OECD Science, Technology and Industry Working Papers
2014/01

Environmental Policies and Risk Finance in the Green Sector: Cross-country Evidence

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https://dx.doi.org/10.1787/5jz6wn918j37-en

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ENVIRONMENTAL POLICIES AND RISK FINANCE IN THE GREEN SECTOR: CROSS-COUNTRY EVIDENCE*

By Chiara Criscuolo and Carlo Menon, OECD Directorate for Science, Technology and Industry

ABSTRACT[1]

Start-up firms play a crucial role in bringing to the market the innovations needed to move to a greener growth path. Risk finance is essential for allowing new ventures to commercialise new ideas and grow, especially in emerging sectors. Still, very little is known about the drivers and the characteristics of risk finance in the green sector. This paper aims to fill this gap by providing a detailed description of risk finance in the green sector across 29 OECD and BRIICS countries over the period 2005-2010 and identifying the role that policies might have in shaping high growth investments in this sector. Results are drawn from a comprehensive deal-level database of businesses seeking financing in the green industry combined with indicators of renewable policies and government R&D expenditures. The results suggest that both supply side policies and environmental deployment policies, designed with a long-term perspective of creating a market for environmental technologies, are associated with higher levels of risk finance relative to more short-term fiscal policies, such as tax incentives and rebates. In addition, when focusing on renewable energy generation, the results confirm the positive association of generous feed-in tariffs (FITs) with risk-finance investment. However in the solar sector excessively generous FITs tend to discourage investment.

* We thank Fabio Bertoni, Massimo Colombo, Stefano Elia, Ivan Haščič, Nick Johnstone, Pietro Moncada-Paternò-Castello, Sandro Montresor, Dirk Pilat, Victoria Shestalova, Mariagrazia Squicciarini, Peter Voigt, Andrew Wyckoff, and Karen Wilson for useful discussions and comments. We are also grateful to the members of the OECD Committee on Industry, Innovation and Entrepreneurship (CIIE), to participants in the seminar at the Dipartimento di Ingegneria Gestionale at Politecnico di Milano and in the ZEW-CODE Conference 2012 for valuable comments, to Hélène Dernis for help with the patent data, and to Teresa Taló and Linda Haie-Fayle for excellent editorial assistance.

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POLITIQUES DE L'ENVIRONNEMENT ET FINANCEMENT PAR CAPITAL-RISQUE DANS LE SECTEUR VERT : DONNÉES INTERNATIONALES*

Par Chiara Criscuolo et Carlo Menon, Direction de la science, de la technologie et de l'industrie de l'OCDE

RESUMÉ

Les jeunes entreprises jouent un rôle fondamental dans la mise sur le marché des innovations nécessaires à l'évolution vers une trajectoire de croissance plus respectueuse de l'environnement. Le financement par capital-risque est essentiel pour leur permettre de croître et de commercialiser de nouvelles idées, notamment dans les secteurs émergents. Pourtant, les déterminants et les caractéristiques de ce financement dans le secteur vert sont toujours en grande partie méconnus. Le présent document vise à combler cette lacune en décrivant de façon détaillée le financement par capital-risque dans le secteur vert dans 29 pays de l'OCDE et BRIICS au cours de la période 2005-2010, et en mettant en évidence l'influence qu'ont pu avoir les politiques publiques sur la configuration des investissements dans les entreprises à forte croissance de ce secteur. Les résultats proviennent d'une vaste base de données des transactions des entreprises du secteur vert à la recherche de financements, qui a été croisée avec des indicateurs des politiques relatives aux énergies renouvelables et des dépenses publiques de R-D. Ils donnent à penser qu'aussi bien les politiques agissant sur l'offre que les politiques de déploiement conçues dans une perspective à long terme pour créer un marché pour les technologiques environnementales donnent lieu à un volume plus important de financement par capital-risque que des mesures budgétaires à plus court terme comme les incitations fiscales et les allégements d'impôts. En outre, les résultats concernant la production d'énergie renouvelable confirment la corrélation positive entre tarifs d'achat généreux et investissements en capital-risque. Cela étant, les tarifs d'achat excessivement généreux dans la filière solaire ont tendance à décourager l'investissement.

* Nous tenons à remercier Fabio Bertoni, Massimo Colombo, Stefano Elia, Ivan Haščič, Nick Johnstone, Pietro Moncada-Paternò-Castello, Sandro Montresor, Dirk Pilat, Victoria Shestalova, Mariagrazia Squicciarini, Peter Voigt, Andrew Wyckoff et Karen Wilson pour les échanges de vues bénéfiques que nous avons eus avec eux et leurs commentaires utiles. Nous sommes également reconnaissants aux membres du Comité de l'industrie, de l'innovation et de l'entrepreneuriat de l'OCDE (CIIE), ainsi qu'aux participants au séminaire tenu au Dipartimento di Ingegneria Gestionale de l'École polytechnique de Milan et à la Conférence ZEW-CODE de 2012 pour leurs précieux commentaires, à Hélène Dernis pour son aide concernant les données sur les brevets et à Teresa Taló et Linda Haie-Fayle pour leur excellent travail d'assistance éditoriale.

TABLE OF CONTENTS

1. INTRODUCTION

Shifting economies from environment- and resource-intensive trajectories to ‘green growth’ will require structural transformation and technological innovation. For this reason, start-up companies play a crucial role in moving towards green growth, as they often exploit opportunities ignored by incumbent firms.

Risk finance[1] is essential to enable new ventures to grow in emerging sectors such as IT-software and biotech, but also in environmental technology (hereafter referred to as the *green sector*).[2] However, private equity financing of green sector companies faces more challenges than in other sectors, due to gaps in managerial skills, the long term investment period, risky exit opportunities, and regulatory uncertainty. The latter source of risks is particularly relevant, as environmental policy has proved, over the last decade, to be remarkably volatile in many countries. This can be a crucial issue for green sector ventures, as their profitability prospects often depend on public regulation. This is probably the most distinctive characteristic of green investments, as compared to risk finance deals in other sectors (e.g. information technology (IT) or medical devices). For instance, White et al. (Forthcoming) discuss the negative effects, in terms of risk capital supply, of two recent major renewable policy changes: a revision of feed-in tariffs (FITs) in Ontario, Canada, and an unexpected major change in bioenergy policy in Norway.

The level of risk finance in green sectors differs significantly across countries, stages of financing, and across sectors. The empirical evidence on what drives these differences is somewhat limited. Firstly, most of the discussion on the gaps in risk finance for green sector is based on case studies, anecdotal and/or survey evidence, but is not supported by econometric analysis. Secondly, most of the evidence on private equity financing, also in the green sector, is limited to venture capital financing, as discussed below.

This paper aims to fill this gap by providing policy makers with some evidence on the national-level determinants of private equity financing. It investigates the relationship between national level “environmental” policies and private equity financing in the green sector using cross-country, cross-industry micro-aggregated data. In particular, it presents estimates of the impact of national level supply-push policies, such as public R&D, as well as deployment policies such as regulations and standards, on the likelihood of obtaining and the amount of green sector private equity financing.

The analysis exploits comprehensive deal-level information on private equity financing and on businesses seeking investment in environmental technologies over the period 2005-2010 in 29 OECD and BRIICS economies,[3] as well as indicators of government renewable policies and government R&D expenditures.

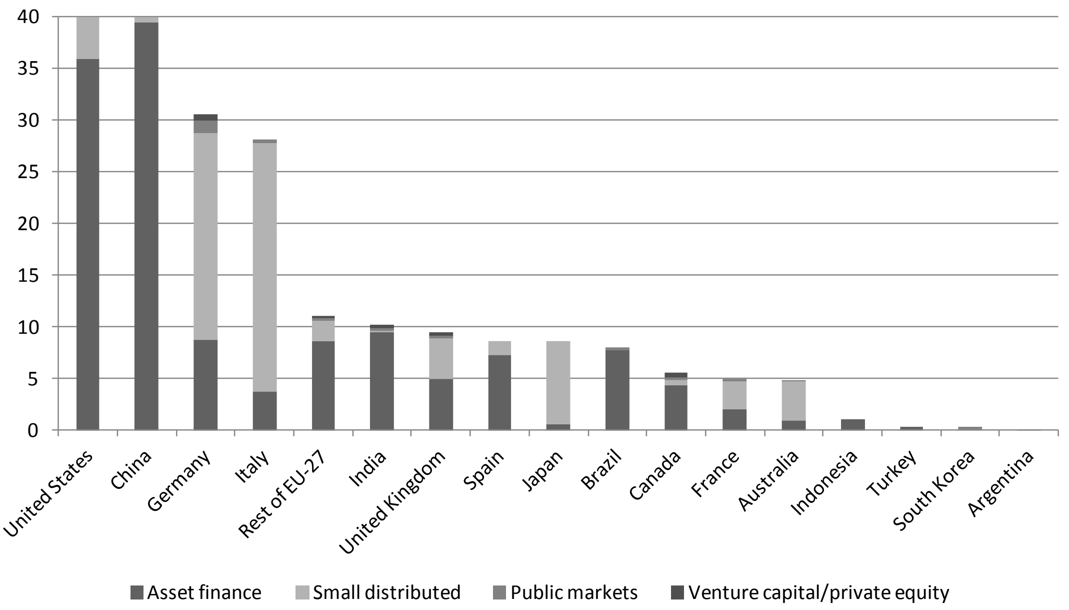
This paper is organised as follows: section 2 describes the financing cycle and the challenges that innovative ventures face in the green sector and summarises the debate on the role of venture capital and government policies in ensuring private equity financing in this sector, and on the role of venture capital for innovation and growth. Section 3 describes the databases and the sources of information that were used to construct the dataset and presents some interesting patterns in the data. Section 4 discusses the econometric framework and reports estimation results, highlighting possible limitations of the analysis. Finally, section 5 concludes and provides policy implications.

2. START-UPS AND PRIVATE EQUITY FINANCING IN THE GREEN SECTOR

Start-ups have been the engine behind growth and breakthrough innovations in sectors such as software, nanotechnology and biotechnology. More recently the importance of start-ups as a source of radical and architectural innovations[4] has also become evident in the green sector.[5] Start-ups therefore play a crucial role in ensuring the shift to a greener growth paradigm and are complementary to "greening Goliaths" (i.e. incumbent large companies; Hockerts and Wuestenhagen, 2010). They are better at, and more likely to, introduce incremental and modular green innovations. Both actors are important in ensuring the broad technological change needed for a more sustainable growth.

Figure 1 illustrates the flow of activities and financing sources as well as government policies that characterise innovative ventures in the green sector. It shows that governments play an important role in the basic R&D phase with technology push measures such as the financing of technology research in government R&D labs, or through grants and prizes in universities. The challenge for policy makers in this phase is not to pick "national champions" and to allow as much experimentation as possible, especially in the early stage of research and technological development.

Figure 1. Investment by financing type in the clean energy sector (billions USD), 2009-2011



Source: PEW Trust (2010), Who's Winning the Clean Energy Race? 2010 Edition G-20 Investment Powering Forward.

For example, China has a number of government related green R&D programmes, such as the National High-Tech R&D programme (USD 2.9 billion) and the National Basic Research Programme with funding of USD 585 million; environmental technologies research institutes and laboratories can be found in several Chinese universities (Cleantech, 2010). The US Department of Energy has its National Renewable Energy Laboratory (NREL) which has contributed to a number of renewable energy advancements. A first financing challenge that entrepreneurs/inventors face is to evolve from the lab phase to the development of the technology (the so-called "technological valley of death"). Governments can play a role with grants and prizes and advanced R&D support, or through funding very early stage investments via special programmes, such as the Advanced Research Projects Agency-Energy (ARPA-E) programme in the United States. Philanthropists are also increasingly playing a role in this phase.

In recent years, venture capital/private equity (VC/PE) has played an increasingly important role especially in the United States, the United Kingdom and more recently in China, although – as shown in Figure 1 – venture capital and private equity represents only a small percentage of overall funding sources for the green sector.[6] These funding sources are relatively more important in countries where venture capital is already developed, such as the United States, but they are also growing in importance in emerging economies, such as Brazil and China. The largest sources of funding, however, remain asset finance[7] and public markets.

This is in line with the fact that VC backing is focused on a particular type of project, characterised by high technology risk and low capital intensity. In fact, as exemplified in the typology outlined in Figure 2, bank debt might be the more appropriate source of funding for projects with low capital and low risk profiles, while project finance better suits projects with high capital intensity and low risk (Kerr and Nanda, 2009 and Ghosh and Nanda, 2010).

On the other hand, venture capitalists are crucial investors for entrepreneurial high growth start-ups operating in young, dynamic and uncertain industries. In the software and biotech sectors, venture capitalists have been key providers of finance where the selection process of an investment is based on an uncertain valuation, with a lack of a clear performance history and a very high technology risk. At the same time, venture capitalists have generally tended to finance projects with low capital intensity and projects that can show rapid commercial viability (3 to 5 years), and that can be sold within the life of a fund (about 10 years), because they need to diversify their high-risk portfolio and increase the chances of positive "tail" outcomes in their investments' portfolio. Venture capital is therefore more likely to finance projects in the bottom right panel of the diagram in Figure 2.

Figure 2. Many green sector ventures are "hard to fund"

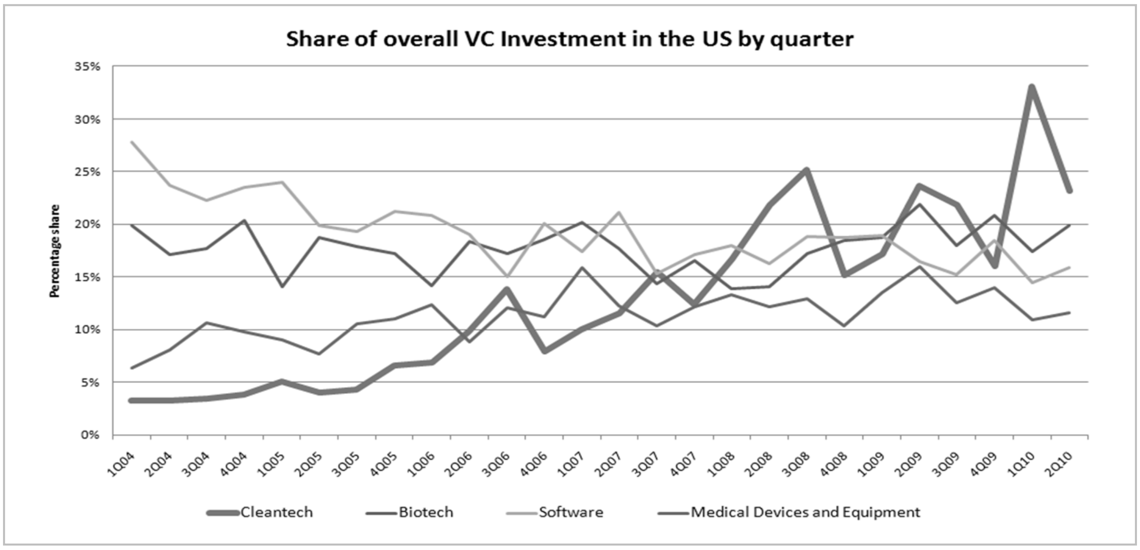
Capital intensity	Low *Technology risk*	High
High	**Project Finance/Existing firms** • Wind farms • Utility-scale solar • First-generation biofuel refineries • Manufacturing of solar cells using established technologies	**Hard to Fund ("Valley of Death")** • First commercial plants for unproven technologies • Advanced biofuel refineries • Offshore wind farms • Carbon sequestration
Low	**Bank Debt/ Existing firms** • Wind and solar component of proven technologies • Internal combustion engines • Insulation/building materials • Energy efficiency services	**Venture Capital** • Energy efficiency software • Lightning • Electric drive trains • Fuel cells / Power storage • Wind and solar components of unproven technologies

Source: Ghosh, S. and Nanda R, (2010), "Venture Capital Investment in the Clean Energy Sector." Harvard Business School Working Paper, 11-020.

Venture capital has been considered a key feature of the successful take off of industries, such as IT, in particular software and biotech and, more recently, is becoming increasingly important for the green industry. In fact figures for the United States market show that since 2004 VC investment in green sector has steadily grown and represents almost a quarter of overall VC investment (Figure 3).

Figure 3. VC investment in the United States in the green sector, 2004-2010

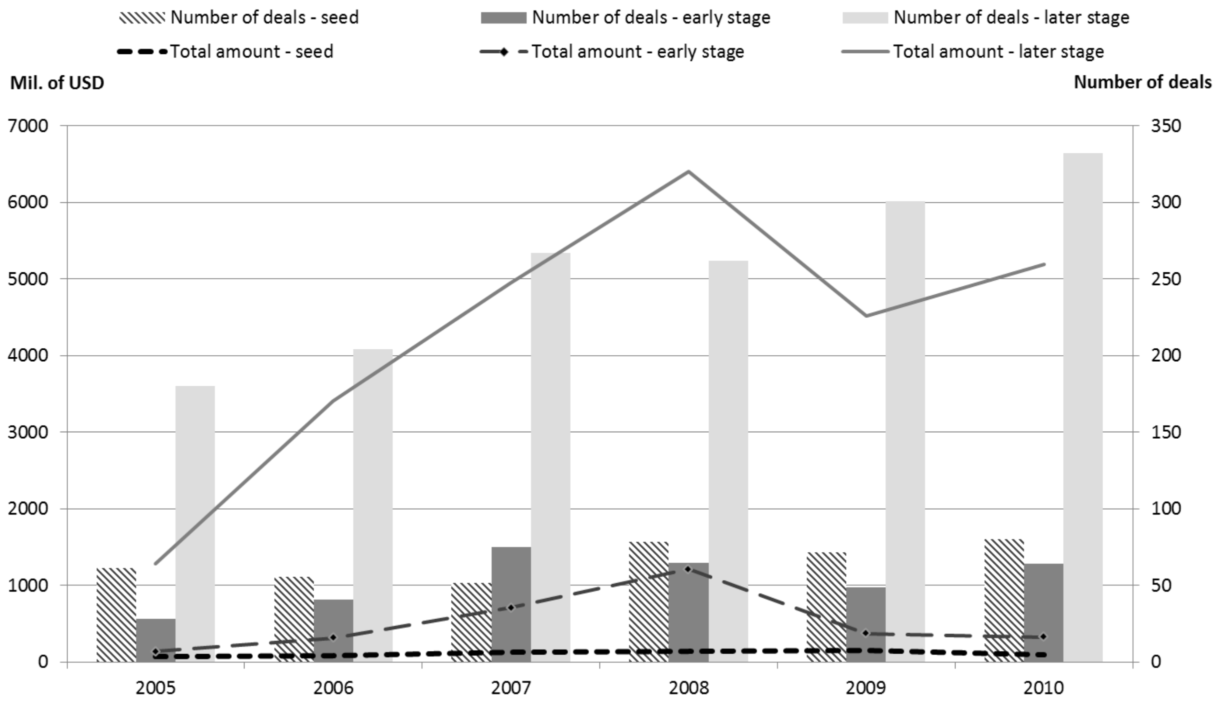
(As compared to Biotech, Software and Medical devices and equipment)



Source: Cleantech Group, PWC/NVCA Money Tree Report.

The importance of environmental technologies in the United States VC market is in line with the growth of green venture capital in North America, Europe, Israel, China and India, both in terms of number of deals and of amount invested, as shown in Figure 4. One feature of this increase is that the overall growth in volume of deals and dollar values is not accompanied by an increase in the average value of each deal. This might reflect several trends, but a possible explanation is that, following the financial crisis, venture capitalists have become more selective in their choice of projects. They cherry-pick projects that are less capital intensive and therefore require less financing on average, thus having a lower impact in terms of risk for the fund.

Figure 4. Cleantech venture investments by deal stages



Source: OECD based on the Cleantech Market Insight Database.

The data available is for too short a period to extrapolate which of the mechanisms is at work, but available information suggests that VCs are moving into less risky projects, with an increased focus on follow-on financing rather than early-stage financing, especially after the financial crisis. This may be due to lower risk propensity.

Overall the risks in the green sector might have particularly important implications for VC financing compared to other sectors such as IT, where VCs have traditionally been very active. These risks are related to managerial gaps, financing gaps, long horizons, uncertain exits, and also to regulatory uncertainties.

In the green sector, VCs are faced with an increased level of managerial and operational risks that could hinder the success of green start-ups. Managerial risks can arise because of the mismatch between the skills needed to manage green sector companies and the skills of CEOs/entrepreneurs/managers that have experience in being backed by VC and, similarly, between skills needed in the initial stage of idea vetting and up scaling/deployment. In addition, the experience of VC investors in mentoring, networking, etc., are not as developed in the green sector as it is in Internet-based start-ups; thus there is the risk of a *managerial valley of death*, in addition to the *commercialisation valley of death* discussed below at the stage of deployment and commercialisation.

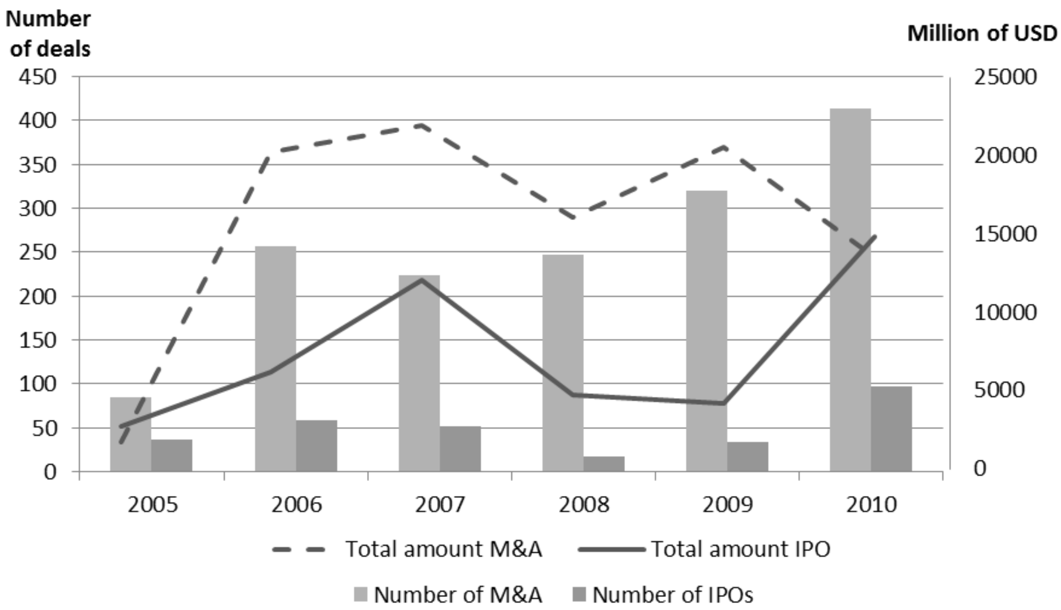
Using the classification of Figure 2, a financing gap is likely to arise for those projects that have both a high *technology risk* profile and are capital intensive; this gap is worsened if in addition the prospects of the project's commercial viability has a long horizon and VCs' exit opportunities are highly uncertain. This is particularly true for projects that are characterised by technology risk at the stage of lab development, but also applies to later stages, such as demonstration and early commercialisation. The main reason for this funding gap is that the longer the time horizon, the higher the *financing risk* for seed and early stage VCs of being unable to ensure a successful exit, or to raise follow-on funding before the end of the life of the VC fund (Nanda and Rhodes-Kropf, 2010). These projects are therefore very hard to fund with either project or debt financing or VC, and can fall into a *"valley of Death"* in terms of financing.

Projects in certain areas of the green sectors fall exactly into this category. Examples could be offshore wind farms, advanced biofuel refineries and first commercial plants for unproven solar cell technologies. These are projects that are very capital intensive and have a very high technology risk, not only in the seed stage, but also in the deployment stage. The risk of failure persists even if the project succeeds at the "lab experimentation" level. Other projects in the green sector industry, however, fall into the category of high-risk, low-capital intensive projects that have been traditionally backed by VC: examples are energy efficiency software, fuel cells etc. Anecdotal evidence (see discussion in Ghosh and Nanda, 2010) suggests that VCs are increasingly shifting their investments towards these latter types of projects. The development and the commercialisation of radical technologies in those green sectors characterised by high-risk high-capital intensive are at risk if they fall short of VC capital backing.

This type of highly risky and capital intensive projects are not funded through project finance either, even though the latter source of financing has been steadily growing since 2004 for projects employing proven clean energy equipment (projects that in Figure 2 would be in the top left quadrant). Recent data report that even before the financial crisis almost no private project finance capital was available for projects whose aim was to deploy unproven technologies, and the financial crisis has made capital availability for this type of project even scarcer (Bloomberg New Energy Finance, 2010).

As mentioned above, exit strategies for VCs, be it under the form of merger and acquistions (M&As) or initial public offerings (IPOs), can be particularly difficult both at the level of manufacturing scale up and at the level of full commercialisation. These difficulties arise also because of the inherent regulatory risk in the green sector, which might arise because private investors are unsure that established policies and regulation will remain in place over the longer term. There are still very few IPOs in the green sector, as shown in Figure 5, with a big drop observed during the crisis.

Figure 5. IPOs and M&As in the green sector, 2005-2010



Note: dollar values are expressed in real terms.

Source: OECD elaboration based on the Cleantech Market Insight Database.

However, encouraging signs of development in this stage in the green sector are due to the increasing role of major corporations as acquirers of successful start-ups. In 2009, the share of green M&As rose to over 5% of global M&A transactions (Cleantech, 2010). In line with the experience of biotech, ICT and semiconductors, this might lead to a take-off of innovation from the seed stage to large-scale deployment and commercialisation. This is because of the increased likelihood of successful exits via M&As, which might lead to a virtuous circle in the financing and development of innovative ventures in the green sectors: VCs will increasingly have positive expectations about exit strategies and therefore will carry on investing at the seed, early and follow on stage; start-ups will be able to upscale their activity and exploit knowledge, networks, marketing experience and reputation of more mature companies; and finally incumbents can increase their innovation[8] and clean production capacity, securing supply chain inputs.

The extent to which the current level of activity in the M&A market of green companies is sufficient to develop a virtuous circle of financing, is still open to debate, but recent trends show an upward trend in M&A activity by large corporations, as shown in Figure 5 (and as discussed in Criscuolo et al., Forthcoming).

The difficulties due to the lack of financing at the commercialisation phase and the uncertainties of the exit strategies can lead to a drying up of finance early on in the innovation chain (already at the seed stage), since venture capital companies might be unwilling to take the risks. The problems can be further exacerbated by policy risk and uncertainty.

Policy makers can play an important role in different dimensions. As mentioned before, governments can provide direct support to university and/or government programmes through grants and/or prizes, but can also help green sector entrepreneurs during the up scaling phase through loans or loan guarantee programmes. An example is the US Department of Energy Loan Guarantee Programme (LPG) designed to support the development of early stage clean energy projects (for more details of the programme see Bloomberg New Energy Finance, 2010).

The importance of policy consistency for the decision of venture capital has been confirmed in a recent survey of VC funds involved in investment in green sector and might partly explain the success of FITs[9] in Europe, with the long track and stable policy record of its application in Germany (Burer and Wuestenhagen, 2009). At the same time, this type of mechanism is very sensitive to long-term support and very much depends on getting prices right, as shown by Spain's recent experience, when the government, which had been very generous with its FITs, cut down on the programme which almost led to a collapse of the Spanish renewable energy market (Bloomberg New Energy Finance, 2010).

Most importantly governments need to ensure policy consistency and the appropriate regulatory framework, and minimise policy uncertainty, which can hinder access to finance for green sector start-ups.

The role of venture capital for innovation and growth

Company development and innovation

A variety of studies have shown that venture-backed companies are responsible for a disproportionate number of patents and new technologies, and bring more radical innovations to markets more rapidly than lower growth businesses that rely on other types of finance.

Kortum and Lerner (2000) examined the influence of venture capital on patented inventions in the United States across twenty industries over three decades. They found that increased venture capital investment in an industry was associated with significantly higher patenting rates. While the ratio of venture capital to R&D averaged less than 3% from 1983-92 they estimated that venture capital may have accounted for 8% of industrial innovations in that period. The strong relationship between venture capital and patenting at the industry level is also indicative of a relationship between venture disbursements and innovative output. Kortum and Lerner (2000) also examined the possibility that venture capital-backed firms would be keener to patent inventions compared to those with no venture capital. This was due to mainly two reasons: venture backed companies could fear that the venture investors would exploit their ideas; and investors are keener to invest in companies with patents already granted. In order to address these issues, the researchers examined three additional measures of innovation activity: i) number of patent citations and the economic importance of a patent; ii) frequency and extent of patenting; and iii) trade secret litigations in which the company has engaged. All the tests of differences in means and medians in these three categories were significant at least at the 5% confidence level, as well as when the study employed regression specifications. Given the rapid increase in venture funding since 1992 in the United States, the study suggested that by 1998 venture funding accounted for about 14% of the country's innovative activity.

Studies undertaken in the United Kingdom covering a period of ten years (i.e. 1995–2006) showed that companies backed by venture capital invested more in R&D than those that were not (BVCA? 2008). Research by CASS Business School (Levis, 2010) found that the typical private equity-backed or venture capital-backed initial public offering (IPO) spends more on R&D, GBP 1 million and GBP 1.4 million respectively, than their equivalent non private equity-backed counterparts (GBP 0.3 million), at the time of flotation.

Other empirical research in the United States has shown that VC can significantly enhance the ability of new companies to create wealth and jobs (Gompers and Lerner 2001). Hellmann and Puri (2000, 2002) show that VC backed companies aim for more radical innovation, are significantly faster in introducing their products to the market, and pursue more aggressive market strategies than other start-ups. Venture capitalists carefully screen companies, structure contracts to strengthen incentives and monitor companies (Kaplan and Stromberg 2001), add value to the new company, promote their professionaliSation and induce them to behave more aggressively.

Creation of new industries

Venture capital has played a unique role in the formation and commercialisation of entire new industries (Bygrave and Timmons 1992); personal computers, mobile phones, microcomputer software, biotechnology, and overnight delivery to name a few. Recently, venture capital has become a major source of finance in cutting edge industries such as health care and the web 2.0. This underlines Zook's (2000) observation about the high positive correlation between internet companies and venture capitalists in the United States.

Zook (2000), using empirical data, analysed how the spatial structure of knowledge used by venture capitalists during the development of the Internet industry contributed to its clustering. He argues that "venture capitalists are best understood as tacit information brokers who acquire and create tacit knowledge about industries, market conditions, entrepreneurs and companies through a constant process of Marshallian interaction and observation" (pp. 628).

The determinants of VC investment

There is an important but not extensive strand of literature on the determinants of venture capital investment (see for example Gompers and Lerner, 2001; Jeng and Wells, 2000; Schertler, 2003 and Romain and Van Pottelsberghe de la Potterie, 2004; da Rin et al., 2006).

This literature suggests that public policies can in part explain cross-country differences in venture capital intensity. Corporate and capital gains tax regimes, stock market regulations, volatility of interest rates, and employment protection laws all affect VC finance. Market capitalisation and GDP have a positive impact on VC investment. An active stock market can play an important role for VC finance, especially for later stage financing, given that IPOs are possibly the best indication of potential returns to VC investment. This can be proxied for by the number of IPOs in a country's stock market (Jeng and Wells, 2000), or by market capitalisation growth and GDP (Gompers and Lerner, 2001)

Government programmes for entrepreneurship, bankruptcy laws, private pension funds levels and accounting standards also explain a significant part of cross-country differences in VC investments; as do labour market rigidities that might be an obstacle for VC, especially for early stage financing (Jeng and Wells, 2000).

3. DATA

The data used in the analysis comes from combining a private commercial database on financing, initial public offerings (IPO) and merger and acquisition activity (M&A) in the clean tech sector (from the Cleantech company, www.Cleantech.com) with databases on innovative activity at the regional and national level and with indicators of relevant policies and conditions at the national level. The empirical analysis in this paper makes use only of financing deal data, while information on IPOs and M&As will be used in future research.

Data on financing

In this report we mainly exploit the information on financing of green companies from the commercial database. The dataset comprehends different forms of financing for high-growth firms. More than half of investors are venture capital firms, while private equity funds and corporations represent together more than 20% of all investors. The remaining investors are classified as business angels, public investments, investment banks, non-profit, university, and non-VC funds. Investors that could not be categorised in any of the above groups were included in a residual category "other".

This information is provided at the deal level and provides details on companies receiving funding, (number and identity of investors – including name, address and web pages) and the development stage of their investment activity, and dates and amounts of the investment. However, when a syndication of investors is involved in the deal, data on the exact contribution of each individual investor are not reported. In a few cases – less than 30% of the sample – the year in which the business seeking investment was founded and the names of the management team of the company are also included. Table 1 reports the example of two deal records (some entries have been replaced with fictitious records to avoid the identification of the two companies and of investors).

Table 1. Examples of the Cleantech database

Name	Clean Ideas	Greener World
Primary	Air & Environment	Water & Wastewater
Secondary industry	Air & Environment, Cleanup/Safety, Remediation	Oil and Gas, Wastewater Treatment, Water & Wastewater
One sentence description	Developer of a variety of bioremediation technologies	Provider of oilfield wastewater treatment services
Website	www.cleanideas.com	www.greener-world.cn
Address	1345 Green Drive	3rd Fl., Alley 342, #23 Jeaihi Road
City	Ottawa	Shanghai
Country	Canada	China
Deal date	2Q2006	8/19/2009
Amount	USD 1 440 000	USD 500 000
Invt. Stage	Follow-On	Seed
Investors	VentureFun Funds, Covent Group of Funds	Rich Partners, iSecond Capital, Rockfeller intln

Source: OECD elaboration based on Cleantech Market Insight Database. Some details of the two companies and of investors' names have been replaced with fictitious records to avoid disclosure of proprietary data.

The deal data contain detailed information on the stage of the investment, which were consistently aggregated into the five following categories: seed; early stage; later stage; buy out; and other.

The data cover Europe, North America, and BRIICS countries starting in 2000 until 2011. Given that only the first semester of 2011 was included and that coverage up to 2004 was possibly less comprehensive, the regression analysis is limited to the period 2005 - 2010.

Table 2. Environmental technology sectors covered by the Cleantech database

Primary industry	Secondary industry
Agriculture	Aquaculture*; land management; natural pesticides
Air & environment	Cleanup/safety; emissions control; logistics; monitoring/compliance; trading & offsets; vehicles; water treatment
Energy efficiency	Advanced packaging; biofuels; buildings; chemical; glass; lighting; monitoring & control; monitoring/compliance; smart production; trading & offsets*; transmission
Energy generation	Biofuels; geothermal; hydro/marine; solar; wind
Energy infrastructure	Management; transmission
Energy storage	Advanced batteries; fuel cells; hybrid systems
Manufacturing;/industrial	Advanced packaging; monitoring & control; smart production
Materials	Bio; chemical; glass*; nano
Recycling & waste	Recycling; waste treatment
Rransportation	Advanced batteries; fuels; logistics; structures; vehicles
Water & wastewater	Bio; cleanup/safety; glass*; wastewater treatment; water conservation; water treatment

* The secondary industries “acquaculture” and “glass” are not generally included in the “green sector”. Similarly, “trading & offsets” may be an unusual area of activity for startups. However, their exclusion does not affect the results of the empirical analysis (results available from the authors upon request).

As described in Table 2 the sectors covered in the data span from energy generation, to waste water treatment, to materials. Most of the deals in the sample are in the energy generation sector, but there is wide variation across countries (for further detail on sectors included see Table A1 in the Appendix). In addition to companies receiving investments, the data include information on companies that are actively seeking funding. Although the point in time when the company started looking for funding cannot be identified, the data provide an approximate date for when the company made this information public. This is used to build a control variable based on information on those companies actively but unsuccessfully looking for funding. This control variable helps reach a cleaner identification of the factors leading to successful deals in the green sector in a given economy, taking into account the entrepreneurial activity and the level of demand for risk finance in the same sector and economy.

The data was extensively checked for inconsistencies and cleaned using information from different sources, including the web pages of the companies in the sample. When possible (for about a third of the sample), the data was complemented with punctual information from another venture capital database

(Thomson One);[10] this enabled the improvement of the extent and quality of the information on investees' and investors' location founding year, and on type of investors.

Information on country level policies

National environmental policies can strongly affect the expected commercial viability and future profitability of nascent ventures in the green sector. Although part of the goods and services produced by the green sector are in principle tradable, the domestic policy environment still plays a prominent role, for various reasons. First, barriers to technology diffusion hinder patent transfer across borders: for instance, empirical evidence on the wind power sector shows that the marginal effect of domestic policies on innovation is 25 times stronger than that of foreign policies (Dechezleprêtre and Glachant, 2012). Similarly, it is well known that the energy market is heavily regulated in many countries, and there are non-trivial costs in the storage and transfer of electricity; this also limits the international tradability of energy. As a consequence, domestic policies are of prime importance in the energy generation sector, and are likely to be even more so in other domains covered by the database, e.g. wastewater treatment, soil remediation, etc.

The main source of information on environmental policies is the Renewable Energy Policy Network for the 21st Century (REN21) with reports starting in 2005 and later updates. The information has been complemented and cross-checked with information from the International Energy Agency (IEA); Pew Trust reports for 2009 and 2010 and from the OECD Environment Directorate on FITs and tradable energy certificates (Johnstone, Haščič and Popp, 2010) for 2005 (which is the latest year for which information from this source is available).

Policies to promote renewable energy that are covered in the analysis can be classified as: i) price-driven regulation policies, such as FITs; ii) quantity-driven regulation policies, e.g. tradable renewable certificates; iii) sale tax or VAT reduction and related mechanisms; and iv) fiscal incentives, such as direct capital investment subsidies, grants, or rebates, tax incentives, and tax credits for renewable energy. Table 3 describes in detail the adopted classification and the policies included in each group, as well as the countries and the dates when these policies were enacted.

As shown in Table 3, government support for renewable energy differs both across countries and over time in the sample included in the analysis. One of the most commonly used renewable policies is FITs, which were first introduced in 1978 in the United States (PURPA).[11] In the early 1990s feed-in policies were introduced in Denmark, Germany, Greece, India, Italy, Spain, and Switzerland and in 2005 in Ireland. Of the BRIICS, India was the first to adopt FITs, followed by Brazil, Indonesia, and in the first half of 2005 by China, as part of a comprehensive renewable energy promotion law enacted in February 2005. FITs vary in design across countries: some policies only apply to some technologies or maximum capacity. Most differentiate tariffs across different technologies, usually related to the cost of generation (e.g. differentiated between off-shore and onshore wind power). Some also distinguish location/region, year of plant operation, and operational season of the year. Tariffs for a given plant may decline over time, but typically last for 15–20 years. Some policies provide a fixed tariff while others provide fixed premiums added to market- or cost-related tariffs, or both (e.g. Spain).

Renewable portfolio standards (RPS) and public competitive bidding for specified quantities of power generation are also increasingly being used. Most of the RPS policies require renewable power shares in the range of 5–20%. Most RPS targets translate into large expected future investments. For example, as highlighted in the special report on renewable energy sources and climate change mitigation (IPCC, 2011), existing estimates suggest that, based on current state RPS legislation in the United States, an additional 52 GW of renewable energy would be required by 2020, which would more than double existing US renewable capacity.

Table 3. Renewables policy measures

Category	Policy measures	Country and year of adoption*
Regulation ***price***	**Feed-in tariffs** set a fixed price at which power producers can sell renewable power into the electric power network. Countries can offer a fixed tariff or provide fixed premiums added to market – or cost related tariffs. Some provide both.	Germany, Sweden, Denmark, China, France, Austria, Spain, Israel, Ireland, Canada, Switzerland (2004 or before); Greece, Indonesia, Italy, Netherlands (2005); Czech Republic, Hungary, Brazil (2006); South Africa, Portugal (2007); Poland, Luxembourg (2008); United Kingdom, Finland, Japan (2009); India (2010).
Regulation ***quantity***	**Renewable portfolio standards or quotas (RPS)** require that a minimum percentage of generation sold or capacity installed be provided by renewable energy. Obligated utilities are required to ensure that the target is met, either through their generation, power purchase from other producers, or direct sales from third parties to the utility's customers.	Australia, Belgium, Italy, Japan, Sweden, United Kingdom, United States (2004 or before); Poland (2005); China (2006); India (2006); India (2007); Portugal (2010).
	Tradable renewable certificates represent the certified generation of units of renewable energy. They allow trading of renewable energy obligations among consumers and/or producers, and in some markets like the United States allow anyone to purchase separately the green power "attributes" of renewable energy.	Australia, Austria, Belgium, Denmark, Finland, France, Ireland, Italy, Japan, Norway, Sweden, United Kingdom (2004 or before); Netherlands (2005); Czech Republic, Hungary, Russia (2006); India, Poland, Spain, United States (2010).
	Public competitive bidding means that public authorities organise tenders for a given quota of renewable supplies or capacity, and remunerate winning bids at prices that are typically above standard market levels.	Australia, Canada, China, France, Germany, India, Japan, Spain (2004 or before); Austria, Denmark, Poland (2005); Brazil, Hungary, New Zealand (2006); Greece, Italy, Norway, Portugal, South Africa, Sweden, United Kingdom (2008), United States (2010).
Sales tax reductions	**Sales tax, energy tax, excise tax or VAT reduction** are fiscal policy tools providing consumption tax exemptions or reductions on the sale of renewable energy and equipments.	Canada, China, Finland, France, Germany, India, Sweden, United Kingdom (2004 or before); Belgium, Denmark, Poland (2005); Czech Republic, Hungary, (2006); Portugal (2007); Indonesia, Israel, Italy, Luxembourg, Netherlands, Norway, South Africa, Spain, Switzerland (2008); Brazil, United States (2010).
Fiscal incentives	**Public investments, loans or financing** are public policies aimed at directly acquiring renewable power generators, or at providing ad-hoc subsidised financing for private investors.	Australia Canada China France, Germany India, Japan, Spain (2004 or before); Austria Denmark, Poland (2005); Brazil, Hungary, New Zealand (2006). Greece, Italy, Norway, Portugal, South Africa, Sweden, United Kingdom (2008), United States (2010).
	Capital subsidies, consumer grants or rebates are one-time payments by the government or utility to cover a percentage of the capital cost of an investment, such as a solar hot water system or rooftop solar PV system.	Australia, Austria, Belgium, Canada, China, Finland, France, Germany, India, Ireland, Italy, Japan, Norway, Spain, Sweden, United Kingdom, United States (2004 or before); Greece, Netherlands, Poland, South Africa (2005); Czech Republic, New Zealand, Russia (2006); Portugal (2007); Denmark, Luxembourg, Switzerland (2008); Hungary (2009).
	Investment or other tax credits allow full or partial deduction from tax obligations or income for investments in renewable energy.	Austria, Belgium, Canada, China, Denmark, France, Germany, India, Ireland, Italy, Norway, Spain, Sweden, United States(2004 or before); Greece, Netherlands, (2005); Czech Republic(2006); Portugal(2007); Brazil, Luxembourg (2008); Hungary, Indonesia, Japan (2009).
	Energy production payments or tax credits provide investors or owners of qualifying property with an annual tax credit or a payment based on the amount of electricity generated by that facility.	Finland, Sweden, United States (2004 or before), India, Netherlands (2005); China, (2008); United Kingdom (2010).

Note: * For a few country-year pairs for which the information was not available it has been imputed based on information on the previous or following year.

Source: REN21 (2005, 2006, 2007, 2008, 2009, 2010, 2011) Renewables Global Status Report (Paris: REN21 Secretariat).

Other forms of regulatory policies for renewables include tradable renewable energy certificates, and a number of other policies with more limited impact, such as: appliance/equipment efficiency standards, building energy codes, energy efficiency resource standards, energy standards for public buildings, equipment certification requirements, generation disclosure, green power purchasing policies, interconnection standards, mandatory utility green power option, and net metering. Sales tax reductions are also demand-side policies which have been increasingly implemented in a number of countries in recent years.

Such short or long term regulatory measures can spur renewable energy markets and might significantly affect the perception that investors have of the renewable energy sector.

There are other forms of support for renewables: fiscal incentives, such as direct capital investment subsidies or rebates, tax incentives and credits, direct production payments or tax credits (i.e. per kWh). Some type of direct capital investment subsidy, grant, or rebate is offered in as many as 30 countries globally. The US federal production tax credit is possibly the most noteworthy example of such policies. Although the credit has applied to more than 5 400 MW of wind power installed from 1995 to 2004 alone and has increased over time, it has gone through a series of expirations and renewals. This cycle of expiration and renewal has been highlighted as a weak point of the policy that has limited its effectiveness (Barradale, 2008).

Governments are also increasingly providing direct public investment or financing. Some countries and regional authorities have established renewable energy funds that are used to directly finance investments, provide low-interest loans, or loan guarantees.

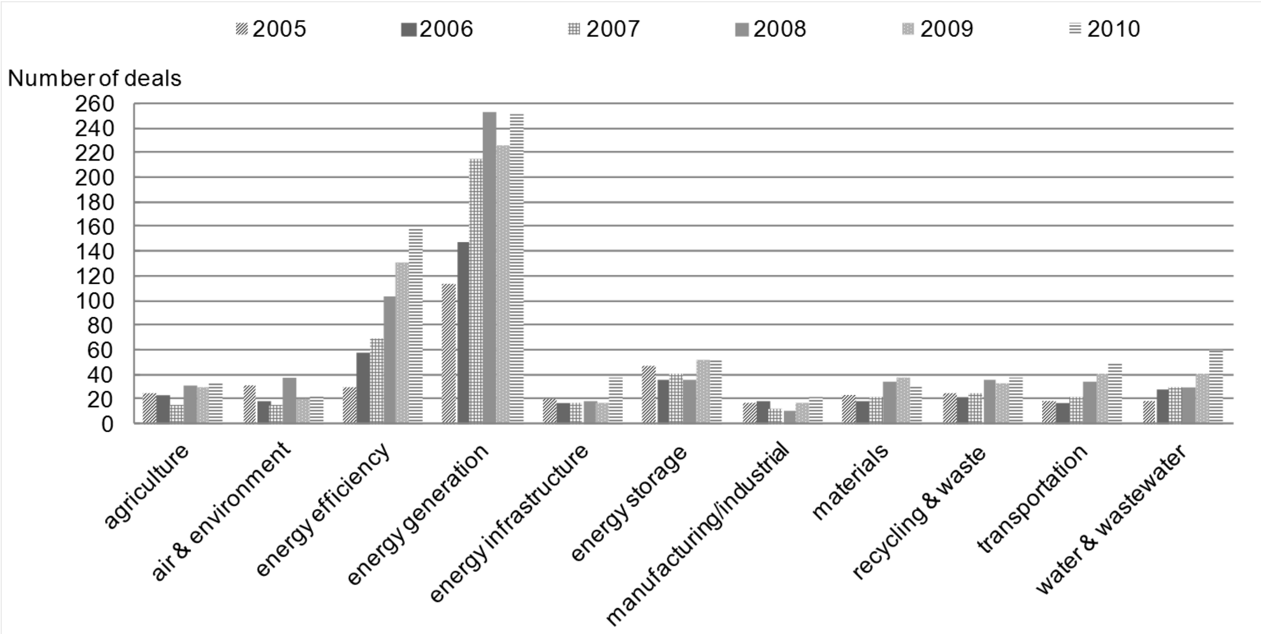
Additional support includes supply-push policies, of which research and development funding is a significant part. R&D and demonstration (RD&D) budgets in the energy sector, i.e. the total amount and allocation of funding by category of energy technologies for research, development and demonstration, would have been the best proxy for supply-push policies in energy. However, due to concerns over comparability and availability of data for non-IEA member countries, data on government R&D budgets are used as a proxy for government energy RD&D.

The policy measures used in the analysis have the advantage of being precise on the nature of the policy tool in place, encompassing nine different definitions, which are then grouped into four categories. This allows the disentangling of the different effects of each policy domain, which would not be possible using general indicators of environmental policy stringency.[12] Furthermore, they are timely (the latest available year is 2010) and are available for both the OECD and non-OECD countries included in the sample. On the other hand, the measures present some drawbacks. Firstly, they only contain information on whether a policy is in place, but they do not provide detailed information on the characteristics of the policy (generosity of support; stringency; and other features of the policy design). Secondly, the policies considered are arguably more relevant for the promotion of renewable energy in the electricity generation sector; for this reason, the empirical analysis includes a robustness check limiting the sample to the energy sector. Thirdly, the policies considered are all at the national level; policies offered at the regional or local level are not taken into account. This can be particularly limiting in the case of the United States, as there is a significant degree of variation across federal authorities in the number of policies in place. However, robustness tests excluding the United States are also reported in the empirical analysis.

Data description

The dataset contains 7 268 observations, of which 4 898 are financing deals, and 2 370 are reports of companies seeking funding. It covers 72 different countries over the time period 1999 to July 2011. Deals and seekers from non-OECD and non-BRIICS countries for which it was not possible to find reliable data on environmental policies were dropped from the sample. For the same reason and to ensure the quality of the coverage of deals in the green sector, the analysis is restricted to the time period 2005-2010 and to 29 OECD and BRIICS countries, i.e. to a sample covering 4 792 observations, of which 3 007 are deals, and 1 785 are seekers.

Figure 6. Number of deals by primary industry and year



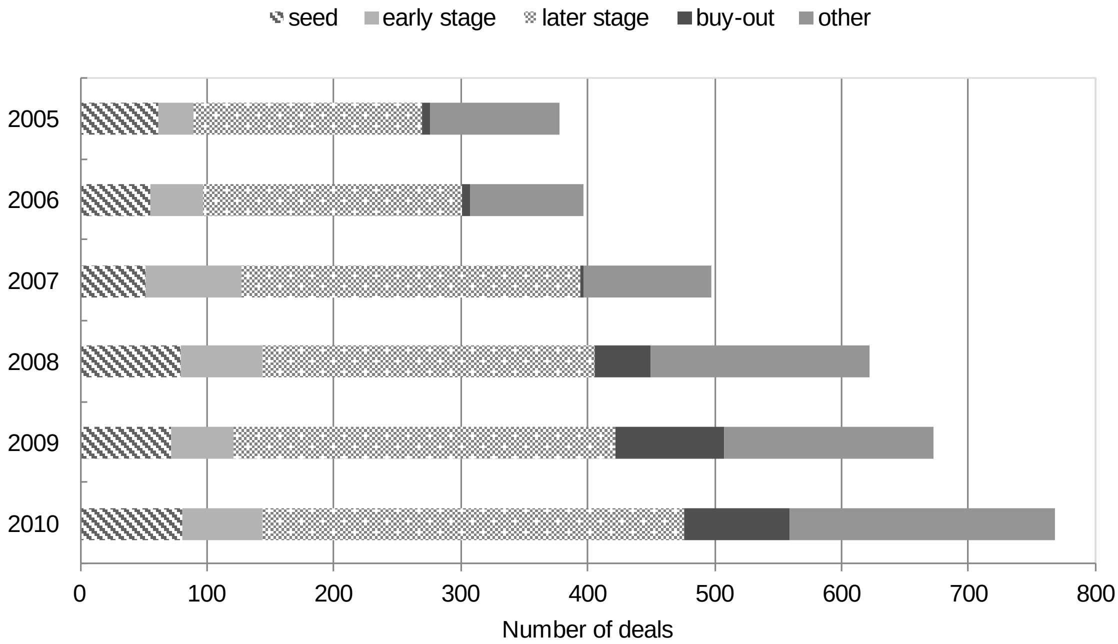
Source: OECD elaboration based on the Cleantech Market Insight Database.

Figure 6 reports the number of deals by year and industry. As shown in the figure, energy generation represents the largest recipient of private equity financing deals (30% of deal in 2005 and up to 44% of deals in 2007), followed by energy efficiency, which is also the sector that grew most in relative terms, from 8% of all Cleantech deals in 2005 to 21% in 2010.[13] This pattern is consistent with anecdotal evidence that venture capitalists have shifted their activity within the green sector towards ventures that are less capital intensive and have features similar to ICT ones, such as those in the energy efficiency sector. In addition, in some industries – such as energy generation – the size of the market for the good or service offered by the firm seeking financing could depend heavily on the regulatory framework in place in a country; given the inherent public nature of the good in question. Others, such as energy efficiency might be more resilient to policy changes.

A similar pattern is shown in Figure 7, which aggregates the number of deals according to the stage of the investment: seed and early stage; later stage; and buy-out deals. Almost half of the deals are later stage investments, while seed and early stage investments represent about one third of the sample. Over the years, seed investments have become less of a target for investors, relative to later stage and buy-out investment. Again, this suggests a shift of high-growth financiers towards less risky investments in the green sector.

Figure A1 in the Appendix complements this information aggregating deals by industry and investment stage, showing that follow-on investments are predominant across all industries.

Figure 7. Number of deals by investment type



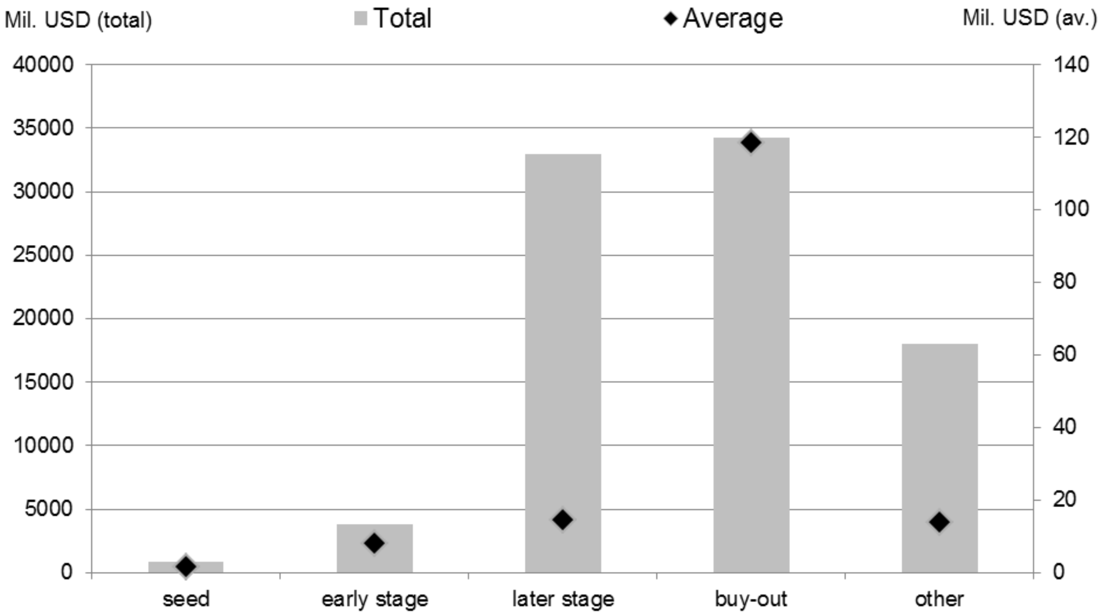
Source: OECD elaboration based on the Cleantech Market Insight Database.

In terms of geographical distribution of the deals and of companies seeking funding in the sample, around half of the deals involve companies based in the United States, and about 40% of companies seeking funding are also located in the United States. This suggests that the larger number of deals partly reflect the higher overall entrepreneurship rate. The United Kingdom and Canada are ranked second and third respectively in the number of deals. When comparing the ratio of companies receiving funding with the number of those seeking funding, the United Kingdom shows a much higher ratio between funded and seeking companies (504 to 143, as compared to 2 456 to 1 519 for the United States, and 308 to 176 for Canada), suggesting that, once the higher number of companies seeking funding is accounted for, the United States is not necessarily the most attractive country for green sector investors.

Up to now the focus has been on the number of deals; however deals might differ significantly in their value. Thus, the following data description also presents figures on average and total amounts invested, aggregated over stage of investment, industry, and year. Looking across stages of investment, the data shows that the average investment amount is smaller than USD 20 million for all but buy-out investments, that reach an average amount of around USD 120 million; i.e. 80 times the average seed investment (worth USD 1.5 million) and eight times the average follow-on investment (which is around USD 14 million – Figure 8). Given the larger number of follow-on deals, follow-on investment accounts for 37% of total amount invested, and buy-out, in which there are fewer but much more sizeable deals, accounts for 38% of total amount invested. Seed and later stage investment together account for only 5% of aggregate total investment amount.

Figure 8. Total (scale on the left) and average (scale on the right) amount by investment type

Millions 2005 USD

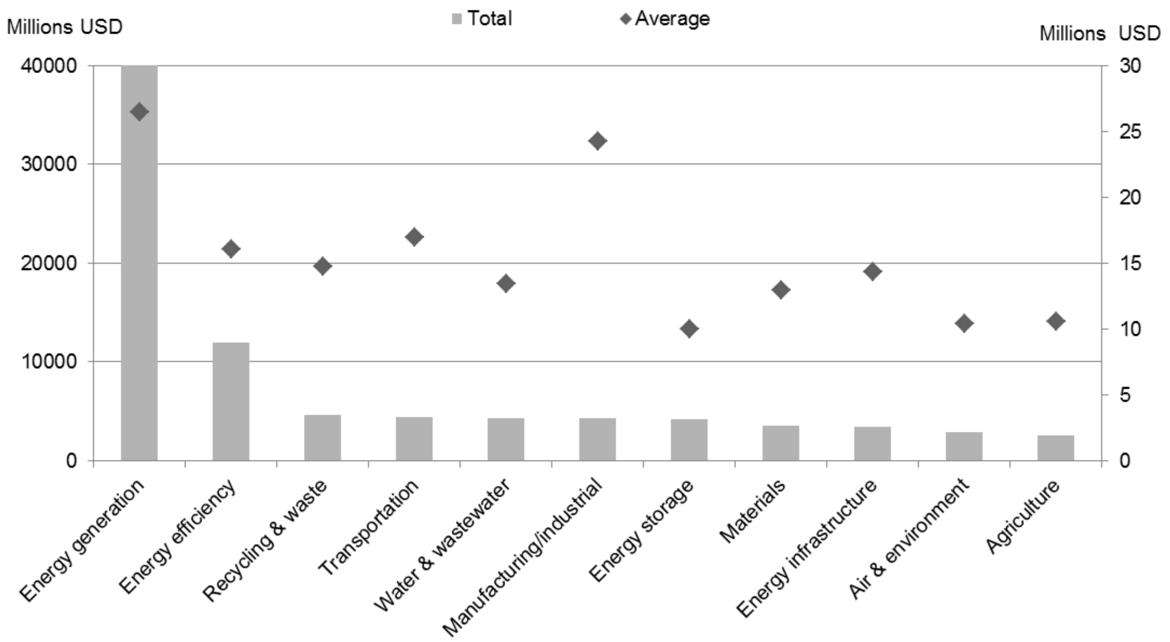


Source: OECD elaboration based on the Cleantech Market Insight Database.

The average investment amount by primary industry is largest in the energy generation and manufacturing/industrial sector(~25 million); it is equal to around 10 million in energy efficiency, while in all other industries is lower than 5 million (Figure 9).

Figure 9. Total (scale on the left) and average (scale on the right) amount invested by primary industry

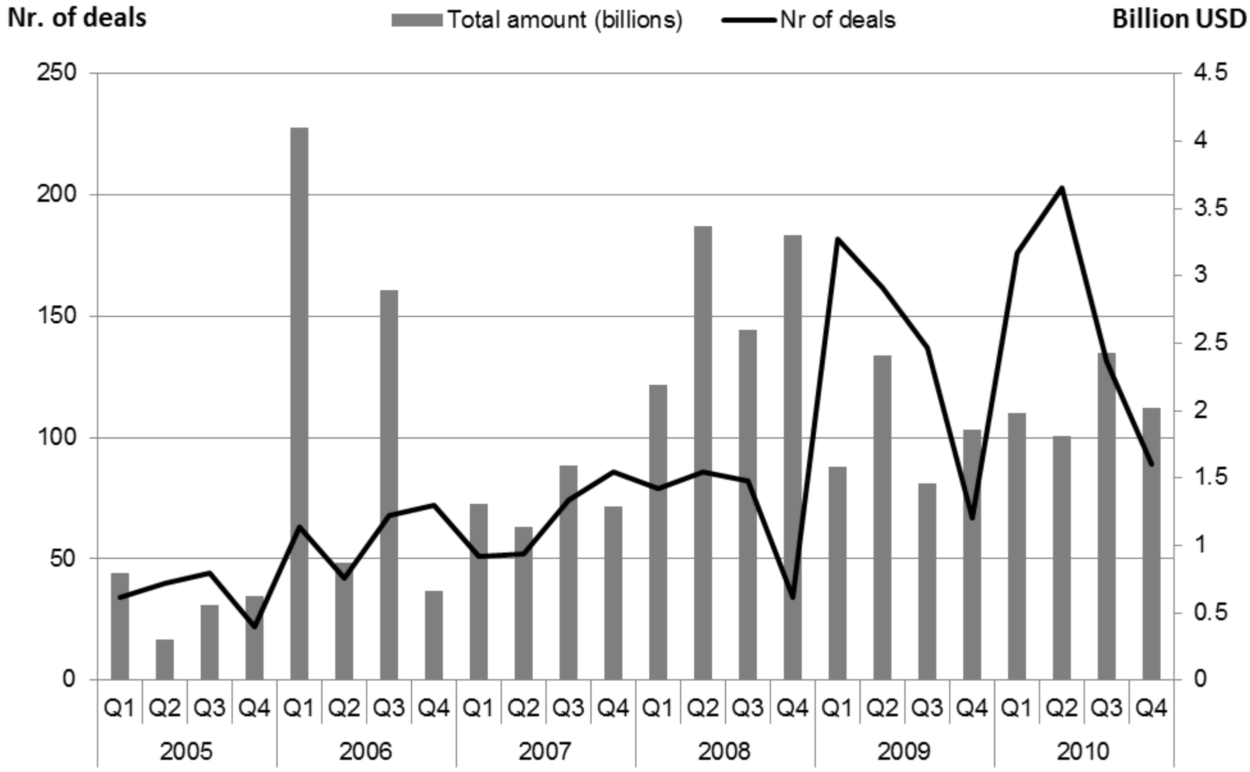
Millions 2005 USD



Source: OECD elaboration based on the Cleantech Market Insight Database.

The average and total amount of investment have overall been growing over time, but with some volatility (Figure 10). The year with the highest average and total volume of investments is 2008, while figures for 2009 and 2010 are somewhat lower, following the international financial crisis (see also Lerner (2011) for the cyclicality of venture capital investment).

Figure 10. Total amount (scale on the left) and number of deals (scale on the right) by year quarter

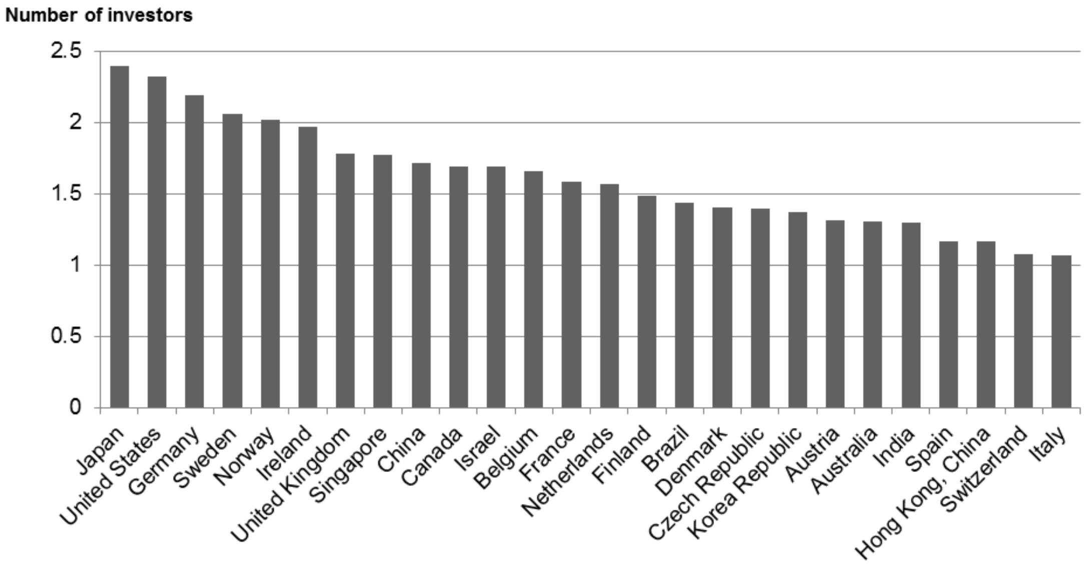


Note: dollar values are expressed in real terms.

Source: OECD elaboration based on the Cleantech Market Insight Database.

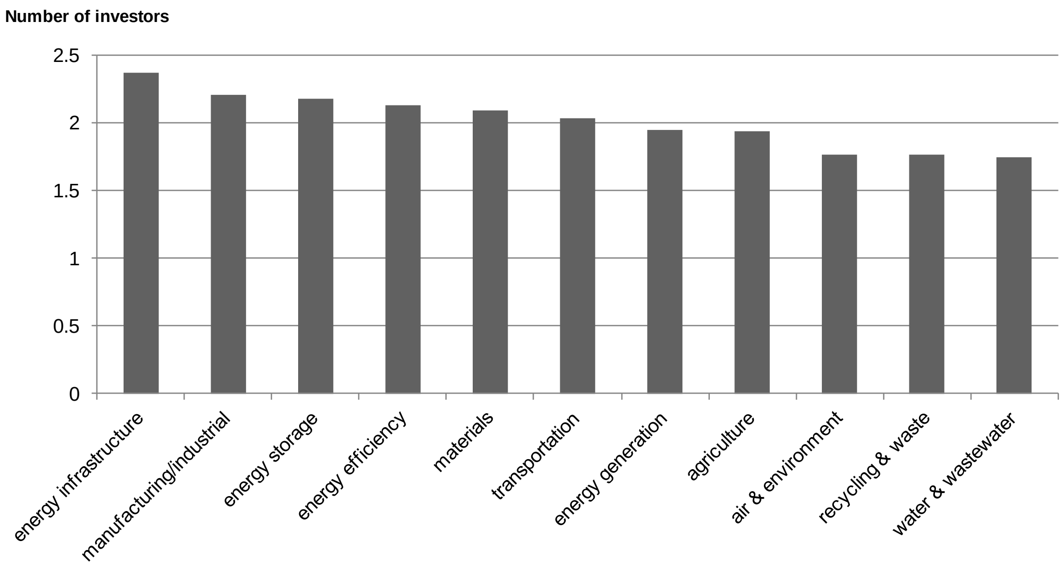
Another interesting dimension of the investment is the size of syndication, i.e. the number of different investors participating in a single deal. The size of syndication is generally constant across industries (Figure 12) and is larger for follow-on investments (Figure 13). There are, however, some differences across countries: syndication size is highest in Japan, where there are more than two investors per deal, and lowest in Switzerland, Italy and Korea, where the number of reported investors is rarely above one (Figure 11).[14] Noteworthy cross-economy differences also exist in the share of deals in which at least one investor is located in a different economy than the funded company (Figure 14): Hong Kong, China; Singapore; and Chinese Taipei attract the highest shares of foreign investment, while investors in the United States, the United Kingdom, and Australia are generally domestic companies.

Figure 11. Average number of investors per deal by funded company's economy



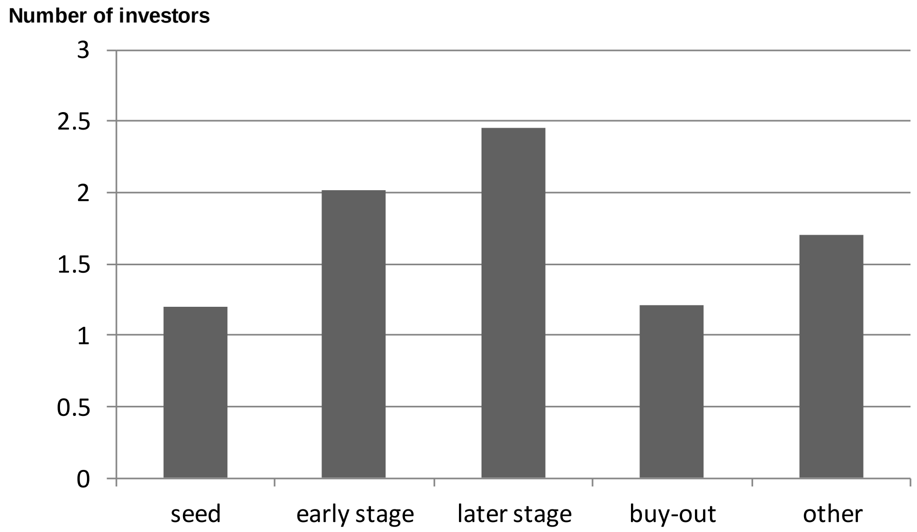
Source: OECD elaboration based on the Cleantech Market Insight Database.

Figure 12. Average number of investors per deal by industry



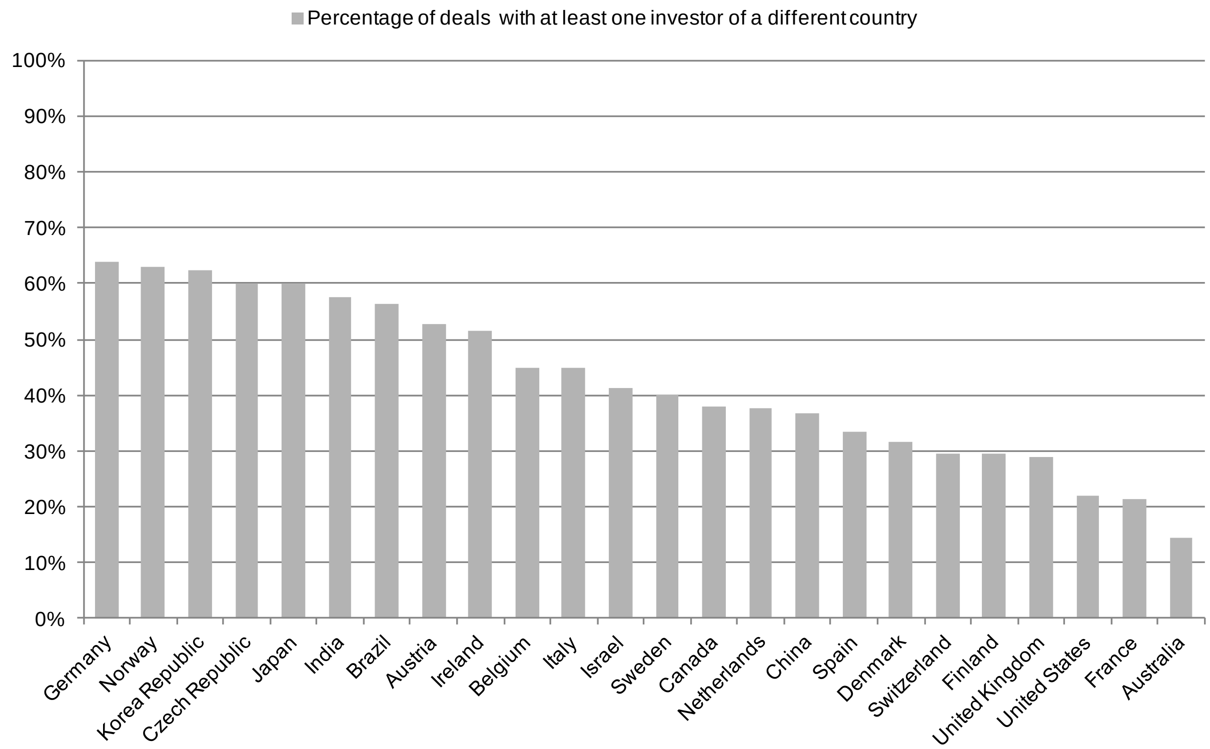
Source: OECD elaboration based on the Cleantech Market Insight Database.

Figure 13. Average number of investors per deal, by investment type



Source: OECD elaboration based on the Cleantech Market Insight Database

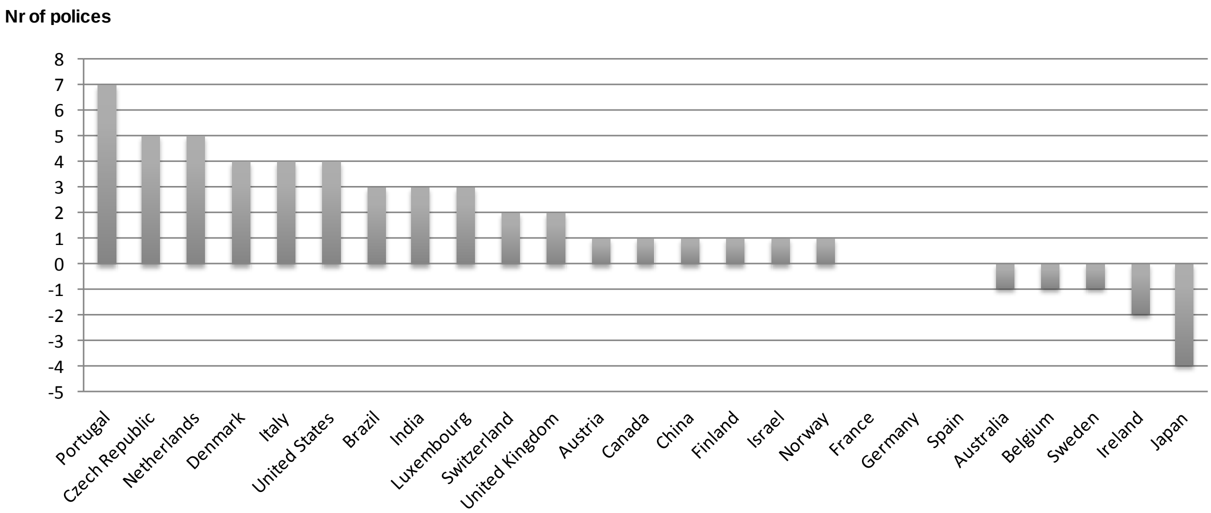
Figure 14. Share of deals with at least one investor from a different economy, by funded company's economy



Source: OECD elaboration based on the Cleantech Market Insight Database.

The empirical analysis assesses whether the amount and probability of investment in a country are correlated with the type and number of environmental policies in force. In the analysis, policies are grouped into regulatory policies, fiscal incentives and public finance. Figure 15 and Table 3 show that there is indeed variation in the extent to which these different policies are used, both across countries and time, with a number of countries drastically increasing the number of policies in force during the 2004-2010 period. As shown in Table 3, the Netherlands, Sweden, and the United States are the countries with the most intense deployment of environmental fiscal incentives, while India and Italy have the highest number of regulatory policies. Most countries increased the number of deployment policies over time. Others – France, Germany and Spain – did not experience any change in the number of policies implemented. Finally, Japan, Ireland, Sweden, Belgium and Australia decreased the number of policies in place.

Figure 15. Changes in number of deployment policies over the 2004-2010 period



Source: OECD elaboration based on the Cleantech Market Insight Database.

4. EMPIRICAL ANALYSIS

Methodology

The aim of the paper is to look at the policy determinants of private equity financing. This is achieved by investigating the relationship between high-growth financing and environmental policies aggregating the available deal-level information (number and amount) into year-country-industry cells. The following equation is estimated:

$$\begin{aligned} Financing_{sct} = f(&regulation\_price_{ct}, regulation\_quantity_{ct}, sales\_tax\_reduction_{ct}, \\ &public\_incentives_{ct}, Government\_R\&D_{c,t-2}, \overline{Z}_{ct}, D_{year}, D_{\mathrm{sector}}) \end{aligned} \quad \text{(Eq. 1)}$$

where the dependent variable *financing* is measured as the i) total amount of private equity financing received in sector *s*, at time *t*, in country *c* and ii) as the total number of deals in sector *s*, at time *t*, in country *c*.

The different nature of the two measures of private equity financing (dollar amount of private equity financing and number of private equity financing deals) dictates different econometric estimators.

The number of private equity financing deals in sector *s*, at time *t*, in country *c* takes only non-negative integer values; therefore we estimate equation (1) via count-data models. We chose a Poisson model (Santos Silva and Tenreyro, 2006).[15] In the Poisson model the estimated coefficients correspond to semi-elasticities. Thus, coefficient estimates can be directly converted into marginal effects. For a continuous regressor x, the marginal effect is $\frac{\partial E[y|x]}{\partial x_j} = \exp(x\beta)\beta_j$. The table reports marginal effects calculated at the mean.

The dollar value of the total amount of private equity financing received in sector *s*, at time *t*, in country *c* is a continuous variable, but it equals zero for 18% of the industry-country-year cells sample: the sample is therefore censored. Accordingly, the regression equation is estimated using the Tobit model, which yields – under certain assumptions – consistent estimates in the case of censored samples. The table reports, as suggested in Wooldridge (2002), the marginal effects of regressors on the dependent variable conditional on the cell having positive investment amounts.

The explanatory variables of interest are deployment and supply side policies. Deployment policies are proxied by a set of dummy variables indicating whether policies of each group are enacted in a country, grouped in regulation price; regulation quantity; sale tax reduction; fiscal incentives, as described in Table 3.

Supply-side policies are proxied by the government R&D expenditure in country *c* at time *t-2.*[16]

The regression equation also controls for other country-level time varying variables that might affect the overall level of high-growth financing in a country, such as GDP per capita; number of days needed to open a business to proxy for entry conditions in a market; and stock trade value to proxy for the development of the stock market in a country (a proxy for the expected exit opportunities for high growth investors).[17] The model also includes the number of green sector companies seeking funding to proxy for the entrepreneurial dynamism in sector *s* and country *c*: the variable is one year lagged to minimize endogeneity bias. Finally, it controls for time and industry fixed effects, to capture the effect of macroeconomic shocks and time invariant unobserved industry level characteristics.

To investigate possible heterogeneous effects of policies at different investment stages, the models are also estimated only taking into account investments at the seed/early stage, follow-on, and other investment stage, respectively. Also, to address concerns regarding the role played by the United States or by secondary green sector industries, equation (1) is also estimated excluding the United States and limiting the sample to the energy generation sector.

Results

Table 4 reports estimates of equation (1) with the number of deals in industry-country-year cells as the dependent variable, while Table 5 reports the results of the Tobit estimation of the total amount of funding.

All regressions in the table also include unreported controls: GDP per capita, number of days it takes to open a business in a country, the value of the stock market and year and sectoral dummies, as reported in the table's notes; dummy variables are meant to control for other country and industry level determinants of private equity financing and for macroeconomic shocks. Regression coefficients are expressed as marginal effects; in columns 5 and 6 the Tobit marginal effects are conditional on the amount of investment being positive.

Table 4. Industry-country level regressions

Number of deals

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Estimation model:	Poisson						
dep. var.:	Number of deals						
Sample	All	Early stage	Follow-on	Other stages	Energy generation	no US	Energy generation no US
Mean dep. var.	4.99	1.07	2.37	6.26	9.37	2.71	4.96
Regulation price	1.011	-0.0175	0.415	1.467	3.265	-0.247	0.584
	(0.735)	(0.192)	(0.341)	(1.010)	(2.038)	(0.351)	(0.763)
Regulation quantity	3.234***	0.711**	1.176**	4.719***	5.427**	0.947**	1.846**
	(1.005)	(0.287)	(0.482)	(1.417)	(2.522)	(0.386)	(0.881)
Sale tax reductions	0.801	0.284	0.221	0.614	6.768***	1.800***	4.395***
	(0.754)	(0.210)	(0.331)	(1.023)	(1.992)	(0.401)	(1.028)
Fiscal incentives	-1.061	-1.433***	0.500	-1.070	2.136	-0.833	0.0642
	(1.694)	(0.461)	(0.826)	(2.514)	(4.128)	(0.625)	(1.243)
Gov. R&D as % GDP	24.81***	5.613***	10.89***	35.47***	35.02***	7.830***	15.27***
	(4.343)	(1.225)	(2.078)	(5.953)	(12.83)	(2.345)	(5.919)
Other controls	YES	YES	YES	YES	NO	YES	YES
Sector F.E.	YES	YES	YES	YES	NO	YES	YES
Year F.E.	YES	YES	YES	YES	NO	YES	YES
Observations	629	629	629	629	123	559	117

Note: Estimates reported in the table are average marginal effects. The unit of observation is the year-industry-country combination (year 2005-2010, countries with at least 5 deals and cells with at least one deal or one company seeking investments). All regressions also include controls for: total stock traded as % GDP; days needed to start a business; GDP p.c. (t-1) in PPP. Robust standard errors clustered at country-year level in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Results in the first column of Table 4 suggest that the number of deals is robustly associated with regulation policies affecting the quantity of renewable energy, like renewable energy certificates (REC) or renewable energy quotas. Moreover, government R&D intensity is also positively associated with the number of deals. Columns 2 to 7 show that these findings hold across different investment stages, as well as when the United States is excluded or when the sample is limited to the energy generation sector. Sales tax reductions, on the other hand, are only significantly positively correlated with the number of deals in the energy generation sector (columns 5 and 7) and if the United States is excluded from the sample (column 6). Finally, fiscal incentives are never significant except in column 2, where the dependent variable is limited to early stage investments: in this case, the coefficient takes a negative sign. One tentative explanation of the result may refer to the perceived instability of these kinds of policies, which might be particularly relevant for investments still far from the commercialisation phase.

All in all, these estimates are suggestive of the importance of both supply-side and deployment policies, however they abstract from the magnitude of the aggregate investment.

Table 5. Industry-country level regressions

Amount of funding

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Estimation model:	Tobit						
dep. var.:	Amount of funding						
Sample	All	Early stage	Follow-on	Other stages	Energy generation	no US	Energy generation no US
Mean dep. var.	83.03	5.50	36.22	97.86	202.47	38.45	88.65
Regulation price	18.075**	1.346*	4.691	30.628***	76.846***	9.310*	41.484***
	(8.325)	(0.776)	(4.673)	(10.044)	(22.661)	(4.820)	(14.807)
Regulation quantity	25.422***	1.890*	17.819***	45.102***	55.850**	16.807***	28.422*
	(7.740)	(0.974)	(6.369)	(13.300)	(24.329)	(5.603)	(15.403)
Sale tax reductions	19.007**	0.353	5.328	2.691	8.181	9.627*	18.012
	(9.217)	(0.787)	(4.684)	(11.909)	(24.831)	(5.173)	(17.198)
Fiscal incentives	-6.627	-4.399***	-9.002	-31.005	13.741	2.395	16.020
	(12.402)	(1.587)	(9.574)	(20.845)	(31.153)	(7.806)	(17.401)
Gov. R&D as % GDP	179.951***	16.293***	93.573***	388.111***	381.252**	119.577***	215.201*
	(52.627)	(5.876)	(31.943)	(82.973)	(157.256)	(39.395)	(109.495)
Other controls	YES	YES	YES	YES	NO	YES	YES
Sector F.E.	YES	YES	YES	YES	NO	YES	YES
Year F.E.	YES	YES	YES	YES	NO	YES	YES
Observations	629	629	629	629	123	559	117

Note: the unit of observation is the year-industry-country combination (year 2005-2010, countries with at least 5 deals and cells with at least on deal or one company seeking investments). All regressions also include controls for: total stock traded as % GDP; days needed to start a business; GDP p.c. (t-1) in PPP. Reported Tobit marginal effects are for the expected value of the dependent variable conditional on being uncensored, E(y | y>0). Robust standard errors clustered at country-year level in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Therefore, Table 5 reports the marginal effects of these same policies on the total amount of funding across industry-country-year cells, conditional on the value being positive. The previous results on the positive effect of "quantity" regulation and public R&D are confirmed; in addition, the coefficients also point to a positive effect of price-targeting policies, such as feed-in tariffs (FITs), and sales tax reductions. The positive correlation between price regulation and amount of funding is robust when the United States is excluded from the sample, and when the estimation is restricted to the energy generation sector and to seed and early stage financing, but it becomes insignificant when restricting the analysis to follow-on investments only. The positive association of sales tax reductions, on the other hand, hinges upon the inclusion of the United States in the estimation sample (col.6). Fiscal incentives, however, seem to play no role in attracting investments; when the sample is restricted to seed and early stage deals, the coefficient is significant and negative.

To summarise, the results show that the number of deals and the total amount of funding are robustly associated with the national regulatory policies in force in a country, as well as with the share of government R&D expenditures in GDP. Among regulatory policies, those targeting the quantity of clean energy produced seem to affect both the extensive (number of deals) and intensive (amount of funding) margin of investment. On the other hand, policies targeting price are not correlated with the extensive margin, nor with the amount of investment in follow-on stages; however, they are positively correlated with seed and early stage investments (both in the whole green sector and in the energy generation sector). Sales taxes have a much weaker and less robust positive effect, while fiscal incentives are never significant.

Evidence on sector-specific feed-in tariffs (FITs)

Finally, the last step of the analysis makes use of a new harmonized dataset (OECD-EPAU Renewable Energy Policies Database) reporting the level (and not just the presence) of FITs adopted by each country in the solar and wind sector.[18] We exploit this information by limiting our analysis to these two sectors, which in our dataset are identified by the secondary industry definition within the e*nergy generation* industry. The fact that the policy variables are now sector-specific allows for the inclusion of a country dummy which controls for the effect of other policies (in average over the period) and time-invariant national factors. The FITs variables are interacted with a sector wind and solar dummy, i.e. the variable is set to zero in the sector which it does not apply to. Formally, the estimated model is specified as follows:

$$Financing_{kct} = f(\sum_{k} FIT_s * D_i, EnvPolicies_{ct}, \overline{Z}_{ct}, D_{year}, D_{country}) \qquad \text{(Eq. 2)}$$

where the dependent variable *financing* is measured as the i) total amount of private equity financing received in sector *s*, at time *t*, in country *c* and ii) as the total number of deals in sector *s*, at time *t*, in country *c*. *k* indexes each of the two sectors in the energy generation industry (solar and wind). The model also includes the other environmental policies and economy-wide controls included in equation (1), although most of their effect is absorbed by the country dummies.

The results are reported in Table 6. The first column shows the results of the Poisson regression with the number of deals as the dependent variable. As shown, FITs are positively associated with the number of funded deals both in the solar and in the wind sector. The second column also includes quadratic terms, which allows exploring whether, at high level of FITs, the effect might become marginally smaller, or even negative. This is motivated by existing evidence showing that excessively generous FITs tend to have a negative effect due to expectations that the policy might be soon revoked due to its perceived fiscal unsustainability (Criscuolo et al., forthcoming). Results in column 2 tend to support this hypothesis for the solar sector: the coefficient on the quadratic term is indeed negative, implying that the estimated association between FITs and the number of deals follow an “inverse U” curve, sloping upwards for lower values of the policy, and downwards for high values. This is not the case for wind power. With much higher average values for FITs for solar than wind power in most countries, this would be consistent with such an interpretation.

Moreover, this might also explain the lack of significance of the price regulation coefficient in column 3 of Table 5, where the analysis is restricted to follow-on investment that is on average much larger than seed and early stage.

Columns 3 and 4 report the results of the Tobit regression, with the total amount of funding as dependent variable. The results are overall in line with the Poisson estimates: FITs are positively associated with the amount of funding in the solar and wind sector, although the coefficient on the former is not significant. The inclusion of quadratic terms in column 4 confirms the “inverse U” relationship between the amount of funding and generosity of FITs in the solar sector.

Table 6. Secondary industry-country level regressions

Energy generation only; number of deals and amount of funding

	1	2	3	4
Estimation method	Poisson		Tobit	
Dep. var.	Number of deals		Amount of funding	
Mean dep. var.				
FIT solar	11.13***	33.45***	-18.020	1,027.732***
	(2.216)	(11.37)	(68.152)	(252.545)
FIT wind	12.86*	-15.29	81.171	234.798
	(7.729)	(31.04)	(182.876)	(369.548)
FIT solar quadratic		-39.17**		-1,632.678***
		(17.57)		(424.096)
FIT wind quadratic		103.0		376.942
		(93.14)		(1,046.093)
other controls	YES	YES	YES	YES
country FE	YES	YES	YES	YES
year FE	YES	YES	YES	YES
Observations	125	125	125	125

Note: the unit of observation is the year-secondary industry-country combination (year 2005-2010, countries with at least 5 deals and cells with at least one deal or one company seeking investments). All FIT variables take positive values only for observation in the relevant sectors. All regressions also include controls for: total stock traded as % GDP; days needed to start a business; GDP p.c. (t-1) in PPP. Reported Tobit marginal effects are for the expected value of the dependent variable conditional on being uncensored, E(y | y>0). Robust standard errors clustered at country-year level in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Some important caveats

As with all econometric estimates, the results reported in tables 3-6 need to be interpreted with caution.

Firstly, the policy measures included in the analysis are very broad and do not take into account the details of environmental policy designs, and are only based on countries’ renewable energy policies. However, they provide a first indication of countries’ aptitude toward environmental policies. The choice for the indicators used was mainly driven by the lack of timely comparable environmental policy indicators for both OECD and BRIICS countries included in the sample.

Secondly, given the limited time variation in the deployment policies considered and the strong serial correlation of government R&D intensity, we could not estimate the role of deployment and supply side controlling for country unobserved fixed effects (except in the regressions restricted to energy generation). We hope that the availability of more detailed information on environmental policies, which would also be industry specific, could help overcome this limitation of the study.

5. CONCLUSIONS

The study has looked at the determinants of high-growth financing in the green sectors. The results suggest that national environmental deployment policies designed with a long-term perspective of creating a market for environmental technologies, such as price and quantity renewable policies, e.g. feed-in tariffs and tradable certificates, are associated with higher investment levels relative to more short-term fiscal policies, such as tax incentives and rebates. This result suggests that long-term policy stability, sustainability and credibility are important to ensure financing of innovative and risky ventures in the green sector.

This result is consistent with econometric evidence from Johnstone *et al*. (2010a), who find a positive correlation between perception of environmental policy stability and patenting applications in environmental technologies. This result is also in line with existing evidence from survey results (Barradale, 2008) that suggests that patterns of repeated expiration and short-term renewal of the US federal production tax credit might have been a cause of uncertainty for returns on investments in wind power and thus might in part be responsible for increased volatility in this sector. The same survey, on the other hand, suggests that regional- and national-level portfolio standards were considered by respondents as stable enough to influence long-term investment planning.

We do not find any significant correlation between public investment loans or financing and the amount of private financing of innovative ventures in the green sector. However, this does not mean that government financing, e.g. through public venture capital funds invested in partnership with private and corporate VCs, could not represent a possible solution to the financing gaps in the green sector. This financing gap arises because the level of investment required by the green sector is on average much larger than in other sectors and because the time span of green projects from the seed to the up scaling phase is much longer than the average life of a venture capital fund; both of these issues might be less problematic for government investments.

Results also suggest that supply push policies have a positive impact on financing: we find that government R&D is an important predictor of the level of investment in clean sectors.

This might suggest that both supply and deployment policies might be useful for countries that would like to diversify the portfolio of environmental technologies and resources to advance for example energy security goals (“letting a thousand flowers bloom”); while the results suggest that fiscal incentives and public finance type measures are not found to matter for this purpose.

Finally, analysis restricted to the energy generation sector focusing specifically on FITs suggest that these policies tend to show marginally decreasing returns, to the point that they might even discourage investments in the case of very generous provisions. The finding is consistent with other contributions in the literature, as well as with anecdotal evidence, suggesting that a very high level of FITs could raise credibility concerns about the fiscal sustainability of the policy in the medium and long term, as FITs are often at least partly funded by the public budget. Anecdotal evidence on sudden reforms of FITs in countries that initially adopted generous provisions provides ground to this hypothesis.

NOTES

1 In this paper, risk finance (or private equity financing) includes all forms of financing other than traditional banking loans.

2 In this paper, the classification of economic activities into the "green sector" is based on the original selection in the source database maintained by the Cleantech Group called "Cleantech", and refers to a broad part of the economy. According to the data provider, "Cleantech is new technology and related business models that offer competitive returns for investors and customers", while "greatly reducing or eliminating negative ecological impact, at the same time as improving the productive and responsible use of natural resources". We also on occasion employ the term "environmental technologies" to identify the same subset of activities.

3 The included economies are Australia, Austria, Belgium, Canada, China, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Israel, Italy, Japan, Luxembourg, Netherlands, New Zealand, Norway, Poland, Portugal, Russia, South Africa, Spain, Sweden, Switzerland, United Kingdom, and United States.

4 For a general discussion of entrepreneurship and radical innovation see Squicciarini et al. (2013).

5 The definition of the cleantech sector includes clean energy generation, infrastructure and storage; energy efficiency; land management; natural pesticides; emissions control; recycling and waste, transportation and water conservation and treatment. However, some of the figures presented refer only to clean energy due to a lack of comprehensive data.

6 Note that the figure reports data only for the clean energy sector rather than the whole cleantech sector.

7 Asset finance is defined as "all money invested in renewable energy generation projects, whether from internal company balance sheets, from debt finance, or from equity finance. This excludes re-financings." (Bloomberg New Energy Finance, 2010).

8 An additional reason for the acquisition of a start-up by an incumbent is to buy IPs pre-emptively, to defend the current market position of the incumbent.

9 FITs offer developers of clean energy based on renewables a price higher than the wholesale price of power with guaranteed purchases and favourable terms for access to the grid on a long term basis. The rationale is for governments to guarantee a return on the investment in renewable energy so that entrepreneurs and investors' risks are reduced.

10 This information was very kindly provided by NESTA. We are particularly grateful to Yannis Pierrakis, Liam Collins and Albert Bravo-Biosca for their help.

11 PURPA was discontinued in most US states in the 1990s.

12 For a review of environmental policy indicators and their properties, see Botta and Kozluk (Forthcoming).

13 The distribution of deals and seekers across industries is also fairly concentrated, with the energy generation sector accounting for more than a third of observations of deals and seeking firms, and energy efficiency accounting for 15% of observations. Both sectors are therefore very dynamic, and not

necessarily the ones in which firms have the highest likelihood of receiving funding. Other sectors, such as energy storage and recycling and waste, show a much higher funded/seekers ratio.

14 The average number of investors can be lower than one because for a few investments there are none reported.

15 Although the dependent variable show a remarkable degree of overdispersion, estimates based on Negative Binomial regressions were similar to those obtained with Poisson regressions, but slightly less precise. Results are available from the authors upon request.

16 The choice of the lag is driven mainly by data availability, but the government R&D expenditure is serially correlated and therefore the results are unlikely to be affected.

17 GDP data come from OECD; the other control variables are sourced from the World Bank.

18 The dataset contains also information on FITs in the Marine and Geothermal sectors, but the number of related deals in our dataset is very small.

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APPENDIX

Table A1. Primary, secondary and tertiary industries in the environmental technology sector covered by the Cleantech database

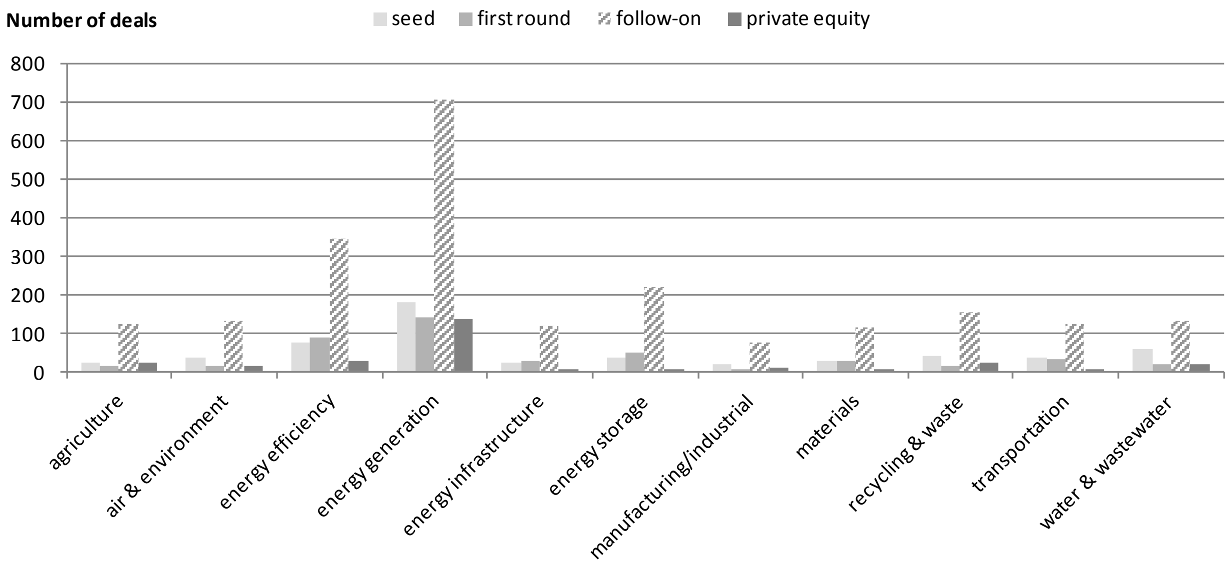
Primary industry	Secondary industry	Tertiary industry
Agriculture	*Aquaculture*	Farms, health & yield
	Land management	Crop yield, erosion control, precision agriculture, smart irrigation, soil products/composting, sustainable forestry
	Natural pesticides	Antimicrobial, beneficial insects, biological control, organic fungicides, sustainable fertilisers
air & environment	*Cleanup/safety*	EHS & ERM, fire suppression, hazardous waste/toxins control, leak detection, remediation, sensors & controls
	Emissions control	Bio-filtration, cartridge/electronic, catalytic converters, clean coal, indoor air quality, sorbents
	Logistics	Transportation efficiencies
	Monitoring/ compliance	Measurement & testing, sensors, software/systems
	Trading & offsets	Carbon/emissions, water
	Vehicles	Water transport
	Water treatment	Filtration
energy efficiency	*Advanced packaging*	Containers
	Biofuels	Biodiesel
	Buildings	Building automation, building envelope & insulation, energy saving windows, home automation, HVACR/R
	Chemical	Coatings
	Glass	Chemical, electronic
	Lighting	Ballasts & controls, smart lighting systems, solid state lighting
	Monitoring & control	Software
	Monitoring/ Compliance	Software/systems
	Other	Appliances, consulting/facility management, consumer education, efficient motors, energy saving, monitoring, metering & control, sensors & controls
	Smart production	Construction/fabrication, process efficiency
	Trading & offsets	Carbon/emissions
	Transmission	Smart grid
energy generation	*Biofuels*	1st generation, algae biodiesel, biodiesel, biogas, biomass, cellulosic ethanol, grain ethanol
	Geothermal	Development, generation, hardware, power plants, wells
	Hydro/marine	Current/tidal, ocean floor, wave
	Other	Combined heat/power, electro textiles, hydrogen production, natural gas, on-site systems, renewable energy providers, turbines, waste heat, waste to energy
	Solar	Cells & modules, combined heat/power, concentrated PV, concentrated solar thermal, photovoltaics, systems, thin films
	Wind	Farms, gearboxes & components, renewable energy providers, turbines

Primary industry	Secondary industry	Tertiary industry
energy infrastructure	*Management*	Power conservation, power monitoring & metering, power protection, power quality & testing, smart grid
	Other	Waste to energy
	Transmission	Sensors & controls, smart grid
energy storage	*Advanced batteries*	Advanced pb-acid, charging & management, flow batteries, lithium-ion, nickle zinc, other technologies, thin film, ultra-capacitors
	Fuel cells	Methanol, other technologies, PEM, solid oxide, systems integrators, zinc air
	Hybrid systems	Flywheels, heat storage, hydrogen storage
Manufacturing /industrial	*Advanced packaging*	Containers, packing
	Monitoring & control	Automation, sensors, software, systems
	Other	Energy saving companies
	Smart production	Construction/fabrication, process efficiency, resource utilisation, toxin/waste minimisation
Materials	*Bio*	Advanced processes, biodegradable products, catalysts, sustainably harvested lumber
	Chemical	Coatings, composites, polymers
	Glass	Chemical
	Nano	Catalysts & additives, detectors/sensors, gels & coatings, lubricants/films, membranes, powders
	Other	Adhesives, ceramics, efficient motors
recycling & waste	*Other*	Combined heat/power, consulting/facility management, waste heat, waste to energy
	Recycling	Chemicals, food, metals, mixed wastes, oils/lubricants, paper, plastic/rubber, services, sorting technologies, wood
	Waste treatment	Biological breakdown, environmental disposal, gasification, hazmat destruction, plasma destruction
Transportation	*Advanced batteries*	Lithium-ion
	Fuels	CNG/engine conversion, fuelling infrastructure, improved petroleum based
	Logistics	Fleet tracking, mass transit, ride sharing, traffic monitoring software, transportation efficiencies
	Other	Efficient motors, hydrogen production
	Structures	Light-weight
	Vehicles	Bicycles & scooters, electric & hybrids, rail transport, vehicle components/engines, water transport
water & wastewater	*Bio*	Catalysts
	Cleanup/safety	Leak detection
	Glass	Chemical
	Wastewater Treatment	Biological, mechanical
	Water conservation	Recycling & management, sensors & controls, smart metering & control, water saving appliances
	Water treatment	Contaminate detection, desalination, filtration, filtration & purification, purification

Table A2. Summary statistics: Explanatory variables

Variable	Nr	mean	s.d.	p10	p25	p50	p75	p90
Regulation: price	629	0.60	0.49	0	0	1	1	1
Regulation: quantity	629	0.70	0.58	0	0	1	1	1
Regulation: quality	629	0.50	0.50	0	0	1	1	1
Regulation: all	629	1.81	0.80	1	1	2	2	3
Public finance	629	0.53	0.50	0	0	1	1	1
Fiscal incentive	629	2.44	1.03	1	2	3	3	3
Value of total stock traded (% GDP)	629	118.4	83.7	32	54	97	170	244
Nr of days to start a business	629	17	18	3	6	13	22	35
GDP PPP p.c.	629	33,149	11,244	15,008	30,684	35,033	38,486	45,140
Gov. R&D exp. (% GDP)	629	0.23	0.08	0.14	0.18	0.23	0.30	0.34
Nr of seekers	629	1.57	5.69	0	0	0	1	4

Figure A1. Number of deals by primary industry and investment type



Source: OECD elaboration based on Cleantech Market Insight Database.