UK.

	Matched Cross Section Sample				Empirical Analysis Sample			
	VC Backed		Control Group		VC Backed		Control Group	
	N	*%*	*N*	*%*	*N*	*%*	*N*	*%*
Country								
Belgium	2	1.48	16	2.91	1	1.19	13	4.29
Bulgaria	1	0.74	6	1.09	1	1.19	3	0.99
Czech Republic	1	0.74	4	0.73	1	1.19	2	0.66
Denmark	1	0.74	5	0.91				
Estonia	1	0.74	1	0.18				
Finland	6	4.44	19	3.46	4	4.76	8	2.64
France	37	27.41	101	18.40	24	28.57	35	11.55
Germany	10	7.41	69	12.57	6	7.14	49	16.17
Israel	1	0.74	2	0.36				
Italy	10	7.41	30	5.46	6	7.14	10	3.30
Lithuania	1	0.74	6	1.09	1	1.19	4	1.32
Netherlands	1	0.74	8	1.46			4	1.32
Norway	1	0.74	9	1.64			9	2.97
Portugal	1	0.74	4	0.73				
Spain	5	3.70	32	5.83	2	2.38	21	6.93
Sweden	12	8.89	19	3.46	7	8.33	8	2.64
United Kingdom	44	32.59	218	39.71	31	36.90	137	45.21
Total	135		549		84		303	
Industry								
Agriculture	2	2.48	4	0.73				
Mining & quarrying	1	0.74	6	1.09	1	1.19	3	0.99
Manufacturing	66	48.89	224	40.80	40	47.62	111	36.63
Electricity, gas, steam	25	18.52	98	17.85	14	16.67	60	19.80
Water supply	12	8.89	71	12.93	7	8.33	44	14.52
Construction	4	2.96	13	2.37	4	4.76	5	1.65
Wholesale & retail trade	6	4.44	30	5.46	5	5.95	17	5.61
Information & communication	5	3.70	25	4.55	4	4.76	14	4.62
Financial & insurance activities	1	0.74	9	1.64	1	1.19	7	2.31
Professional & technical activities	12	8.89	63	11.48	8	9.52	39	12.87
Administrative & support activities	1	0.74	6	1.09			3	0.99
Total	135		549		84		303	
Foundation Period								
1988-1989	4	2.96	6	1.09	3	3.57	4	1.32
1990-1994	11	8.15	26	4.74	9	10.71	20	6.60
1995-1999	13	9.63	73	13.30	10	11.90	47	15.51
2000-2004	35	25.93	179	32.60	23	27.38	98	32.34
2005-2009	60	44.44	221	40.26	36	42.86	126	41.58
2010-2014	12	8.89	44	8.01	3	3.57	8	2.64
Total	135		549		84		303	

Table 4 Distribution of the matched cross section sample and the empirical sample by country, industry and foundation period.

Furthermore, to illustrate some insights of the specific VC-backed firms characteristics and to highlight which are the determinants for receiving VC financing, we report in Table 5 some descriptive statistics (number of observations, mean and median) about the investment specific variables. Independent variables are related to the round characteristics: the equity invested in the year (*EquityInvested*), the number of investors participating to the round (*NInvestors*), the number of independent VC (*NIVC*), the number of governmental VC (*NGVC*) and other typologies of VC (*NOTHER*) engaged in the yearly financial round; and to VC characteristics: investor age in logarithm (*InvestorAge*), number of funds managed, and dummies including if the venture capital is established in a different country than the one of the investee firm (*DForeignInvestor*).

		VC
EquityInvested	Obs	83
	Mean	3’374.45
	Median	1’146.57
NIVC	Obs	84
	Mean	1.18
	Median	1
NGVC	Obs	84
	Mean	.13
	Median	0
NOTHER	Obs	84
	Mean	.24
	Median	0
NInvestors	Obs	84
	Mean	1.55
	Median	1
InvestorAge	Obs	81
	Mean	15.55
	Median	12
NFundsManaged	Obs	56
	Mean	10.34
	Median	6
DForeignInvestor	Obs	84
	Mean	.57
	Median	0

Table 5 Determinants of the likelihood of receiving VC investments.

Table 6 shows summary statistics (number of observations, mean and median) of the dependent variables analysed in the monitoring model: sales, employment (i.e. headcount), total assets, intangible and fixed assets. Data reported are relative to the average value for the 5 years before the first investment received time and the average value for the 5 years after it.

For all performance measures we also perform a t-test on the difference-in-mean between the VC backed firms and the matched control group. In the pre-investment period, we find statistically significant the difference in total assets and intangible assets, being the control group on average bigger than the backed one. After the first VC round, VC-backed firms continue to be, on average, smaller than non-VC-backed firms in terms of total assets (p-value is slightly higher than 10%). The lack of a significative evidence in the traditional performance growth (i.e. sales and employment) warn us from drawing preliminary conclusions on a relevant effect of VC on the growth of portfolio firms.

		Pre investment			Post investment		
		CG	VC backed	VC backed vs CG	CG	VC backed	VC backed vs CG
Sales	Obs	239	70		302	80	
	Mean	59’853.30	33’037.21	26’816.09	61’731.76	40’850.83	20’880.93
	Median	8’998.53	2’050.30		12’542.92	5’437.45	
Fixed Assets	Obs	303	84		303	84	
	Mean	51’062.25	36’389.05	14’673.20	8’5360.52	5’5058.83	30’301.69
	Median	3’396.64	686.74		5’263.97	2’228.13	
Total Assets	Obs	303	84		303	84	
	Mean	83’084.94	48’769.84	34’315.10*	128’429.86	75’815.29	52’614.46**
	Median	9’971.27	3’078.37		19’603.88	8’620.91	
Intangibles	Obs	291	82		297	84	
	Mean	7’414.71	1’137.88	6’276.83**	6’473.30	4’552.96	1’920.32
	Median	6.72	32.429		6.91	122.90	
Employment	Obs	186	56		241	67	
	Mean	215.08	156.08	59	221.24	176.25	44.99
	Median	48.67	19		54.63	48.00	

*Table 6 Descriptive statistics of performance variables. Significance is defined as: * $p<.15$. ** $p < .10$. *** $p < .05$*

An additional evidence on perfomances (Table 7) shows difference between post and pre investment periods. For all those variables we estimate the difference between the average of a growth measure five year after the first investment received and five years before that time[13]. The t test on the difference-in-mean highlights a significant difference (p<5%) on intangibles, as if VC impact will be on stimulating innovation.

		Growth difference		
		CG	VC backed	VC backed vs CG
Sales	Obs	238	68	
	Mean	17.32	8.48	8.83
	Median	2.51	2.22	
Fixed Assets	Obs	303	84	
	Mean	36.51	26.59	9.92
	Median	.48	1.01	
Total Assets	Obs	303	84	
	Mean	54.14	39.56	14.57
	Median	3.06	3.33	
Intangibles	Obs	289	82	
	Mean	.2826	2.15	-1.87**
	Median	0	.30	
Employment	Obs	178	50	
	Mean	43.98	49.62	-5.64
	Median	6.51	17.15	

*Table 7. Descriptive statistics on performances difference variables. Significance is defined as: *= significant at 15%; **= significant at 10%; *** = significant at 5%.*

In Table 8 the descriptive statistics for the selection analysis is provided. Data are referred to the average of the two years before the investment for VC backed firms, and to the average of the two years before the matching year for the control group. In this model we report also Profitability and Opportunity.

We perform a t test difference-in-mean between the VC backed firms and the matched control group. We find statistical difference in Profitability and SalesGrowth (p

[13] *With the exception of Employment, all the other variables differences are computed in thousandths.*

value<1%). This result is a preliminary evidence that VC backed firms are on average less productive than the control group but are growing in sales at a faster pace.

		Control Group	VC backed	Control group vs VC backed
Sales Growth (%)	N	3'258	57	
	Mean	.3476	.7660	-.4185***
	Median	14'373.91	3'321.7	
Total Assets	N	3'258	57	
	Mean	97'242.83	77'131.86	20'110.97
	Median	14'373.91	3'321.70	
Profitability	N	3'258	57	
	Mean	.0714	-.0634	.1347***
	Median	.0899	.0138	
Opportunity to grow (%)	N	3'258	57	
	Mean	.0612	.0759	-.01478
	Median	.0031	.0047	

*Table 8 Descriptive statistics for selection. Significance is defined as: *= significant at 15%; **= significant at 10%; *** = significant at 5%.*

Overall, VC-backed firms prove to be as productive as matched non-VC-backed firms after the receipt of VC financing, because the difference in sales, employment (i.e. headcount), total assets, intangible and fixed assets in the post-investment period is not significant. Concerning screening, VC backed seems to be selected in the view of their unprofitable business and growth opportunities. These summary statistics suggest that VCs: i) VC seems to show good screening abilities in cleantech; and ii) VC's contribute to firms' growth performances is not consistent.

3 Results

Monitoring

Table 9 reports the results of the empirical models described in Model specification section. The dependent variables are the dummy growth of sales, fixed assets, total assets, intangible assets and employees (*DSales, DFixAss, DTotAssets, DIntass and DEmp*, respectively). In general, we find statically significant the impact of VC and its characteristics on intangible assets growth, and just once on sales growth.

Concerning H1, we find that there is a positive and statistically significant (p-value < 1%) impact of VC on the growth of intangible assets. This evidence could be interpreted as if the VC action is committed to R&D expenses and patents development. Therefore, available data on entrepreneurial ventures in cleantech accept H1 but limits the monitoring activity to the field of intangible assets.

In H2, H3, H4 and H5 we dig deeper into VC firms features, to disentangle their characteristics and the different effect on investee companies. As regards H2, it aims at detecting the existence of a greater positive impact due the presence of IVC rather than other captive investors (i.e. GVC, corporate venture capital, banks, universities, crowdfunding) as shareholders in a firm. In all cases, the typologies of VC funds show a positive impact solely on the growth of intangibles. Both the coefficients are significant with p-value < 1%, but captive VCs have a bigger impact than private ones. Nonetheless, the Wald test on the IVC effect does not unveil any relevant and significative difference among them, and we discard H2.

	Coefficient	MONITORING ANALYSIS				
		DSales	*DFixAss*	*DTotAss*	*DIntAss*	*DEmpl*
VC_{backed}	β_{VC}	-0.1526 (0.307)	0.6281** (0.288)	0.1627 (0.304)	0.9191*** (0.271)	0.2898 (0.354)
IVC	β_{IVC}	-0.4004 (0.350)	0.6481** (0.316)	0.0258 (0.332)	0.8607*** (0.299)	0.0166 (0.426)
$captive$	$\beta_{captive}$	0.5987 (0.643)	0.5783 (0.428)	0.5861 (0.551)	1.0578*** (0.410)	0.7537 (0.576)
$mono$	β_{mono}	-0.2465 (0.318)	0.5587* (0.299)	0.1080 (0.314)	0.8396*** (0.278)	0.2694 (0.357)
$synd$	β_{synd}	0.5766 (0.647)	0.8795** (0.422)	0.4302 (0.507)	1.3143*** (0.406)	1.4062 (0.890)
$maturity$	β_{mat}	0.4070 (0.393)	0.4936 (0.308)	0.4257 (0.365)	1.0326*** (0.300)	0.4385 (0.425)
$not\_maturity$	β_{not_mat}	-1.216** (0.500)	0.7740* (0.400)	0.1528 (0.434)	0.8172** (0.355)	-0.3425 (0.513)
$largeness$	β_{larg}	-0.4501 (0.363)	0.6096* (0.312)	0.1167 (0.346)	0.8348*** (0.293)	-0.2438 (0.393)
$not\_largeness$	β_{not_larg}	0.4124 (0.501)	0.5510 (0.410)	0.8526 (0.584)	1.2294*** (0.411)	0.000 (.)
$cross\_border$	β_{cross}	-0.1721 (0.440)	0.4123 (0.354)	0.1270 (0.407)	1.0157*** (0.338)	0.2753 (0.527)
not_cross_border	β_{not_cross}	-0.1429 (0.346)	0.7860** (0.330)	0.1838 (0.344)	0.8560*** (0.300)	0.2953 (0.384)
Equity Invested	β_{equity}	0.1580** (0.062)	-0.0179 (0.046)	0.0614 (0.053)	-0.0068 (0.042)	0.0429 (0.065)
Age	β_{age}	-0.2548* (0.153)	-0.2392* (0.123)	-0.3915*** (0.138)	-0.0715 (0.127)	-0.4737** (0.190)
Dummy Country		Yes	Yes	Yes	Yes	Yes
Dummy Industry		Yes	Yes	Yes	Yes	Yes
Dummy Year		Yes	Yes	Yes	Yes	Yes
N Obs		300	387	379	369	222
N firms		300	387	379	369	222
IVC effect	$\beta_{IVC} - \beta_{capt}$	-.9990 (0.7033)	0.0698 (0.4449)	-0.5602 (0.5789)	-.01971 (0.4325)	-0.7371 (0.6796)
Syndication effect	$\beta_{synd} - \beta_{mono}$	0.8232 (0.6224)	0.3209 (0.3885)	0.3221 (0.48156)	0.4747 (0.3574)	1.1368 (0.8174)
Experience effect	$\beta_{larg} - \beta_{not\_l}$	-0.8625* (0.5761)	0.0586 (0.4624)	-0.7360 (0.6477)	-0.3945 (0.4431)	-0.2438 (0.3930)
	$\beta_{mat} - \beta_{not\_m}$	1.6227*** (0.5987)	-0.2804 (0.4401)	0.2729 (0.5127)	0.2154 (0.3805)	0.7810 (0.5851)
Cross Border Effect	$\beta_{cross} - \beta_{not\_c}$	-0.0293 (0.4733)	-0.3736 (0.3666)	-0.0568 (0.4327)	0.1596 (0.3317)	-0.0200 (0.5408)

Table 9 Impact of VC on firm's likelihood to grow.

*Significance is defined as: *= significant at 10%; **= significant at 5%; *** = significant at 1%.*

Concerning H3, syndication effect, both single and syndicated investments have the same statically significant positive impact on intangible assets (p-value < 1%). However, the difference of the coefficients is not validated by the Wald test, and we discard H3.

Concerning H4, VC experience deserves some considerations. As already described, we disentangle the experience dimension into two parts: maturity and largeness. The study reveals positive and statistically significant (p-value < 1%) coefficients of the maturity and the not-maturity of investors on the growth of intangible assets, where the former has a greater value. As expected, a negative and significant impact (p-value <1%) of not-maturity on the sales growth shows that younger VC firms seems to bring a degradation on sales performances. Moreover, the difference among elder and younger VC is validated by the Wald test on the two coefficients, which is significant positive at 1% on *DSales*. Regarding the other experience dimension, largeness, we find that both the coefficients are positive and significant at 1% on *DIntAss*, with β_{not_larg} bigger. Unfortunately, Wald test on largeness measures does not validate their difference. Thus, we can argue that an elder VC firm brings a better impact on sales than younger one, while the effect of the number of funds managed is negligible. We partially validate H4.

To assess if investments performed by at least one foreign investor increase VC-backed likelihood to grow, we look H5 results. Cross border and not cross border dummies have a significant and positive impact (p-value < 1%) on the growth of intangibles for the whole model, being β_{cross} bigger than β_{not_cross}. Unfortunately, their difference is not significant, and H5 cannot be validated.

Overall, the results concerning VC characteristics do not show any relevant different impact, except for the level of maturity.

Regarding the variable that represents the natural logarithm of cumulative equity invested in the yearly round, in all models it shows positive and significant coefficient (between 1-10%) on *DSale*s. Therefore, evidence is found on the positive impact of the capital invested in the first VC round related to the likelihood to grow on sales.

The coefficient of the company age in logarithm is always negative and significant on each dependent variable, with exception for intangibles. This result is coherent with the literature, where age is either significant with negative sign or not significant.

Screening

To test whether there are any screening capabilities of VC in selecting cleantech firms (H6 and H7) we perform two models, reported in Table 10 (Columns MODEL I and MODEL II, respectively).

The variable expressing the logarithmic profitability of the firm is significant at 1% level with a negative sign, as expected. Even the logarithm of total assets coefficient is negative and significant at 5% in both models. Those results exhibit that VC in cleantech select smaller companies that show lower profitability. Unfortunately, the average growth in sales performed by the firm in the two years before the investment time is not significant in the model, and H6 cannot be validated by our empirical analysis (despite there is a positive and significant difference between the sales growth of invested and of control group before the investment, as noticed in the descriptive statistics).

Concerning H7, it is not validated because patents do not seem to play as a signal for investors. In fact, $lnOpportunity$ does never show significant coefficients. This result was expected due to the first empirical evidence provided by the descriptive statistics. Concerning Age, it does not have any significant impact.

Hence, we do not validate the hypotheses on VC screening capabilities. The fact that they do not select companies with higher growth opportunities and intangibles, is quite doubtful. Nonetheless, some of the results are in line with the nature of VC: selecting the smaller and less profitable firms in order to resell their shares at higher prices realizing a profit.

	Coefficient	SELECTION ANALYSIS	
		Model I	Model II
$lnTotalAssets$	β_{TotAss}	-0.0696** (0.030)	-0.0717** (0.030)
$lnProfitability$	β_{Prof}	-0.7692*** (0.209)	-0.7744*** (0.214)
$lnSalesGrowth$	β_{Growth}	0.0382 (0.045)	0.0378 (0.045)
$lnOpportunity$	β_{Opp}		0.5572 (0.563)
Age	β_{age}	0.0284 (0.134)	0.0356 (0.135)
Dummy Country		Yes	Yes
Dummy Industry		Yes	Yes
Dummy Year		Yes	Yes
N Obs		3324	3315
N firms		769	768

*Table 10 Screening results. *** = significant at 1%; ** = significant at 5%; * = significant at 10%.*

Robustness check

We carry out several checks to test the robustness of our econometric results. First, even though the sample adopted to run the analysis has been matched (PSM procedure is detailed described in Matched cross section sample section) to control for unobservables, as robustness check we perform a narrower matching, by including an additional matching variable: the logarithmic average of sales growth between the investment time and the year before. Second, we estimate the VC effect with a different time window. In order to assess performances in the short term, we shorten the timeframe from five years to two years before and two years after the first VC round. Third, we assess the significative positive impact on fixed assets by defining a variable for fixed tangible assets, *machinery*, to decouple the effect on fixed assets of tangibles and intangibles.

On the whole, our results do not change significantly from those shown in the main analysis[14].

Some results are remarkable and worthy of mention. While testing H2 on the robustness check matched sample, the impact of independent VC is negative and significant at 5% level on the sales growth. This evidence suggests us an incapability of private venture capital to bring cleantech business models to the market, but rather deteriorating their sales performances. In addition, the Wald tests on coefficients results are significant at 1% and with negative signs on DSales and DIntass.

[14] *Results of the robustness check on the matched cross section sample are reported in the Appendix.*

4 Discussions

Here, the main results of our empirical work are discussed and compared with the academic literature.

Selection

VCs in cleantech do not show scouting capabilities that many declare in general (Baum & Silverman, 2004; Chemmanur et al., 2011) in the selection of entrepreneurial start-ups with early stage technologies, and neglect their growth potential. The empirical results suggest that VCs seek less profitable and smaller size companies. Concerning the growth of sales, we observe a preliminary positive difference between VC-backed companies and control group before the investment in the descriptive statistics, but we do not find validation in the model. Moreover, in contrast with Lahr & Mina (2016) who find positive correlation between VC and developmental R&D and patents, patents in cleantech do not attract other VCs investments. They do not act as signals. Thus, our evidences do not highlight VCs' excellent capabilities in identifying new firms with superior technological capabilities. It is worth noting that having a patent means in general that the technology is in relatively later stages, almost ready to be launched onto the market. This may run counter intuition, as VC should be as much short term oriented as possible, and thus oriented toward already ready technologies. Furthermore, the ex-ante patenting performance of potential investee is a firm quality signal to decrease information asymmetry (Hsu & Ziedonis, 2008; Mann & Sager, 2007). The thesis that cleantech backed companies do not show better performances before the investment is in accordance to Bertoni et al. (2011) and Balboa et al. (2006). This finding could be partially explained by the lack of venture capital expertise in clean technologies and suggests the idea of some imperfections in the selection process.

Monitoring

Monitoring results show that VCs are the financial actors covering technology research and technology development stages: once ventures have been VC-backed, VCs encourage their intangibles to grow. This finding is in line with some previous academic studies by Kortum & Lerner (2000) and Popov & Roosenboom (2012), that argue the nurturing service provided by VCs to produce greater technological output.

The missed positive impact on sales could be due to the fact that cleantech innovations, differently from biotech and IT sectors, take more time to be developed in labs and then reach the market availability (Ghosh & Nanda, 2010b). Moreover, the lack of statistically significant evidences on traditional performance measures could be justified by increased level of managerial and operational risk faced in cleantech (Criscuolo & Menon, 2015). Managerial risk can occur because the skills required to manage green sector ventures and the skills of entrepreneurs are not aligned and, similarly, because of the gap between skills needed in the initial stage of idea testing and upscaling/deployment: the experience of VC investors in mentoring and networking, are not as developed in the green sector as within software-based start-ups. As Ghosh & Nanda (2010b) and Randjelovic et al. (2003) argue, there are problems related to the management capabilities of companies in this sector.

According to our work, VC characteristics have a very weak impact on the overall performances. In the robustness check, we validate the different impact between private and captive VC in the impact on intangibles. This could be explained because private funds are more focused on sales and employment performances instead of patents creation, while universities and governments are better mentors in innovation development. These results are slightly in contrast with those ones of Alperovych et al. (2015) that argue the degradation of efficiency brought by GVC. Also, VC’s experience plays a crucial role in determining VC-backed performances. Results illustrate that when funds are younger, their impact on sales growth is even negative. Those results are in line with the Alemany & Martí (2005) work that VC experience is a determining element in the performance outcome, together with the cumulated equity received throughout the year. The syndication effect is not significant for growth, differently from the academic results of Douglas et al. (2013).

5 Conclusions

VC is a main financial provider for cleantech innovations at early stages, despite all the difficulties. While it is well known that the development of cleantech is pivotal for the transition to a more sustainable economy, it is not clear yet whether VC can play as an ambassador in driving the change. Literature has been focusing mainly on the linkages between public policies and the appetite of VC for cleantech but, to the best of our knowledge, no one before has assessed the VC impact on investee companies in cleantech. This study wants to be the first in exploring this field.

Findings are quite interesting. Concerning the screening capabilities of VC to select the most promising star-ups, they seem to prefer smaller sized and less profitable companies before the investment time. Surprisingly, we do not find any statistical evidence both on the attracting role of patents and sales growth. During the monitoring period, VC seems to devote a relevant effort in doing R&D. Cleantech identified issues may help us out in our analysis. The not-significant impact on sales growth of VC-backed companies suggests that there may be a lack of managerial competencies (i.e. Managerial Valley of Death). The fact that the impact is exclusively on the intangible assets' growth suggests that these ventures are not likely to go for an exit imminently, and this is coherent with the need for a longer lifecycle of the VC-backed companies in cleantech. Finally, we can assume that an unfavourable regulatory framework may prevent capable and profit oriented VCs from investing in cleantech. Research objectives have been achieved, but our analysis gives an alarming insight: maybe it is too soon to see positive VC impact because we are still at the beginning stages of the adoption of clean technologies.

However, our study presents some limitations. First, the geographical area in which companies are established is restrained to European countries. Nonetheless, the sample is biased toward UK, due to the construction process of the database. Second, the cross-sectoral analysis performed disregards the sub-sectorial differences. In fact, while for the capital-intensive technologies VC has evident structural mismatch and difficulties in financing them, margins of growth for cleantech lighter sectors such as software and platform business models may be flourishing. Third, the limited number of cleantech invested companies identified could distorts model results. It may be possible to work on a bigger sample by categorising business models of companies through alternative processes.

The results of this paper lead to a number of future research questions. It could be studied the VC impact on performances in rounds following the first one, accounting for short term and long-term effects. Then, it could be investigated how growth is related to national regulations, in order to define a set of appealing policy scheme. Also, a detailed analysis on patents and cleantech business models could help in saying which are the leaks. A more enlarged study on the impact of captive VC can also shed a light on the topic. Finally, it could be interesting to inquire on the survival rate of VC-backed cleantech companies.

We conclude our thesis mentioning examples of other emerging trends that may foster further the diffusion of clean technologies and the consequent redemption of the environment, calling for a forth phase (of sprint) of cleantech emergence. Along with top down forces such as governmental and supra-national institutions intervention, also a bottom up approach is emerging. Real applications show the power of small local communities and grassroots movements in promoting green projects. A case in point is the carbon neutral Municipalities network (HINKU) born in 2008 in Finland: starting from the engagement of municipalities to decrease local environmental emissions, it is now planned to achieve carbon neutrality within 2030, as a demonstration that an ambitious climate policy is attainable.

We argue that there is a sense of community overreaching national boundaries that could play as a major force of change in the shift to a different, cleaner, economy.

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Appendix

A.1 Transition to a Low carbon economy

"In order to limit global warming to 2 degrees Celsius and avoid the worst effects of climate change, investments in low-carbon energy technologies will need to at least double, reaching $500 billion annually by 2020, and then double again to $1 trillion by 2030." International EnergyAgency (IEA), 2012

Even though in 2010 the sector reputation expanded to popular and commercial media (Caprotti, 2016; O'Rourke, 2009), the literature does not report any relevant event. This seems to be the forth phase of cleantech emergence. There is an urgent need to deal with issues regarding the mitigation of climate change and the relative effects, as warming temperatures, changes in precipitation and sea level which, in turn, will affect the supply and quality of water, habitat, and food production. The alarming environmental conditions compel to figure out a new economy, based on cleaner technologies. Supra national organizations for environment safeguards are promulgating international agreements: the Kyoto protocol, the EU emission Trading Scheme, the Paris Agreement.

The European Commission (EC) is in the front row in promoting the shift to a Low Carbon Economy (LCE) or decarbonized economy. Though prices have felt down in the last decades, conferring to clean technologies a more competitive position, technology state seems to be still at its embryonal status. Additional investments are now more than ever required. But the economy would not drive alone to that direction, without the lead of channelling polices. The EC proposes several legislative measures to lay out the right business environment that encourages private investments, lowers the financial risk and a boosts R&D research. An extended adoption of existing energy efficiency technologies across building stocks, transportation systems, and manufacturing practices is necessary to fast the energy transition.

The public good nature of the environment makes everyone on the Earth to pay the bill of a pollution. In addition to government measures, a bottom up approach starting from the engagement of smaller communities at the local level, is necessary to put down the roots of the economic and technological shift and to compensate top-down national actions limitations.

A.2 Cleantech clusters

This paragraph shows real applications of cleantech activities and canvases of actors in geographically limited contexts, previously studied as districts or clusters (Marshall, 2009). Being located in a cluster or science park is beneficial for biotech firms and it is expected to hold the same also for clean-tech enterprises (Bjornali & Ellingsen, 2014; Maine, Shapiro, & Vining, 2010).

Physical proximity gives to cleantech firms the traditional benefits of activities agglomerated in one single location: knowledge Spillovers, availability of highly skilled labour pooling and resource advantage (Porter, 1998). Where companies belonging to same or different industries are established close to each other, the first advantage is the result of interactions and networking: joint projects and shared cultural environment give a momentum to innovation, to run for being the first in launching a novel product or idea. Small and medium enterprises are keener to move their operations there, as well as R&D intensive firms, to exploit the wide set of the advantages supplied by district knowledge plethora. There is no competition in knowledge, more a collaboration: “co-location contributes to mutual learning and knowledge exchange between organizations and that this ultimately leads to innovation” (Fogelberg & Thorpenberg, 2012).

Findings show a positive economic correlation between cleantech and eco-districts (Weber & Reardon, 2015). Low carbon cities may look suitable locations for cleantech firms to relocate there one business branch or the entire organization. Both the public financial aid and the greater demand for cleantech products strengthen this assertion. On the other side, a questionnaire addressed by Kapsalyamova et al. (2014) investigating the perceived benefits of being located in a low carbon city reveals a cleantech enterprises neutrality towards the establishment of a business unit in low carbon cities. In a study of 2010, Davies endeavours to uncover the real possibility that cleantech clusters will lead the global radical transformation towards the “Green Economy”. In addition to traditional clusters, there are meta-clusters (transnational clustering of cleantech clusters), that constitute the “nexus” for going abroad, establishing collaborative relationships with other players and upsizing current operations (Davies, 2013). The missing answer to the question is a consequence of the lack of stable rules and goals: nonetheless, the vigorous and strong goal to expand the movement towards decarbonized activities, the means and mechanisms remain rather obscured.

Another case of cleantech cluster is the carbon neutral Municipalities network (HINKU) in Finland. The project started in 2008 to decrease local greenhouse gases emissions through social innovations and clean technologies adoption through small municipalities engagement as experimental laboratories. The adhesion is free but under an energy efficiency signed agreement. In 2017 it comprised of 34 small medium municipalities, attracted by the HINKU power to attract media attention. The good result achieved by HINKU network demonstrated that ambitious climate policy is possible and feasible. HINKU operates as a strategic intermediary: its action is in between local national measures and local entrepreneurs. The success of the initiative stands in its complementary bottom up action to cover the weak aspects in the national innovation.

Thus, commitment to cleantech solutions can also starts at local level, through communities. A system of open innovation is essential to create valuable innovation, not only about technologies deployed, but also about business models. This is what Horwitch & Mulloth (2010) showcased with three grassroot movements raised in New York City. The Vision42 aim is to eliminate traffic in 42nd Street in Midtown Manhattan in favouring of a pedestrian area; instead, GREEN.US is a cleantech movement promoted by Polytechnic of New York for establishing “green rooftops” throughout the city. Those rooftops will be realized by a team of researchers and design experts to include environmental cut-edge technologies, urban gardening and deployment alternative energy. Eventually, Green Drink is simply a happy hour for chatting about green topics. What emerges from the three initiatives is that even though they have different commercial structures and missions, they share a common underpinning vision: to popularize green ideals and raise interest and awareness about the environment issue in order to create "green communities". As Horwitch & Mulloth (2010) argue, "cleantech seems to belong to everyone on the planet".

From the case studies, we infer that there is a sense of community overreaching national boundaries: grassroots and meta clusters illustrate how green shared ideas constitute linkages that are strong enough to endure outside country boundaries. Even though there is clear vision, cleantech communities lacks the mission: an understandable set of mechanisms and means to achieve that purpose. Just an extended and systematic practical adoption of cleantech solution could give an answer to what is the most suitable scheme to spur the transition to an environmental-friendly economy.

A.3 Robustness Check Results

In Table A. 1 the results retrieved from the robustness check on the differently-matched sample are shown.

	Coefficient	MONITORING ANALYSIS				
		DSales	DFixAss	DTotAss	DIntAss	DEmpl
VC_{backed}	β_{VC}	-0.4283 (0.295)	0.5864** (0.298)	0.2795 (0.311)	0.7678*** (0.274)	0.0643 (0.367)
IVC	β_{IVC}	-0.8221** (0.347)	0.5874* (0.336)	-0.0763 (0.341)	0.5269* (0.307)	-0.5331 (0.73)
$captive$	$\beta_{captive}$	0.5031 (0.575)	0.5841 (0.468)	0.0000 (.)	1.5209*** (0.540)	0.9194 (0.615)
$mono$	β_{mono}	-0.4566 (0.300)	0.4462 (0.310)	0.0829 (0.333)	0.6805** (0.281)	0.062 (0.369)
$synd$	β_{synd}	-0.0995 (0.640)	1.1788** (0.500)	0.0000 (.)	1.2587*** (0.449)	-0.1152 (0.842)
$maturity$	β_{mat}	0.0992 (0.369)	0.4916 (0.324)	0.2330 (0.365)	0.7468** (0.301)	0.3456 (0.426)
$not\_maturity$	β_{not_mat}	-1.5229*** (0.498)	0.9223** (0.451)	0.0652 (0.504)	0.2471 (0.371)	-0.4926 (0.533)
$largeness$	β_{larg}	-0.7025** (0.354)	0.5839* (0.344)	-0.1365 (0.389)	0.4173 (0.299)	-0.3994 (0.417)
$not\_largeness$	β_{not_larg}	0.0564 (0.470)	0.6633 (0.434)	0.7428 (0.555)	0.9911** (0.421)	0.000 (.)
$cross\_border$	β_{cross}	-0.3968 (0.441)	0.8669** (0.398)	1.2556** (0.639)	0.9573*** (0.360)	-0.1420 -0.4419
not_cross_border	β_{not_cross}	-0.4419 (0.327)	0.4038 (0.338)	-0.1617 (0.367)	0.6551** (0.305)	0.1642 (0.418)
Equity Invested	β_{equity}	0.1558*** (0.057)	0.0066 (0.050)	0.1390* (0.076)	0.0681 (0.044)	00898 (0.066)
Age	β_{age}	-0.3829*** (0.138)	-0.2419* (0.126)	-0.4536*** (0.142)	-0.2114* (0.122)	-0.2665 (0.174)
Dummy Country		Yes	Yes	Yes	Yes	Yes
Dummy Industry		Yes	Yes	Yes	Yes	Yes
Dummy Year		Yes	Yes	Yes	Yes	Yes
N Obs		390	391	382	389	243
N firms		390	391	382	389	243
IVC effect	$\beta_{IVC} - \beta_{capt}$	-1.3252** (.6419)	.00333 (0.5152)	-.07625 (0.3411)	-.9939* (0.5802)	-.1452 (.7461)
Syndication effect	$\beta_{synd} - \beta_{mono}$	.3571 (.6103)	.7325 (.4813)	-.08290 (.3334)	.5782 (.4125)	.05324 (.7903)
Experience effect	$\beta_{larg} - \beta_{not\_l}$	-.7589 (.5475)	-.0794 (.4765)	-.8793 (.6580)	-.5738 (.4379)	-.3994 (.4170)
	$\beta_{mat} - \beta_{not\_m}$	1.6220*** (.5847)	-.4307 (.4539)	.1678 (.5715)	.4997 (.3818)	.8382 (.5894)
Cross Border Effect	$\beta_{cross} - \beta_{not\_c}$	.0451 (.4691)	.4631 (.4181)	1.4172*** (.7149)	.3021 (.3706)	-.3062 (.5818)

Table A. 2 Robustness check result