

Which renewable energy policy is a venture capitalist's best friend? Empirical evidence from a survey of international cleantech investors

Mary Jean Bürer, Rolf Wüstenhagen *

Ecole Polytechnique Fédérale de Lausanne (EPFL), CH-1015 Lausanne, Switzerland

University of St. Gallen, Institute for Economy and the Environment (IWO-HSG), Good Energies Chair for Management of Renewable Energies, Tigerbergstrasse 2, CH-9000 St. Gallen, Switzerland

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ABSTRACT

Governments around the world have adopted ambitious targets to increase the share of renewable energy and reduce greenhouse gas emissions. They pursue a variety of policy approaches to achieve these targets. It has been a popular theme for contributions in *Energy Policy* to investigate the effectiveness of such policies. This article adds a new perspective to the debate, namely looking at the policy preferences of private investors in innovative clean energy technology firms. We surveyed 60 investment professionals from European and North American venture capital and private equity funds and asked them to assess the effectiveness of various policies, in terms of stimulating their interest to invest in innovative clean energy technologies. In addition to quantitative rankings, we use qualitative interview data to capture additional information on why investors prefer some policies over others. The combined analysis compensates for the inherent limitations of a quantitative ranking using generic policy types. The results of this exploratory analysis demonstrate that, all other things being equal, investors in our sample perceived feed-in tariffs to be the most effective renewable energy policy. The overall preference for feed-in tariffs is even more pronounced among investors based in Europe and with higher exposure to clean energy.

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1. Introduction

Venture capital and private equity investments are an important source of financing for innovative entrepreneurial firms (Gompers and Lerner, 2004). While venture capitalists have traditionally focused their investments in a small set of industries such as information and communication technologies or biotechnology (Wüstenhagen and Teppo, 2006), there has recently been increasing attention to “cleantech”, an investment category which consists of renewable energy technologies such as solar energy, wave energy and biofuels, as well as a collection of other sustainability related subsectors (Usher, 2008). As experience in other industries has demonstrated, venture capital and private equity investments can significantly accelerate the market diffusion of new technologies (Florida and Smith, 1990; Kortum and Lerner, 2000), despite the fact that the early stage investments provided by these types of investors are a relatively small subset of overall investment flowing to clean energy (Usher, 2008). The venture capital and innovation literature offers a

variety of explanations for the prominent role of early stage investors in shaping technological innovation and stimulating the entire investment cycle. One aspect is that early stage investors aid entrepreneurial firms in the most precarious stage of the innovation chain—the “technology valley of death” (Grubb, 2006) or the original concept “the cash flow valley of death” (Murphy and Edwards, 2003). Another explanation is that venture capitalists, by acting as scouts and coaches, are overcoming some of the inherent information asymmetries that prevent traditional investors from entering the high-uncertainty business of investment in new technologies (Hellmann, 2000; Baum and Silverman, 2004). Finally, recent literature points at venture capitalists' ability to influence the expectation dynamics of other, less-than-fully rational investors as a potential explanation for their importance in the commercialization of innovation (Wüstenhagen et al., forthcoming).

Meanwhile, a particular feature of the energy sector compared to other investment areas is that it is characterized by a high importance of regulatory drivers. Therefore, energy and climate policies have a direct or indirect influence on the performance of venture capital and private equity investments in this area. Understanding investor perceptions of the risks (and opportunities) associated with specific energy and climate policies may provide policymakers with an opportunity to leverage private

* Corresponding author. Tel.: +41 71 224 25 87; fax: +41 71 224 27 22.

E-mail address: rolf.wuestenhagen@unisg.ch (R. Wüstenhagen).

URL: <http://goodenergies.iwoe.unisg.ch> (R. Wüstenhagen).

investment for the achievement of climate and renewable energy targets. On the other hand, policies that are based on a poor understanding of investor preferences run the risk of crowding out, rather than facilitating, private investment in renewable energy technologies. Based on a survey among 60 European and North American private equity investors, this paper provides empirical evidence about which policies are perceived to be more effective at stimulating interest to invest in innovative clean energy technology firms.

2. Literature review

2.1. Low-carbon innovation policy: technology-push versus market pull

In his survey of issues and options of technology innovation and climate change policy, Grubb (2004) outlines the full menu of approaches that policymakers have at hand to promote low-carbon innovation (Fig. 1). The challenge is to bring new technologies from research laboratories to market, and to do so while surviving the “technology valley of death”, namely the middle phase of the innovation chain where successful prototypes have been developed but the commercializing firm is facing the tough challenge of successful market introduction. It is in this middle part between government-funded R&D and self-sustaining funding from customers where innovative technology firms struggle most. At the same time, this is also exactly the area where venture capital and private equity investors focus their investment, hence understanding their preferences is particularly relevant (Moore and Wüstenhagen, 2004). However, Fig. 1 also shows that there are a number of other important investors along the innovation chain. In particular, it is worth noting that investors further downstream in the innovation chain (e.g.

providers of project finance and corporate finance) may not have the visibility and leverage of venture capital and private equity investors, but due to the relatively larger funding volumes are at least equally important when it comes to deploying technologies that have become commercial.

As can be seen from Fig. 1, policies to promote low-carbon innovation can basically be divided into technology-push and market-pull policies. The basic idea of technology-push policies (such as innovation policies like government-funded research and development) is to increase the amount of technology “supply”. The rationale for market-pull policies (such as public procurement or production tax credits (PTC)) on the other hand is to increase “demand” for new technologies and provide firms and consumers with economic incentives to apply them. There is a vivid debate among climate policy scientists and modellers as to which of the two approaches is more adequate to reach long-term mitigation targets, with some scholars articulating the need for technology push in order to come up with breakthrough innovation (e.g. Hoffert et al., 2002), while others are leaning towards market-pull instruments based on the assumption that new technologies only make a difference if they are in fact applied in the marketplace, and that government’s role should rather be in stimulating demand for innovative products and thereby contributing to induced technological change (Grubb et al., 1995, 2002; Dowlatabadi, 1998). At the same time, many experts agree that the two approaches are complementary. While we concur that both types of approaches (and a mix of different policies from each side of the line) are needed, our survey aims at empirically testing which policies among the entire set of technology-push or market-pull policies are perceived to be more effective at stimulating venture investors’ interest to invest. We compiled the average scores for each generic policy based on the scores provided to us by the venture capital and private equity investors that we surveyed and interviewed.

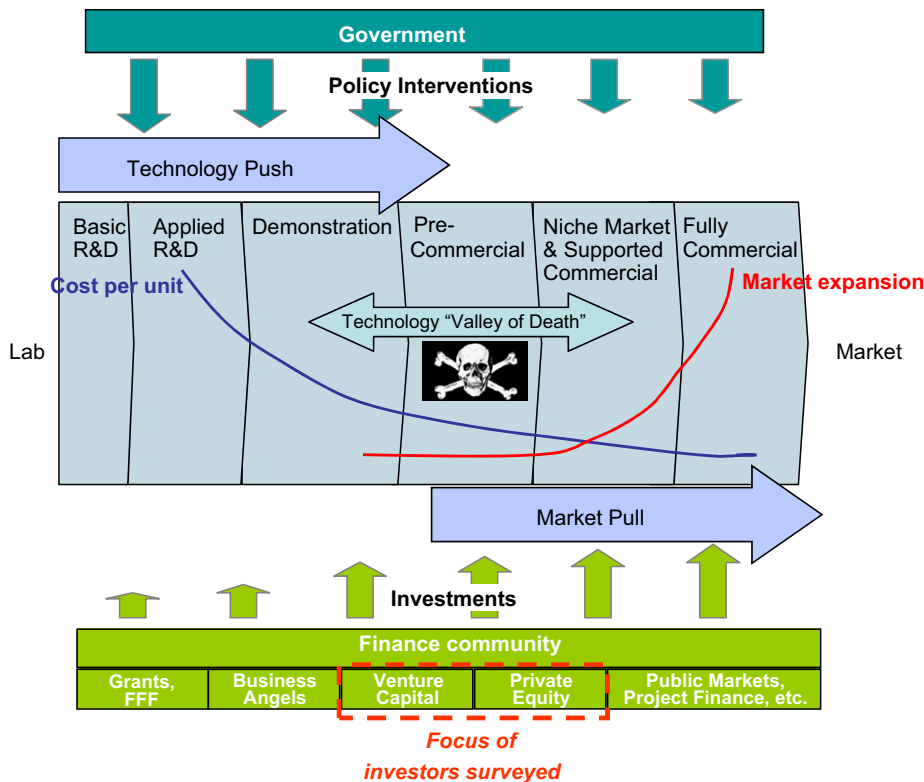


Fig. 1. The innovation chain and the technology “valley of death” (adapted from Grubb 2004).

2.2. Efficiency and effectiveness of renewable energy policies

The multitude of policy approaches that governments in different countries have recently adopted for promotion of renewable energy has created an interesting experimental setting for discussions of policy efficiency and effectiveness. While early studies of this topic had to rely on theoretical considerations, there is now an increasing amount of empirical evidence to draw on. Much of the earlier discussion was led along the line of quantity-based (e.g. renewable portfolio standards) versus price-based systems (e.g. feed-in tariffs). It seemed to be commonplace in the early days of this analysis that quantity-based systems outperform price-based systems in terms of economic efficiency (e.g. Drillisch and Riechmann, 1998; Kühn, 1999; Lenz and Pfaffenberger, 1999). As more experience with practical implementation was gained, however, it has been increasingly realized that there are some deviations between the elegance of economic models and the realities of markets and policymaking processes. For example, it became soon visible that the UK's (quantity-based) Non-Fossil Fuel Obligation (NFFO) scheme failed to deliver the quantities of renewable energy generation that it had aimed for. Even though the design of the scheme was not the only factor contributing to the scheme's failure (Mitchell, 2000), a comparison of effectiveness seemed to result in a lead for price-based systems as they had been introduced in Denmark, Germany and Spain (Wüstenhagen, 2000, p. 278). In a more recent update of the UK versus Germany comparison, Butler and Neuhoff (2004) point out that not only has the UK system been less effective, but they can also not find evidence for a higher efficiency, since prices paid for the amount of wind power that has actually been fed into the grid are in the same order of magnitude in both countries, despite poorer wind resources in Germany. Attempts to explain the success of feed-in tariffs in effectively increasing the share of renewables have highlighted the fact that it provides lower risk to investors compared to other support mechanisms (Menanteau et al., 2003; Langniss, 1999; Lüthi and Wüstenhagen, 2008). Quantity-based schemes such as the Renewables Obligation in the UK are posing price, volume and balancing risks that only large, integrated energy companies tend to be able to overcome (Mitchell et al., 2006), which points to a possible positive correlation between feed-in tariffs and entrepreneurship in the renewable energy sector (Ragwitz et al., 2007; Toke and Lauber, 2007). Furthermore, a study by the European Commission (2005) defined effectiveness by the ratio of additional annual normalised electricity generation to realisable remaining potential until 2020. The study performed an assessment of the support systems separately for different renewable technologies. The study by the European Commission concluded that the most effective systems in wind energy are currently in Germany, Spain and Denmark with feed-in tariff systems, although the green certificate systems, where they apply, present currently a significantly higher support level than the feed-in tariffs. While wind energy has started to become a mature renewable energy technology, studying the evolution of this market provides good insight on which policies are most effective at creating the right market environments for new innovative energy technologies. Sawin (2004) concludes that 'feed-in systems have been responsible for most of the additions in renewable capacity and generation whilst the record of quota systems is more uneven'. Finally, other than the effectiveness and efficiency of policies, a long-term and stable policy environment has been shown to be actually the key criterion for the success of developing renewable electricity markets (Held et al., 2006)—in other words, renewable energy policies need to be "loud, long and legal" (UNEP SEFI, 2004). Obviously the way a country applies any given policy has a huge impact on its perceived success. For example, the very stable and supportive policy framework that

was put in place in Germany and in other European countries for renewable energy, alongside of the feed-in tariffs, contributes to the perceived success of feed-in tariffs in Europe.

2.3. Facilitating private investment in renewable energy

Only a few years after authors like Diefendorf (2000) and Wüstenhagen and Teppo (2006) have investigated why so little venture capital investment is directed to clean energy technologies, there has been a recent surge in investments in this area. As Usher (2008) points out, new investment in the renewable energy sector has matured and has recently surpassed \$100 billion per year, the largest part being asset financing of renewable energy projects such as wind farms or biofuel projects. Venture capital and private equity has a share of approximately 10% of the overall investment, but the experience in other sectors shows that these actors at the beginning of the innovation financing chain have a strong influence on innovation and economic development (Florida and Smith, 1990; Gompers and Lerner, 2004).

While general factors like increasing awareness about climate change have probably contributed to the recent sharp increase in levels of renewable energy investment, an important role is widely attributed to favorable regulatory conditions in some key markets such as Germany, Spain or California. However, relatively little is known about how investors actually view given policy measures. In one of the few empirical studies in this area, Kasemir et al. (2000) conducted a policy exercise with six venture capitalists about European climate policy and concluded that investors perceive subsidies and tax exemptions as effective measures. However, there are also indications that venture capitalists and private equity investors may not be univocally positive about policy, and that some of them may have a stance that can perhaps be described as policy aversion. A particularly pronounced example of this is given by Wüstenhagen and Teppo (2006), quoting a venture capitalist who said: "If there is no clear need for the government, make them stay out of the way." There is anecdotal evidence that some leading venture capital investors may recently have changed their view about energy policy and are starting to proactively manage regulatory risk as part of their overall risk management strategy in this sector (Richtel, 2007; Bürer and Wüstenhagen, 2008). The survey and interview results presented in this paper are a first attempt to move beyond anecdotal evidence and provide a more comprehensive picture of venture investors' preferences with regard to renewable energy and climate policies.

3. Data and methods

In a survey we conducted in early 2007, a principal or senior fund manager from each of the 60 participating fund management firms was asked to rate the effectiveness of policy options in terms of stimulating their interest to invest in clean energy technology private equity or venture capital investments. We therefore used a stated-preference approach rather than relying on revealed preferences of investors. The advantage of a stated-preference approach is that we were able to ask about investors' preferences with regard to a variety of policies, regardless of which policy had actually been introduced in their home country, while revealed preferences (e.g. looking at the actual investment levels that resulted from introduction of a specific policy) will only provide information about one policy at a time. Also, while revealed preferences can only be observed several years after a given policy has been introduced, the stated-preference approach allows for an earlier assessment. Our analysis is based on the assumption that these empirical results are an indication of how such fund

managers might actually react with regard to their investment decisions in practice when faced with different policy environments. On the other hand, a major limitation of this approach is that in order to collect information on a variety of policies, we were not able to reflect the true complexity and interdependency of policies in our surveys and interviews with investors.

Since private equity and venture capital investors are a time-constrained population that is notoriously difficult to access, we chose to leave our respondents a choice between three formats of answering our questions. They could either participate in the full version of our web-based questionnaire, or reply to a shorter paper-and-pencil version, or go through the questionnaire while doing a telephone interview. In the interviews we were able to also extract further information about investors' reasoning. Answers were evenly distributed between the three formats, while six of the respondents in the telephone sample expressed particular time constraints, and hence only responded to an abbreviated version of the full questionnaire focusing on technology-push and market-pull policies.

In the interviews, respondents were asked to rate policies in the same way as in the surveys, but in the discussion they were sometimes replying that they never make an investment decision based on a supportive policy like a subsidy scheme, or in some cases they were questioning the need for policy at all. We asked them to explain their views. In many cases they spoke about trusting "the power of the market" to make correct investment decisions. They were particularly adverse to market-push policies that appeared to choose the best technologies. We look at a few statements from these interviews in Section 4.3 below.

3.1. Description of our sample

Table 1 provides a summary of the characteristics of the respondents in our survey. These characteristics were used in our full analysis of the investors' individual policy preferences (Section 4.3). The majority of our sample is evenly split between

Table 1
Characteristics of private equity investors in our sample.

Energy experience	Already invested in clean energy	80%
	Of those already invested in clean energy: made last clean energy investment within last 12 months	97%
	Already investigated relevant energy and climate public policies	80%
Investment focus (financing stage)	Focus on seed and start-up financing	28%
	Focus on expansion stage financing	44%
	Focus on later-stage financing	12%
	Investing across different stages	16%
Investment focus (geographical)	Funds investing in clean energy mostly in North America	44%
	Funds investing in clean energy mostly in Europe	28%
	Funds investing in clean energy in both Europe and North America	10%
Location	Funds investing in clean energy globally	18%
	Funds based in North America	50%
	Funds based in Europe	50%
Fund size	Among funds based in Europe, funds based in the UK	33%
	Small funds (less than 10 million Euros)	27%
	Medium-sized funds (10–100 million Euros)	31%
	Large funds (100–250 million Euros)	30%
Investment horizon	Very large funds (250–500 million Euros)	12%
	Expected time to exit (average for all funds)	6 years

private equity funds based in North America and Europe, and between small, medium-sized and large funds. Twelve per cent of the funds interviewed are very large private equity funds with more than 250 Mio Euros under management. The large majority of the funds interviewed had active investment experience in clean energy. We chose this break-up of funds in order to survey and interview the widest diversity of venture capital and private equity funds active in the clean energy sector, as possible. This would allow us to generalize the findings for the venture capital fund manager category. We also did not want the average scores for each policy (the key general findings of this study) to be too biased towards either the American or the European continent as policy experience clearly affects respondents' views. Therefore, we made sure we had an equal split among the funds in terms of geography.

Meanwhile, with the sample characteristics we were able to analyze the responses according to various fund characteristics. This led to further understanding the reasoning that investors have behind their individual policy preferences, and it explained why certain types of investors tend to have similar opinions.

Besides basic fund characteristics such as clean energy fund size (clean energy exposure), fund type (e.g. early stage venture capital or later-stage private equity), firm size, firm type, location of business and geographical focus of investments, we also collected information on the technologies that the funds had invested in so far, key drivers for investment, hindering factors for investment, core investor types, team backgrounds, information sources, typical time to exit, investment criteria, fund experience (time since first clean energy investment), and time spent with policymakers versus entrepreneurial firms. With this information we identified relationships between certain fund characteristics and their various policy preferences and perceptions. We also supplemented our findings with qualitative results from interviews with some of the investors in our sample. The next section reviews some of the key results from this analysis.

4. Results

We will report the results of our survey and qualitative interviews in three parts. Sections 4.1 and 4.2 present the descriptive results about investor preferences for technology-push and market-pull policies, respectively. Section 4.3 presents the rest of the results and discusses the observed findings against the background of investor characteristics such as energy investment experience, location and fund size and explores some of the underlying reasons for investors' policy preferences, drawing on qualitative interview data.

Before moving into our quantitative findings on technology-push policies and market-pull policies, it is important to explain how we chose the set of both technology-push and market-pull policies. We started with the idea of the innovation chain and the way policies interact at different stages of the chain (Grubb, 2004). Indeed, policies interact in reality but the placement of policies along the chain helps to visualize where they are most pertinent (upstream or downstream along the innovation process). We selected a comprehensive list of policies that are currently being applied quite extensively around the world. Other than the general term used for the policy, there were no other details provided about the policies. Investors were asked to answer how effective these policies are at stimulating their interest to invest in innovative clean energy technologies. They were asked to rate the policies in terms of their perceived level of effectiveness on a scale from 1–5, where 5 was the highest effectiveness score, 3 was considered moderately effective and 1 was considered low effectiveness. They also had the option to answer that the respective policy had no effect or that they did not know.

The policies were to be considered independent from any given country's policy environment. However, one caveat of this research approach is that we cannot exclude that respondents have considered existing policy experiences in their answer. For example, the production tax credits seemed to be considered in the context of the current US "stop and go" application of this policy, which may have led to a negative bias in the results for this generic type of policy. In addition, the positive experience in Germany with the feed-in tariff could have contributed to the positive feedback we received about this particular policy type, while this positive experience is in the end the result of the full mix of policies in Germany and not just the feed-in tariffs. In future work, a focus on fewer policy sets and the use of more policy details or policy characteristics in surveys or interviews could address this issue.

4.1. Investor preferences for technology-push policies

The first set of policies that we asked private equity investors to assess are technology-push policies, which range from basic R&D funding to market engagement programmes and those strategic deployment policies that focus on early stage, pre-commercial technologies. Results are presented in Fig. 2.

The two policies receiving the lowest scores (both 2.3) were government venture capital funds and soft support measures, such as training entrepreneurs about writing a business plan and how to gain access to venture finance. The first result provides empirical support for an observation in the venture capital literature that "designing an effective governmental venture capital program is not an easy task" (Cumming, 2007), and yet it is striking to see the low level of support for government venture capital funds from their peers in the investment community, given that there are indeed successful examples of such policies (Lerner, 1999, 2002). One reason for this low score, according to our interviews, might be a lack of trust among investors for the governments' choice of technologies (or firms) to invest in, as the following statement of one investor illustrates:

Government should not choose winners—simply establish incentives and let the market sort it out

An alternative explanation, which we could neither confirm nor reject based on our interviews, might be that these programs are to some extent competing with the role of private equity investors, hence there may be a bias in the assessment of government venture capital funds by these investors. Also, the low score for "soft" support measures reveals a healthy dose of skepticism on behalf of the venture capitalists towards the plethora of networking events and business plan competitions that are often a cornerstone of innovation policies.

On the other end of the spectrum, the highest score was 3.75 for government grants for demonstration plants. Interestingly, this score for demonstration grants (or what is apparently the fund managers' favorite technology-push policy) is also greater than most of the market-pull policies discussed below (Section 4.2), except for feed-in tariffs. This observation gives support to Grubb (2004) "technology valley of death" hypothesis that the hardest part of the innovation chain is right in the middle between laboratory and market, and that hence government support should extend beyond just funding basic R&D. Against this background, it appears that countries like Switzerland who had cut down on their energy pilot and demonstration grants in recent years were well advised to reconsider their policy priorities (IEA, 2007).

A couple of other policies on the technology-push side were given relatively good scores. That is, overall fund managers thought they were effective at encouraging the development of innovative clean energy technologies, and thus private equity investment in such clean energy technology ventures. These included a doubling of public R&D for public institutions (3.39), the provision of investment subsidies for manufacturing facilities (3.21), grants for SMEs or communities to install equipment, etc. (3.21), doubling of R&D for private institutions (3.21) and tax breaks for entrepreneurs (3.05). Doubling of R&D was defined as taking the existing amounts of R&D budgets for renewable energy technologies and doubling them.

4.2. Investor preferences for market-pull policies

Market-pull policies as defined in this paper include strategic deployment policies relevant to the pre-commercial stage of

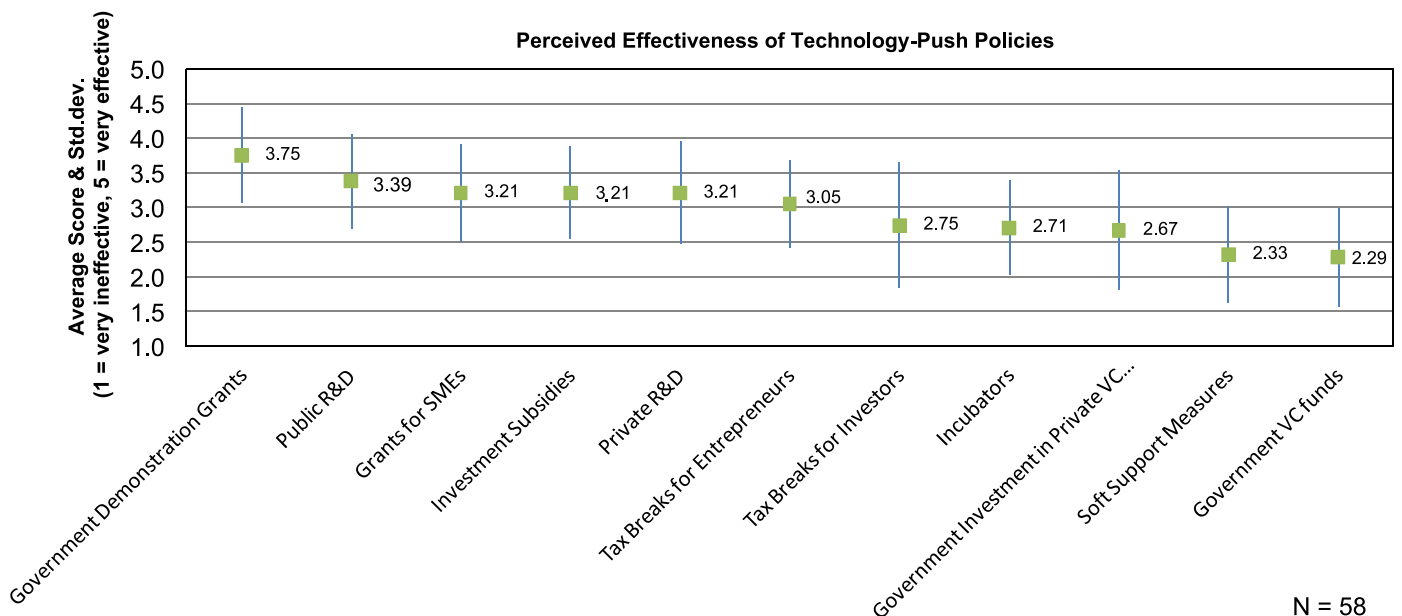


Fig. 2. Venture capital and private equity investor assessment of effectiveness of technology-push policies.

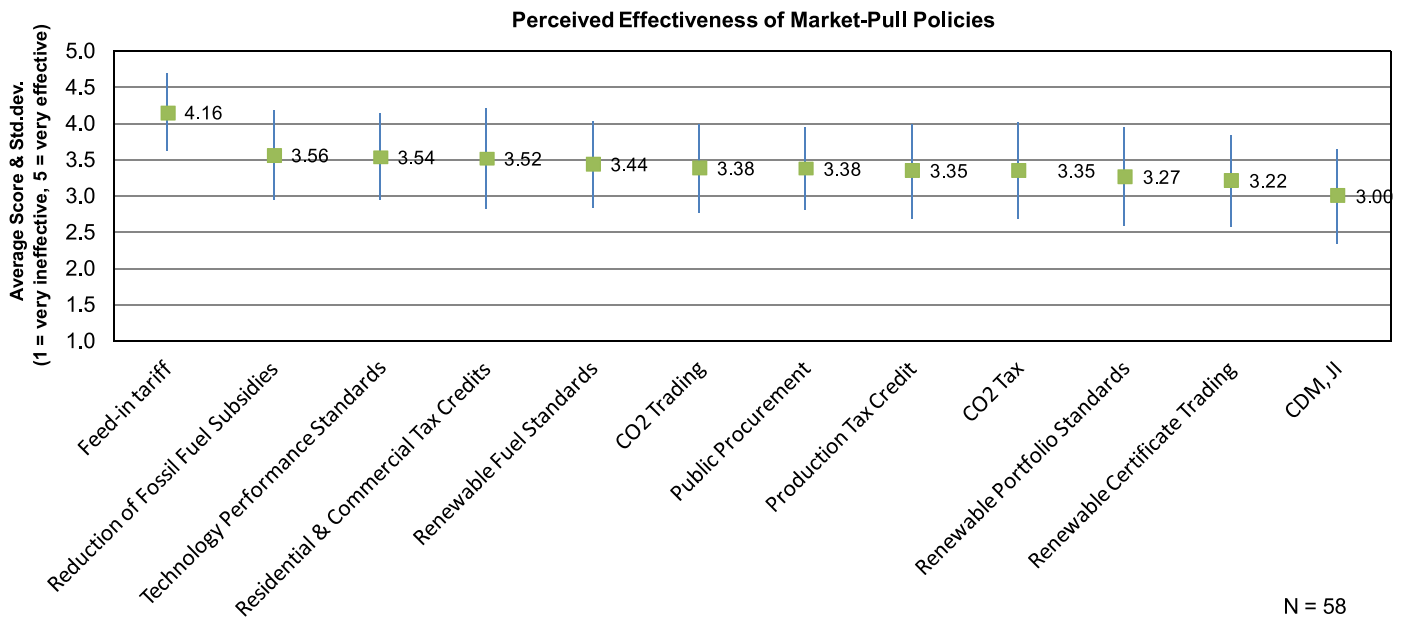


Fig. 3. Venture capital and private equity investor assessment of effectiveness of market-pull policies.

technology development all the way down to the supported commercial stage of technology maturity. Market-pull policies also include barrier removal policies that are more effective at deploying already fully commercial technologies than newly developed technologies. Among such policies are climate policies such as CO₂ emissions trading. Looking at investor assessment of market-pull policies as presented in Fig. 3, a first observation is that on average they get higher scores than technology-push policies. Based on our interview results, this seems to indicate that market-pull policies seem to be at least as important as technology-push policies when it comes to promoting private investment in clean energy technologies, while government may often be inclined to focus on technology-push policies. However, in our discussions with the investors we interviewed, they generally agreed that it is not a matter of replacing one set of policies by another. Instead, those interviewed believed that a policy mix should include both technology-push and market-pull instruments, including market engagement programmes, strategic deployment policies and barrier removal, in order to stimulate investment along the entire innovation chain and ensure the continual process of innovation for a variety of new clean energy technologies which are currently at different stages along the innovation chain.

Looking at results for individual market-pull policies, a striking result is that private equity fund managers rated feed-in tariffs higher than any other policy option provided, reaching an average score of 4.16 on the five-point scale. Only 10 out of 60 funds rated feed-in tariffs with a score of three or lower. Feed-in tariffs also rank significantly higher than the quantity-based instruments that have traditionally been discussed as possibly superior policy alternatives, such as renewable portfolio standards and tradable green certificates. These two policies rank among the three least preferred policy options among the private equity investors in our sample, only being followed by the Kyoto trading mechanisms (clean development mechanism and joint implementation) as the policy being considered as least effective in promoting private equity investment in renewable energy. This makes sense as the CDM is intended to fund carbon reduction projects in developing countries, and until now small-scale innovative technology projects are not particularly favored under this scheme.

Other policies that were ranked as rather effective were the reduction of fossil fuel subsidies (3.56), technology performance standards (3.54) and residential and commercial tax credits (3.52), (not to be confused with the congressional production tax credit which received a lower score).

4.3. Other results

We examined a variety of characteristics of funds to understand the reasons for such differences in policy perceptions. Major characteristics shown to have a relationship with differences in their perceptions were clean energy exposure, fund type and stage of investment. There were also differences between North American and European-based investors. We will discuss each of these factors, as well as some particularly insightful findings on other aspects, in this section.

As for *clean energy exposure*, there seemed to be a positive correlation between the level of clean energy investment and a fund's preference for feed-in tariffs. The average clean energy fund size for funds which rated feed-in tariffs as highly effective was 107 million US\$ compared to only 12 million US\$ for funds which rated feed-in tariffs as less effective. Funds which rated feed-in tariffs as less effective also tended to be mostly general funds (investing the majority of their funds in non-clean energy related deals), therefore they may have had less opportunity to experience the positive implications of feed-in tariffs on clean energy investments. Another observation is that those funds that rated feed-in tariffs as highly effective tended to rely more on internal staff intelligence than other funds, which may be an indication of their stronger in-house expertise related to renewable energy markets and policies.

In addition to clean energy exposure, the link between the type of investment (e.g. early stage venture capital or later-stage private equity) and assessment of policies has also been emphasized by one of our interviewees stating that:

How policy impacts investments depends on the attitude of the investors. Investors in on-shore wind turbine technology are very different from those in biofuels and fuel cells today. With wind, you get corporates, which are well-established

businesses with track-records. Whereas a lot of investments in emerging sectors are really option plays, so their regulatory risk analysis is also far less robust... Experienced investors will ask if the overall direction of policy is good... The key thing about policy to stimulate their interest, however, is signal intent and consistency.

Indeed, in terms of *fund type and stage of investment*, our results from the quantitative and qualitative parts of our research show that funds that focused on the expansion stages (investing in companies with somewhat of a longer track record) found feed-in tariffs very effective. Fifteen of such funds rated feed-in tariffs with a high score (4 or a 5), compared to 3 funds in this category that rated feed-in tariffs with a 3 or less.

On another point, as in the latter part of the previous quote, most of the investors interviewed mentioned the importance of policy consistency. This provides support to previous literature pointing to the importance of stability in the regulatory framework (see Section 2.2 above). Indeed, some of the positive assessment of feed-in tariffs may be a result of its long track record as a stable policy in Germany, so that investors attribute effectiveness to this particular policy while other policies could in fact show similar levels of effectiveness when applied with the same consistency. This phenomenon of investor preferences being formed by the specific experience of a policy's application in real-life settings is confirmed by the following statements from two European investors:

Germany, the UK, and sometimes the US have good sized markets and good policy support, so that is where we are looking... I prefer European power policies for renewable energy like feed-in tariffs...

The most important policy is the feed-in tariff in Germany and Spain. I am not a big fan of the ROCs scheme. The ROCs system is not predictable, so it should not be repeated. Tax credits are not the way either. ...Production tax credits pose a barrier for European investors in the sector in the US; first you need to use the tax credits, and then in addition, there is the uncertainty in the regulation...

In terms of *geography*, among the minority (11 funds) that did not find feed-in tariffs very effective, they were mostly focused on the North American clean energy market and were based in the United States (8 funds). Meanwhile, only 18 of the 47 funds that found feed-in tariffs effective were based in the United States. This might partly be explained by the fact that there is much less experience in the United States with feed-in tariffs, so those investors may have been less familiar with this particular policy. As for North American investors, they rather found the reduction of fossil fuel subsidies and technology performance standards to be the most effective market-pull policy choice offered in the survey.

As for overall *drivers*, we asked the investors to rank four possible major drivers of the clean energy industry—competitive advantage, climate change, security of energy supply and air pollution. Among these four choices, the main driver according to the funds was competitive advantage. This was followed by security of energy supply and climate change. Air pollution was the least important driver. Large firms tended to give climate change a greater importance than small-sized firms. Small to large funds gave competitive advantage the most importance and very large funds ranked climate change and energy security high. Climate change was more often mentioned as a key driver by European investors compared to American investors. American investors tended to mention mostly security of energy supply and competitive advantage as the key drivers. Related to these key drivers, in the interviews held, US-based investors also tended to

be more skeptical in general about clean energy support schemes as a way of increasing investment in the clean energy sector, and were more likely to refer to the power of market signals such as high oil prices as the key driver for their investment. For example, one North American investor said:

Price of oil is more important. Policy plays into the equation, but you can't invest where there are government subsidies because it is not necessarily sustainable. We need more of a free market approach. We need to strip out the subsidies, because we are looking for a long-term approach.

On the other hand, there were also more nuanced statements by North American investors, which concluded that government support has a role to play, although they would not invest only based on policy, as reflected for example in the following statement:

We have to be convinced that there is a market and (our market analysis) includes considering regulations. In general, policy would affect our decision to invest or not in a deal, but only by a slight percentage.

Another American investor, who avoided rating policies, expressed a similar view:

We invest assuming there are no government subsidies at all. What government can give can be taken away. So, we never want to invest in anything that depends on a tax credit or a subsidy. Having said that, if there is a tax credit available, we will take it. The best subsidy helps get the market started and then goes away. So, depending on the particular company we are talking about, or subsidy, we would hope to see a 3–5 years sunset of that credit, and then it has to stand on its own feet. But as for regulatory issues, it is comical when you go to every different state and they have different problems. Standards are needed. Otherwise, I prefer R&D spending over all the mentioned policies. Money in the hands of entrepreneurs gets things done and policies distort markets, although sometimes they go in your favor. Still, I prefer to look for businesses that do not need that support.

This healthy belief in the power of undistorted markets and capable entrepreneurs “getting things done” seemed to be somewhat popular with several of the investors in our sample. In particular, when asked about hindering factors for clean energy technology deployment, fund managers which rated feed-in tariffs low (3 or less on the five-point scale) also rated lack of competent venture managers as high importance and lack of government commitment as low importance. Along the same lines, this group of investors tended to have a strong preference for reduction of fossil fuel subsidies, assuming that eliminating all subsidies that currently apply to the energy sector would create a level playing field for clean energy technologies, and hence make further government support redundant.

Among the market-pull options, it is interesting to note that *CO₂ emissions trading* received the largest diversity of ratings (many very low, as well as a few very high ratings). Of interest is to examine how other characteristics of funds might correspond with a high or low rating for this policy option. As for geographical location of funds, an interesting finding is that US-based funds are more critical about the effectiveness of CO₂ trading than European investors. This may partly be the result of a lack of experience of US investors with carbon trading, because only Europe has experience with a mandatory CO₂ emissions trading scheme (the EU ETS).

Differences in opinion on effectiveness of CO₂ emissions trading seemed to be correlated with the funds' stage of

investment focus and fund size. Later-stage investors and larger funds rated the effectiveness of CO₂ emissions trading significantly higher than early stage investors and smaller funds. Also, among those that considered CO₂ trading to be very effective, their clean energy funding compared to their total funding was small compared to funds that rated CO₂ emissions trading with lower scores. This may be due to the fact that large funds and later-stage investors tend to invest mostly in technologies at the later-stages of the innovation cycle. Therefore, as we expected, these later-stage investors benefit more from CO₂ emissions trading than venture capitalists at the earlier stages of the cycle. This is confirmed by the following statement from the venture capital division of a large institutional investor based in Europe:

Feed-in tariffs are the best perceived policy because they set a steady cash flow and for us this is important... CO₂ related policies are like an incentive and down the line it may impact us, but it is an indirect benefit...

Overall, this finding seems to resonate with [Toke and Lauber \(2007\)](#) observation that feed-in tariffs are more compatible with the needs of entrepreneurial firms than trading schemes, also from the perspective of their investors.

In a final section of our survey, we asked investors to rank *national policy environments* as to how favorable they were for various renewable energy technologies. For solar photovoltaics, for example, 69% of the investors rated Germany as the most favorable country (followed by Japan, Spain and the US). Since Germany also happens to have a favorable feed-in tariff for solar energy, this seems to correspond with our findings on this policy instrument as discussed above.

5. Limitations and further research

Our research provides a new angle to investigating the effectiveness of renewable energy and climate policies by investigating the preferences of those players who are eventually supposed to act upon policy incentives, investors. We selected venture capital and private equity investors as our focus because of their particular role in the early stages of the innovation chain where technologies pass through the “technology valley of death”. As an early venture into this new area of research, our work is subject to a number of limitations that can be the starting point for further research into the relationship between policy and investment.

First of all, our research has focused only on a subset of the investment community—venture capital and private equity fund managers. While this subset has been demonstrated to be active at a critical stage of the innovation process, and is therefore worthwhile investigating, it would also be valuable to extend the analysis to other kinds of investors, notably in the project financing part of the renewable energy value chain. We would expect project financiers to have a similarly close relationship to policy incentives, because policies have a fairly direct influence on the profitability of wind farms and other large-scale renewable energy projects. It would also be interesting to survey institutional investors who are important because of the large amounts of capital that they can potentially provide to fund managers investing in the renewable energy sector.

Second, our approach to ask investors to rate policy instruments based on their general term and without detailed description of their specific attribute levels was a simplification of the real-life complexities of implementing such policies. As the effectiveness of policies within each category can vary substantially based on how it is designed in detail and how implementa-

tion is done, future work should explore ways of capturing more nuanced policy preferences. This could be done, for example, by conducting choice experiments with investors where bundles of policy instruments are described with varying attribute levels ([Lüthi and Wüstenhagen, 2009](#)).

Third, a limitation of our study is the relatively small sample size. While the 60 funds in our sample already go clearly beyond previous work in this area ([Kasemir et al., 2000](#); [Randjelovic et al., 2003](#); [Wüstenhagen and Teppo, 2006](#)), notably because until recently the overall population of venture capital and private equity investors in the clean energy technology sector was also quite limited, the recent upsurge in investor interest in this area opens the opportunity to extend the analysis to larger samples, which would obviously add to the robustness of findings.

One fourth limitation concerns the results of quantitative policy ratings. We believe that combining our qualitative interview results with a quantitative element of rating policy effectiveness provides some interesting information, however, the average scores in Sections 4.1 and 4.2 have to be compared with caution. For example, there were sometimes large differences in opinion for a given policy among different investor types (for example, CO₂ trading received very diverse scores, but the average score does not reflect this). Also, when we asked about technology-push policies we were referring to new emerging technological innovations that are not applicable to the business of certain private equity investors in our sample. Similarly, when we asked about market-pull policies we were speaking about technologies that are already existing and commercially available on the market, which is not directly relevant to some of the seed-capital funds or early stage venture capital funds in the sample. Therefore, we must consider the data we collected on fund characteristics when we compare policies across these two basic categories. For example, the market-pull policies are indirectly impacting the market potential of future technologies and therefore policies that are more applicable to the later innovation stages might receive relatively lower scores from very early stage investors compared to policies which are more directly impacting such early stage investors, and vice versa.

Finally, one issue that we briefly discussed in Section 4 and deserves further attention is the tendency of investors to base their assessment of policies on their experience with a specific application of this policy in one or just a few countries. This may limit the validity of results in international comparisons. A classical example that we have mentioned in Section 4.3 above is that the strong preference for feed-in tariffs presented here was often connected in interviews to the fact that they have in fact created a favorable policy environment in Germany. It seems that there is no easy solution to this issue, not least because similar policy instruments are applied differently in different countries, but nevertheless this methodological challenge should be kept in mind when designing further research.

6. Conclusions

Fortunately, there is recently a sharp increase in attention to the renewable energy technology sector from the private investment community. While this leads some observers to believe that energy policy might soon become redundant, we concur with most readers of this journal that policy will have a role to play for some time, notably because of the traditionally political nature of the energy sector and the presence of externalities that make it challenging for renewable energy technologies to compete on equal terms with incumbent conventional forms of energy. Obviously, most venture capital and private equity investors are not political scientists, so their preferences should not be

considered as perfect substitutes for scientifically grounded policymaking. Nevertheless, as investors are an important target audience for policymakers and their investment decisions have an important impact on markets, it is worthwhile studying their view about which policies actually work. Venture capital and private equity investors are particularly important to the innovation chain as they provide the early stage financing needed for new ventures to launch new clean energy innovations onto the market. However, indeed other investors, particularly project financiers, should be further studied in the future. Their views would be relevant to policymakers that want to know the immediate impacts of various policies on major energy infrastructure projects.

A key finding from the empirical results is that certain policies, such as feed-in tariffs, are considered especially effective, by a wide variety of fund manager types with a variety of characteristics, at stimulating investor interest to invest in new renewable energy technologies. This supports previous research suggesting that feed-in tariffs tend to be an effective way to reduce investment risk—a feature that seems to be the weak point of (the real-life applications of) trading mechanisms such as renewable portfolio standards or green certificates. One factor that might also contribute to the skeptical attitude of venture capital and private equity investors towards renewable energy and carbon trading schemes is that they are seen as “big corporation” policies, and hence as having neutral or negative effects on smaller, entrepreneurial firms (Toke and Lauber 2007; Schleich and Betz 2005).

The paper also provides support for an active role of government in market-pull policies, not just technology-push policies. Overall, several market-pull and technology-push policies were rated highly effective showing that adequate policy indeed does increase private equity fund managers' interest to invest in new clean energy technologies. The best technology-push policy considered was government demonstration grants. Finally, from the interviews we saw that investors which were not adverse to policy had agreed that a mix of policies was needed, that technology-push and market-pull policies were complementary, and that the most important aspect of policy was that it should be consistent.

Finally, from the interviews we conducted, it was clear that especially experienced clean energy investors consider supportive policy environments as an important way to encourage investment in clean energy technologies, even though a good policy environment, alone, is not enough reason for them to invest in a given deal. However, the interview results also revealed that some investors (especially some fund managers which invest in a wide variety of economic sectors) are deeply skeptical about government involvement in any form. This view may be a factor that hampers their entry into this new and emerging sector. There are two possible solutions to this problem: either, policymakers can increase their efforts to communicate the benefits of good policies and educate investors about their rationale; or one can hope that the market will eventually figure it out. Investors who are better at understanding and managing regulatory risks and opportunities are likely to outperform those who are not, as is the case for any other type of investment risk.

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