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COLD START FOR THE GREEN INNOVATION MACHINE

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Highlights

- The private green innovation machine has not yet taken off. The number of green patents is still small and not growing as fast as other emerging technologies. R&D and innovation activities in the electricity generation and distribution sector, having a central role to play in the fight against climate change, are weak.
- Government intervention is needed to turn on the private green innovation machine. As an accompanying Policy Brief demonstrates, this government intervention requires a combination of carbon pricing and R&D subsidies.
- The two instruments of policy intervention, carbon pricing and R&D subsidies, are currently shapeless and do not manage to create the necessary incentives to invest in clean innovation:
  - The implicit tax rate on energy in the EU27 is low and fragmented. The carbon price in the EU Emissions Trading System is too volatile;
  - Public R&D expenditures dedicated to energy and environment are relatively low and not coordinated among countries. Moreover, its dynamics send mixed signals to investors.
- With signs from the venture capital market that the green innovation machine is ready to take off, but waiting for the push from government, this momentum is not to be wasted.

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COLD START FOR THE GREEN INNOVATION MACHINE

REINHILDE VEUGELERS AND CLÉMENT SERRE, NOVEMBER 2009

1 THE IMPORTANCE OF THE INNOVATION MACHINE FOR TACKLING CLIMATE CHANGE

The evidence provided by climate scientists clearly signals the size of the climate change challenge, meaning that a large-scale and speedy reaction is required. Economic simulations (eg Carraro *et al*, 2008) show that to keep the costs of mitigating and adapting to climate change 'manageable', we need a sufficiently broad portfolio of active technologies. For mitigation these include (i) technologies to reduce emissions such as energy efficiency, carbon capture and storage, and (ii) low-carbon technologies such as renewable-energy generation and nuclear power. Although much can be done if existing technologies are diffused (McKinsey, 2009), new technologies also need to become available, particularly backstop technologies that are zero-emission and not dependent on constrained resources. These new technologies are not yet available or still far from large-scale commercialisation.

Given the size and nature of the climate challenge, the innovation machine needs to work optimally. Will it be effective to deal with the climate challenge if left operating as it currently does, ie if we follow a business-as-usual scenario? To answer this question, we look in this policy contribution at the recent performance of the green innovation machine. We first provide evidence showing that the innovation machine has so far not functioned as it needs to in the face of the climate challenge. We explain why private green innovation cannot be expected to do the job without proper government intervention. We then illustrate the poor historical record of green public intervention, before concluding with some more hopeful signals for the future. In an accompanying policy brief[1] we discuss in more detail how policy should be (re)designed to build and sustain a well-functioning private green innovation machine, capable of dealing with the climate-change challenge.

2 EVIDENCE FROM THE PAST PERFORMANCE OF THE PRIVATE GREEN INNOVATION MACHINE

We evaluate the performance of the private green innovation machine by considering its capacity to (i) implement green innovations (ii) generate new green innovations (as measured by green patents) and (iii) commit resources to research and development to generate green innovations. We use only the standard official R&D, patent and innovation datasets because they are comparable across sectors, technologies, countries and time[2,3].

2.1 Evidence on the take-up of green innovations

We first review the evidence on the take-up of green innovations by the business sector. These green innovations are either developed by the firms themselves or (as is mostly the case) adopted from elsewhere.

For EU27 countries, the Community Innovation Survey provides data on the innovation activities of firms[4,5]. It includes information on what innovative firms identified as the major motives for innovation. The set of possible motives includes *'improving energy efficiency'* and *'reducing environmental impact or improved health and safety'*. For 2004-2006, the most recent period available, both of these motives were ranked lowest in importance among the set of motives considered[6]. Also, when looking at individual EU countries, neither motive shows up as important[7]. Furthermore, the data show no increase over time in the importance given to energy efficiency; if anything, there is a decrease[8].

Overall, the available statistics do not show an appetite within the business sector for the introduc-

1. Aghion, Hemous and Veugelers, No green growth without innovations, Bruegel Policy Brief 11/2009.

2. Identifying the green component in innovation statistics turned out to be a surprisingly difficult exercise, showing that the importance of green innovation is not yet reflected in the standard statistical framework. A first priority for an evidence-based green innovation policy is therefore to improve green innovation statistics.

3. The definition of what 'green' includes is specific to the different sources and hence will be detailed on a source-by-source basis.

4. The Community Innovation Survey is a bi-annual Eurostat survey covering all EU member states and some associated countries. The survey assesses the innovation activities of firms. To date, there have been five waves of the CIS survey, starting in 1992, with the most recent in 2006.

5. The data used here is only for the firms that reported themselves as being 'innovation active'. Innovation-active firms are a selected subset of all firms, typically biased towards larger firms in higher-tech industries. In CIS2004-2006, 38.9 percent of all sampled firms claimed to be innovation-active (EU-27; all sectors). The numbers reported are therefore likely to be higher than they would be if the total population of firms was considered.

6. Of all innovative firms, only 10 percent identified 'reduced energy per unit of output' as a highly-important motive for their innovation activities. 14 percent rated 'reduced environmental impact or improved health and safety'. The most important motives were 'improved quality in goods and services' (37.5 percent) and 'increased range of goods and services' (34 percent).

tion of green innovations. At best, environmental benefits are a side-effect of companies' other innovation activities.

2.2 Evidence from green patents

Although not all new green technologies are patented, information on applications for green patents can be used to assess the capacity of the innovation machine to produce new green technologies.

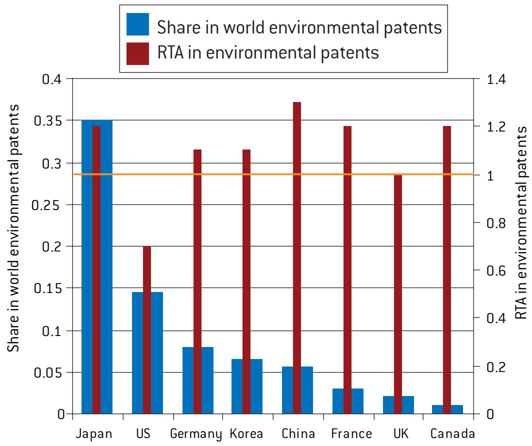
The most recent data from the World Intellectual Property Organisation (WIPO, 2009) shows that only 2.15 percent of all patent applications under the Patent Cooperation Treaty are categorised as 'environmental technologies' (world average 2002-2006). This is a staggeringly low proportion.

If we look at the countries that are active in patenting environmental technologies, **Japan** is the clearest positive outlier (Figure 1). Not only does Japan hold 35 percent of all environmental patents, it is also specialised in environmental patents. China also specialises in environmental patents. By 'specialised', we mean that the country has a relative technological advantage (RTA) greater than 1, where RTA is the share of the country in world environmental patents relative to the share of the country in total world patents (see Figure 1).

The United States, despite its 15-percent share of world 'green patents', is the least specialised in environmental technologies of the countries shown in Figure 1. In Europe, Germany is by far the biggest producer of environmental patents, being somewhat specialised in environmental technology. The UK has a low profile for environmental technologies[9].

OECD patent data permit us to take a closer look at the trends in the various subfields of environmental technology (Table 1)[10]. Not only are the shares of all environmental subfields very low relative to total patents, but their growth rates are also not very impressive, being 'only' around the average growth rate of patents. The exception is fuel cells, which have grown strongly from a low base. Nuclear technology has the most limited growth rate.

Figure 1: Countries' share of and specialisation in environmental patents



Source: WIPO 2009, Patent Cooperation Treaty applications relating to environmental technologies (2001-2005 average). Note: RTA is share of the country in world environmental patents relative to the share of the country in total world patents; RTA > 1 measures specialisation in environmental patents.

Table 1: Environmental technology patenting

	Share of technology 2003-05	Av. annual growth rate 1995-2005
All tech	100%	12.1%
Renewables	0.42%	15.8%
Auto-pollution control	0.85%	12.9%
Fuel cells	0.6%	24.6%
Nuclear	0.45%	5.8%
ICT	36%	15.5%
Nanotech	1.1%	18%
Biotech	5.8%	5.5%

Source: On basis of OECD, Compendium of Patent Statistics, 2008. Note: Renewables: wind (28.8 percent), solar (29.2 percent), geothermal (28 percent), ocean (7.6 percent), biomass (4.8 percent), waste (26.7 percent).

When the share of world environmental patents is looked at by region, the weak position of the US in all environmental sub-technologies, compared to the EU and Japan, again becomes evident (Figures 2 and 3 on page 4).

7. The positive 'outliers' on energy-efficiency are France (15 percent), the Netherlands (13 percent) and Portugal (26 percent). Surprisingly, Scandinavian countries are at the bottom end for the energy-efficiency motive (Finland and Sweden six percent, Denmark seven percent).

8. Comparing over time across different waves of CIS is notoriously unreliable, as the survey changed over time. Nevertheless, Eurostat reports that the percentage of innovating firms that quote effects of innovation on material and energy efficiency as highly important increases from 8.6 percent in 2000 to 9.5 percent in 2004 (EU-27). Source: Eurostat/Innov website, main tables.

9. Also, some other countries are specialised in environmental technologies (RTA>1) but are nevertheless small players (<1 percent share of environmental patents), for example Spain RTA of 1.3; Brazil 1.2; Norway 2.0; Poland 2.6. India is absent both in size and specialisation (RTA=0.7).

10. The OECD uses a more refined procedure for allocating patents to environmental technologies than the classification used by WIPO.

Figure 2: % share of world environmental patents by subfields and by country

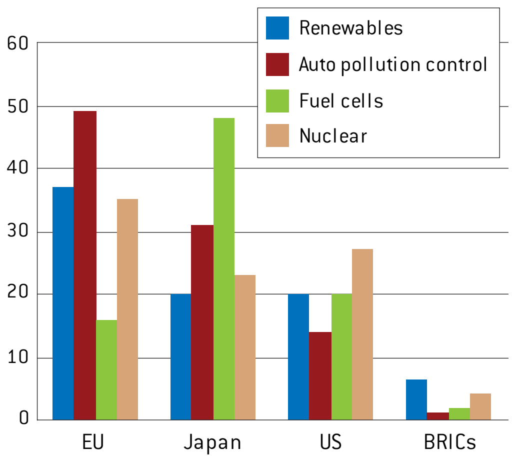
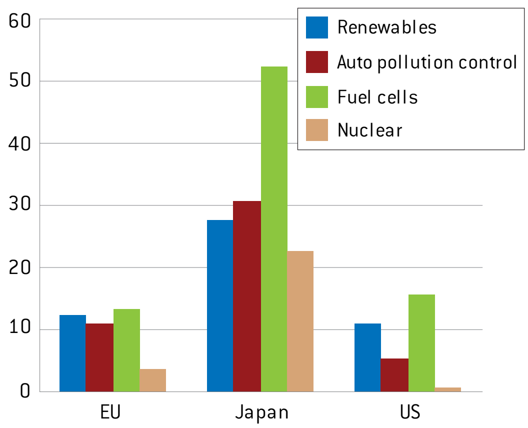


Figure 3: Average annual growth rates (%) of environmental patents 1995-2005



Source: OECD, Compendium of Patent Statistics, 2008.

2.3 Evidence on private green R&D

Business R&D expenditures on green innovation would provide a useful measure by which to assess the green innovation machine, but the OECD dataset on private R&D expenditures does not report by technology[11], but rather by economic sector in which firms investing in R&D are active.

2.4 Evidence for green innovation in the electricity generation and distribution sector

Electricity generation and distribution (EGD)[12] is responsible for a large share of greenhouse-gas emissions. In this section we look more closely at R&D and innovation by firms in this sector[13].

The EGD sector is remarkably inactive in R&D. It represents less than one percent of total world R&D expenditures by the business sector. Even more alarmingly, rather than increasing, the sector's low R&D activities have decreased over time[14]. Data from the OECD Analytical Business Enterprise Research and Development Database (ANBERD, 2007) show that the EGD sector's share in world business R&D went from 0.9 percent in the period 1990-95 to 0.5 percent in the period 2000-04. By comparison, in the EU in 2004, the EGD sector accounted for 2.2 percent of value added.

When looking at EGD R&D in different regions, the US emerges as a minor player, while Japan and the EU on aggregate are relatively strong. Within the EU, France is the positive outlier, both in terms of size and specialisation; the UK is second in size, but its position has declined over time. Spain is a relatively big spender on EGD R&D (Table 2).

Table 2: EGD R&D expenditures, selected countries and regions

	Growth in R&D average annual growth rate, 2000-03	Share of country in total world EGD R&D, 2000-04	Share of country in EGD R&D relative to share of country in total R&D (RTA)
US	-2.5%	6.8%	0.15
Japan	-2.7%	27.9%	1.55
EU	-2.8%	46.5%	1.69
Germany	0.6%	3.8%	0.42
France	-0.3%	21.3%	2.07
UK	-27.8%	7.6%	1.05
Spain	31.1%	3.4%	3.20
Sweden	15.2%	1.9%	1.05

Source: OECD, ANBERD (2007). Note: The Spanish increase reverses the downward trend seen from 1995-2000; the Swedish trend was downwards between 1992-2001.

11. The latest JRC-IPTS Scoreboard on the largest R&D spenders (http://iri.jrc.ec.europa.eu/research/scoreboard_2009.htm) shows that, in 2008, among the EU's thousand largest R&D spenders, there are six companies from the alternative energy sector. Together they represent €324 million in R&D expenditures, or 0.25 percent of total R&D spending by the 1000 largest EU R&D spenders. The largest company is Vestas Wind from Denmark with an R&D budget of €223 million; all others are smaller German companies. The non-EU largest R&D spending scoreboard includes no alternative energy category.

12. This includes all types, including nuclear.

13. A caveat: not all R&D and innovation activities by firms in this sector are necessarily related to climate change.

14. While the average annual growth rate of total business enterprises increased by 3.5 percent in the period 2000-04, the average annual growth rate of the EGD sector was -3.5 percent (Source: OECD, ANBERD (2007).

15. While the OECD uses questionnaire information from an inventory of all R&D-active firms, the IPTS-R&D Scoreboard data uses company account information from the 1000 largest EU and non-EU R&D spenders.

The European Commission's R&D scoreboard (European Commission, IPTS, 2009) provides more recent information on R&D spending by large companies[15]. The latest data (2009) confirm the weak R&D picture for the EGD sector. For the EU, there are 15 EGD companies among the top thousand EU R&D spenders. These companies have an average R&D-to-sales ratio of only 1.3 percent in 2008. Of these 15 companies, only two – Areva and EdF, both French – are among the EU's top 100 R&D spenders. In the non-EU scoreboard of the top thousand R&D spenders, there are 11 EGD companies (of which none are from the US) with an average R&D-to-sales ratio of 0.8 percent in 2008, compared to a 3.7 percent average in the non-EU scoreboard. These figures show the low innovation activity of EGD companies generally, with low R&D-to-sales ratios compared to other sectors.

The low rate of R&D spending in the EGD sector implies that this pivotal sector will not be active in generating its own innovations to reduce emissions of greenhouse gases. Furthermore, marginal R&D activity in this sector hampers the effective adoption of innovations developed elsewhere. The innovation data for this sector show that in most EU countries, EGD firms are less active than firms from other sectors in implementing new innovations (CIS, 2004-2006). Furthermore, 'green' motivations for R&D seem to be given a low priority by the EGD sector, as is the case for other sectors[16]. While other sectors typically quote high innovation costs and access to finance as the main barriers to innovation, in the EGD sector the factor that is rated by most non-innovative companies as hampering them is that there is no demand for innovative products[17].

Even allowing for poor data availability, the empirical picture seems consistent: innovation and R&D activities in the EGD sector are low and are not increasing; on the contrary, they are often in decline.

3 EXPLAINING THE FAILING PRIVATE GREEN INNOVATION MACHINE

The picture of the private green innovation machine presented in section 2 is not an attractive one either for the generation of green technologies, or for the adoption and diffusion of green technologies. There are several possible reasons why private green innovation activities are not progressing as they could and should.

- The greatest benefits from green technologies are public rather than private (a reduction of the environmental externality). As a consequence, the private willingness to pay for green innovation will be low unless there is a clear and appropriate price put on the externality.

- A classic reason for a lack of innovation is the appropriation problem. Firms will be reluctant to innovate when they cannot fully appropriate the returns from their innovations. This argument may hold particularly for green innovations as they are typically complex, cumulative-process innovations, where classic patent protection may need to be complemented with other appropriation mechanisms if it is to be effective.

- Another classical barrier to innovation is access to finance. Financial constraints will be even more limiting for green innovations, especially the more breakthrough type of green innovation, because such innovations carry a high technical risk/uncertainty. But also important for green innovation are the higher commercial risks arising from uncertain market conditions. The combination of technological and market uncertainties will be particularly important for early-stage green technologies. As these are often introduced by small-scale, radical innovators lacking collateral and reputation, such young, radical green innovators may be particularly held back by financial constraints.

- For green technologies that have passed the prototype stage, there are still significant learning effects during the initial stage of marketing. Customers may want to wait to adopt the new technologies until they are at a later stage, when their costs are lower. In the absence of early lead-users, learning effects cannot materialise, preventing these technologies from

16. The Netherlands has the highest score for the innovativeness of its EGD sector, with 63 percent of firms classed as innovation-active. Italy and the UK are at the bottom with 30 percent. Only for a few countries do we have information on the motives for innovation in the EGD sector. In line with the results for other sectors, 'environmental, health & safety' and 'energy reduction' are of little importance.

17. For instance, in Spain, half of non-innovative EGD firms report 'no demand for innovation' as a limiting factor, compared to 32 percent for all sectors and compared to 12 percent who say innovation costs are too high.

reaching their most cost-efficient configurations.

- Once on the market, new green technologies face competition from existing dirtier technologies, which enjoy an initial installed-base advantage. As discussed in more detail in the accompanying policy brief (Aghion *et al*, 2009), taking into account that R&D resources will be directed towards the most profitable ends, the innovation machine if left on its own will favour continued work on dirty technologies, impeding the roll-out of clean technologies (Acemoglu et al, 2009).

In addition, incentives for innovation in the EGD sector are particularly lacking, due to:

- Regulation, which induces risk aversion, reducing the incentives to invest;
- Low levels of competition in the sector nationally, and fragmentation internationally;
- Difficult access to the electricity supply grid for new technologies such as wind or solar power;
- Technological issues still to be resolved, such as energy storage (batteries).

4 SOME EVIDENCE ON CLIMATE CHANGE POLICY INTERVENTION

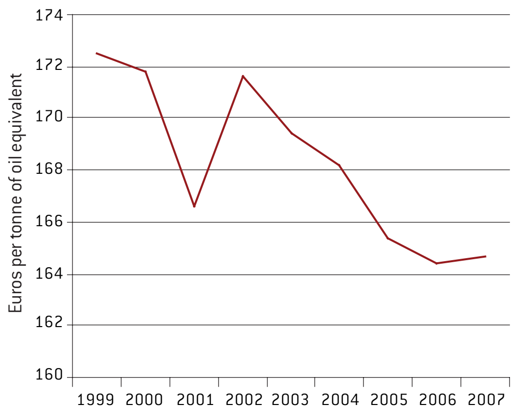
As the private green innovation machine, when left on its own, cannot be expected to rise to the climate-change challenge, government intervention is needed. In an accompanying Bruegel policy brief (Aghion *et al*, 2009), we draw on the insights provided by an economic model of directed technological change for the environment (Acemoglu et al, 2009), to set out the optimal policy intervention that is needed to turn on the private green innovation machine. Addressing environmental and knowledge externalities will require an early and sizeable combination of carbon pricing and R&D subsidies. In this section, we look at the empirical evidence on how these two pivotal policy instruments have been implemented so far: establishing a price for carbon (section 4.1), and public spending on green R&D investments (section 4.2).

4.1 Carbon pricing: carbon taxes and cap-and-trade

A price for carbon that is sufficiently high and predictable over the longer term would be an incentive for R&D investments leading to the creation of new green technologies, as well as for the adoption by the market of emissions-reducing investments. These benefits would be most clearly obtained through a carbon tax.

Environmental taxes averaged in the EU27 6.4 percent of total tax revenues in 2006. This is a very low number, which is even slightly decreasing over time. Denmark is the country with the highest share of 12 percent (Environment Policy Review, 2008). When focusing on energy taxes only, a similar downward trend over time can be observed (Figure 4). More recently, new carbon taxes have been introduced or are planned. France is the notable example, having said it will introduce by 2010 a €17 levy per tonne of carbon dioxide, with a non-specified regular increase.

Figure 4: Implicit tax rate on energy (EU27)

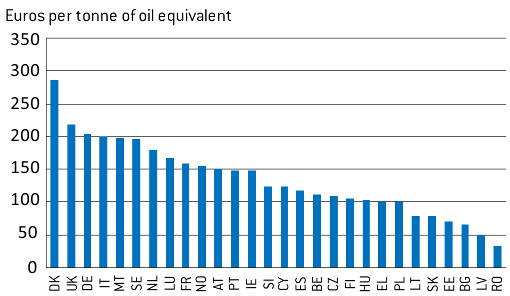


Source: Eurostat (2009).

The low level and the short-term nature of EU carbon taxes translates into low incentives for green innovations. There is also a high dispersion of carbon taxes across EU countries. This fragmented picture undermines the effectiveness of carbon taxes in leveraging innovation, whatever the level of the tax. Although the fragmentation has reduced somewhat over time, there is nevertheless substantial variance in implicit tax rates on energy[18].

Denmark and the UK have the EU's highest rates, while Romania and Latvia the lowest rates (Figure 5).

Figure 5: EU states, implicit tax rate on energy



Source: Eurostat (2009).

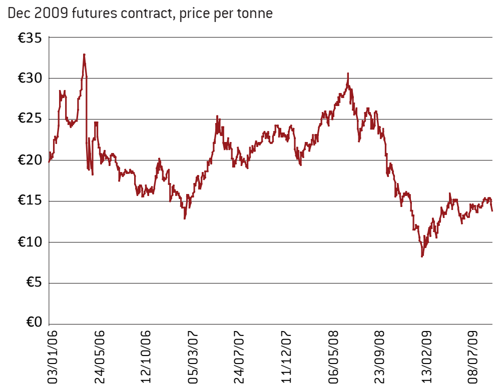
Cap-and-trade systems also generate a carbon price, but because a great deal of information and expertise is needed to get the emissions-capping and allowance-allocation processes right, there is more room for error and exposure to political pressure, compared to carbon tax schemes. The European Union's Emissions Trading System (or EU ETS) opened in 2005 and can still be considered to be in a learning phase. Carbon-price volatility has proved to be an issue for the ETS in its early years.

The EU carbon price reached its highest level of €32.90 in April 2006, but stood at around €13.70 in mid-November 2009. The drop in the price in early 2007 (the spot price reached almost zero in April 2007) marked the end of the first phase of the EU ETS. This was due to the absence of bankability between the first and second ETS phases (2005-07 and 2008-12), as first-phase allowances could not be used for later phases[19].

Reforms have been introduced to make the ETS more predictable after 2013 (for example through a more centralised allocation of allowances), but factors such as the uncertainty about the allocation of emissions allowances for free for some sectors could continue to disrupt the carbon price.

Overall, the evidence on carbon pricing is consistent with the inadequate performance of the private green innovation machine. Current carbon-tax levels and cap-and-trade systems are not generating a sufficiently high carbon price to induce green innovation. Furthermore, the carbon price has not been stable, which is a disincentive for green innovation.

Figure 6: Carbon price, Dec 09 futures contract



Source: ECX historical contracts data (daily futures, futures and options).

4.2 EVIDENCE ON PUBLIC GREEN R&D

Alongside carbon prices, green R&D subsidies are a complementary policy instrument. Subsidies are particularly important in the early phases of development of new green technologies, for addressing the installed-base disadvantage of new technologies and the financing barriers faced by new innovators.

In this section, we look at the most recent evidence on the size of public green R&D expenditures, in the form either of financing of R&D by public-sector research organisations, or of subsidies to private sector R&D [20].

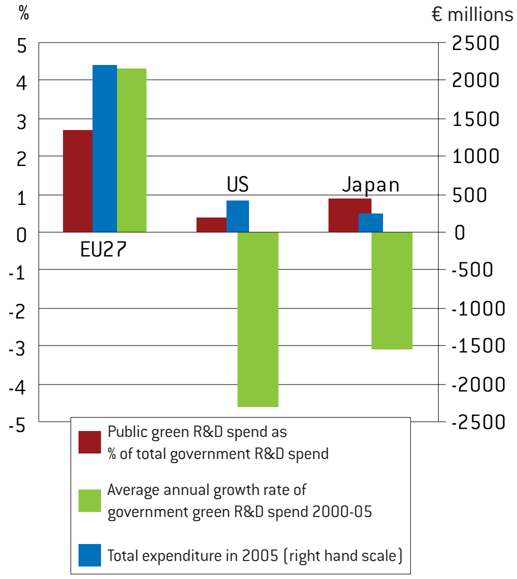
Public R&D spending for the 'control and care of the environment' category is almost negligible as a share of total public R&D spending. Furthermore there is little indication in the data that this share is increasing, at least for the period up to 2005. Compared to the US and Japan, the EU27 as an aggregate performs relatively well. But this European Union aggregate hides a lack of coordination by EU countries of these outlays, making them less effective compared to US or Japanese public spending.

18. Calculating the standard deviation over 3 years across all EU 27 countries (+Norway), it evolves from 10 in 1996-1998 to 6 in the last period available (2005-2007). Source: Own calculations on the basis of Eurostat.

19. See also Tirole, 2009.

20. Unfortunately, there is little data available on public spending that is comparable across countries. As a source for R&D subsidies, we use the GBAORD Government Budget Appropriations or Outlays on R&D data (Eurostat). Although the data has serious limitations and was only reported after a large time lag, it is available for a wide set of (OECD) countries. GBAORD is split according to 'socio-economic objectives' (NABS classification). These include the two groups we are interested in: NABS03: control and care of the environment, and NABS05: production, distribution and rational utilisation of energy.

Figure 7: Public R&D expenditure on 'control and care of the environment'



Source: Own calculations on basis of Eurostat, Statistics in Focus, 29-2008. Note: 'Control and care of the environment' corresponds to NABS03 in the GBAORD classification. EU-27 is a Eurostat estimate; EU average annual growth rate is for EU15. US values are provisional; total GBAORD excludes General University Funds; Japanese values are provisional.

Table 3: Public R&D expenditures for 'control and care of the environment' (GBAORD- NABS03 data)

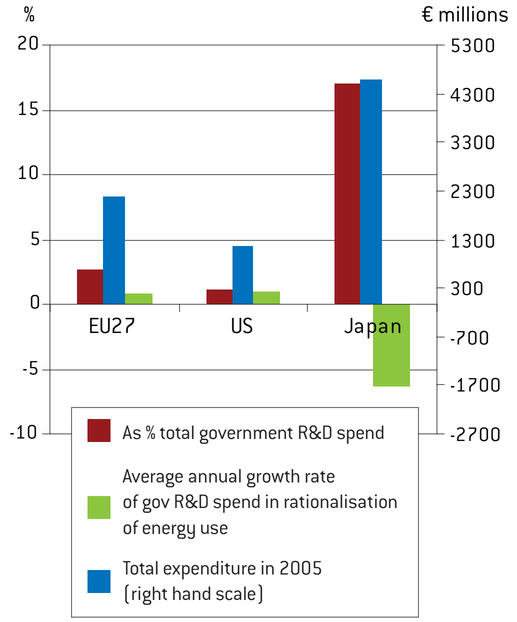
	Total expenditure, €m, 2005	As percentage of total government R&D expenditure	Av. annual growth rate of government green R&D expenditure, 2000-05
Germany	585	3.1%	1.8%
France	431	2.7%	12.7%
UK	233	1.8%	-1.4%
Italy	259	2.7%	8.6%
Spain	229	3.0%	8.6%
Sweden	56	2.2%	17.2%

Source: Own calculations on basis of Eurostat, Statistics in Focus, 292008. To compare, average annual growth rate of total GBAORD for EU15= 4.2 percent, US: +3.2 percent, Japan: -5.0 percent.

Among EU countries, France and Germany are the major green public spenders, while the UK scores low and in fact saw a declining spend during the period under consideration (2000-05).

Public R&D spending on 'production, distribution and rational utilisation of energy' shows a similar pattern to 'environment'. Again, the US is doing badly both in levels of public spending and in growth rates (at least up to 2005). The EU spends moderately with little growth. Japan is a strong public spender on energy, though its spending is declining. This correlates with the relative strength of Japan in energy technologies, as illustrated by the patent applications data.

Figure 8: Public R&D expenditure on 'production, distribution and rational utilisation of energy'



Source: Own calculations on basis of Eurostat, Statistics in Focus, 292008. 'Production, distribution and rational utilisation of energy' corresponds to NABS05 in the GBAORD classification. EU-27 is a Eurostat estimate; EU average annual growth rate is for EU15; US values are provisional; total GBAORD excludes General University Funds; Japanese values are provisional.

Within the EU, France and Germany are the most important public funders of energy R&D, but with little or negative growth rates. The UK again lags behind. Spain is expanding its public R&D budgets for energy, correlating with a higher level of innovative behaviour in its electricity sector (cf supra).

More recently (2007), US federal government spending on basic research dedicated to energy represented 0.1 percent of total research spending, with 0.5 percent for natural resources and environment. These are even lower proportions than in 2005. However, there is an indication that the downward trend may have started to reverse in 2008, with the $1.5 billion for the US Climate Change Science Program and Hydrogen Fuel Initiative.

Table 4: Public R&D expenditures for 'production, distribution and rational utilisation of energy' (GBAORD- NABS05 data)

	Total expenditure, €m, 2005	As percentage of total government R&D expenditure	Av. annual growth rate of government green R&D expenditure, 2000-05
Germany	482	2.8%	-2.5%
France	718	4.5%	1.5%
UK	52	0.4%	0.8%
Italy	383	4.0%	4.7%
Spain	168	2.2%	7.7%
Sweden	59	2.3%	-11.2%

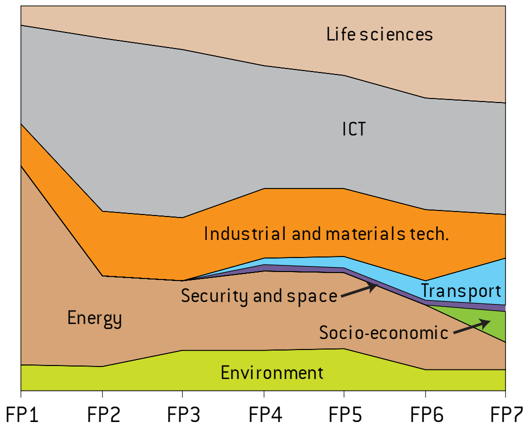
Source: Own calculations on basis of Eurostat, Statistics in Focus, 292008.

At the EU level, research funding through the EU's Seventh Framework Programme (FP7)[21], which covers the period 2007-2013, has increased substantially to €50 billion for the five-year window (the global budget for FP6 was €18 billion). Of the FP7 budget, €2.35 billion is dedicated to energy research, €1.89 billion to environment (including climate change), and €2.7 billion for Euratom. While these numbers represent a serious increase over past budgets, in relative terms the share of energy and environment has decreased over successive FPs, as Figure 9 shows. The first FP was heavily concentrated on energy (in the context of the oil crisis), but the focus gradually shifted to ICT and broader applications in support of industrial competitiveness.

The recently adopted European Economic Recovery Package (May 2009) includes a substantial budget for carbon capture and storage and for offshore wind power projects, as well as for some of the cross-border infrastructure connections that will increase the efficiency of the electricity grid[22].

Beyond FP funding, the technological approach to climate change is developed through the European Technologies Action Plan (ETAP). The European Commission adopted this in 2004, with the intention of overcoming the barriers hindering the development of environmental technologies. This includes action on emissions standards for new passenger cars and on fuel quality. Several energy-efficiency standards have recently been adopted or were already in place. In terms of public funds, no clear EU budget is associated with ETAP, as it aims to leverage other public and private funding. ETAP attempts to mobilise green versions of existing EU instruments such as JTI (Joint Technology Initiative), ETP (European Technology Platforms), LMI (Lead Market Initiative) and the CIP (Community Innovation Programme). ETAP also supports environmental technology action in developing countries.

Figure 9: EC-FP funding by technological area, a comparison across FPs



Source: EC, DG-RTD

5 VENTURE CAPITAL FINANCING OF GREEN INNOVATION

The evidence presented so far is not favourable for the green innovation machine. The low level of private green innovation activities correlate with the low level of public green intervention, in terms of both carbon pricing and public green R&D expenditure. However, as most of the regular data on innovation (R&D expenditures, patents and innovations) is only reported with a time-lag, they may fail to pick up the very recent trends, which could be more positive for green innovation, particularly because a more favourable climate for public in-

21. The Framework Programmes (FP) represent the EU budget commitment to research. They are multi-annual programmes, with the latest (FP7) running from 2007-2013.

22. The total amount of the package is €5 billion. €3.98 billion is allocated to energy infrastructure projects to strengthen the EU's energy security. Within the energy funding, big energy utilities get €1 billion for carbon capture and storage and €565 million for offshore wind farms. See http://www.euractiv.com/en/energy/parliament-approves-4-energy-projects/article-182096.

tervention seems to be developing.

Venture capital financing gives a more recent overview of green innovation trends. Data from Dow Jones VentureSource shows the increasing interest from venture capitalists in the 'cleantech' category, which includes not only renewable energies but anything associated with alternative energy. As Figure 10 shows, this interest has taken off since 2007. Although both the US and EU saw a similar increase in the number of cleantech deals, the US outperformed the EU in terms of the amounts raised.

Figure 10: Euro raised in Europe and the US by venture-backed cleantech companies, annual data

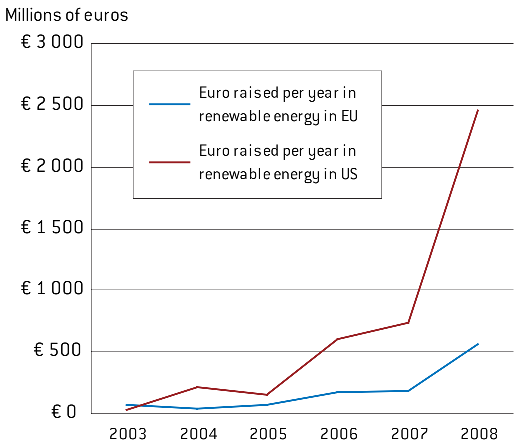
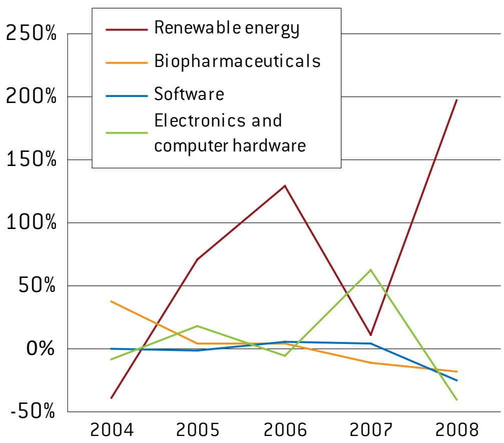


Figure 11: Growth rates of amounts raised by venture-backed companies by sector

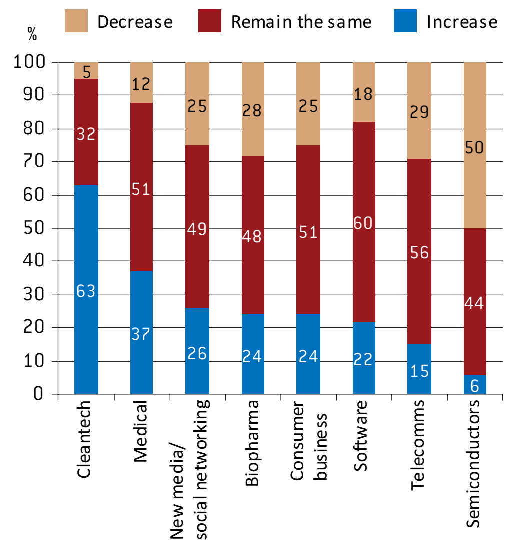


Source: Dow Jones VentureSource.

In terms of growth rates, venture capital investment in cleantech outperforms any other venture capital sector. In 2008 especially, when other sectors have seen declining rates of investment, renewable energy continued its growth (Figure 11). Interestingly, the dip in the renewable energy growth rate seen in 2007 (Figure 11) corresponds to a drop in EU ETS carbon prices from mid-2006, illustrating the sensitivity of the green innovation machine to too-low carbon prices.

Despite increasing venture capital volumes, cleantech only accounts for seven percent of all equity investment into European venture capital backed companies in 2009 (second quarter). Nevertheless, momentum seems to have been created. Deloitte in their 2009 Global Trends in Venture Capital[23] report note that, despite the economic and financial crisis, 63 percent of surveyed venture capitalists anticipate an increase in their cleantech investments. This was the highest score among all sectors considered (Figure 12). This increase is particularly high in the Asia-Pacific region and for continental Europe, but less so in the US and the UK. The report attributes this increasing interest to an anticipated increase in government support for cleantech, both through public (co-) financing and provision of incentives for the private sector.

Figure 12: Anticipated level of investment change in selected sectors over the next three years



Source: Deloitte, 2009.

23. The survey was conducted in cooperation with venture capital associations globally (eg EVCA, NCVA). There were 725 responses from general partners of venture capital firms from the Americas, Asia Pacific (AP), Europe and Israel.

6 CONCLUSIONS

In view of the real and sizeable climate change challenge, we need a green innovation machine operating at full speed. The private green innovation machine, left on its own, is not up to the challenge. It needs government support. As detailed in Aghion et al (2009), a suitable policy to turn on the private green innovation machine should combine consistent carbon pricing with initial substantial research subsidies.

Overall, the admittedly not very up-to-date data on public green R&D spending shows that public budgets for environment and energy R&D are very low. Only very recently can some more promising signs of increased public R&D budgets be observed. More importantly, recent and current low budgets come on top of the lack of a clear long-term consistent global carbon price. Government policy remains far from where it needs to be if the green innovation machine is to be turned on and start running efficiently.

Although past evidence on private green R&D and innovation shows low levels of activity and little dynamism, momentum seems to be building. Observations of the venture capital market provide the clearest support for this assertion. But as venture capital optimism seems to be based on an anticipation of government support for cleantech, the question is if we are seeing the seeds of a prolific public-private partnership or the beginnings of a bubble – a green tech bubble – which may burst when expectations are not met.

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