What is the impact of Private and Public R&D on Clean Technology Firms' Performance? An International Perspective.

Catherine Boulatoff
Dalhousie University
Halifax, Nova Scotia, Canada, B3H 3J5
email: Boulatoff@dal.ca

Carol Marie Boyer*
Long Island University, Post Campus
720 Northern Boulevard, Brookville, NY 11548
email: carol.boyer@liu.edu
*Corresponding author

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Abstract

Research and Development (R&D) has often been cited as key to promote the development of clean technologies in both the short and long run. Robust economic performance for clean technology firms may occur in countries in which research and development is conducted by governments as well as by businesses. The goal of this paper is to examine how private and public R&D affects firm profitability. Utilizing an international data set of clean technology firms, this study finds performance of clean technology firms to be quite favorable when compared to firms in the MSCI World index. The study examines how different countries perform in these industries. Finally, the impact both corporate and public R&D have had on these firms' performance is analyzed.

Introduction

The deployment of viable clean technologies follows from a motivation to reduce greenhouse gas emissions, slow climate change and reduce dependence on foreign sources of energy. Some positive externalities include fostering job creation and promoting improvements in health, education and gender equality. Challenges in these industries remain however. While the typical energy cost for onshore wind energy amounts to 5-16 U.S. cents/kWh, offshore wind cost of energy still ranges between 15 and 23 U.S. cents/kWh in OECD countries (REN21, 2013).[1] Other, more difficult challenges, may relate to risk-return profiles, social and environmental factors, and an overall rethinking of how energy systems are designed, operated and financed.

Public support could be key to further foster a societal move to adopt sustainable clean technologies. In fact, a number of national and regional policies in place worldwide to promote the development and use of clean technologies in general have been implemented in an

[1] REN21 – Renewables 2013 Global Status Report.

increasing number of countries[2] over the past fifty years. Such policies include regulatory policies and targets, such as feed-in-tariff and biofuels targets and mandates, fiscal incentives such as capital subsidy, grants and/or energy production payment, as well as public financing in the shape of public investment, loans and grants. Strong financial performance for clean technology firms could potentially be observed in countries in which Research and Development (R&D) is undertaken by both businesses and governments. By allocating funds to promote key clean industries, governments are also choosing to foster some clean-tech industries, thereby potentially contributing to that country leading in some green industries compared to others. For example, Germany has a reputation for generating a relatively large portion of their energy from solar and wind relative to other countries. Germany achieved a record 20.8 percent of its electricity from renewable sources such as wind, solar, biomass and hydro in 2010 (Singh, 2013).[3] Another example is China, which has excelled in the manufacture of solar panels (Oremus, 2013).[4] Could this be due, at least in part, to the emphasis taken by these governments to support these industries?

The main points addressed by this paper are threefold: To look at how clean technologies industries have performed in the last 10 years (2004-2014), to determine how various countries fare in each of these industries, and to analyze to what extent government's involvement in specific industries promote performance of clean technologies over time, taking into account corporate R&D efforts within the industry.

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[2] See n.1 above for more detailed information.

[3] Singh, Timon (7 Feb. 2013) "Germany Sets New Solar Record By Meeting Nearly Half of Country's Weekend Power Demand | Inhabitat - Sustainable Design Innovation, Eco Architecture, Green Building." *Inhabitat - Sustainable Design Innovation, Eco Architecture, Green Building*. N.p., n.d. <http://inhabitat.com/germany-sets-new-solar-record-by-meeting-nearly-half-of-countrys-weekend-power-demand/>.

[4] Oremus, Will (7 Feb. 2013) "Solar Disarray: China is stealing America's solar manufacturing industry. Should we fight back—or rejoice?" *Slate*. N.p., n.d. <www.slate.com/articles/technology/technology

Many studies have concentrated on analyzing the financial performance of these clean technologies investment choices (Adamson, 2008;[5] Galema et al, 2008;[6] Boulatoff and Boyer, 2009)[7]. Mallett and Michelson (2010)[8] found that there was no significant difference in financial performance between green, socially responsible firms, and general index funds overall over the 1998-2008 period. Because of the higher rate of larger capital expenditures investment, green firms' performance was further expected to improve over time (Boulatoff and Boyer, 2009;[9] Climent and Sorinao, 2011).[10] Others have analyzed the impact of R&D on firms' profitability, as well as the link between private and public R&D (Bartelsman, 1990;[11] Capron, 1992;[12] David et al., 2000;[13] Hall et al., 2010;[14] Zúñiga-Vicente et al., 2014)[15], we extend our analysis to measuring the effect of public and private R&D in the clean technology industries.

To compile our sample list of firms, the holdings from 24 clean technology mutual funds and exchange traded funds were downloaded from Bloomberg. This yielded a sample of 508 firms from 34 countries. Following the widely accepted definition of clean technology

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[5] Adamson Gavin (Aug. 7, 2008) "Going Green with Mutual Funds and ETFs." *Globe and Mail*.
[6] Galema, Rients, Auke Plantinga, & Bert Scholtens (2008). "The stocks at stake: Return and risk in socially responsible investment." *Journal of Banking & Finance*, 32(12).
[7] Boulatoff Catherine and Carol M. Boyer (2009) "Green Recovery: How are Environmental Stocks Doing?" *The Journal of Wealth Management*, 12(2): 10-20.
[8] Mallet James E. and Stuart Michelson (2010) "Green Investing: Is it Different from Socially Responsible Investing?" *International Journal of Business*, 15(4): 396-410.
[9] See n.7 above.
[10] Climent Francisco and Pilar Soriano (2011) "Green and Good? The Investment Performance of US Environmental Mutual Funds." *Journal of Business Ethics*, 103: 275-287.
[11] Bartelsman, Eric J. (1990) "Federally sponsored R&D and productivity growth," *Finance and Economics Discussion Series*, Board of Governors of the Federal Reserve System (U.S.), no121.
[12] See the *Proceeding of the Workshop on Quantitative Evaluation of the Impact of R&D Programmes*, held in Brussels in 1992 (Henri Capron Editor, Commission of the European Communities).
[13] David, Paul, Bronwyn Hall, & Andrew Toole (2000) "Is Public R&D complement or substitute for private R&D? A review of the econometric evidence." *Research Policy* 29: 497-529.
[14] Hall, Bronwyn H., Jacques Mairesse, & Pierre Mohnen (2010) "Measuring the Returns to R&D", in *Handbook of the Economics of Innovation*, v. 1, B. H. Hall and N. Rosenberg editors, North Holland.
[15] Zúñiga-Vicente, José Ángel, César Alonso-Borrego, Francisco Javier Forcadell, & José Gálan –Zazo (2014) "Assessing the effect of public subsidies on firm R&D investment: A survey." *Journal of Economic Surveys* 28, no1: 36-67.

firms as providing a products, services, and processes that harness renewable materials and energy sources, dramatically reduce the use of natural resources, and cut or eliminate emissions and wastes, we included the biomass, biofuels, clean tech indexes, efficiency, energy storage, fuel cells, geothermal, recycling, green chemicals, environmental building, renewable energy project developers, solar energy, and environmentally conscious transportation, water, and wind energy industries. The Data on government R&D was obtained from the International Energy Agency (IEA) Research and Development budget/ expenditure statistics, providing data from 1990-2011. This covers basic research, applied research and experimental development, most of which is conducted at universities and research institutions.

Our findings suggest that the performance of clean technology firms was virtually equal to that of firms in the MSCI World Index over the past decade (2004-2014). The top four green industries predominantly receiving government R&D in that time period were the LED, batteries, transport and solar energy industries. Countries were also found to vary widely in their choice of allocation of public R&D across industries. Finally, using regression analysis, we found that corporate R&D was significantly positively correlated to firms' performance over the period 2006-2011. However, government R&D was negatively correlated to firms' net income (even with lagged variables). Yet, government R&D was found positively correlated with corporate R&D.

The next section describes the data and methodology used, and the following section analyzes findings.

Background

Following the belief, in the aftermath of World War II, that R&D expenditures were vital to stimulate economic growth in the long run, public support was called for in addition to corporate R&D. Government agencies were created to support science and engineering in many civilian industries. Public support has often been seen as being essential in promoting clean industries,[16] and has come in many different shapes, whether it be financial support aiming at improving technology development, or regulatory and economic instruments devised to lower the cost of say energy production or consumption to end users. In addition, governments can promote given clean industries by conducting research in research labs and universities. For example, as early as 1974, and still in force, Canada implemented the Program of Energy Research and Development (PERD). Through this federal and interdepartmental program, Natural Resources Canada funds research and development in ocean development (as well other renewable energy sources).

The underlying rationale for government support through these policy measures is that scientific and technological knowledge have "public good" characteristics. These characteristics have to do with incomplete appropriability of R& D returns, high risk associated with R&D, and problems of markets tarred with incomplete information (Stiglitz, 1988).[17] In this context, public R&D for socially desirable projects such as renewable energy sources are hoped to be complementary to private R&D, both in the short and long run, as informational spillovers from public R&D and training of new scientists and engineers might stem from public funding.

Following the model developed by David et al. (2000)[18] for understanding the impact of government R&D on private R&D, we assume that firms' investment behavior depends on the

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[16] Specially when considering that, as chief economist at the International Energy Agency, Dr. Fatih Birol, calculated, fossil fuel subsidies amounted to $409 billion in 2011 alone (IEA). Keeping fossil fuel energy production costs artificially low has made it more difficult even for renewable energy industries to become competitive, all else constant. It also has encouraged fossil fuel consumption, and as a result has led to further environmental damage.

[17] Stiglitz, Jeffrey. *Economics of the Public Sector.* New York: W.W. Norton and Company, 1988.

[18] See n. 13 above.

cost of and expected return associated with private R&D. The return portion, also called the marginal rate of return of capital (MRR), in effect the derived demand for R&D, is downward sloping. As R&D investment increases, the expected return of the additional (or marginal) investment decreases. In contrast, the marginal cost of capital (MCC) is expected to be upward sloping. The additional cost of capital increases as the firms undertakes more R&D. Following David et al. (2000) notations,[19] we can write the following two equations to capture the above schema:

$$MRR = f(R, X) \quad (1)$$

$$MCC = f(R, Z) \quad (2)$$

Where R is the level of R&D expenditure, and X may include technological opportunities, the (potential) market or line-of-business, and/or institutional and other conditions affecting the appropriability of innovation benefits. As for Z, it includes technology policy measures that affect the private cost of R&D projects, macroeconomic conditions and expectations affecting the internal cost of funds, bond market conditions affecting the external cost of funds, and/or the availability and terms of venture-capital finance, as influenced by institutional conditions.

The firm's profit maximizing equilibrium is reached when the additional benefit from R&D equates its extra cost, or when MRR = MCC. This is also the level at which the optimal level of R&D investment is found (R*)

$$R^* = h(X, Z) \quad (3)$$

Any change in X and/or Z variables would be reflected in a shift in the corresponding MRR or MCC. For example, if we assume that government R&D provision is exogenous, then an

[19] See n. 15 above, page 504 in the original text.

‘injection’ of public funding would shift the MCC or the MRR to the right, or both, increasing the overall optimal level of investment in the industry to say R**.[20] Similarly, direct R&D subsidies or tax incentives might lower the cost of doing research to renewable energy industries firms. It might also send a positive signal to consumers who will be more apt to demand energy from these renewable sources.

One key question in the realm of clean technology is to know to what extent R&D impacts firms’ performance. Further, is this performance impacted more when R&D comes from private hands or from government entities?

The impact of R&D on profitability of firms has been analyzed for the past fifty years or so.[21] Many studies have found that public R&D often contributed less to firms’ profitability than corporate R&D (see for example Bartelsman, 1990).[22] This could stem from the type of industry studied. Typically, studies have concentrated on analyzing the impact of R&D on manufacturing firms, even though public R&D is predominantly associated with service industries, (where output is harder to measure). Further, it can be noted that often, public R&D occurs in industries considered high risk, or when there is a public good concern (Hall et al., 2010).[23] This is particularly true for several renewable energy sources, such as offshore wind, wave and tidal energy industries.

Several studies have been conducted over the years to test the impact of public funding on private R&D investment. Of particular interest is to know whether public R&D acts as a complement to private R&D or as a deterrent (or substitute) to it. The most recent work on the

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[20] Note also that a shift of the MCC to the right would decrease the rate of return on R&D overall, while a shift to the right of the MRR would increase it.
[21] See n. 12 above.
[22] See n.11 above.
[23] See n.14 above.

topic, done by Zúñiga-Vicente, Ángel, Alonso-Borrego, Forcadell, and Gálan –Zazo (2014),[24] is a review of the empirical literature on the relationship between public subsidies and private R&D investment over the past fifty years. Their findings indicate that differences in the results obtained from these studies are still considerable. Still, despite the heterogeneity in (a) the industry, (b) the type of public funding, (c) the country considered, and (d) the methodology used, complementarity between public and private R&D seemed to prevail. David et al. (2000)[25] also reached similar conclusions.

Data

In this paper, clean technology firms are defined as firms that directly focus on providing environmental benefits and are developing technologies to solve environmental problems. This includes the biomass, biofuels, clean tech indexes, efficiency, energy storage, fuel cells, geothermal, recycling, green chemicals, environmental building, renewable energy project developers, solar energy, and environmentally conscious transportation, water, and wind energy industries. To compile our sample list of firms, the holdings from 24 clean technology mutual funds and exchanged traded funds along with accompanying financial data were downloaded from Bloomberg in July 2011 (see Table 1 below).

From these clean technology and alternative energy mutual funds, we gathered the component firms and accompanying financial data using Bloomberg data. This yielded a sample of 508 firms from 34 countries (see Table 2).

The hypothesis tested is that R&D increases profitability for clean tech firms. Two different types of R&D are tested, namely private and public R&D and differences were found in the impact each had on firms' profitability. We also tested several time spans (lags) for which

[24] See n. 15 above.
[25] See n. 13 above.

the impact of R&D (government, in particular) could be significant in the immediate, the short run, and the longer run.

The three individual countries with the largest sample of clean technology industries are the US (218), Canada (37) and China (35). European Union member countries, together, represent 89 companies (or 17.5% of the overall sample), while the North American continent represents still the vast majority of clean technology firms (255, or 50.2%).

Data on government research and development (R&D) allocated by countries for each industry was obtained from the European based International Energy Agency (IEA) Research and development budget/ expenditure statistics, providing data from 1990-2011 for member countries. The IEA government R&D data covers basic research, applied research and experimental development, most of which is conducted at universities and research institutions. The mean contribution by governments to R&D was 62.51 Million USD (in 2011 dollar), and the standard deviation was 152.07 Million USD. As illustrations, figures 1 and 2 below show how much government R&D (in Millions of 2011 USD) has been distributed for the wind and solar industries respectively in this time period in Canada, Germany, Spain, Japan, and the U.S. (these countries were chosen because of their relatively important number of firms in clean technology industries overall, as described in Table 2).

It is worth noting here that government R&D allocated in both these industries has been relatively stable, except in the case of the U.S. where we observe a spike in public funding in 2009. This is also true overall for other clean technology industries included in our sample.

Clean Technology industry performance in the Recent Past.

Because it typically takes time for firms to benefit from the injection of R&D overall, and as available data about public R&D in particular started in the early 1990s, we limited our analysis of clean industry firms' performance for the past 5 years (i.e. allowing enough time to see the impact of R&D on the industries). Table 3 below shows the stock price performance of clean technology firms compared to the Morgan Stanley Country World Index (MSCI). Given the international component of our sample, the MSCI World Index is a good comparison. The MSCI World Index is a market capitalization weighted index that is designed to measure the equity market performance of developed markets. Also shown for comparison are the MSCI North America, MSCI Europe, and MSCI Far East.

As can be seen, the year 1 return for the clean technology firms is 30.45%, which is higher than the returns for the MSCI World, MSCI North America, MSCI Europe and MSCI Far East. In year 3 (i.e. July 7, 2014 – July 7, 2013) and year 5 (i.e. July 7, 2014 – July 7, 2011) returns for the clean tech firms are much lower than the MSCI World, as well as the other indexes. Yet, and interestingly, over a 10 years time horizon, results show that the performance of clean technology firms regained momentum and remained higher (8.52) than that of firms in the MSCI World Index (July 7, 2014 – July 7, 2004).

These results are consistent with findings observed by earlier studies **(**Boulatoff and Boyer (2009),[26] for the period 2003-2008 and Climent and Soriano (2011),[27] for the period 1987-2009 in that both studies suggest that clean technology performance should improve over time due to investments being made.

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[26] See n. 5 above.

[27] Climent Francisco and Paul Soriano (2011) "Green and Good? The Investment Performance of US Environmental Mutual Funds." *Journal of Business Ethics*, 103: 275-287.

Turning to the performance of these industries at the country level, we now look at the overall performance of clean technology firms in various countries over time. Results are summarized for the highest performing ten countries for year 1, year 3 and year 5 returns in Table 4 below.

For the 1 year return, the highest performing country was Spain with a return of 73.08%, followed by Denmark with a return of 62.94%. The Spanish returns comprise 8 wind industry firms and 4 solar firms. Denmark remains strong in the 3 year and 5 year returns, again first in the 3 year return with an annualized return of 17.16%, and second in the 5 year return outperformed by companies from The Netherlands which had an annualized return of 8.08%. The seven Italian firms have high performance due to a mix of alternative energy firms and the transport firm, Piaggio. The countries of Canada, Denmark, France, Hong Kong, Italy, The Netherlands and Switzerland all have high stock returns in years 2014-2009.

We now turn to industries' performance over the past 5 years, regardless of their country of origin. Table 5 shows the performance of each industry for the 1 year, 3 year, and 5 year returns.

The time period of 2014 – 2013 was a time of high performance for the clean tech industries overall, with the categories of batteries, electric cars, solar, biofuels, wind, geothermal, hydropower and water outperforming the MSCI World Index. Possibly this could be a trend with investors becoming more conscious of the effects of climate change on the world economy. However, this trend was reversed in both time periods of 2014 – 2011 and 2014 – 2009, with few clean tech industries outperforming the index. Despite the somewhat shuffling in the ranking for the top positions, electric cars and biofuel seem to be the highest performing industries over time.

Corporate Research &Development (R&D)

Turning first to the issue of corporate governance, we look at corporate R&D by industry and then by country, as summarized in Tables 6a and 6b below (see Appendix for the complete table). As shown in Table 6a, the degree of corporate R&D involvement in each of our clean technology industries varies, with the Wind, Solar, and Biofuels industries being the most represented (with 17, 15 and 13 countries respectively). Interestingly, the two top countries in which corporate R&D seems to be most abundant are Japan (leading in 5 industries), and the U.S. (leading in the Biofuel, Hydropower, and Transport industries).

Table 6b above reveals some additional characteristics of our sample, as it describes which industry receives the most corp. R&D in each country (as well as the number of industries receiving corp. R&D in each country). Looking at Japan for example, the country that seemed to be leading in several industries (see Table 6a), most of its Corp. R&D is allocated to the Geothermal industry (66.75%). In some countries, such as Austria, Ireland, and New Zealand, corporate R&D appears to be spent on a few industries only, while in other countries, such as Japan, the Netherlands, and the U.S., the number of industries receiving corp. R&D is more significant.

The percentage of corp. R&D receives by a given leading industry also varies greatly, from 99.56% in the Netherlands for the Wave industry (even though 8 industries are receiving corp. R&D in the country), or 99.09% for the Hydropower in Italy (6 industries represented), while others, such as the U.S. and to a lesser extent Canada, seem to experience a more evenly spread allocation of corporate R&D across industries.

It is also interesting to look at the investments specifically in sustainability relative to capital expenditures firms are making. As can been seen from Table 7 below, the battery industry comes in first with a ratio of .40. The second highest industry specifically reporting investments in sustainability is the wind industry at .11, followed by biofuels at .07 and solar at .03. It should be noted that not all firms reported this data item.

Because we are dealing with clean tech firms, one can assume that corporate research and development is in improvements in clean technology. The industry conducting the highest percentage of R&D relative to sales is biofuels with 199.67 (Table 7). This means that the biofuels industry is investing about 2 dollars into R&D for every sales dollar earned. The solar industry and LED industry are investing about 20 cents into research and development for every sales dollar earned. Hydropower and water are investing about 14 cents into research and development for every sales dollar earned.

Finally, we look at the Corporate Governance Quotient for the clean tech firms relative to their market index (i.e., the S&P 500, Russell 2000 Index, etc.) and their industry using the 23 industry groups in Standard & Poor's Global Classification Standard (Table 8 below). Good governance of firms is important as it helps to ensure that the R&D expenditures are utilized to their fullest extent. Effective corporate governance can ensure that R&D is actually maximizing shareholder wealth. Eccles et al. (2014)[28] for example found that the boards of directors of high sustainability companies were more likely to be formally responsible for sustainability, with these high sustainability companies then outperforming their counterparts in the long-term. Research regarding the market value of R&D spending, both for U.S. firms (Hall et al., 2005)[29] and for firms in a number of major European countries (Hall and Oriani, 2006)[30] have been

[28] Eccles, Robert, Ioannis Ioannou, & Geroge Serafeim (2012) "The Impact of Corporate Sustainability on Organizational Processes and Performance." *NBER Working Paper No. 17950*.
[29] Hall, Bronwyn, Adam Jaffe, & Manuel Trajtenberg (2005) "Market Value and Patent Citations", *Rand Journal of Economics* 36: 16-38.
[30] Hall, Bronwyn and Raffaele Oriani (2006) "Does the market value R&D investment by European firms? Evidence from a panel of manufacturing firms in France, Germany, and Italy." *International Journal of Industrial Organization*, Volume 24, Issue 5: 971–993.

examined. Although the number of firms publicly traded on financial markets in such countries as France, Germany, and Italy is substantially smaller than in the United States or United Kingdom, such firms do account for a major share of privately performed R&D in these countries.

Table 8 describes firms' corporate governance. The scores represent the company's percentile rank. The Governance Metrics International (GMI) companies are scored on a scale of 1 (lowest) to 10 (highest). GMI global ratings measure the strength of corporate governance relative to all other companies in the GMI universe.

As can be seen from the table, clean tech firms perform above average in this area. The Corporate Governance Quotient relative to the index is 55.44, meaning that their overall corporate governance is higher than other firms in the index. The rank of clean tech firms relative to their industry (for example a solar manufacturer relative to another manufacturing company) scores even higher at 59.38. In terms of sub-scores, a score of 3 would be considered average and the clean tech firms all score above 3, with the clean tech sub-score for Board Composition being 3.38, Audit at 3.88 and Executive compensation at 3.40. The Governance Metrics International score is also above average at 6.69.

After having described private R&D allocated in Clean Technology industries by different countries, we now turn to the public R&D component.

Government R&D

Table 9 below shows the total dollar amount of government R&D received by different industries over the time span 1990-2011 in million USD amount and percentage respectively. As mentioned earlier, IEA government R&D data in our sample covers basic research, applied research and experimental development, most of which is conducted at universities and research institutions.

From the data above, one can see significant differences in government R&D spending overall between countries. Some of it can be explained of course by the difference in country size (for example, the U.S. compared to the U.K.), but notably, small countries spent considerably more than larger ones. Japan for example spent 14,473.18 Million USD (in 2011 dollar) across all industries between 1990 and 2011, while Canada allocated 3,672.726 Million USD, and Germany spent 4,419.014 Million USD in that same time period across all clean technology industries.

Looking at the government support received across industries between 1990 and 2011, LED seems to have gathered most of government R&D (37.87%), followed by the Batteries (13.85%), the Solar (12.24) and Transport (12.61) industries. In contrast, hydropower and wave energy appear to have received little support overall (1.29% and 0.28%). This may be due to historical, geographical, or even technical reasons. For example, many countries developed hydropower at the beginning of the 18th century, and there is little left these countries could expand on nowadays (Schlager and Lauer, 2000).[31] Wave and tidal energy is still in its infancy as it faces many technical challenges still (Boulatoff and Boyer, 2015).[32] Historically, The Dutch have been known for their windmills and are now making significant advancements in wave and tidal energy. Surprisingly, the Wind industry only received 3.95% of these countries government R&D. This is paired with a much larger corporate R&D (as described in Table 6b above).

[31] Schlager, Neil and Josh Lauer (2000) *Advances in Construction and Building Design during the Eighteenth Century: Science and Its Times*. Detroit: Gale, 4: 408-411.

[32] Boulatoff Catherine, and Carol Boyer, *"Performance of Offshore Renewable Energy (ORE) Firms: An International Perspective,"* Ocean Yearbook, 30: 417-438.

Table 9 also highlights the significant government R&D spending in renewable energy overall for countries such as the US, Japan, Germany, France, Canada, Italy, the Netherlands and Switzerland. This would indicate the will by many governments to be supporting renewable energy in the last 20 years. This could stem from the realization that spending more on renewable energy would benefit the environment as well as their tax base as these industries become successful. These calculations do not include government subsidies and therefore should not be interpreted as full government support for each industry.

Turning now to Table 10 below, which describes the top three industries each country has been allocating government R&D to, the one industry which is predominantly receiving public funds across countries in that time period are LED (18.74% by Denmark to 51.69% by Finland). Other industries receiving large public support include Solar, Biofuels, Batteries, and Wind to some extent (smaller countries typically).

That being said, countries differ in their choice of 'supported' industries. Ireland allocates all its government R&D to solar energy, while Portugal seems to have bet exclusively on wind energy (it was also the case when looking at Corp. R&D, see Table 6b above). Austria, and Sweden have concentrated most of their efforts on LED (37.04% and 38.61% respectively), biofuels (21.17% and 21.40% respectively), and Transport (12.21% and 19.61% respectively), Except for Sweden, this is also very much in line with the picture described in Table 6b earlier.

For others, there seems to be a somewhat diversified spending pattern across industries. For instance, Switzerland has invested in LED (26.08%), batteries (22.04%), and solar (25.46%) Also diversifying their investment in government R&D, New Zealand is pursuing interest in both hydropower (64.48%) and wind energy (35.52%), Canada spends almost as much on biofuels (12.38%) and Batteries (12.91%). Transport, which refers to R&D activities focusing on the design of energy-efficient vehicles (ex. aerodynamics), the development for new materials and assembling techniques allowing for better energy performances and better reusability/

recyclability, the development or optimization of power trains, as well as the use of alternative fuels, metro and tramways, is being actively pursued by Australia (16.27%), Austria (12.21%), Belgium (17.52%), France (21.19%), the US (38.14%) and the UK (16.29%). Even though public support for Ocean, Wave and Tidal industries is not listed in the top three industries receiving government R&D during this period, it is worth noting that significant investment in wave power has been promoted most by Canada (35.924 million USD), Japan (32.538 million USD) and Korea (32.575 million USD), the U.K. 122.805 million USD) and the U.S. (109.928 million USD). Public support is particularly key in this industry in particular, which still faces many uncertainties and in which investors are often still wary of.

Impact of research and development (R&D) on firms' profitability

To measure the direct effect of R&D on profitability of clean tech firms, we used econometric analysis to regress R&D (private, public, with lag) on firms' net income[33]. Net Income can be defined as an entity's revenue minus cost of goods sold, expenses and taxes for a year.[34] This number is found on a company's income statement and shows how profitable the company is. In order to be able to compare R&D investment in different energy sectors, the data was segmented based upon different clean tech sectors. For example, the solar firms corporate R&D[35] was aligned with solar government R&D in the country where the firms was regressed upon those firms' net income. Further, as technological progress is expected to lag R&D

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[33] Public, private R&D, and net income data were found to be stationary (using Stata Harris-Tzavalis unit-root test).

[34] The mean for Net income data was 6431.38 million USD (standard deviation 88122.8 million USD, min. value: -2394.74 million USD, max value: 1,507,131 million USD).

[35] The mean for corporate R&D data was 7486.141 million USD, with standard deviation of 60304.24 million USD, a minimum value of 0.02 and a maximum value of 942,753 million USD.

expenditures, in particular when it comes to public basic research (Capron, 1992),[36] we considered the impact of R&D, which started being spent by governments[37] in the 1990s, on firms' productivity in the past 5 years.

Results of our regression estimation for our panel data can be found in Table 11 below.

Firms' profitability as measured by the net income is found to significantly depend on both corporate and government R&D. However, unlike for the corporate R&D, public support appears, at first, to have a negative impact on profitability. In the short term, it is possible that government investment in scientific advances are not felt on firm profitability, as these advances may take years to materialize and bear fruit. The impact of government R&D over time (estimated with 6 years, 20 years and 30 years lags) was also found to be significant. Further, as time passes, and as shown by the coefficients found for gov. R&D lagged 20 years and 30 years, the impact of public expenditures become positive (and the magnitude increases somewhat). Only the 6 year lag was found to be negatively correlated with profitability. The 20 year and 30 year lagged effect of the government investment in R&D makes sense as many projects, such as pure research at university may take years before it is discovered, developed, applied and marketed. As could be expected, the type of industry (industry) was also found to be significant to some extent in determining firms' profitability. Hydropower and solar for instance were more prone to be profitable, compared to wave and tidal energy firms. The country of origin was also found to be significant in determining profitability of clean industries. It is worth mentioning that there was no significant difference in our results when using Generalized Least Square (GLS) estimation.

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[36] Capron, Henri (1992) "The applied econometrics of R&D public funding: what's that for?" In *the Quantitative Evaluation of the Impact of R&D Programmes*, edited by H. Capron. Brussels: Commission of the European Communities. Capron estimated this lag to be at least 2 years for manufacturing firms.

[37] The mean for government R&D data was 775.391 million USD, with standard deviation of 5477.065 million USD, a minimum value of zero and a maximum value of 105,513 million USD.

Following more standard practice in financial economics, we also estimated the impact of relative corporate R&D (given by the ratio of corporate R&D expenditure to total assets) and pubic expenditure (ratio of public R&D to real GDP) on returns (1 year, 3 years and 5 years). Tables 12a, b and c below summarize our findings.

Just like in our earlier results, corporate R&D (here relative to total assets) is found to be positively correlated with firms' returns. The short term impact of public expenditures on returns is found to be negative for one year and three year returns, but positive for both the five year returns. The longer the lags of the time public expenditures, the more positive (and significant) their impact is on returns. As a side note, it is worth mentioning here that compared to our original set of regression (Table 11 above), the overall R^2 is much lower when estimating the impact of these variables on returns, as compared to their effect on firms' profitability.

Interestingly enough, and as shown in equation 4 below, when regressing government R&D (GRD) on corporate R&D (CRD), results indicate that public support had a positive, significant effect (99%) on firms R&D. Similarly coefficient outlining the impact of private R&D on government R&D (equation 5) was also found to be significantly positive (99%).

$$CRD = 2352.31 + 1.42\ GRD + 0.628\ \text{net income} \qquad (4)$$

$$(t) \quad (7.95) \quad (26.89) \quad (132.73) \qquad \text{Adj. } R^2 = 0.76$$

$$GRD = 520.50 + 0.076\ CRD – 0.05\ \text{net income} \qquad (5)$$

$$(t) \quad (7.61) \quad (26.89) \quad (-22.33) \qquad \text{Adj. } R^2 = 0.11$$

The level of profitability (net income) of firms was also found to have a positive impact on corporate R&D, which would point to the endogeneity problem associated with private investors allocating R&D to the most profitable industries. Yet, profitability was negatively correlated with government R&D, which might suggest that public support is less likely to be determined based on profitability of given industries, but rather following the political will by governments to promote a given industry, maybe even taking on the task of providing support to the most risky industries (such as wave and tidal for example).

Limitations of this study include the somewhat narrow definition of public support. It would be interesting to have more precise data on government involvement in promoting different clean industries. Other factors, besides R&D, are also likely to affect clean technology firms profitability. For example, corporate R&D might be more present as a result of promising results for a given industry, and therefore results of higher performance may come as a result of this self-fulfilling promise. It would also be interesting to include in our analysis the impact of foreign direct investment (FDI).

The fact that the industries described in our sample of Clean Technology firms typically face very different risks is also something requiring further investigating. For example, the wind and tidal energy industries might attract very different types of R&D. One would expect the wind industry to attract a short run one, more likely to be private, aiming for immediate applications and short-term returns, while ocean and tidal energy sectors require and attract longer-term (and more costly, maybe even counter productive at first) R&D, which is more likely to be government sponsored. In the latter case, and even though government R&D may not lead to increased firms' net income (even with lag), its effect might be to draw private R&D.[38]

Conclusion

This research studies the performance of clean technology industries. Specifically, we looked at the extent to which R&D investment, both at the private (firm) and public

[38] Costa-Campi M T, N Duch-Brown, and J. García-Quevedo (2014) "R&D drivers and obstacles to innovation in the energy industry." Energy Economics 46: 20-30.

(government) levels are beneficial to shareholders, in terms of higher profitability of the industry.

Using data on international clean technology firms our results suggest that the overall performance of clean technology firms has been quite healthy compared to firms in the MSCI World index. In particular, clean technology investments have performed better than the MSCI World Index in the most recent time period of 2013 – 2014.

Looking at stock performance within each of these industries, electric cars and biofuel seem to be the highest performing industries over time. Based on stock performance over a 5year period (2009-2014) by country, the top three highest performing countries were found to be the Netherlands, Denmark, and Canada.

Our analysis also sheds some light on the involvement of each country in clean technology firms. Not surprisingly, countries differ greatly in the sample size of clean technologies they have invested in, as well as in the mix of industries they have developed. The three individual countries with the largest sample of green industries are the US, Canada and China. European Union member countries, together, represent 17.5% of the overall sample. Looking at the number of different countries involved in each industry in our sample, the wind and solar energy, and biofuels seem to gather most interest.

The amount of corporate R&D differs across countries by industry, and is not only a result of the country size overall. Japan for example, is most involved in the industries of electric cars, geothermal, and wind energy. In some countries, such as Austria, Denmark, and Ireland, corporate R&D is allocated only in a few (sometimes unique) industries, while in others, such as Canada, Netherlands, Italy, Japan, and the U.S., the amount of corporate R&D is spread over many different industries.

Keeping in mind that our definition of government R&D is limited to basic and applied research, and experimental development (most of which is conducted at universities and research institutions), the allocation of government R&D also varies greatly between industries and across countries. The three clean technologies predominantly receiving government R&D from 1990 to 2011 are LED, solar energy, and Batteries.

Using econometric analysis, we investigated to what extent corporate R&D and government R&D had an impact on clean technology performance. In terms of policymaking, this is an important issue, as it indirectly addresses the question of whether governments are able to help in fostering the growth of an industry. Regressions results show that corporate R&D was positively correlated to firms' performance, while government R&D was, at first negatively correlated with firms' net income. Yet, the impact of public expenditures on both profitability and returns was shown to become positive with time.

Further, a positive correlation was found between government and corporate R&D. This may suggest that corporate R&D, often a short-term oriented venture, has a positive impact on profitability of these firms and therefore should be encouraged. The negative correlation between public support (here aiming at long run impact, considering our definition of government R&D) could reflect the fact that often governments will be researching and developing high risk clean tech industries (such as offshore wind or tidal energy) which can experience poor performance for some time due to the risk. Interestingly enough, by giving an initial 'push' to these industries, public support might attract corporate R&D.

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Table 1. Clean Tech Exchange Traded Funds (ETFs) and Mutual Funds

CTF   Clean Technology Fund
EVX   Market Vectors Environment Index
FAN   First Trust Global Wind Energy
GEX   Market Vectors Global Alternative Energy
ICLN   iShares S&P Global Clean Energy
KWT   Market Vectors Solar Energy
PBD   PowerShares Global Clean Energy
PBW   PowerShares WilderHill Clean Energy
PTRP   PowerShares Global Progressive Transport
PUW   PowerShares WilderHill Progresive Energy
PWND   PowerShares Global Wind Energy
PZD   PowerShares Clean tech Portfolio
QCLN   First Trust NASDAQ Clean Edge Green Environment Index
TAN   Guggenheim Solar
AECOX   Allianz RCM Global EcoTrends A
ALTEX   Firsthand Alternative Energy
ATEAX   American Trust Energy Alternatives Fund
CGAEX   Calvert Global Alternative Energy A
GAAEX   Guinness Atkinson Alternative Energy
LGCTX   Leuthold Global Clean Tech Retail
NALFX   New Alternatives
SRIGX   Gabelli SRI Green AAA
WGGFX   Winslow Green Growth Investments
WRMAX DWS Clean Technology A

Table 2. Countries represented in Clean Technology firms sample

Australia	8	Korea	5
Austria	4	Luxembourg	2
Belgium	3	Netherlands	10
Brazil	10	New Zealand	2
Canada	37	Norway	4
Chile	3	Philippines	1
China	35	Portugal	1
Denmark	8	Russia	1
Finland	3	Singapore	2
France	14	South Africa	1
Germany	25	Spain	13
Great Britain	20	Sweden	3
Hong Kong	14	Switzerland	10
India	2	Taiwan	16
Ireland	1	Turkey	1
Italy	7	Ukraine	1
Japan	23	United States	218
		n =	508

Table 3: Stock Price Returns: Clean Technology versus World Indexes, 2004-2014.

	1 year return	3 year return	5 year return	10 year return
Clean Tech	30.45	1.88	8.59	8.52
MSCI World	21.10	9.07	13.54	5.27
MSCI N. America	21.71	12.31	17.01	6.16
MSCI Europe	26.30	5.37	10.38	4.42
MSCI Far East	6.82	4.77	6.19	2.27

1 year return: July 7, 2014 – July 7, 2013
3 year return: July 7 2014 – July 7, 2011
5 year return: July 7, 2014 – July 7, 2009
10 year return: July 7, 2014 – July 7, 2004

Table 4: Highest Performing Countries based on Stock performance

1 yr return	(2014-2013)	3 yr return	(2014-2011)	5 yr return	(2014-2009)
Spain (12)	73.08	Denmark (8)	17.16	The Netherlands (8)	19.02
Denmark (8)	62.94	The Netherlands (8)	8.08	Denmark (8)	15.24
Hong Kong (14)	58.32	Hong Kong (14)	3.92	Canada (36)	13.94
China (34)	46.91	France (13)	3.91	Brazil (10)	13.36
Italy (7)	35.72	US (215)	3.31	US (215)	12.82
France (13)	34.70	Canada (36)	2.65	Switzerland (10)	11.51
Canada (36)	34.36	Japan (23)	2.58	UK (20)	10.02
Switzerland (10)	32.23	Italy (7)	2.50	France (13)	6.45
The Netherlands (8)	30.25	Switzerland (10)	2.12	Hong Kong (14)	6.32
Taiwan (16)	30.11	UK (20)	1.22	Italy (7)	2.65

(Number of firms) – We Included here only countries with 7 or more firms in the Clean Technology industries.

Table 5: Stock performance by industry – annualized in percentage.

1 yr return	(2014-2013)	3 yr return	(2014-2011)	5 yr return	(2014-2009)
Batteries	69.47	Electric Cars	32.35	Electric Cars	14.92
Electric Cars	61.52	Biofuel	9.43	Biofuel	14.21
Solar	40.97	Water	4.14	Water	11.35
Biofuel	37.17	Solar	3.01	Hydropower	9.32
Wind	33.95	Wind	2.61	Wind	6.35
Geothermal	24.88	Hydropower	2.07	Geothermal	5.34
Hydropower	24.86	Geothermal	1.58	Batteries	3.82
Water	23.03	Batteries	-4.67	Recycling	2.94
Recycling	12.31	LED	-4.70	LED	2.73
LED	9.91	Recycling	-8.39	Solar	1.03
MSCI World	21.10	MSCI World	9.07	MSCI World	13.54

Table 6a. Corporate R&D by industry in Million USD (2011 prices and exchange rates), 1990-2009.

Industry (# countries involved in)	Countries most involved in corp. R&D	Corp. R&D Millions $	Corp. R&D/ total in that industry across countries %
Batteries (7)	Korea	942753	98.77*
Biofuels (13)	U.S. Spain Denmark	2858.1695 1847.858 1828.6821	36.34 23.50 23.25
Electric cars (2)	Japan	56317	97.74
Geothermal (5)	Japan	183304	96.06
Hydropower (10)	Italy U.S.	6591 2439.116	58.48 21.64
LED (6)	Japan	223242.309	81.28
Solar (15)	Japan Norway	273253.81 22272	81.82 6.67
Transport (7)	U.S. Canada	5619.6 2207	50.96 20.01
Wave (2)	Netherlands	6.191	96.41
Wind (17)	Japan Korea	202026.25 33544.462	64.29 10.67

** Reads: Within the battery industry, there are 7 countries currently in which corp. R&D is taking place, Korea is the country with the most corp. R&D in that industry (98.77% of all corp. R&D received in the battery industry comes from Korea).*

Table 6b. Corporate R&D by country in Million USD (2011 prices and exchange rates), 1990-2009.

Country	Industry the country is most involved in	Number of industries corp. R&D involved in	Corp. R&D/ total in that country across industries %
Austria	Biofuels	2	79.83
Belgium	Solar	3	63.94
Canada	Wind	7	57.08*
Denmark	Biofuels	2	51.11
Finland	Solar	3	97.67
France	Wind	5	93.57
Germany	Solar	4	75.30
Ireland	Solar	1	100.00
Italy	Hydropower	6	99.09
Japan	Geothermal	8	66.75
Korea	Batteries	4	94.68
Netherlands	Wave	8	99.56
New Zealand	Wind Hydropower	2	50.00 50.00
Norway	Solar	1	100.00
Portugal	Wind	1	100.00
Spain	Biofuels	4	55.68
Sweden	Wind	2	81.41
Switzerland	Wind	4	50.62
U.K.	Wind	6	45.12
U.S	Solar	10	21.69

	Wind LED		21.58 21.26

** Reads: In Canada, a country involved in 7 clean tech. industries, the bulk of corp. R&D is undertaken in the Wind industry (57.08% of all corp. R&D undertaken in Canada in Clean tech. industries is allocated to the Wind industry).*

Table 7: Indicators of future growth: Investments

Investments in Sustainability to capital expenditures		Research and Development to Sales	
BATTERIES	0.40	BIOFUELS	199.67
WIND	0.11	SOLAR	20.46
BIOFUELS	0.07	LED lighting	20.07
SOLAR	0.03	HYDROPOWER	14.57
ELECTRIC CARS	0.02	WATER	14.29
TRANSPORT	0.01	BATTERIES	10.56
WATER	0.01	WIND	5.43
HYDROPOWER	0.00	ELECTRIC CARS	4.69
ORGANIC FOODS	nr	ORGANIC FOODS	4.66
GEOTHERMAL	nr	TRANSPORT	2.05
LED lighting	nr	GEOTHERMAL	0.86
RECYCLING	nr	RECYCLING	0.55

Industries with firms not reporting data are designated with nr (not reporting)

Table 8: Corporate Governance

Corporate Governance Quotient		Corporate Governance Quotient			Governance Metrics International
Percentile rank Relative to Index (1-100)	Percentile rank relative to Industry (1-100)	Board Subscore (1-5)	Audit Subscore (1-5)	Compensation Subscore (1-5)	Overall score (1-10)
55.44	59.38	3.38	3.88	3.40	6.69

Table 9. International Energy Agency member countries and their government R&D spending allocations, cumulative 1990-2011, in million USD, 2011 prices and exchange rates.

	Batteries	Bio-fuels	Electric cars	Geo-thermal	Hydro-power	LED	Solar	Transport	Wave	Wind	Total
Australia	126.843	123.168	5.285	30.182	6.997	397.489	282.288	194.326	6.562	21.378	**1194.518**
Austria	132.387	192.854	22.47	4.073	14.563	337.43	84.48	111.242	0.381	11.133	**911.013**
Belgium	54.434	16.629	0.742	0.637	4.32	131.98	21.048	49.463	0.003	3.072	**282.328**
Canada	474.173	454.653	352.849	15.725	139.338	1485.53	200.291	412.918	35.924	101.325	**3672.726**
Denmark	151.552	237.687	173.75	4.265	0.092	225.361	103.329	20.489	27.858	258.474	**1202.857**
Finland	368.194	277.546	0	0	20.179	940.186	26.907	136.635	0	49.289	**1818.936**
France	1238.986	346.278	469.309	77.801	9.364	1255.027	372.609	726.76	9.186	34.245	**3429.565**
Germany	427.608	308.36	265.893	198.062	4.323	902.25	1663.669	44.608	3.471	600.77	**4419.014**
Ireland							19.36				**19.36**
Italy	1452.89	211.864	124.599	20.262	5.078	1553.393	895.851	254.276	1.253	157.634	**4677.1**
Japan	2156.028	555.728	1388.664	387.539	9.916	7287.538	1773.1	689.679	32.538	192.448	**14473.18**
Korea	589.946	87.664	493.805	46.504	17.219	841.937	488.803	119.937	32.575	249.821	**2967.732**
Netherlands	349.14	437.743	56.576	23.641	0.218	1565.981	444.09	248.873	5.847	247.623	**3379.72**

New Zealand					3.83					2.11	**5.94**
Norway	93.392	54.635	56.9	0.939	53.726	168.944	80.71	33.624	12.447	53.853	**609.17**
Portugal										2.43	**2.43**
Spain	27.003	193.525	23.838	4.696	14.369	261.191	432.027	21.185	9.179	134.586	**1121.599**
Sweden	188.725	442.029	20.346	8.199	14.942	797.329	87.704	405.072	21.59	79.261	**2065.197**
Switzerland	417.374	124.327	81.381	66.165	68.958	493.918	482.166	144.693	0	15.102	**1894.084**
UK	168.486	299.331	137.337	26.233	3.339	811.853	220.331	416.279	122.805	349.408	**2555.402**
US	4151.639	4255.033	2535.055	1118.463	143.556	14899.52	3427.772	7406.222	109.928	1019.243	**39066.43**
Total	**12568.8**	**8619.054**	**6208.799**	**2033.386**	**376.402**	**34356.86**	**11106.535**	**11436.28**	**431.547**	**3583.205**	**90720.869**

Table 10. International Energy Agency member countries and their government R&D spending allocations, cumulative from 1990-2011, top three industries, in percentage.

	Batteries	**Bio-fuels**	**Electric cars**	**Geo-thermal**	**Hydro-power**	**LED**	**Solar**	**Transport**	**Wave**	**Wind**	**Total**
Australia						33.28	23.63	16.27			100
Austria		21.17				37.04		12.21			100
Belgium	19.28					46.75		17.52			100
Canada	12.91	12.38				40.45					100
Denmark		19.76				18.74				21.49	100
Finland	20.24	15.26				51.69					100
France			13.68			36.59		21.19			100
Germany						20.42	37.65			13.60	100
Ireland							100				100
Italy	31.06					33.21	19.15				100
Japan	14.90					50.35	12.25				100
Korea	19.88		16.64			28.37					100
Netherlands	10.33					46.33	13.14				100
New Zealand					64.48					35.52	100
Norway	15.33					27.74	13.25				100
Portugal										100	100
Spain		17.25				23.29	38.52				100
Sweden		21.40				38.61		19.61			100
Switzerland	22.04					26.08	25.46				100
UK						31.77		16.29		13.67	100
US		10.89				38.14		18.96			100
Total*	13.85	9.50	6.84	2.24	0.41	37.87	12.24	12.61	0.48	3.95	100

** These totals were calculated from the last row (total) in Table 9 above.*

Table 11. Impact of Corporate R&D and Government R&D on firm profitability

Net Income = B_0 + B_1(corporate R&D) + B_2(government R&D)+ B_3(government R&D lagged 6 yrs) + B_4(government R&D lagged 20 yrs) + B_5(government R&D lagged 30 yrs) + B_6(country)+ B_7(industry) + u

Number of observations 6364
R-squared = .87

	Coefficent	Standard Error	t Value	Pr > |t|
Constant	-2213.36	1445.60	-1.53	0.126
Corporate R&D	1.37	0.01	199.77	0.000
Government R&D	-1.61	0.88	-18.28	0.000
Gov. R&D lagged 6 yrs	-0.79	0.88	-8.95	0.000
Gov. R&D lagged 20 yrs	0.30	0.81	3.67	0.000
Gov. R&D lagged 30 yrs	0.40	0.08	4.73	0.000
Country	248.82	57.19	3.94	0.000
Industry	-515.18	136.19	-3.56	0.000

Corporate R&D is measured in $US, Government R&D is measured in $US and profitability is measured with Net income in $US.
Econometric software used: Stata.

Table 12a. Impact of relative Corporate R&D and Government R&D on firms' one year returns.

One Year return = B_0 + B_1(corporate R&D/assets) + B_2(government R&D/real GDP)+ B_3(government R&D/ real GDP lagged 6 yrs) + B_4(government R&D/ real GDP lagged 20 yrs) + B_5(government R&D/ real GDP lagged 30 yrs) + B_6 (country)+ B_7(industry) + u

Number of observations 6354
R-squared = .027

	Coefficent	Standard Error	t Value	Pr > |t|
Constant	34.85	2.57	13.53	0.000
Corporate R&D/assets	0.00009	0.00002	5.28	0.000
Government R&D/real GDP	-2.59	0.76	-3.42	0.001
Gov. R&D/real GDP lag 6 yrs	-1.25	0.75	-1.67	0.095
Gov. R&D/real GDP lag 20 yrs	-0.91	0.73	-1.23	0.218
Gov. R&D/real GDP lag 30 yrs	-1.54	0.72	-2.14	0.032
Country	0.90	0.11	7.98	0.000
Industry	-1.86	0.26	-7.19	0.000

Table 12b. Impact of relative Corporate R&D and Government R&D on firms' three year returns.

Three Year return = B_0 + B_1(corporate R&D/assets) + B_2(government R&D/real GDP)+ B_3(government R&D/ real GDP lagged 6 yrs) + B_4(government R&D/ real GDP lagged 20 yrs) + B_5(government R&D/ real GDP lagged 30 yrs) + B_6 (country)+ B_7(industry) + u

Number of observations 6354
R-squared = .046

	Coefficent	Standard Error	t Value	Pr > |t|
Constant	3.482	0.93	3.76	0.000
Corporate R&D/assets	0.00005	6.27e-06	8.13	0.000
Government R&D/real GDP	-0.80	0.27	-2.95	0.003
Gov. R&D/real GDP lag 6 yrs	-0.72	0.27	-2.65	0.008
Gov. R&D/real GDP lag 20 yrs	0.08	0.26	0.31	0.759
Gov. R&D/real GDP lag 30 yrs	0.92	0.26	3.54	0.000
Country	0.90	0.04	10.60	0.000
Industry	-1.86	0.93	-9.93	0.000

Table 12c. Impact of relative Corporate R&D and Government R&D on firms' five year returns.

Five Year return = B_0 + B_1(corporate R&D/assets) + B_2(government R&D/real GDP)+ B_3(government R&D/ real GDP lagged 6 yrs) + B_4(government R&D/ real GDP lagged 20 yrs) + B_5(government R&D/ real GDP lagged 30 yrs) + B_6 (country)+ B_7(industry) + u

Number of observations 6354
R-squared = .033

	Coefficent	Standard Error	t Value	Pr > |t|
Constant	3.942	0.70	5.61	0.000
Corporate R&D/assets	0.00001	4.7e-06	2.31	0.021
Government R&D/real GDP	0.91	0.21	4.42	0.000
Gov. R&D/real GDP lag 6 yrs	0.47	0.21	2.27	0.023
Gov. R&D/real GDP lag 20 yrs	0.53	0.20	2.67	0.008
Gov. R&D/real GDP lag 30 yrs	1.09	0.20	5.56	0.000
Country	0.31	0.03	9.91	0.000
Industry	-1.86	0.70	-6.51	0.00

Appendix A.

Table 6. Corporate R&D in Million USD (2011 prices and exchange rates), 1990-2009. (to be included in the appendix)

Country	**Industry**	**Corp. R&D Millions $**	**Corp. R&D/ total in that industry across countries %**	**Corp. R&D/ total in that country across industries %**
Canada	Batteries	0.603	6.31774E-05	0.02152105
France	Batteries	16.7	0.001749689	0.598576392
Germany	Batteries	1.123	0.000117659	0.025206697
Korea	Batteries	942753	98.77392323	94.67811219
Japan	Batteries	11102	1.163176458	4.042628325
Netherlands	Batteries	292.7	0.030666704	0.153452829
U.S.	Batteries	289.229374	0.03030308	0.517463553
Total		**954455.355**	**100**	**NA**

Austria	Biofuels	70.55	0.897083492	79.83207541
Belgium	Biofuels	16.39	0.208408199	6.175211743
Canada	Biofuels	362.758	4.61267489	1.645142398
Denmark	Biofuels	1828.6821	23.252736	51.10458737
France	Biofuels	75.817	0.964056402	2.717500976
Italy	Biofuels	11.705	0.148835752	0.175972901
Japan	Biofuels	260	3.306048306	0.094675136
Netherlands	Biofuels	6.191	0.078722096	0.003245734
Spain	Biofuels	1847.858	23.4965685	55.68047093
Sweden	Biofuels	451	5.734722254	18.59027205
Switzerland	Biofuels	45.623	0.580122469	11.33355469
U.K.	Biofuels	29.63019	0.376764767	1.060126772
U.S.	Biofuels	2858.1695	36.34325688	17.33519854
Total		**7864.3739**	**100**	

Japan	Electric cars	56317	97.73836751	0.651408271
U.S.	Electric cars	**1303.156172**	2.261632489	0.197596358
Total		**57620.15617**	**100**	---

Canada	Geothermal	224.0537	0.117413198	4.117386444
Italy	Geothermal	6591	3.453950483	0.239326153
Japan	Geothermal	183304	96.05870723	66.74742771
Netherlands	Geothermal	6.191	0.003244334	0.003245734
U.S.	Geothermal	699.726077	0.366684755	0.057529054
Total		**190824.9708**	**100**	---

Austria	Hydropower	531.536	4.716011937	20.16792459
Canada	Hydropower	388.44002	3.446403952	24.72715154
Finland	Hydropower	13.7	0.121552188	1.163895025
France	Hydropower	65.3	0.579369186	2.340541221
Italy	Hydropower	6591	58.47813634	99.08905542
Netherlands	Hydropower	6.191	0.054929167	0.003245734
New Zealand	Hydropower	33.886	0.300650907	50
Spain	Hydropower	95.628	0.848452014	2.881505004
U.K.	Hydropower	1106.082	9.813626764	1.101084169
U.S.	Hydropower	2439.116	21.64086755	0.057529054
Total		**11270.87902**	**100**	**---**

Germany	LED	1.123	0.000408884	0.025206697
Japan	LED	223242.309	81.28243854	20.50699868
Korea	LED	50642.76	18.43900937	5.085914246
Netherlands	LED	524	0.190788198	0.27471569
U.K.	LED	0.615	0.000223921	0.003638948
U.S.	LED	239.305639	0.087131091	21.25672147
Total		**274650.1126**	**100**	**---**

Belgium	Solar	169.705	0.050754722	63.93925008
Canada	Solar	239.69008	0.071685592	8.520622832
Finland	Solar	350.7	0.105014595	97.67220995
France	Solar	412.817	0.123615084	0.437104138
Germany	Solar	3886.878	1.163897685	75.30119421
Ireland	Solar	48.592	0.014550525	100
Italy	Solar	11.705	0.003504978	0.175972901
Japan	Solar	273253.81	81.82388971	7.354565599
Korea	Solar	1582.092	0.47374608	0.158885184
Netherlands	Solar	6.191	0.00185385	0.003245734
Norway	Solar	22272	6.669190346	100
Spain	Solar	6301.824	1.88703591	18.91139074
Switzerland	Solar	1985.468	0.594534124	25.78982254
U.K.	Solar	160.973	0.048202208	46.1670628
U.S.	Solar	23680.53123	0.594534124	21.68838598
Total		**334362.9763**	**100**	**--**

Canada	Transport	2207	20.0132648	3.886351937
France	Transport	9.269	0.084052085	0.332227819
Italy	Transport	48.754	0.442105443	0.037574747
Japan	Transport	1581	14.33664325	0.575697656
Switzerland	Transport	1267.263	11.49164929	12.25344494
U.K.	Transport	294.8	2.673271618	6.544674846
U.S	Transport	5619.6	50.95901352	17.31058074

Total		**11027.686**	**100**	**---**

Netherlands	Wave	6.191	96.41000507	99.55560281
U.S.	Wave	0.239449	3.589994929	1.842E-05
Total		**6.430449**	**100**	---

Belgium	Wind	79.321	0.02524035	29.88553817
Canada	Wind	2667.03002	0.848662661	57.08182373
Denmark	Wind	913.741	0.290757083	48.89541263
Finland	Wind	13.7	0.00435941	1.163895025
France	Wind	2125.782	0.676434759	93.57404946
Germany	Wind	17525.28138	5.576634618	24.64839249
Italy	Wind	6693.705	2.129971338	0.282097866
Japan	Wind	202026.25	64.2857912	0.026598615
Korea	Wind	33544.462	10.67402023	0.077088376
Netherlands	Wind	6.191	0.001970008	0.003245734
New Zealand	Wind	33.886	0.010782699	50
Portugal	Wind	3417.533	1.087476567	100
Spain	Wind	16812.598	5.349855104	22.52663333
Sweden	Wind	1975	0.628455152	81.40972795
Switzerland	Wind	2233.42	0.710685724	50.62317783
U.K.	Wind	1148.56919	0.36548062	45.12341247
U.S	Wind	23046.20995	7.333422468	21.57897683
Total		**314262.6795**	**100**	---

Figure 1. Amount of government R&D allocated by different countries to the wind industry between 1990 and 2011 (in Millions of 2011 USD).

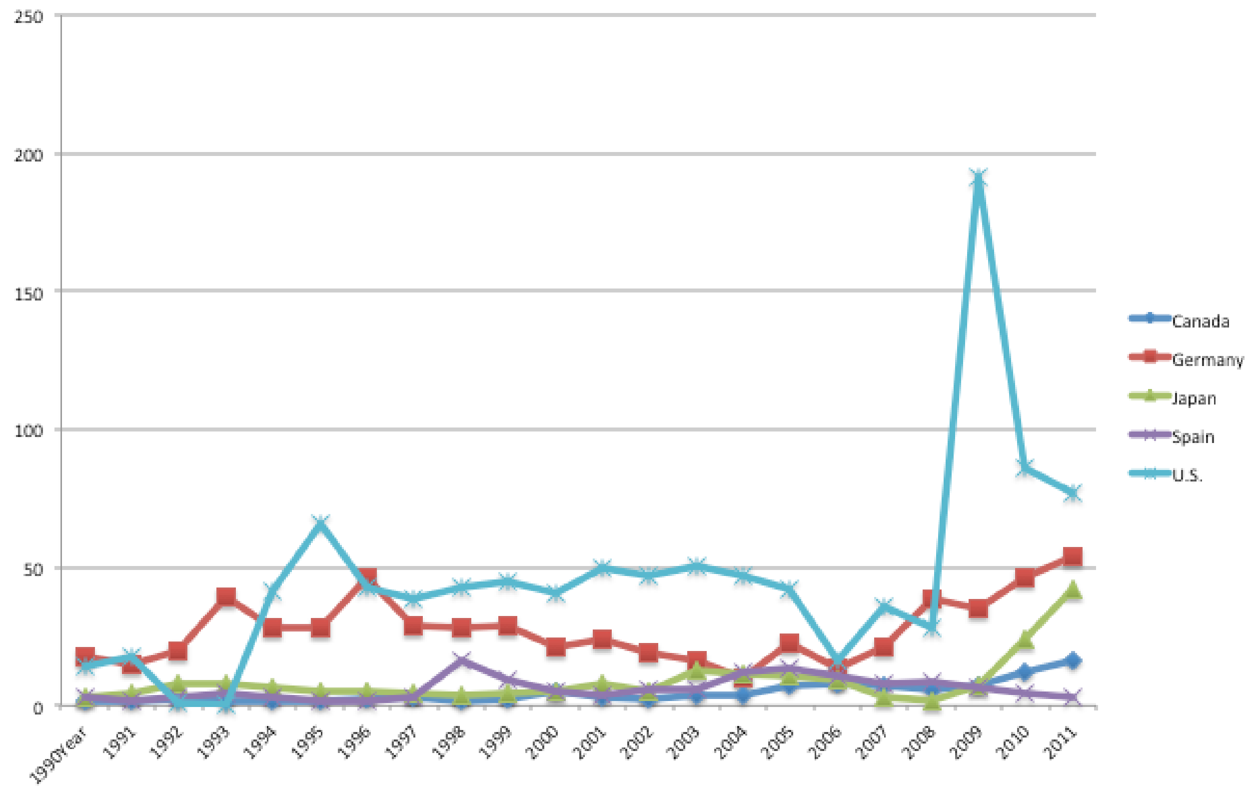

Figure 2. Amount of government R&D allocated by different countries to the solar industry between 1990 and 2011 (in Millions of 2011 USD).