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'Cleantech' venture capital around the world☆

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ABSTRACT

Cleantech venture capital investment differs from the typical venture capital investment in that it tends to be very capital intensive and faces greater technology risks associated with the functioning of the technology, scalability and exit requirements than the typical venture capital investment. Moreover, unlike the typical venture capital investment, the benefits arising from cleantech cannot be totally captured by the venture capitalist as many of its benefits accrue to society via reduced environmental degradation and better health and quality of life outcomes. The public goods literature posits that such externalities reduce investment in cleantech below the socially optimal level. We seek to determine whether there are countervailing factors which may incite greater cleantech investment. We argue that oil prices, increased stakeholder attention, as well as the impact of various formal and informal institutions are such factors. This paper provides a cross-country analysis of the determinants of cleantech venture capital investment with a unique worldwide dataset of 31 countries spanning 1996–2010. The data show consistent evidence of a pronounced role for oil prices in driving cleantech venture capital deals, which is more important than other economic, legal or institutional variables. Cleantech media coverage is likewise a statistically significant determinant of cleantech venture capital investment and as economically significant as other country level legal, governance, and cultural variables. Uncertainty avoidance has a negative impact on cleantech venture capital investment, as well as a moderating effect on other variables.

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

1. Introduction

There is indeed great urgency to deal with issues regarding both the mitigation of climate change and the effects of climate change such as warming temperatures, changes in precipitation and sea level which, in turn, will affect water supply and quality, habitat, and food production. According to the Cleantech group (http://www.cleantech.com/), a cleantech company is a company whose primary focus is on clean technology. Pernick and Wilder (2007: 2) state that "cleantech refers to any product, service, or process that delivers value using limited or zero nonrenewable resources and/or creates significantly less waste than conventional offerings." Cleantech segments include: advanced materials, agriculture & forestry, air and environment, biofuels & biochemicals, biomass generation, conventional fuels, energy efficiency, energy storage, fuel cells & hydrogen, geothermal, hydro & marine power, nuclear, recycling and waste, smart grid, solar, transportation, water and waste water, and wind. This paper represents a first attempt to document and explain worldwide cleantech venture capital investment patterns across countries and over time.

According to Pernick & Wilder (2007), clean technology or 'cleantech' as it will be referred to in this paper, covers four main broad sectors: energy, transportation, water, and materials. Cleantech comprises energy efficient technologies that include but are not limited to recycling, renewable energy (wind power, solar power, biomass, hydropower, biofuels), information technology, green transportation, electric motors, green chemistry, composite materials, and lighting. Energy and energy efficiency technologies represent about 70% of all cleantech funding (PWC, 2015). Energy security issues, climate change, fossil fuel depletion, new technologies, and environmentally conscious consumers are powerful forces shaping the renewable energy sector, which is the largest segment of cleantech (Sadorsky, 2011).

The cleantech product/process cycle consists of four stages (Bloomberg New Energy Finance, 2012). The first stage is technology research and the second stage is technology development. The third

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and fourth stages are manufacturing and scale-up, and roll-out respectively. In terms of funding, government funding is used to finance stage one. Venture capital funds and private equity are used to finance late stage one, stage two, and early stage three phases. Public equity markets and mergers and acquisitions are used to finance stages three through four. Debt markets are used to finance stage four. Venture capital investment is an important source of funding especially in the technology development stage.

One critical difference between cleantech and other types of VC is the public good nature of cleantech VC investments. Environmental resources generally do not have well defined property rights (Demsetz, 1970). For example, no one organization or person owns the atmosphere, the air, the oceans or large aquifers. Given that cleantech investments seek to clean our air, waters and land, there are significant benefits to society which private owners of such environmental assets are unable to capture. The public good nature of cleantech relates to the fact that the benefits of the product or service (clean air, clean water, carbon mitigation) are not depleted by an additional user and for which it is generally difficult or impossible to exclude people from its benefits, even if they are unwilling to pay for them. In contrast, a private good is characterized by both excludability (that is, someone who does not pay for it can be kept from enjoying it) and non-renewability (a commodity is used up when someone consumes it). As a result, a socially efficient equilibrium or outcome cannot be reached via the market and the cleantech good or service in question will be undersupplied (Teece, 1986; McWilliams and Siegel, 2001). Our objective is to determine the economic, social, formal institutional and informal institutional factors that tend to increase the supply of cleantech VC. Although cleantech VC investment has grown tremendously over the last 20 years, these investments, as noted in our introductory quote, will

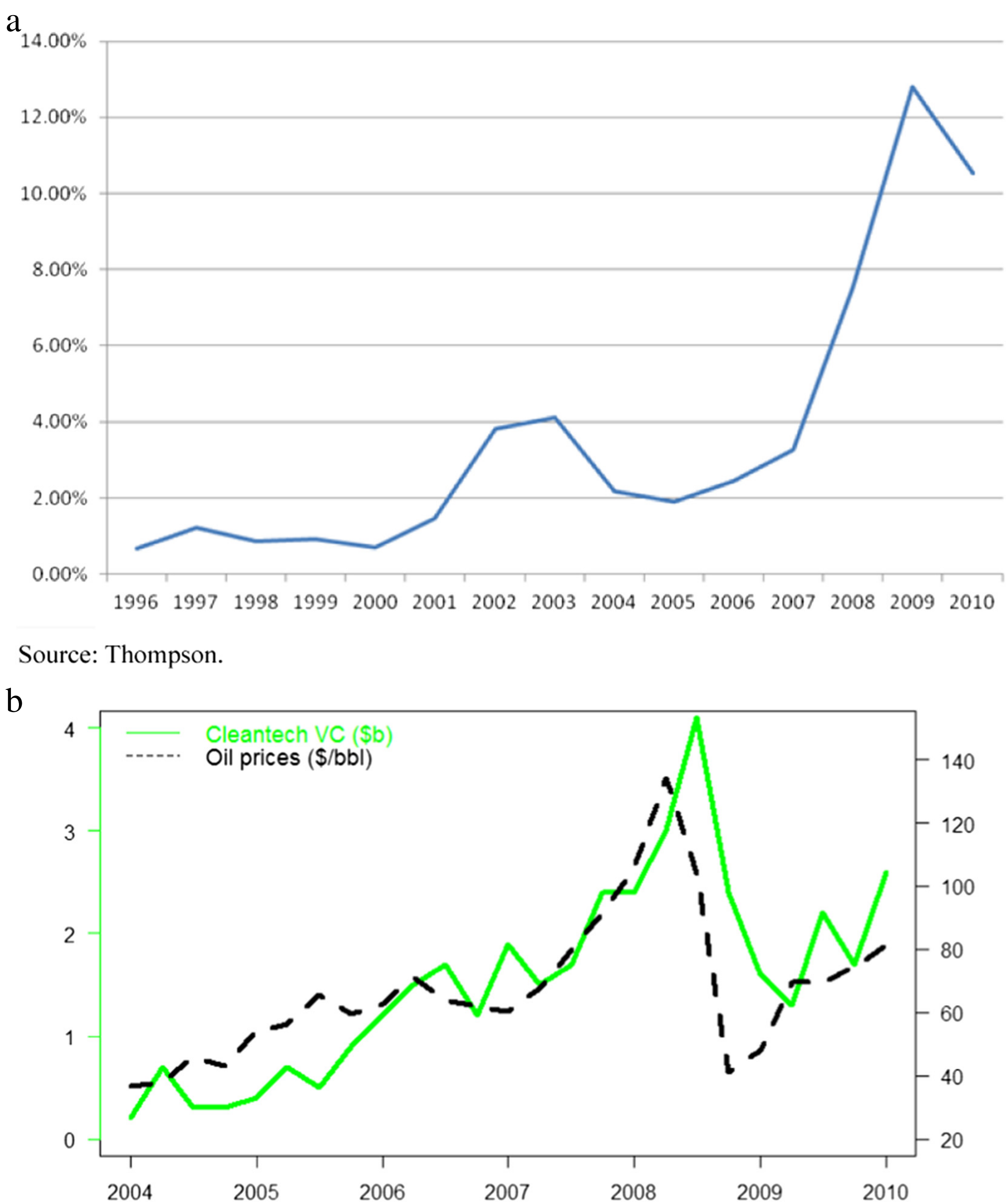

Fig. 1. a. Percentage of venture capital deals that are cleantech Source: Thompson. b. Venture capital investment in Cleantech ($billions) vs oil prices ($/bbl). VC data sourced from Bloomberg New Energy Finance (2012), and oil prices sourced from Federal Reserve of St. Louis (http://research.stlouisfed.org/fred2/).

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not be sufficient to meet humanity's needs. The share of cleantech VC deals as a percentage of all VC deals has risen from around 1% in 1996 to over 10% in 2009 and 2010 (Fig. 1a).

More market related differences also exist. Ghosh & Nanda (2010) present a framework describing how cleantech VC investments differ from more traditional VC investments by comparing clean energy subsectors according to their capital intensity, risk and exit requirements (i.e., a venture capitalist's ability to exit the venture via sale or merger and acquisition). Energy production technologies, for example, are very capital intensive and face greater technology risks associated with the functioning of the technology, scalability and exit requirements. Ghosh & Nanda (2010) point out that in biotechnology and information technology, for example, venture capitalists can sell their investment to incumbent firms. In the case of cleantech VC, however, the incumbent firms are in many cases large companies focused on, or large users of, fossil fuels and therefore, unlikely to be interested in buying an upstart cleantech company. Together these differences make cleantech VC investments different from more traditional VC investments in biotechnology and information technology where the accrual of benefits is clearer, capital intensity is lower and the overall risks are lower.

There has been some work about what drives VC investment in the cleantech sector (e.g., Wüstenhagen and Teppo, 2006; Wüstenhagen, Wuebker, Bürer, and Goddard, 2009; Marcus, Ellis, and Malen, 2012). Wüstenhagen & Teppo (2006) use interviews with venture capitalists and surveys to study the risk and return factors affecting VC investments in cleantech. They find that VC investment in cleantech requires specialized knowledge and experience. Wüstenhagen et al. (2009) point out that when it comes to breakthrough energy innovations, policy makers often focus on the role of large established companies and that this can be detrimental to small startup companies. In some cases, like fuel cells, for example, policy focused on expanding the role of VC may be more desirable. Marcus et al. (2012) study VC investment in the US clean energy industry over the period 2002 to 2009. They find that deal making experience, deal making success, and media attention are important drivers in the number of clean energy VC deals.

This paper makes a number of contributions to the existing literature. First, this paper provides a comprehensive cross-country analysis of the determinants of cleantech VC investment with a unique worldwide dataset of 31 countries in an unbalanced panel spanning 1996–2010. While there are a number of papers showing how VC activity varies across countries (Zacharakis, McMullen, and Shepherd, 2007; Li and Zahra, 2012; Chahine, Arthurs, Filatotchev, and Hoskisson, 2012; Cumming, 2014; Espenlaub, Khurshed, and Mohamed, 2014; Tykvova and Shertler, 2014), little is known about how *cleantech VC activity* varies across countries. In addition to variables that account for economic, financial, and legal factors, we examine other factors that are of particular interest to the cleantech sector, including but not limited to oil prices, media coverage, and environmental sustainability. Second, this paper highlights the role that governance (formal institutions) and culture (informal institutions) can have on the cleantech VC decision. Formal and informal institutions can not only reduce the transaction costs and opportunity costs that venture capitalists face but also provide an increased private incentive for the provision of the social good. Given that cleantech VC investment tends to be both riskier, more capital intensive, and have greater social benefits than other types of investment, we seek to analyze the impact these institutions, which are country specific, have on cleantech VC activity.

This paper is organized as follows. The following sections set out the theoretical developments, methods and data, and empirical results. The last section of the paper presents the conclusions and discussion.

2. The determinants of cleantech VC activity

Cleantech VC investment differs significantly from traditional VC investment in three areas: accrual of benefits, assessment of risks and market opportunities, and ability to exit. First cleantech investments have a strong public good component. The provision of cleantech investments has two salient properties. Once an investment has been made, the benefits of such an investment are non-excludable for all stakeholders. For example, if firm A were to adopt cleantech investments thereby improving air/water quality, everyone benefits, including competitors. Second, the consumption of the benefits associated with improved air/water quality by a firm does not affect the consumption of other firms: that is, it is non-rival. Given the existence of these two characteristics, one would predict that the private provision of cleantech investments would be undersupplied (McNutt, 2002). Since firm B cannot be excluded from securing the environmental benefits supplied by firm A, there is no incentive for firm B to pay the costs of undertaking such an investment. Cleantech is, therefore, a public good whose benefits are both non-excludable and non-rival (Henriques, Husted, and Montiel, 2013). Consequently, private provision (i.e., market) will not be sufficient to meet demand – a market failure. Given this market failure, the argument that cleantech VC alone will solve the world's environmental problems is weak.

The second difference relates to the ability of the venture capitalist to assess the risks and market growth opportunities of the investment in question. While all VC investments are risky, one could argue that investments in cleantech are even more so (Nanda, Younge, and Fleming, 2015). Many successful cleantech products or processes operate on the production side of the economy (e.g., electricity generation, energy efficiency, composite materials, wastewater treatment) where it is harder to evaluate the risks and market growth opportunities. Cleantech products do not share the same media exposure and fascination as do consumer-oriented products. This makes it more difficult to evaluate the risk and return tradeoff of cleantech VC investments. For example, many consumers are unaware of the generation source (renewable vs non-renewable) of their electricity or their environmental impacts (Zarnikau, 2003). By comparison, many VC-backed high-tech start-ups have grown into large multinational companies with an easily recognized line of products (e.g., Apple, Intel, Microsoft). VC investors tend to prefer investing in less capital intensive sectors or at stages of the product cycle where the capital requirements are lower. VC investors also seek to sell their stake in a company once a sufficient scale is reached.

The third difference is cleantech's weak exit mechanism which creates a bottleneck in the innovation pipeline thereby reducing take-off. According to Ghosh & Nanda (2010), energy producing firms and utilities, for example, have not been active acquirers of promising cleantech start-ups. In the biotech sector, on the other hand, a clear exit mechanism exists whereby incumbents perceive target companies as complementary assets rather than substitutes or threats which have encouraged the biotech take-off (Nanda et al., 2015). Efforts by incumbents in the energy sector to invest in renewable technologies, however, tend to be perceived as attempts to greenwash rather than substantive efforts to find alternative energy sources to replace or complement their core activities (Cherry and Sneirson, 2011; Ghosh and Nanda, 2010). So while the increase in energy prices may incite entrepreneurs to want to invest in cleantech entrepreneurial ventures, cleantech's weak exit mechanism may dissuade venture capitalists from such investments.

Table 1 summarizes the three major differences between cleantech VC and the typical biotechnology or high tech VC.

Despite these three barriers to investment, cleantech investment has increased suggesting that there are countervailing forces at play. Oil price movements, governments' sustainability stance, increased stakeholder concerns regarding the environment and a country's formal and informal institutions may each counter such barriers by increasing the benefits that may accrue to the venture capitalist thereby countering the public good characteristic of cleantech.

Many cleantech ventures are energy related. In fact, 70% of all cleantech investments are energy related (PWC, 2015). Fig. 1a plots global cleantech venture capital (VC) investment and oil prices ($ per barrel) between 2004 and 2010. Cleantech VC rose over 300% from 2004 to mid-2008 before slumping in response to the global financial

Table 1
What differentiates Cleantech from other venture capital?

Characteristic	Cleantech venture capital	Biotechnology or high tech venture capital
Accrual of Benefits	Although there are private benefits to production, the benefits to society are significant due to the public good nature of the service or good.	Private benefits are significant as property rights tend to be well defined (copyrights, patents) and there may or may not be benefits to society.
Assessment of risks, returns and market growth opportunities	Operates on the production side of the economy making it difficult to evaluate the risks, returns and market growth opportunities.	Operates on the consumption side of the economy making it easier to evaluate the risks, returns and market growth opportunities.
Ability to exit	Tends to be very capital intensive and faces greater technology risks associated with the functioning of the technology, scalability and exit requirements (Ghosh and Nanda, 2010)	Capital intensity is lower than cleantech and exit requirements are lower given that incumbents are more likely to purchase the investment.

crisis. Oil prices grew over 200% during this same period. Notice how closely cleantech VC correlates with oil prices suggesting that oil prices may be significant driver of cleantech VC activity. Consequently, energy prices, in general, and oil prices, in particular, may be an important determinant of cleantech VC activity by increasing the incentive to undertake cleantech investments. Innovation may switch away from dirty to clean technologies in response to changes in prices (Acemoglu, Akcigit, Hanley, and Kerr, 2014). Newell, Jaffe, & Stavins (1999), for example, find that following the oil price hikes, innovation in air-conditioners turned towards producing more energy-efficient units compared to the previous focus on price reduction while Popp (2002) finds that higher energy prices are associated with a significant increase in energy-saving innovations. Oil is the life blood of modern economies and by some estimates 98% of everything that is produced uses oil at some stage of the value chain (production, transportation). Rising oil prices can have a dramatic effect on the economy. Hamilton (2011), for example, documents that all but one of the 11 postwar recessions in the US were associated with an increase in the price of oil. Rising oil prices provide an incentive to use more energy efficient production and modes of transportation. Rising oil prices also provide a strong incentive to switch to alternative fuel sources like renewable energy. Greater interest in renewable energy and energy efficiency increases interest in cleantech entrepreneurial activity and cleantech VC funding by increasing the associated benefits.

On the other hand, as energy prices increase, energy companies will seek to invest in their core activities rather than supporting clean technology startups that may cannibalize or threaten their core business. Higher oil prices increase the incentive to exploit more expensive, harder to reach and more polluting oil deposits (like shale oil or tar sands) that become more economically attractive with rising oil prices. This has the effect of lengthening the time to exit for a typical cleantech startup thereby reducing cleantech VC activity. We, therefore, hypothesize that increases in oil prices will have an inverted U-shaped relationship with cleantech VC activity.

Hypothesis 1. Oil prices have an inverted U-shaped relationship with cleantech VC activity.

The economics literature argues that since environmental problems arise from market failures, government interventions such as taxes and/or regulations are the best way to deal with these problems (Crifo and Forget, 2015). Unfortunately, the political consequences and costs associated with such interventions tend to delay its implementation. Citizens are reluctant to accept higher taxes and companies often lobby to remove or reduce regulations. Consequently, a country's sustainable development stance may be an important determinant of cleantech VC activity because of the link between sustainable development and entrepreneurship.[1] Natural resource scarcity (fossil fuels, water), climate change, and green consumers are powerful forces shaping the course of sustainable development. One approach to linking sustainable development with entrepreneurship is to use Schumpeter's (1942) concept of "creative destruction". Dean & McMullen (2007) highlight the fact that since environmental degradation results from market failures and since entrepreneurship exploits the opportunities in market failure, entrepreneurial solutions are one way to deal with environmental problems. Cohen & Winn (2007) examine the sources of entrepreneurial opportunities related to market imperfections linked to environmental degradation. Hart & Christensen (2002) argue that disruptive technologies – technologies that establish a new market or value network – are usually missed by established firms. For example, the lack of access to reliable energy in the developing world has incited entrepreneurs to invest in the provision of basic, clean renewable energy (Cohen and Winn, 2007; Hart and Milstein, 1999) which, in a carbon constrained world, will likely become highly competitive in developed economies. Countries that are supportive of environmental sustainability are more likely to have formal government policies in place to encourage the development and adoption of sustainable initiatives. These countries are therefore more likely to be more supportive of cleantech VC activity.

Hypothesis 2. Countries espousing environmental sustainability have greater cleantech VC activity.

Stakeholders can exercise influence indirectly via other stakeholders in the network they are embedded in depending on the network's density and their centrality in the network (Rowley, 1997) or they can exercise indirect influences via other stakeholders on whom the firm is resource dependent (Frooman, 1999). Henriques & Sharma (2005) find that increased pressure perceived from the media was positively and significantly associated with customers canceling orders, with environmental groups protesting at company facilities, with environmental groups lobbying provincial governments, with environmental groups releasing information to the media and with local community protests at company facilities. The media's ability to inform the public enables it to withhold legitimacy and, in turn, affect the influence strategies of other stakeholders.

Media coverage helps to build image, reputation, and legitimacy and these factors help to increase the growth of new markets (Deephouse, 2000; Pollock and Rindova, 2003; Rindova, Pollock, and Maggitt, 2008). The financial/economic perspective argues that the media serves as reliable experts because the information has the capacity to influence markets. The institutional perspective argues that the media augments stakeholder perceptions through repeated exposure. The number of stories increases familiarity with a topic. Media coverage of cleantech promotes image, reputation, and legitimacy and this, in turn, may attract the attention of venture capitalists and potential consumers of this new technology. Cleantech media coverage will tend to increase as cleantech activity rises. As cleantech tends to operate at the production side of the economy, greater media attention linking cleantech investments as a solution to a public goods problem such as climate change, clean water or other environmental challenges will increase pressure on governments to value such investments thereby inciting

[1] According to the United Nations' World Commission on Environment and Development (WCED, 1987: 43), "Sustainable development is development that meets the needs of the present generation without compromising the ability of future generations to meet their own needs".

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venture capitalists to invest in such ventures as consumers become more aware of the benefits not just producers.

Hypothesis 3. Increased cleantech media coverage is positively correlated with cleantech VC activity.

Formal institutions are economic, political and contractual rules that govern economic behavior (Fukuyama, 1995; North, 1990). If well-defined and enforced, these rules are important in mitigating transaction costs and establishing a level playing field from which businesses can operate. Businesses operating in countries that have stronger well-functioning formal institutions are more likely to face lower costs of doing business and experience more profitable opportunities. Countries with strong formal institutions are also more likely to be more prosperous compared to countries with weak formal institutions.

VC investing is exposed to various information asymmetries and potential opportunism that makes it difficult to evaluate business opportunities, enforce property rights, protect investors, and monitor and enforce contracts (Gompers, 1995; Zacharakis et al., 2007; Bertoni, Colombo, and Grilli, 2013). Formal institutions are important to VC activity because formal institutions that are well designed and enforced can help to reduce transaction costs and opportunity costs. Formal institutions can affect VC activity in many ways. For example, the level of VC activity has been found to depend upon financial market developments (Gompers and Lerner, 1999; Jeng and Wells, 2000; Block and Sandner, 2009; Vismara, 2013; Bertoni, Colombo, and Quas, 2015), labor market regulations (Bozkaya and Kerr, 2014), tax policies (Keuschnigg and Nielsen, 2003, 2004), government sponsored funds and programs (Armour and Cumming, 2006), and bankruptcy laws (Armour and Cumming, 2006). Given that cleantech VC investment tends to be both riskier and more capital intensive than other types of investment (Ghosh and Nanda, 2010), strong formal institutions are not only more likely to encourage cleantech investment, but also more likely to increase the expected private benefits going to the venture capitalist by reducing market uncertainty associated with weak formal institutions. If formal institutions are strong, the public good aspect of cleantech may also provide the venture capitalist with a strong rational with which to engage government support.

Hypothesis 4. Strong country level governance indicators (formal institutions) are positively correlated with cleantech VC activity.

Informal institutions are conventions, codes of conduct, and norms of behavior that are part of a country's culture. Uncertainty avoidance is an important cultural dimension that is likely to be of great importance to cleantech VC activity. Hofstede (1991: 113) refers to uncertainty avoidance as "the extent to which the members of a culture feel threatened by uncertainty or unknown situations". Uncertainty avoidance reflects society's preference for uncertainty (Hofstede, 1980, 1991, 2001). Hofstede found that in societies with high uncertainty avoidance, there is a greater fear of failure, a lower willingness to take risks, lower levels of ambition, and a lower tolerance for ambiguity (Hofstede, 1980, p. 184). By comparison, in societies with low uncertainty avoidance, there is a lesser fear of failure, a higher willingness to take risks, a higher level of ambition, and a higher tolerance for ambiguity: all characteristics that tend to foster entrepreneurial behavior (Hayton, George, and Zahra, 2002). The connection between entrepreneur behavior and innovation has long been recognized (eg. Schumpeter, 1934). Investors in higher uncertainty avoiding countries are more likely to require a higher risk premium on their risky investments than members in lower higher uncertainty avoiding countries. This raises the opportunity cost of capital for investors in higher uncertainty avoiding countries. Uncertainty avoidance has been shown to have a negative impact on innovation, entrepreneurial behavior, and VC activity (Shane, 1993, 1995; Hayton et al., 2002; Mueller and Thomas, 2001; Li and Zahra, 2012). Given that cleantech VC investments tend to be both riskier and more capital intensive than other types of investment (Ghosh and Nanda, 2010), greater uncertainty avoidance will tend to discourage cleantech investment.

Hypothesis 5. Uncertainty avoidance is negatively correlated with cleantech VC activity.

The possibility exists, however, that uncertainty avoidance can moderate the relationship between cleantech VC activity and governance. In regions with high uncertainty avoidance, venture capitalists may require additional incentives to invest in cleantech such as a stronger governance structure. Cleantech VC is more capital intensive, riskier, less likely to scale up, more difficult to exit (Ghosh and Nanda, 2010) than VC investments in other risky industries like biotechnology or information technology. Moreover, the public good nature of cleantech investments decreases the benefits that may accrue to venture capitalists. Cleantech VC investors in high uncertainty avoiding societies would require a higher risk premium to compensate them for their risk taking or in some instances may choose to invest in less risky investments (Li and Zahra, 2012). Strong formal institutions can provide additional assurances and incentives to engage in risk taking or risk sharing as a result of the public goods nature of the investment which helps offset the impact of high uncertainty avoidance. In regions with low uncertainty avoidance, the positive effect that governance has on cleantech VC activity will be weaker. Cleantech venture capitalists in these societies do not need additional incentives to take on risk and find that formal institutions can burden them with unnecessary governance issues which inhibit their ability to take on risky investments.

Hypothesis 6. Uncertainty avoidance moderates the relationship between cleantech VC activity and governance. Governance substitutes for uncertainty avoidance so that the positive main effect is strongest in regions of high uncertainty avoidance.

3. Methods and data

The following 31 countries are included in the study: Australia, Austria, Belgium, Brazil, Canada, Switzerland, Germany, Denmark, Spain, Finland, France, Great Britain, Greece, Hong Kong, Indonesia, Ireland, Israel, Italy, Japan, Korea, Mexico, Malaysia, Netherlands, Norway, New Zealand, Portugal, Singapore, Sweden, Thailand, United States, South Africa. The data set is an unbalanced panel covering the years 1996 to 2010 (See Appendix A).

VC activity, our dependent variable, is measured by the number of cleantech VC deals. To help define cleantech VC deals, information was gathered from The Cleantech group (http://www.cleantech.com/) on what constitutes a cleantech company. Companies were identified as cleantech if their primary focus was on clean technology. Cleantech segments include: advanced materials, agriculture & forestry, air and environment, biofuels & biochemicals, biomass generation, conventional fuels, energy efficiency, energy storage, fuel cells & hydrogen, geothermal, hydro & marine power, nuclear, recycling and waste, smart grid, solar, transportation, water and waste water, and wind.[2] This variable was constructed by the authors using VC data sourced from VentureXpert.[3] The number of cleantech VC deals is left centered at zero. Dividing the number of deals by the population and then taking the natural logarithm of this ratio produces a variable with a histogram that more closely matches that of a normal distribution. This transformed variable is used as our dependent variable in the econometric modeling.

[2] http://www.cleantech.com/upcoming-events/ Note that climate change impacts such as warming temperatures, changes in precipitation and sea level will affect water supply and quality, and food production – hence the inclusion of agriculture & forestry, and water and waste water segments.

[3] This variable has a mean of 84.88 and a standard deviation of 251.12.

We hypothesize that cleantech is affected by movements in oil prices. Higher oil prices create incentives to look for oil substitutes or to increase energy efficiency. Thus higher oil prices should help to spur investment in cleaner technologies. Unfortunately, higher oil prices also provide incumbents an incentive to exploit higher cost oil deposits rather than facilitating an exit strategy for venture capitalists who count on incumbent firms to buy startups (Ghosh and Nanda, 2010). Cleantech VC investors may also be wary of making investing decisions based solely on the high price of energy. If energy prices fall, so will the value of their investment. For capital intensive investments, the loss can be very sudden. To capture the possible non-linear relationship between cleantech VC investment and oil prices, a quadratic oil price term is added along with a linear oil price term. The oil price variable varies across time but does not vary across country.

A country's cleantech VC investment may be affected by how environmentally sustainable the country is. One might expect that countries that rank as more sustainable do more cleantech VC investing. In order to account for this possibility, adjusted net saving is included as a proxy for a country's sustainability. This sustainability indicator is based on the concepts of green accounting and measures the true rate of savings in a country after taking into account investments in human capital, depletion of natural resources and damage caused by pollution.[4] The World Bank calculates adjusted net savings as total net national savings and education expenditure less resource rents (depletion of energy, minerals and forest) and carbon dioxide damage. Adjusted net savings is a very useful policy indicator of sustainability (Hamilton and Clemens, 1999). Negative values indicate that total wealth is in decline and that policies leading to persistently negative net savings are policies that are socially unsustainable.

Media coverage can be viewed as a channel for information flow. Existing research has demonstrated that media coverage helps to build image, reputation, and legitimacy and these factors help to increase the growth of new markets (Deephouse, 2000; Pollock and Rindova, 2003; Rindova et al., 2008). Media coverage as measured by the number of stories, increases familiarity with a topic. A media variable is included as an explanatory variable for cleantech VC deals. Clean technology, or cleantech as it is often referred to, has gone from a relatively obscure term that was hardly used ten years ago to a term that is widely circulated today. We use Factiva to quantify the amount of media coverage. A search for each year, 1996–2010, using the keywords "clean technology or renewable energy" was employed. In 1999, for example, according to data sourced from Factiva, there were 5761 articles that mention the keywords clean technology or renewable energy. In 2009, there were 152,262 articles that mention these terms (Fig. 2) amounting to a 2543% increase in media coverage in just 10 years. Like oil prices, the media variable varies across time but does not vary across country.

Uncertainty avoidance (UAI) is measured using the dimension set out by Hofstede (1980, 1991, 2001). A brief description can be found at http://geert-hofstede.com/national-culture.html. The uncertainty avoidance dimension reflects society's preference for uncertainty. Societies with high uncertainty avoidance are more risk adverse. Societies with weak uncertainty avoidance are less risk adverse. Societies with weak uncertainty avoidance are also associated with societies that value practice more than rigid principles. We have chosen the Hofstede uncertainty avoidance index because it has been subjected to many validity checks, its reliability has been confirmed and it has been replicated in many studies (Shane, 1993). This indicator varies across countries but not time.

Formal institutions are measured using the World Bank's Governance Indicators.[5] These governance data were chosen because of their methodological consistency, country coverage, and granularity. Unlike many other indices that are produced as country rankings, the World Bank Governance Indicators are scored as standard normal units ranging from −2.5 to 2.5, thereby producing variables that are continuous and centered. These data vary across time and country. Kaufmann, Kraay, & Mastruzzi (2010) define the indicators which cover six broad dimensions of governance as follows. The first, *voice and accountability* captures perceptions of the extent to which a country's citizens are able to participate in selecting their government, as well as freedom of expression, freedom of association, and a free media. The second, *political stability and absence of violence* captures perceptions of the likelihood that the government will be destabilized or overthrown by unconstitutional or violent means, including politically-motivated violence and terrorism. The third, *government effectiveness* captures perceptions of the quality of public services, the quality of the civil service and the degree of its independence from political pressures, the quality of policy formulation and implementation, and the credibility of the government's commitment to such policies. The fourth, *regulatory quality* captures perceptions of the ability of the government to formulate and implement sound policies and regulations that permit and promote private sector development. The fifth, *rule of law* captures perceptions of the extent to which agents have confidence in and abide by the rules of society, and in particular the quality of contract enforcement, property rights, the police, and the courts, as well as the likelihood of crime and violence. The sixth, *control of corruption* captures perceptions of the extent to which public power is exercised for private gain, including both petty and grand forms of corruption, as well as "capture" of the state by elites and private interests.

The literature on VC identifies control variables for economic activity (Gompers and Lerner, 1999), financial market activity (Armour and Cumming, 2006; Jeng and Wells, 2000), and legal rights (La Porta, Lopez-Silanes, Shleifer, and Vishney, 1998). Following this literature, economic activity is proxied by real GDP, financial market activity is proxied by stock market turnover and legal protection is measured by anti-director rights (Spamann, 2010).[6]

Table 2 provides a listing of the variables, their definitions and data sources. Summary statistics and correlations are shown in Tables 3 and 4 respectively. The correlations show some significance, and as such, in the subsequent section we investigated issues of multicollinearity. We present alternative specifications with different right-hand-side variables, and show our results are robust.

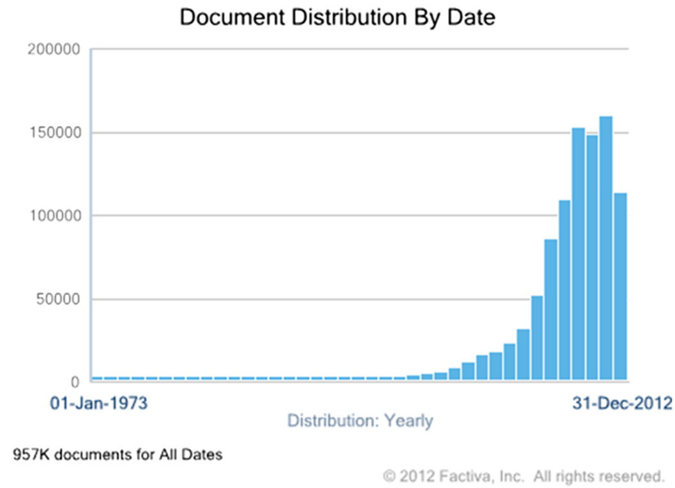

Fig. 2. Document search for clean technology or renewable energy.

[4] http://web.worldbank.org/WBSITE/EXTERNAL/TOPICS/ENVIRONMENT/EXTEEI/0,contentMDK:20502388~menuPK:1187778~pagePK:210058~piPK:210062~theSitePK:408050,00.html.

[5] http://info.worldbank.org/governance/wgi/index.aspx#home.

[6] See Table 2 for more details regarding these controls.

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Table 2
Variable definitions.

Variable	Definition	Data source
Deals	Natural logarithm of (Number of venture capital cleantech deals divided by the population). "Venture capital" includes early and expansion stage investment, but does not include buyout and turnaround private equity investment.	VentureXpert database
GDP	Natural logarithm of GDP, PPP (constant 2005 international $) per capita	World Development Indicators
Turnover	Natural logarithm of stock market turnover of listed companies (% of GDP)	World Development Indicators
Ad rights	Antidirector rights is an index of the number of shareholder protection mechanisms based on a country's laws.	Spamann (2010)
Oil	Natural logarithm of real 2005 oil prices. Real oil prices are calculated as Brent spot prices ($US) deflated by US CPI	BP 2012 Statistical Review of World Energy
Oil sq	Natural logarithm of real oil prices squared	BP 2012 Statistical Review of World Energy
Adj sav	Adjusted net savings, including particulate emission damage (% of GNI)	World Development Indicators
Media	Natural logarithm of the media variable. Media variable is the number of hits of the key words clean technology or renewable energy	Factiva
UAI	Hofstede Uncertainty avoidance	http://www.geerthofstede.nl/research-vsm.aspx
Corrupt	Control of corruption	Worldwide Governance Indicators
Gov Eff	Government effectiveness	Worldwide Governance Indicators
Pol Sta	Political stability	Worldwide Governance Indicators
Reg Qu	Regulatory quality	Worldwide Governance Indicators
Rul Law	Rule of law	Worldwide Governance Indicators
Voi Acc	Voice and accountability	Worldwide Governance Indicators

4. Empirical results

Econometric models are estimated using random effects generalized least squares (GLS). The main reason for using random effects estimation over fixed effects estimation is because the culture variable (UAI) does not display time variation. Thus, estimating a fixed effects model with this culture variable results in a multicollinearity problem where the country specific fixed effects dummy variable is perfectly correlated with the culture variable. This problem is avoided with a random effects specification.

Table 5 reports[7] results showing the impact of oil prices, sustainability (proxied by adjusted net saving), media,[8] formal institutions and uncertainty avoidance on cleantech VC deals. The estimated coefficient on GDP is positive and statistically significant in each specification indicating that increases in economic activity increase cleantech VC deals. A 1-standard deviation increase in GDP is associated with a 7.3% increase in cleantech VC deals per capita relative to the mean. The estimated coefficient on the stock market turnover variable is positive and statistically significant indicating that increases in financial market activity increase the number of cleantech VC deals. A 1-standard deviation increase in turnover is associated with a 2.3% increase in cleantech deals per capita. The estimated coefficient on the administrator rights variable is statistically insignificant in each specification possibly due to the fact that its impact is over shadowed by the rule of law variable which covers a broader classification of protecting property rights and contract enforcement.

The estimated coefficient on the oil variable is positive and statistically significant in three of the specifications while the estimated coefficient on the oil squared variables is negative and statistically significant in all specifications supporting hypothesis 1. These results show that increases in oil prices have a curvilinear effect on cleantech VC deals. Increases in oil prices encourage more cleantech VC deals but the rate of increase slows as oil prices move higher. This is consistent with the response of renewable energy use to higher oil prices. Higher oil prices initially encourage a substitution from fossil fuel energy sources. As oil prices continue to rise, however, there is an incentive to exploit more expensive, harder to reach and, in most cases, higher polluting oil deposits because deposits that weren't economically feasible at low oil prices become feasible at higher oil prices. In terms of the economic significance, a 1-standard deviation increase in oil prices gives rise to a 9.9% increase VC deals per capita relative to the mean value, accounting for the nonlinearity and based on the Model 1 estimates.

The estimated coefficient on the environmental sustainability variable (adjusted net savings) is statistically insignificant in each specification. This is somewhat unexpected and may be due to the fact that cleantech venture capitalists focus more on short term economic and financial indicators, governance, and culture factors when making their investment decisions rather than long term measures of sustainability. Hence, hypothesis 2 is not supported.

The estimated coefficient on the media variable is positive and statistically significant in each specification. Increases in cleantech or renewable energy media coverage increases cleantech VC deals. Hypothesis 3 is therefore supported. In terms of the economic significance, a 1-standard deviation increase in media coverage gives rise to a 3% increase in VC deals per capita (Model 1).

Two of the governance indicators have significant impacts on cleantech VC deals. The estimated coefficient on government effectiveness is positive and statistically significant. This provides support for Hypothesis 4. Government effectiveness captures perceptions of the quality of public services, the quality of the civil service and the degree of its independence from political pressures, the quality of policy formulation and implementation, and the credibility of the government's commitment to such policies. Countries with higher levels of

[7] The reported t statistics are calculated using cluster robust standard errors. We have also estimated the standard errors using a block bootstrap with 500 replications. The t statistics from the two approaches are very similar.

[8] In order to address the question as to whether cleantech VC activity and media are endogenous, we estimated a random effects instrumental variables regression. The results from this regression are very similar (in terms of estimated coefficient sign, magnitude, and significance) to those from a random effects regression. Our conclusion is that endogeneity between VC activity and media is not a problem.

Table 3
Summary statistics.

Variable	mean	sd	p50	min	max	N
Deals	−14.772	1.903	−14.461	−20.792	−11.458	288
GDP	10.159	0.658	10.318	7.121	10.803	288
Turnover	4.434	0.605	4.455	2.344	6.002	288
Ad rights	3.750	0.859	3.5	2	5	288
Oil	3.636	0.481	3.476	2.724	4.480	288
Adj sav	13.093	6.362	12.176	1.509	40.500	288
Media	9.768	1.498	9.762	6.227	11.933	288
UAI	57.066	23.137	51	8	112	288
Corrupt	1.585	0.736	1.865	−0.497	2.586	210
Gov Eff	1.579	0.548	1.734	−0.139	2.408	210
Pol Sta	0.665	0.744	0.895	−1.696	1.665	210
Reg Qu	1.371	0.506	1.537	−0.441	2.120	210
Rul Law	1.436	0.523	1.612	−0.566	2.002	210
Voi Acc	1.156	0.483	1.331	−0.522	1.826	210

Variable definitions provided in Table 2.

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Table 4
Correlations.

	Deals	GDP	Turnover	Ad rights	Oil	Adj sav	Media	UAI	Corrupt	Gov Eff	Pol Sta
Deals	1.000										
GDP	0.597	1.000									
Turnover	0.028	0.096	1.000								
Ad rights	−0.082	−0.326	−0.122	1.000							
Oil	0.077	0.220	0.351	−0.031	1.000						
Adj sav	0.031	−0.025	−0.007	0.163	0.048	1.000					
Media	0.137	0.217	0.346	−0.013	0.881	0.006	1.000				
UAI	−0.368	−0.092	0.032	−0.423	−0.033	−0.301	−0.039	1.000			
Corrupt	0.591	0.720	−0.053	−0.124	0.055	0.027	0.046	−0.483	1.000		
Gov Eff	0.648	0.769	−0.037	−0.173	0.077	0.113	0.069	−0.410	0.941	1.000	
Pol Sta	0.261	0.581	0.015	−0.294	−0.035	0.124	−0.070	−0.276	0.714	0.689	1.000
Reg Qu	0.638	0.818	0.027	−0.088	0.165	0.026	0.167	−0.460	0.897	0.888	0.630
Rul Law	0.593	0.749	0.123	−0.242	0.140	−0.011	0.135	−0.373	0.924	0.913	0.710
Voi Acc	0.322	0.443	0.156	−0.451	0.059	−0.439	0.027	0.008	0.594	0.560	0.500

	Reg Qu	Rul Law	Voi Acc
Reg Qu	1.000		
Rul Law	0.848	1.000	
Voi Acc	0.481	0.681	1.000

Variable definitions provided in Table 2. 210 observations.

government effectiveness do more cleantech VC deals. A 1-standard deviation increase in government effectiveness gives rise to an increase in VC deals per capita by 2.7% (Model 4). The estimated coefficient on rule of the law is positive and statistically significant. This provides support for Hypothesis 4. Rule of law captures perceptions of the extent to which agents have confidence in and abide by the rules of society, and in particular the quality of contract enforcement, property rights, the police, and the courts, as well as the likelihood of crime and violence. Countries with higher levels of rule of law do more cleantech VC deals. The estimated coefficients on the other governance variables are not

Table 5
The impact of oil prices, media, governance, and culture on cleantech venture capital deals.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
GDP	1.64[a]	1.44[a]	1.43[a]	1.33[a]	1.97[a]	1.52[a]	1.27[a]	1.72[a]
	(7.15)	(5.63)	(3.24)	(3.95)	(5.27)	(3.60)	(3.82)	(7.00)
Turnover	0.32[c]	0.33[b]	0.39[b]	0.38[b]	0.44[a]	0.39[b]	0.33[b]	0.38[b]
	(1.95)	(2.03)	(2.41)	(2.24)	(2.75)	(2.41)	(2.06)	(2.24)
Ad rights	0.26	−0.15	0.25	0.27	0.31	0.27	0.31	0.42
	(1.02)	(−0.48)	(0.95)	(1.12)	(1.11)	(0.97)	(1.22)	(1.33)
Oil	3.65[c]	3.59[c]	3.10	2.66	2.78	2.85	3.49[c]	2.59
	(1.93)	(1.88)	(1.51)	(1.28)	(1.31)	(1.39)	(1.85)	(1.32)
Oil sq	−0.61[b]	−0.60[b]	−0.56[b]	−0.50[c]	−0.52[c]	−0.53[c]	−0.61[b]	−0.50[c]
	(−2.38)	(−2.33)	(−1.97)	(−1.72)	(−1.76)	(−1.87)	(−2.34)	(−1.84)
Adj sav	0.0060	−0.0025	−0.0047	−0.015	−0.0093	−0.0067	−0.0057	−0.00094
	(0.23)	(−0.10)	(−0.20)	(−0.63)	(−0.38)	(−0.30)	(−0.27)	(−0.04)
Media	0.30[b]	0.31[b]	0.36[a]	0.35[a]	0.30[b]	0.33[a]	0.34[a]	0.35[a]
	(2.34)	(2.49)	(2.89)	(2.82)	(2.31)	(2.68)	(2.91)	(2.79)
UAI		−0.025[b]						
		(−2.25)						
Corrupt			0.46					
			(1.42)					
Gov Eff				0.73[b]				
				(2.22)				
Pol Sta					−0.11			
					(−0.37)			
Reg Qua						0.54		
						(1.46)		
Rul Law							0.84[b]	
							(2.16)	
Voi Acc								0.54
								(1.13)
Constant	−42.0[a]	−36.9[a]	−39.9[a]	−38.4[a]	−43.8[a]	−40.1[a]	−39.3[a]	−42.2[a]
	(−10.02)	(−7.44)	(−6.89)	(−6.75)	(−8.12)	(−6.30)	(−7.95)	(−9.05)
R2(O)	0.41	0.51	0.42	0.43	0.37	0.40	0.42	0.38
Wald	94.3	167.0	159.2	161.0	97.6	134.1	176.0	123.8
Wald(p)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Observations	288	288	210	210	210	210	210	210
Countries	31	31	30	30	30	30	30	30

t statistics in parentheses.
Estimation is of an unbalanced panel data set by random effects GLS models. The t statistics are calculated using cluster robust standard errors. Wald is a chi-squared test for all slope coefficients equal to zero (p denotes the p value for this statistic). R2 (O) denotes R2 overall.
[a] $p < 0.01$.
[b] $p < 0.05$.
[c] $p < 0.10$.

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statistically significant. A 1-standard deviation increase in rule of law gives rise to an increase in VC deals per capita by 3% (Model 7). However, the estimated coefficients on control of corruption, regulatory quality, and voice and accountability are each positive providing some partial support for Hypothesis 4.

The estimated coefficient on the uncertainty avoidance variable (UAI) is negative and statistically significant. This supports Hypothesis 5. Increases in uncertainty avoidance reduce the number of cleantech VC deals. Uncertainty avoidance is associated with how comfortable societies are with ambiguity and uncertainty. The negative and significant coefficient on the UAI variable indicates that societies that are more comfortable with ambiguity and uncertainty will do more cleantech VC deals. A 1-standard deviation increase in UAI gives rise to a reduction in VC deals by 4% (Model 1).

Uncertainty avoidance moderates the impact of government effectiveness on cleantech VC deals (Table 6). The estimated coefficient on the interaction term is positive and statistically significant. To further understand this effect, an interaction graph was produced (Fig. 3). Uncertainty avoidance is fixed at either its 10 percentile (UAI = 29) or 90 percentile (UAI = 92). Government effectiveness is allowed to vary over a plausible range of values. The other variables are fixed at their sample means. Notice that with high uncertainty avoidance (UAI = 92), increases in government effectiveness increases cleantech VC deals. This provides support for Hypothesis 6.

The estimated coefficient on the interaction term between uncertainty avoidance and regulatory quality is positive and statistically significant indicating that uncertainty avoidance moderates the effect of regulatory quality on cleantech VC deals. An interaction graph (See Fig. 4.) shows that with high uncertainty avoidance (UAI = 92),

Table 6
The moderating effect of uncertainty avoidance on the relationship between cleantech venture capital deals and institutional factors.

	(1)	(2)	(3)	(4)	(5)	(6)
GDP	1.64[a]	1.66[a]	1.76[a]	1.90[a]	1.36[a]	1.47[a]
	(4.55)	(5.38)	(4.98)	(5.39)	(3.67)	(6.47)
Turnover	0.38[b]	0.34[b]	0.43[a]	0.35[b]	0.36[b]	0.38[b]
	(2.33)	(2.11)	(2.77)	(2.20)	(2.25)	(2.44)
Ad rights	−0.036	0.013	−0.16	0.034	0.0043	0.036
	(−0.11)	(0.04)	(−0.50)	(0.10)	(0.01)	(0.09)
Oil	2.97	2.66	2.76	2.67	3.27[c]	2.65
	(1.44)	(1.30)	(1.31)	(1.29)	(1.71)	(1.36)
Oil sq	−0.54[c]	−0.50[c]	−0.52[c]	−0.51[c]	−0.58[b]	−0.51[c]
	(−1.90)	(−1.75)	(−1.75)	(−1.76)	(−2.19)	(−1.86)
Adj sav	−0.016	−0.015	−0.017	−0.015	−0.015	−0.015
	(−0.64)	(−0.63)	(−0.69)	(−0.64)	(−0.68)	(−0.51)
Media	0.33[b]	0.33[b]	0.29[b]	0.31[b]	0.34[a]	0.35[a]
	(2.53)	(2.56)	(2.13)	(2.35)	(2.71)	(2.69)
Corrupt	−0.36					
	(−0.55)					
UAI	−0.035[c]	−0.054[a]	−0.026[c]	−0.060[a]	−0.026	−0.033[c]
	(−1.68)	(−2.63)	(−1.88)	(−2.98)	(−0.98)	(−1.77)
Corrupt X UAI	0.0080					
	(0.82)					
Gov Eff		−1.01				
		(−1.29)				
Gov Eff X UAI		0.021[b]				
		(2.01)				
Pol Sta			−0.015			
			(−0.02)			
Pol Sta X UAI			−0.0040			
			(−0.30)			
Reg Qua				−1.56[c]		
				(−1.95)		
Reg Qua X UAI				0.027[b]		
				(2.47)		
Rul Law					0.26	
					(0.20)	
Rul Law X UAI					0.0040	
					(0.25)	
Voi Acc						0.050
						(0.08)
Voi Acc X UAI						0.0088
						(0.62)
Constant	−37.6[a]	−36.4[a]	−38.1[a]	−38.0[a]	−36.5[a]	−36.4[a]
	(−6.78)	(−6.84)	(−6.64)	(−6.77)	(−7.10)	(−6.84)
R2(O)	0.46	0.48	0.50	0.47	0.47	0.45
Wald	307.3	344.7	245.8	370.0	313.1	355.9
Wald(p)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Observations	210	210	210	210	210	210
Countries	30	30	30	30	30	30

t statistics in parentheses.
Estimation is of an unbalanced panel data set by random effects GLS models. The t statistics are calculated using cluster robust standard errors. Wald is a chi-squared test for all slope coefficients equal to zero (p denotes the p value for this statistic). R2 (O) denotes R2 overall.
[a] $p < 0.01$.
[b] $p < 0.05$.
[c] $p < 0.10$.

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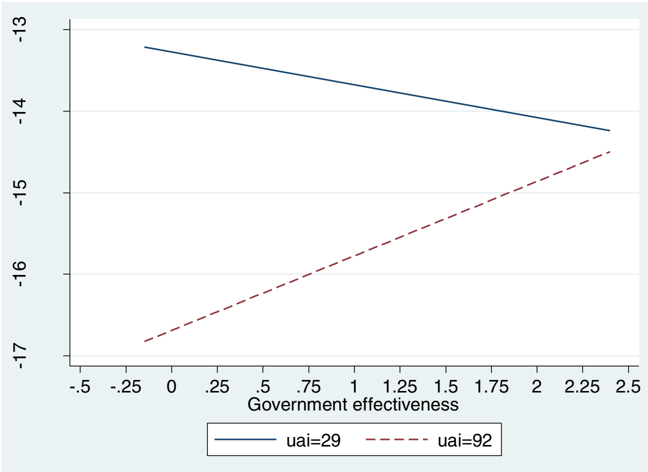

Fig. 3. The moderating effect of uncertainty avoidance on the relationship between government effectiveness and cleantech VC deals.

increases in regulatory quality increases cleantech VC deals. This provides support for Hypothesis 6.

5. Conclusions

While there have been much research on the determinants of VC investing, there is considerably less known about the determinants of cleantech VC capital investing. Cleantech VC investing is a rapidly growing sub-sector of VC investing. Using a unique data set of 31 countries followed over the years 1996 to 2010 this paper provides a comprehensive cross-country analysis of the determinants of cleantech VC deals.

While increasing energy prices may incite entrepreneurs to want to invest in cleantech entrepreneurial ventures, it may also dissuade incumbents – that is, energy producers (utilities, oil and gas producers) – from buying start-ups. We find that oil prices have a curvilinear effect on cleantech VC investing. Increases in oil prices increase cleantech VC deals but with a slowing rate of increase. The ethical implications are that increasing oil prices are not a panacea. The unintended consequence of higher oil prices is the increased incentive to exploit more expensive, harder to reach and, in most cases, more polluting oil deposits. Incumbents will not value clean alternatives unless they are required to account for their externalities. Cleantech venture capital is an option but countervailing forces need to be addressed. Consequently, taking a wait-and-see attitude in the hope that rising oil prices will create the incentive needed for the cleantech VC market to change would be incorrect.

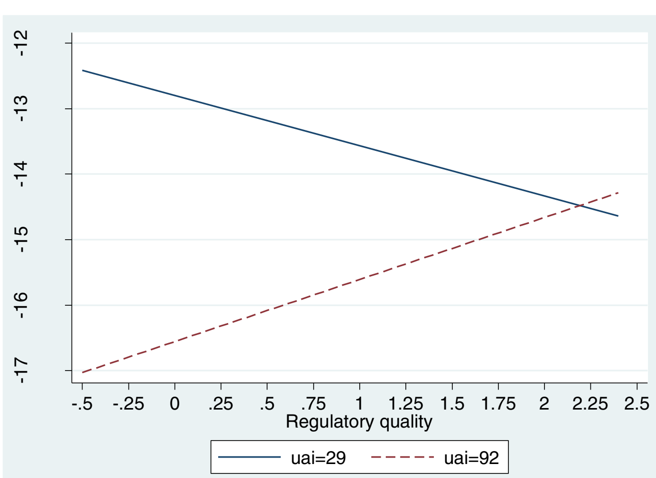

Fig. 4. The moderating effect of uncertainty avoidance on the relationship between regulatory quality and cleantech VC deals.

Media is found to be an important explanatory variable of cleantech VC deals. Such information is used both by the suppliers of cleantech and the customers of cleantech. Existing literature points out that media coverage can be considered as channel for the flow of information and this helps to build image, reputation, and legitimacy and these factors help to increase the growth of new markets. The positive and significant impact of media on cleantech VC deals is consistent with this view. Hence positive media coverage of alternative energy sources should be encouraged.

Formal institutions, like economic, political and contractual rules, are important to cleantech VC activity because formal institutions that are well designed and enforced can help reduce transaction and opportunity costs. This provides a better business environment from which to conduct cleantech VC investing. Formal institutions can be measured using governance indicators on factors like government effectiveness, regulatory quality, the control of corruption, voice and accountability, political stability, and the rule of the law. The empirical results show that government effectiveness and rule of the law to each have positive and statistically significant impacts on cleantech VC deals. As the social benefits of cleantech are a significant component of cleantech, sound government and laws reflecting concern for citizens would allow venture capitalists to feel more confident that such social benefits may be of value to government, thereby increasing the venture capitalist's potential private expected benefits.

The impact of uncertainty avoidance, a culture dimension, on cleantech VC deals was analyzed. Uncertainty avoidance has a negative and statistically significant impact on cleantech VC deals. Uncertainty avoidance refers to a society's preference for uncertainty. Higher uncertainty avoidance is characteristic of societies with rigid codes of conduct, beliefs and behavior. Innovation and VC investing requires risk taking and openness to new ideas. Given that cleantech VC investment is riskier than the typical VC investment, countries with an aversion to uncertainty may need to consider incentives that may counter such preferences if they wish to promote cleantech.

The results of this paper lead to a number of future research questions that tie into policy implications for increasing the amount of cleantech VC deal making. Societies with high uncertainty avoidance are more likely to do less VC investing compared to countries with low levels of uncertainty avoidance (Li and Zahra, 2012). Since culture is time invariant, governments of these types of countries need to find alternative ways to increase VC. One possible approach that could be explored in future research is for policy makers to push for more governance. Increases in rule of the law would be particularly useful since this variable was found to have a positive and statistically significant impact on cleantech VC deals. A rule of law policy that increases the quality of contract enforcement, property rights, policing, and judicial systems, as well as reducing the likelihood of crime and violence is an important determinant of cleantech VC deals.

Uncertainty avoidance was found to moderate the relationship between governance and cleantech VC deals when governance is measured using government effectiveness or quality of regulation. Our research is consistent with the view that government policy focused on the quality of energy policy formulation and implementation and the credibility of the government's commitment to such policies would be beneficial for promoting cleantech VC activity in societies with high uncertainty avoidance. Future research on this topic is warranted.

Ghosh & Nanda (2010), characterize cleantech VC as more capital intensive, riskier, less likely to scale up, and more difficult to exit then VC investments in other industries like biotechnology or information technology. Our findings herein are consistent, and we hope there is further research on the topic of cleantech VC exits. Cleantech start-ups also tend to be more susceptible to the "Valley of Death" than start-ups in other industries (Bloomberg New Energy Finance, 2010). The valley of death refers to a shortage of funding at the technology development stage and a shortage of funding for proving the viability of a new technology for commercialization. In response there are several suggestions as to how government can stimulate investing in cleantech. First, government can create long-term, stable and predictable policy to encourage the demand for clean energy. Here, government has a number of policy tools at its disposal including feed-in-tariffs, reduction of fossil fuel subsidies, renewable fuel standards, technology standards, CO2 trading, production tax credits, carbon taxes, renewable portfolio standards (Buer and Wustenhagen, 2009). In their study of private equity and VC investors in the cleantech sector Buer & Wustenhagen (2009) find that these investors have a preference for feed-in-tariffs. The feed-in-tariff policy, however, needs to be credible. Germany, Spain, and the province of Ontario in Canada each initiated very generous feed-in-tariffs for solar power (upwards of 50 cents per KWH, depending on the size of the project). As expected, these incentives substantially increased investment in solar power. As these governments realized that much more solar power was being generated than expected and that the cost of the program was higher than expected, the feed-in-tariffs were cut. This created policy uncertainty resulting in a large drop in investment for solar power. Government policy on these matters needs to be both credible and dynamically consistent.

Second, government can stimulate M&A activity through regulatory initiatives or corporate incentives. Government for example, can create policy to encourage incumbents to become first adopters of new technology. This is particularly relevant in the electric power generation sector where power generators have a choice of fuels (oil, natural gas, coal, or renewables). In the US, renewable portfolio standards, regulations that require the increased production of energy from renewable energy sources, are one successful way of implementing this approach. Again, further research on topic is warranted.

Third, government can create and support public-private partnerships between governments, universities, and companies to help combat the market failure arising due to the public good nature of cleantech. Government funding for research and development could then be integrated with matching funds from the private sector. As an example of how this could work, government funding could be used for technology research, cleantech VC funding could be used for technology development, and company funding could be used for scale-up and roll-out. These issues, among others, could be explored in future work on cleantech VC.

Fourth, China was not included in our sample due data availability issues (although Hong Kong was). According to Bloomberg's Climatescope 2014 (Bloomberg New Energy Finance, 2014), it is only since 2013 that China has become the largest demand market for renewables. It is also in 2013 that China has improved its domestic policy framework for green energy investment. As much of this investment appears to be due to domestic policy changes, a study of cleantech in China alone, when data become available, with an emphasis on government versus private cleantech venture capital would be warranted.

Finally, the public good aspect of cleantech suggests a significant amount of positive benefits accrues to society which results in private sector underinvestment. One possibility is to examine whether a crowdfunding approach to VC financing would be more appropriate here. Given the enormity of climate change, leaving cleantech to be decided by venture capitalists alone may not be sufficient.

Appendix A

Mean number of cleantech VC deals by country by year.

Country	mean	Years
Australia	20.64	11
Austria	1.00	4
Belgium	7.25	4
Brazil	5.67	3
Canada	173.83	12
Denmark	8.78	9
Finland	8.30	10
France	33.09	11
Germany	18.08	12
Hong Kong	7.43	7
India	8.00	7
Ireland	9.67	3
Israel	13.82	11
Italy	2.40	5
Japan	8.09	11
Malaysia	2.00	1
Mexico	1.00	1
Netherlands	13.50	10
New Zealand	2.00	1
Norway	9.67	6
Portugal	11.00	1
Singapore	9.00	7
South Korea	17.00	10
Spain	3.11	9
Sweden	12.38	8
Switzerland	18.11	9
Thailand	1.00	1
United Kingdom	58.67	12
United States	1043.67	12

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