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Who drives smart growth?

The contribution of small and young firms to inventions in sustainable technologies

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Who drives smart growth? The contribution of small and young firms to inventions in sustainable technologies

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Contribution to the Project

Concentrating on sustainable patenting as an indicator for inventions in sustainable, green technologies, this study first presents the overall development in sustainable patenting at the European Patent Office. We then analyze green patenting in Germany by focusing on the role of small and young firms in the generation of green patents. Our results show that the contribution of SMEs to green patenting is similar to their contribution to overall patenting

What might be the contribution to the central questions of the wwwforEurope project? First of all, young and small firms might not able to drive the technology development towards a more sophisticated use of energy resources and renewable energies. Like in most other fields of technology the direction of technical change is determined by established large firms. Hence, under the current framework of innovation and industrial policies, the development of the "more entrepreneurial economy" will probably not form forerunners on the ways towards a new growth path. Secondly, private sector's production of invention activities became not stronger directed towards technologies which aim at production, storage, distribution, and management of new energy technologies compared to other fields of technology. Given the societal need for new energy technologies the paper speaks in favor of government regulation, invention and incentives to stimulate research, development, and implementation new energy technologies. However, we do not find arguments that such stimuli should favor SMEs or young firms..

Keywords: Green patents, sustainable patenting, SMEs, young firms

Jel codes: O31; M13; C81

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Executive Summary

Europe's innovation potential is currently dominated by well-established large companies. In most member countries the bulk of R&D expenditures is spend by large companies. Following OECD data, SME's share in total R&D spending amount to 8% in Germany or Japan, around 15% in US, France, Korea or Italy, about 20% in Sweden, Finland or Switzerland, about 30% in Netherlands, Austria or Poland, and about 50% in Poland, Ireland, Slovakia or Greece. First of all, these figures point to a considerable heterogeneity with regard to the importance of SMEs in national R&D activities.

However, young companies are said to be the driving force behind radical innovation which will be a source of employment and growth in future. In addition, the weakness of Europe is not only the small number of hightech startups but more specifically the number of hightech startups which accomplish continuing, rapid growth. However, there might be significant technology specific heterogeneity with regard to the contribution of SMEs and young firms to innovation.

The central question of the paper is whether SMEs and young firms might be agents with a special contribution to new growth path in Europe. We took new renewable energy technologies as an example at test whether the contribution of SMEs and young firms is larger in this technology area compared to invention as measured by patenting. In order to focus on the most valuable patents we use patent applications at the European Patent Office which were also applied for patent production at the USPTO and the Japanese Patent Office ("triadic patent applications").

The analysis proceed in two steps: The paper looks first at trends in international patenting and compares triadic patent application in the field of energy with all triadic patent application by country of inventors. The idea is to highlight the role of EU and its member states in invention activity in a technology-field which is of special relevance for a new, sustainable growth path. In the second step we look at the contribution for SMEs and young firms to such a new growth path by a detail analyses of triadic patent application by German companies as the SMEs share to R&D is the smallest compared to all other EU member states as well as compared to OECD member states (except Japan). The focus on Germany is motivated for two reasons - to ease the analysis and to focus on the most extreme case of the firm-size R&D distribution which is observed in EU and OECD member states.

The study employs the WIPO "Green Inventory" classification to identify energy-related patents via the international patent classification used by all patent offices to assign patents by technology and potential fields of application. This classification comprise as main technology classes alternative energy production, transportation, energy storage, waste management, agriculture/forestry, regulatory and design aspects, and nuclear power generation. The number of green inventory patents increased from 1991 to 2007 by a factor of 2.5 to 12.500 patent applications. The majority of this increase is observable in renewable energy product, storage of energy, design and management of energy systems, and waste management. Patents related to nuclear power account for 4% of green inventory patents and this share declined even more to 1% in 2007. Surprisingly, the increase of green inventory patent applications at the EPO more or less equals the increase in overall patent applications at the EPO. Hence, the share of green inventory patents in total patent application at EPO was constant and fluctuating always between 8-10% with not visible trend. Similarly, albeit the increase in the number of triadic patents is less impressive (only by a factor of 1.4) the structural features are the same.

Overall, the importance of green patent activities does not greatly vary between countries or regions. In 2007, the share of green patent applications in all patent applications at the EPO lies between 7% and 12%. Interestingly, the new member states and southern Europe are at the upper end of the range (12% and 10%, respectively) - besides Japan (11%) and the US (10%). Green patents are slightly less important for Northern Europe and China (both 7%). Focusing on more valuable patent application ("triadic patent application"), green technologies become more important in Germany, Korea and China and lose importance in Southern Europe.

The second step linked sustainable growth to the "entrepreneurial" economy by examining to which degree small and young firms are driving sustainable patenting. We find SMEs to be responsible for about 15% of all patent applications. This is the same for the WIPO Green Inventory classified "green" patents.

Around half of patent applications of SMEs are made by young firms. About one half of all patent applications by SMEs are filed by micro firms. When narrowing down the analysis to triadic patents, we find the contribution of SMEs to decrease to about 9% of all patent applications which is probably caused by the larger costs of applying and maintaining triadic patents than EPO patents. The contribution to green patenting is even lower for triadic patents with only 6% of all green patents coming from SMEs.

In the third step of the analysis, based on the link of German firm data to patent applications at the European Patent Office, we analyzed at the firm level whether small and young firms are more or less likely to file sustainable patents than other firms. The results show that large firms are significantly more likely to file both patents in general and green patents. We do find that, for micro, small and medium size firms, the negative effect on patenting compared to the reference category of a large firm is less strong for the younger firms. This effect exists both for the generation of patents in general and the generation of green patents. Therefore there does not seem to be a particular advantage for small or young firms in producing sustainable, green patents. Even more, SMEs and young firms seem to face larger obstacles to start inventing in green energy technologies than in other technology fields. In any case SMEs and young firms will probably not an important driver of new technologies like in some other fields of technology.

Of course we have to admit that our same only covers international patent applications for the priority year 2007 or earlier. Hence, things might have changed in the meantime due to e.g. extended government support for innovation in green energy fields. However, this question can only be examined with future editions of the PATSTAT data which fully covers more recent years. In addition, we cannot rule out the SMEs and/or young firms are especially important for patents which are radical driver of technological change. To address this question several measurement issues need to be solved and/or existing measurement approaches need verification. However, this is beyond the limits of our study.

What might be the contribution to the central questions of the wwwforEurope project? First of all, young and small firms might not able to drive the technology development towards a more sophisticated use of energy resources and renewable energies. Like in most other fields of technology the direction of technical change is determined by established large firms. Hence, under the current framework of innovation and industrial policies, the development of the “more entrepreneurial economy” will probably not form forerunners on the ways towards a new growth path. Secondly, private sector’s production of invention activities became not stronger directed towards technologies which aim at production, storage, distribution, and management of new energy technologies compared to other fields of technology. Given the societal need for new energy technologies the paper speaks in favor of government regulation, invention and incentives to stimulate research, development, and implementation new energy technologies. However, we do not find arguments that such stimuli should favor SMEs or young firms..

1. Introduction

Globalization and an increasing importance of knowledge in the production process caused many developed countries to move from a more "managed" to a more "entrepreneurial" economy (Audretsch and Thurik 2010).

While in a “managed” economy, large and incumbent firms play a dominant role, exploiting economies of scale in production and R&D in a relatively stable economic environment, the “entrepreneurial” economy is characterized by an increasing role for small and new firms in introducing new products and services in highly insecure, rapidly changing economic environments.

At the same time policymakers are increasingly interested in designing policies to promote a sustainable growth path. “The Sustainable Growth concept is applied in the EU context. Sustainable Growth is one of three priority areas in the Europe 2020 strategy. It has a clearly defined focus on the promotion of the competitiveness of the EU economy, including capitalization on its leadership in green technologies, promoting smart grids, improving the business environment, especially for SMEs, and influencing consumer choice. Sustainable Growth is also about attaining environmental objectives such as decreasing the carbon intensity of the economy, promoting the efficient and sustainable use of resources, protecting the environment, reducing emissions andpreventing loss of bio-diversity” (European Commission, Directorate-General for Regional and Urban policy 2012).

In this paper, we concentrate on sustainable patenting as an indicator for inventions in sustainable technologies. We apply a definition introduced by the World Intellectual Property Organization (WIPO 2013) that classifies patents in a Green Inventory Scheme, defining seven sustainable technology fields.

The contribution of this paper is in a first step to analyze the overall growth developments in sustainable patenting, to identify which countries and regions are more or less specialized in certain sustainable technologies and to present how this has changed over time. Our analysis is mainly focused on European countries, but additionally covers the United States, Japan, China and South Korea for international comparisons.

The second step then links sustainable growth to the “entrepreneurial” economy by examining to which degree small and young firms are driving sustainable patenting. Given that SMEs make up a large share of all firms in an economy we ask to what extent these SMEs are relevant drivers of sustainable growth. This analysis is conducted at the example of Germany. In order to undertake this analysis we have linked (almost) the entire population of German firms to their patent applications at the European Patent Office. This link allows us to investigate the relationship between firm characteristics, particularly firm size and age, and sustainable inventions. Our database further allows us to break down the analysis to the individual patent level, enabling us to go beyond simply using patent counts as measure for innovative output. It is an established fact that the value distribution of inventions is highly skewed, with most inventions being of low value. This is also true for patented inventions. We therefore apply an indicator to assess the quality of the patented invention that allows us to distinguish between more and less valuable inventions.

In the third step of the analysis, based on the link of German firm data to patent applications at the European Patent Office, we analyze at the firm level whether small and young firms are more or less likely to file sustainable patents than other firms.

This study contributes to the ongoing innovation policy discussion on how to best promote smart and sustainable growth. It provides policymakers with insights on which countries and which types of firms are most productive in developing sustainable technologies. This opens up the discussion on how to support them to perform even better and on how to assists regions and firms still lagging behind.

2. Literature Review

We review the broad theoretical and empirical literature related to the relationship between firm size, age and the propensity to generate “sustainable” inventions.

2.1 Theoretical Literature

In order to approach the question whether young small companies are more likely to introduce “sustainable” innovations, it is a good start to look at the long history of theoretical literature on driving forces of R&D and innovation. Insights can be obtained both from the literature focusing on the effect of firm size on innovation as well as from the literature concentrating on entrants versus incumbents. Further insights can be obtained by looking at the antecedents of different types of innovations. For an overview on this subject see Cohen (2010).

The justifications for a positive effect of firm size on innovation activity are vast: capital market imperfections are argued to lead to large firms having an advantage for financing risky projects. Hall (2002) argues that, even with perfect appropriability of R&D returns, firms may still find it too difficult to finance their R&D expenditures as the rate of return required by external capital often exceeds the rate of return that can be achieved with the project. This suggests that firms with little own capital may be disadvantaged when it comes to financing innovation. The effect is assumed to get even stronger when more risky R&D projects are undertaken. Further, economies of scale in R&D can put larger firms at an advantage to small ones and returns from R&D are argued to be present when the fixed costs can be spread over more sales. Complementarities to other products such as marketing activities that are conducted large scale in large companies are also thought to increase the productivity of R&D. Another aspect is the enforcement of IP rights: Given the rise in IP infringement disputes and their extremely high costs, larger firms may also be at an advantage when it comes to securing profits from innovation. This aspect has been considered by Lanjouw and Schankerman (2004).

Counterarguments to the positive effect of firm size on innovation can also be found in the literature. Scherer and Ross (1990) argue that in large firms R&D may get less efficient because managers lose control of the ongoing activities. A too high degree of bureaucracy may distract researchers from their core activities and individual incentives may fade when individual performance is not well monitored and compensated (Sah and Stiglitz 1986).

The question on whether incumbent firms or entrants have higher incentives to innovate has been investigated both theoretically and empirically. In order to demonstrate different forces working against each other in determining the innovation incentives of incumbents versus entrants we consider a formal model. The basic model of a memoryless patent race demonstrates the famous efficieny and replacement effect. In this simple model (e.g Dasgupta and Stiglitz (1980), Lee and Wilde (1980), Reinganum (1983) two firms compete in R&D activities (monopolist and entrant) and the first to innovate gets a patent. The question which of the 2 firms spends more on R&D and is thus more likely to innovate and get the patent depends on the efficiency and the replacement effect. The efficiency effect predicts that the monopolist has more incentives to innovate as he wants to avoid competition. Gilbert and Newbery (1982) note that the monopolist may even want to get a patent on an innovation that he will eventually not use as it is inferior to its own technology. The mere incentive to obtain a patent is to deter entry of a competitor. The replacement effect states that the marginal productivity of R&D expenditures of the monopolist decreases with his initial profit. By increasing his R&D expenditures the monopolist speeds up his own replacement, while a potential entrant does not have such a thing as foregone profits. Which of the two effects dominates, and consequently whether the monopolist or the entrant have higher incentives to innovate, depends on the type of innovation. In case of a drastic innovation that will confer monopoly power to the innovator as it significantly reduces marginal costs the incumbent monopolists is concerned about the replacement effect (the efficiency effect does not exist), and thus entry is likely. In case of an incremental innovation the monopolist will be more concerned with the efficiency effect such that he spends more on innovation and the entrant has comparatively lower incentives to innovate (Reinganum 1983). Klepper (1996) stresses that the incentives of entrants and incumbents to innovate depend on the stage in the industry's life cycle: In the early stages of an industry life cycle there is a lot of entry and product innovations exceed process innovations. In later stages then entry reduces and some major firms are established, such that entry becomes more difficult. In this stage the innovations switch to more process innovations than product innovations.

There are different types of innovation outcomes that are usually distinguished as product, process, organizational and marketing innovations. The nature of an innovation can further be classified as a so-called drastic or disruptive, or an incremental innovation. Drastic innovations are characterized as leading to a completely new type of production process with a wide range of applications. Henderson and Clark (1990), Henderson (1993), Baumol (2002) suggest that small firms and particularly new firms are more capable of generating more significant and drastic innovations than incumbents as they are not worried about safeguarding existing market positions (Schneider and Veugelers 2010, p. 970). Incumbents on the other hand are shown to pursue more incremental and process-oriented innovations. Schneider and Veugelers (2010) refer to these differences as “division of labor between entrants and incumbent firms with respect to innovation”.

The classification of sustainable innovations as a certain type of innovation is not straightforward. In their study „Measuring Environmental Innovation“ Kemp and Pearson have adopted the following definition: “Eco-innovation is the production, application or exploitation of a good, service, production process, organizational structure, or management or business method that is novel to the firm or user and which results, throughout its life cycle, in a reduction of environmental risk, pollution and the negative impacts of resources use (including energy use) compared to relevant alternatives" (Kemp and Pearson 2007). Rammer and Rennings (2010) highlight an important characteristic of environmental innovations. The innovation has to be novel only for the firm that introduces it, but not necessarily new to the market or the world. This means that an environmental innovation does not have to be drastic, but can also be an incremental innovation. De Marchi (2012, p. 615) summarizes the major points that differentiate eco-innovations from other types of innovations:

"So far, the literature, especially neoclassical contributions, has focused mainly on two aspects that differentiate them from other innovations, which regard their externalities and drivers – what Rennings (2000) named the "double externality problem" and the "regulatory push/pull effect". As it has been widely discussed in the general innovation literature – the literature on innovation that do not focus specifically on the environmental one – innovation and R&D activities are characterized by positive externalities: the incentive for firms to invest in them lessen as they cannot fully appropriate the value created, because of knowledge spillovers that benefit other firms. In addition, green innovators produce also an environmental positive externality. Since part of the value created is appropriated by society – in the form of reduced environmental damage – rather than by the firms that invested in cleaner technologies, which bear higher costs than polluting competitors, there is a disincentive for firms to invest in products or process that reduce environmental impacts (see Rennings, 2000; Jaffe et al., 2005). The market-failure derived by the interaction of those two externalities induces a second peculiarity of ecoinnovations: the greater importance of the policy intervention to drive their introduction (Rennings, 2000)."

Research on eco-innovation has therefore put a strong emphasis on the role of environmental regulation and policies in the development of eco-innovations (e.g. Porter and Van der Linde 1995).

2.2 Empirical Literature

The empirical literature on the drivers of environmental innovation is rather limited. It can be classified into contributions examining the role of external regulation in the introduction of eco-innovations and contributions focusing on firm-level drivers. Del Rio Gonzales (2009) provides a literature review and proposes a research agenda for this topic. De Marchi and Grandinetti (2012) survey the literature on firm level drivers of environmental innovation. We will focus on a few selected studies in this area of research that provide answers with respect the role of small and young companies in the generation of environmental innovations.

Regarding firm size Hemmelskamp (1999) has used data from the Mannheim Innovation Panel and found that environmental innovation is more frequent in very small or very large companies, but less important for medium-sized com-panies. He gives two possible explanations for this result: While small firms are more likely to invest in niche markets, eco-innovations in larger firms are driven by stronger monitoring by both the consumers and state environmental bodies.

De Marchi (2012) has found firm size to positively affect the likelihood of introducing an environmental innovation for data from the Spanish CIS. Using Italian CIS data De Marchi and Grandinetti (2012) also find a positive influence of firm size on the propensity to introduce environmental innovations. They additionally show multinationals, with headquarters abroad to be more likely to introduce environmental innovations. Being an exporting firm does not have a significant impact. R&D expenditures are shown to have a positive impact. Horbach et al. (2012) have used German CIS data to test whether different types of eco-innovations are induced by different factors. They find government regulation to be determinants for the reduction of air, water, or noise emissions, and the use of hazardous substances. Reductions of energy and material use are rooted in cost saving motives. With respect to firm size they find a positive impact on environmental innovations, but age does not show to have a significant effect. Interestingly, they find probable market entries of new competitors to positively affect the propensity to generate environmental innovations.

Regarding the drivers of patenting of eco-innovations the literature is even more limited, which is why we first review some of the literature on firm level drivers of patenting in general. For all of these studies it needs to be kept in mind that patented inventions are by definition new to the world and cover only those inventions that are patentable, with large differences in patenting rates across technologies. In addition to this firms can prefer to use alternative modes of intellectual property protection, such as secrecy. Patents thus only represent a subset of all types of innovations and environmental patents consequently cover only a subset of all environmental inventions.

Lotti and Schivardi (2005) use a match of European Patent Office applications to the firm database AMADEUS from 1978-2000 for the EU-15 countries and estimate a two-step-model with propensity to patent in the first stage and the number of patents in the second stage. They find that firm size has a positive impact on the likelihood to patent, but that the number of patents per employee decreases with firm size.

Helmers and Rogers (2009) study the patenting activity of the population of UK firms for 2000-2007 and focus on the role of small and micro firms. They find that “the combined patenting activity of micro and SMEs is around the same as that from large firms” (Helmers and Rogers 2009, p.24), suggesting that small and micro firm play a larger role in innovation than suggested by R&D data.

Garcia and Foray (2010) use CIS 3 data (2000) for 7 countries to identify a firm's minimum size needed to patent protect an innovation. Based on the argument that the costs associated with patent protection may be too high for smaller firms, the authors estimate threshold values for the different countries, showing that for several economies the threshold is lower than expected and lies between 40-50 employees.

Fernández-Ribas (2010) analyzes the population of U.S.-owned small (<=500 empl.) and large businesses with patent applications at the World Intellectual Property Organization 1996–2006 in the field of nanotechnology. She finds 37% of global patent applications to be held by SMEs and traces an increase of both share and absolute numbers over time. She further shows that patents by small firms are more domestically embedded than those of larger firms and that they are characterized by fewer backward citations, which is interpreted as being more novel.

Mogee (2009) shows that small firms file their patents outside the US less often than larger firms (1/3 for small firms and 1/2 for large firms).

Belenzon and Patacconi (2012) use a database consisting of Amadeus, EPO patents and publications from the ISI web of science to investigate how a firm’s ability to appropriate the returns from patents and publications as measure for innovation is affected by firm size. They find the relationship of performance with patents to be stronger for small firms, especially in dynamic industries.

A few contributions have examined the drivers of “green” patenting. Brunnermeier and Cohen (2003) study how environmental patenting by US manufacturing industries was affected by changes in pollution abatement expenditures and regulatory enforcement from 1983 to 1992. They find a positive effect for increases in pollution abatement expenditures, but no effect with respect to increased monitoring and enforcement activities for existing regulations. Their results further indicate that industries that are internationally competitive to be more likely to generate environmental patents.

Nameroff et al (2004) use green chemistry patents as an indicator for environmental innovation and provide statistics on how revisions in major US environmental laws in the late 1980s and early 1990s coincide with growth in green chemistry patenting. They do however conclude that, since the overall share of green chemistry patents compared to other chemistry patents is low, the role of green chemistry in responding to new regulations was limited.

3. Overview and Trends of Patent Applications at the EPO on Country Level

3.1 Dataset

In order to identify inventions this project relies on the concept of patent applications. We use all patent applications at the European Patent Office from 1990 to 2007, which we have retrieved from the patent database PATSTAT, Version Spring 2013. Patent applications at the EPO are often used in international comparisons as relevant patents are generally filed at the EPO and as the maintenance of the data by the European Patent Office ensures a high quality. The focus is on patent applications – not on granted patents – since we are interested in the entire research effort put into sustainable technologies and not the number of patent rights eventually granted.

The classification of inventions as sustainable and smart is based on the WIPO Green Inventory. In 2010 the World Intellectual Property Office (WIPO) has released this tool for searching and retrieving patent documents related to green technologies, i.e. the development and transfer of so-called Environmentally Sound Technologies (ESTs) for adaptation to climate change as outlined by the United Nations Framework Convention on Climate Change (UNFCCC). The WIPO Green Inventory classifies patents in seven Green Technology Classes on the basis of the IPC classification of the patent (green patents). Table 1 summarizes the seven technology areas and their contents.[1] There are some overlaps regarding the assigned IPC classes. Thus, the aggregation of the number of patent applications within the individual technology classes exceeds the number of green patent applications. Compared to the tagging system introduced by the EPO to identify sustainable technologies (known as the Y section), the WIPO classification has the advantage that it does not mainly focus on energy generation but also on energy efficiency in the energy use.

Patent applications are counted in the year in which the application was filed at the EPO. The regional classification is based on the country of the patent applicant. In case of more than one applicant, we apply fractional counting[2]. We consider the following countries and country groups: EU-27 – divided into Germany, France, UK/Ireland, Rest Western Europe, Southern Europe, Northern Europe, New Member States –, Japan, South Korea, China, US, World (for a detailed overview see Table 12 in the appendix).

Besides the simple count of patent application, we also count triadic patents- patents that have been applied for at the European Patent Office, the US Patent Office and the Japanese Patent Office- as these are often considered to capture the more valuable set of patents. See Grupp and Schmoch (1999) for more details.

Table 1 WIPO Green Inventory Classification

WIPO Green Inventory Technology Class	Contents
Alternative Energy Production	▪ Bio-fuels ▪ Integrated gasification combined cycle (IGCC) ▪ Fuel cells ▪ Pyrolysis or gasification of biomass ▪ Harnessing energy from manmade waste ▪ Hydro energy ▪ Ocean thermal energy conversion (OTEC) ▪ Wind energy ▪ Solar energy ▪ Geothermal energy ▪ Other production or use of heat, not derived from combustion, e.g. natural heat ▪ Using waste heat ▪ Devices for producing mechanical power from muscle energy
Transportation	▪ Vehicles in general ▪ Vehicles other than rail vehicles ▪ Rail vehicles ▪ Marine vessel propulsion ▪ Cosmonautic vehicles using solar energy

[1] An overview of the IPC assigned to each of the seven technology classes can be found on the WIPO webpage (http://www.wipo.int/classifications/ipc/en/est/).

[2] Fractional counting means that a patent applied for one applicant from Spain and one from Italy is assigned to both countries as ½ patent.

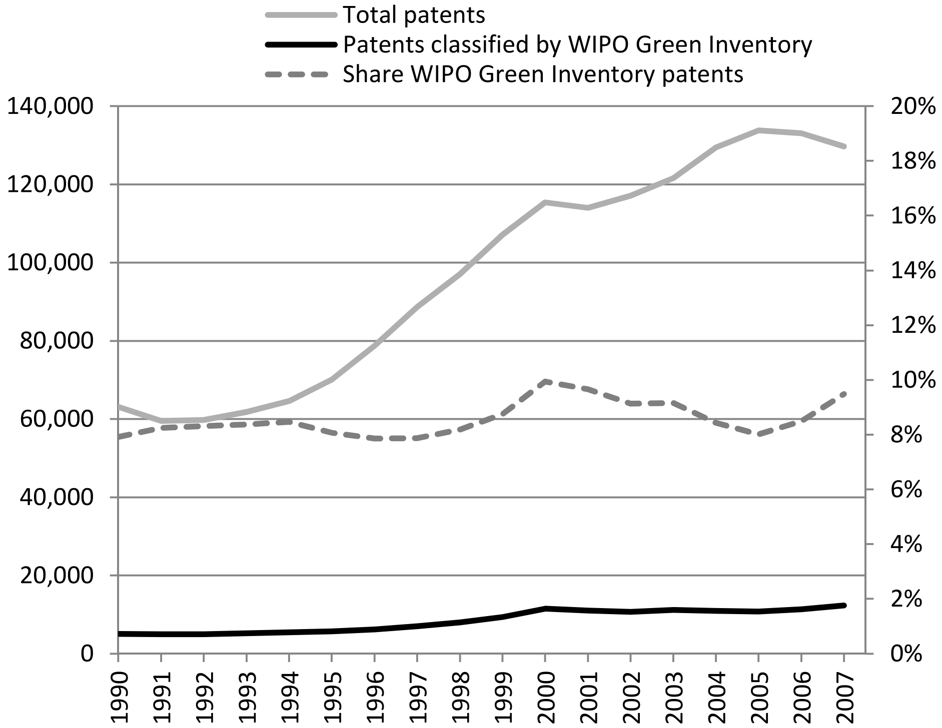
Energy Storage	▪ Storage of electrical energy ▪ Power supply circuitry ▪ Measurement of electricity consumption ▪ Storage of thermal energy ▪ Low energy lighting ▪ Thermal building insulation, in general ▪ Recovering mechanical energy
Waste Management	▪ Waste disposal ▪ Treatment of waste ▪ Consuming waste by combustion ▪ Reuse of waste materials ▪ Pollution control
Agriculture/Forestry	▪ Forestry techniques ▪ Alternative irrigation techniques ▪ Pesticide alternatives ▪ Soil improvement
Administrative, Regulatory and Design Aspects	▪ Commuting, e.g., HOV, teleworking, etc. ▪ Carbon/emissions trading, e.g. pollution credits ▪ Static structure design
Nuclear Power Generation	▪ Nuclear engineering ▪ Gas turbine power plants using heat source of nuclear origin

Source: http://www.wipo.int/classifications/ipc/en/est/.

3.2 Overall importance of WIPO Green Inventory classified patent applications at the EPO

The number of green patent applications at the EPO, i.e. WIPO Green Inventory classified patent applications, increased by the factor 2.5 between 1990 and 2007, from almost 5,000 in 1990 to 12,300 in 2007 (Figure 1). The number of all patent applications more than doubled during the same time period. Correspondingly, the share of green patent applications in all patent applications at the EPO is rather constant and varies between 8 and 10 percent during this time period. One in ten patent applications at the EPO is green in 2007.

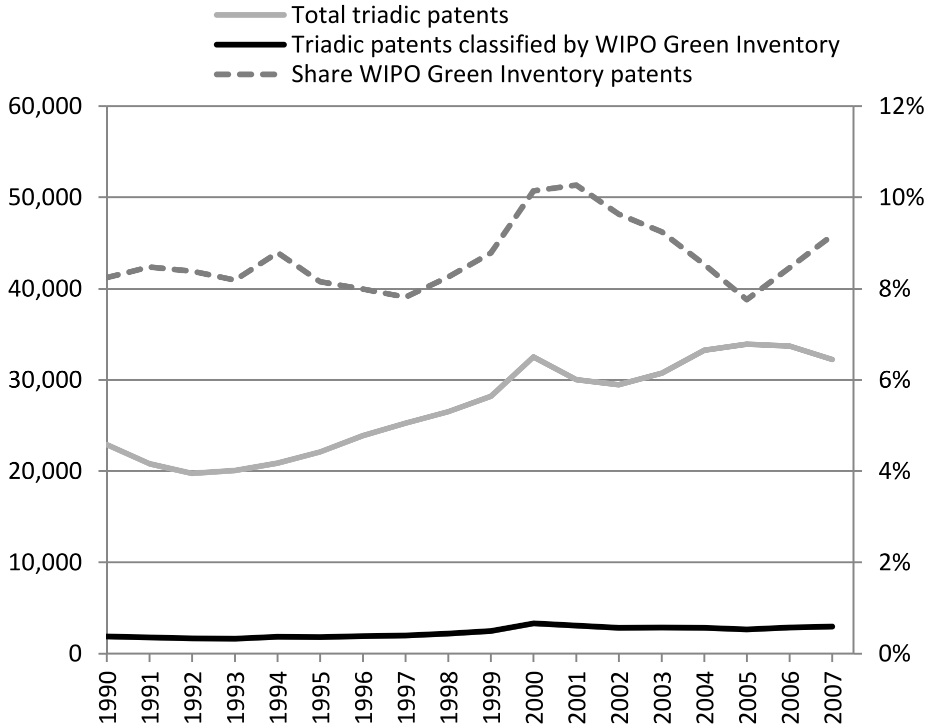
Figure 1 **All patent applications and WIPO Green Inventory classified patent applications at the EPO, 1990-2007**



Source: EPO Worldwide Patent Statistical Database (PATSTAT). Calculations by ZEW

Triadic patent applications grow less than overall patent applications between 1990 and 2007. In 2007, the number of triadic patent applications is 1.4 times higher than in 1990; the number of triadic patent applications in green technologies is almost 1.6 times higher. Similar to all patent applications, the share of green patent applications in all triadic patent applications varies between 8 and 10 percent during 1990 -2007.

Figure 2 **All triadic patent applications and WIPO Green Inventory classified triadic patent applications at the EPO, 1990-2007**



Source: EPO Worldwide Patent Statistical Database (PATSTAT). Calculations by ZEW

The importance of WIPO Green Inventory classified patent applications within regions

Overall, the importance of green patent activities does not greatly vary between different regions. In 2007, the share of green patent applications in all patent applications at the EPO lies between 7 and 12 percent in the considered regions (Table 2). Interestingly, the new member states and southern Europe are at the upper end of the range (12 % and 10%, respectively) - besides Japan (11%) and the US (10%). The share of green patents increases up to 16 percent during the mid-nineties and at the beginning of the new century. Green patents are slightly less important for Northern Europe and China (both 7%). Focusing on more valuable patents, green technologies become more important in Germany, Korea and China and lose importance in Southern Europe (Table 3).

Table 2 **Share of WIPO Green Inventory classified patent applications in all patent applications at the EPO, per region and year (in %)**

	Year																	
Region	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
EU27	9	9	9	9	9	8	8	8	8	8	9	9	8	8	8	8	8	9
DE	9	10	10	10	10	9	9	8	8	8	9	9	9	9	8	8	9	9
FR	9	8	8	8	8	7	7	7	7	8	7	8	7	7	7	6	7	8
UK/Ireland	7	8	8	8	8	8	8	8	8	8	10	10	9	9	10	8	9	9
Rest Western Europe	8	9	8	8	7	6	9	8	8	8	9	10	8	8	7	8	8	9
Southern Europe	6	7	5	7	6	6	5	6	6	6	7	8	7	8	7	8	9	10
Northern Europe	10	10	9	10	10	7	7	7	6	8	8	7	7	7	7	6	7	7
New Member States	9	16	8	13	15	14	14	10	8	9	14	16	13	10	10	10	10	12
JP	6	6	7	7	8	8	8	8	9	10	12	12	11	11	9	9	10	11
KR	4	5	4	9	8	8	7	5	7	8	11	8	8	9	8	7	6	8
CN	4	15	11	7	11	11	8	13	5	8	11	7	8	6	8	6	6	7
US	8	8	8	8	8	8	8	8	9	9	11	10	10	10	9	8	8	10
World	8	8	8	8	8	8	8	8	8	9	10	10	9	9	8	8	8	9

Source: EPO Worldwide Patent Statistical Database (PATSTAT). Calculations by ZEW

Table 3 **Share of triadic WIPO Green Inventory classified patents in all triadic patent applications at the EPO, per region and year (in %)**

	Year																	
Region	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
EU27	9	9	9	9	9	8	8	8	8	9	9	10	9	8	8	8	9	9
DE	9	9	9	9	10	9	9	9	9	9	9	10	10	9	9	9	10	11
FR	11	10	10	9	8	9	7	8	8	8	7	8	8	9	7	8	7	8
UK/Ireland	8	8	10	9	9	9	8	7	9	9	11	11	9	9	8	8	9	8
Rest Western Europe	6	8	8	8	7	6	8	9	9	9	9	11	8	7	7	7	8	8
Southern Europe	5	8	5	6	6	5	5	4	6	7	7	6	7	7	7	7	10	7
Northern Europe	8	11	9	9	9	6	8	7	6	7	10	8	7	6	6	5	7	6
New Member States	6	4	4	12	9	18	4	8	9	16	19	15	8	6	8	5	4	13
JP	7	7	7	8	9	9	8	8	8	9	11	12	11	11	9	8	9	10
KR	1	6	4	10	7	8	4	5	7	7	11	9	8	9	9	8	9	11
CN	14	0	19	7	0	24	11	9	2	7	9	10	7	4	10	9	9	9
US	9	9	8	8	8	7	7	7	8	8	11	10	11	10	9	6	8	10
World	8	8	8	8	9	8	8	8	8	9	10	10	10	9	9	8	8	9

Source: EPO Worldwide Patent Statistical Database (PATSTAT). Calculations by ZEW

3.3 Importance of individual technology classes within WIPO Green Inventory classified patent applications at the EPO

The importance of the individual technology classes for WIPO Green Inventory classified patent applications

The WIPO Green Inventory differentiates between seven technology classes. In 2007, the most active areas are alternative energy production with 26% of all green patent applications, energy storage (21%), and waste management (19%, Table 4). Administration, agriculture/forestry and transportation contribute between 8 and 14 percent to green patent applications at the EPO. Patent applications within the area of nuclear power generation are negligible (1%). The number of patent applications in 2007 outnumbers the patent applications in 1990 in all green technology classes except in nuclear power generation. Administration, transportation and alternative energy production exhibit the highest growth. Thus, the relative importance of waste management decreased during the period 1990-2007, while the importance of alternative energy production increased. Basically, the same pattern applies for triadic patent applications within these technology classes. Again, the growth is much smaller if the focus is only on triadic patent applications at the EPO - compared to all EPO patent applications (Table 17 **Triadic WIPO Green Inventory classified patents**).

The importance of the individual technology classes for WIPO Green Inventory classified patent applications across regions

Table 5 displays for each region, the relative importance of the different green technology areas within the overall number of green patents. We find the distribution for Europe to be quite similar to the overall distribution of green patents, with a slightly higher focus on waste management and a lower share of administration patents in the overall number of green patents. Within Europe Germany exhibits the highest share in green agriculture patenting, whereas France, as can be expected, exhibits the highest share in the nuclear power technology.

Table 4 **Total WIPO Green Inventory classified patent applications at the EPO, by year and technology class**

	Technology						
Year	Alternative Energy	Transportation	Energy Storage	Waste Management	Agriculture	Administration	Nuclear Energy
1990	965	259	1,228	1,752	892	314	198
1991	1,004	286	1,201	1,732	849	281	209
1992	1,093	294	1,187	1,834	776	310	167
1993	1,116	294	1,294	1,906	798	334	166
1994	1,118	337	1,365	1,941	785	496	155
1995	1,219	370	1,367	1,880	871	542	149
1996	1,280	451	1,512	1,990	898	691	137
1997	1,489	511	1,801	2,179	898	891	111
1998	1,810	625	1,961	2,318	965	1,153	117
1999	2,058	664	2,312	2,439	996	1,948	117
2000	2,520	778	2,585	2,703	931	3,157	107
2001	2,668	759	2,642	2,507	1,031	2,510	122
2002	2,720	848	2,666	2,488	979	2,035	112
2003	2,829	925	2,861	2,592	973	2,019	100
2004	2,667	827	2,783	2,509	1,138	1,817	98
2005	2,686	776	2,547	2,429	1,190	1,840	116
2006	3,000	920	2,715	2,553	1,227	1,773	123
2007	3,508	1,078	2,869	2,574	1,331	1,915	134

Source: EPO Worldwide Patent Statistical Database (PATSTAT). Calculations by ZEW

Table 5 **Percent of all green patents belonging to particular green technology class, 1990-2007, by region**

Region	Alternative Energy	Transportation	Energy Storage	Waste Management	Agriculture	Administration	Nuclear Power
EU27	23	6	23	32	13	12	2
DE	24	6	22	32	16	8	1
FR	22	8	22	34	10	13	5
UK_Ireland	20	4	20	31	14	18	1
Western_Europe	20	4	31	31	8	15	1
Southern_Europe	26	12	21	33	8	11	1
Northern_Europe	26	5	20	33	6	20	2
Eastern_Europe	26	6	21	38	9	14	0
JP	28	12	29	23	6	12	1
KR	30	7	39	14	4	13	1
US	21	5	23	23	13	24	2
CN	30	15	24	20	8	17	0
World	24	7	24	27	12	16	2

Source: EPO Worldwide Patent Statistical Database (PATSTAT). Calculations by ZEW. Note that the rows do not sum up to 100 percent due to the fact that a patent can be classified to belonging to several of these technology areas at the same time.

3.4 Stylized facts by technology class and country

This part of the analysis considers each technology class, and all patents belonging to at least one of the WIPO Green inventory classified technology classes at the country level. We consider four different indicators and display them for two time periods, 1990-1999 and 2000-2007. The tables can be found in the appendix. The “sum” indicator sums up all patents in the particular technology class considered by time period and country. “Share” indicates the country’s share in the overall patent applications of the considered technology field. “Growth” denotes the average annual growth rate in the particular technology and country for the two time periods.

The specialization index RPA (Revealed Patent Advantage) is defined as (Frietsch and Jung 2009):

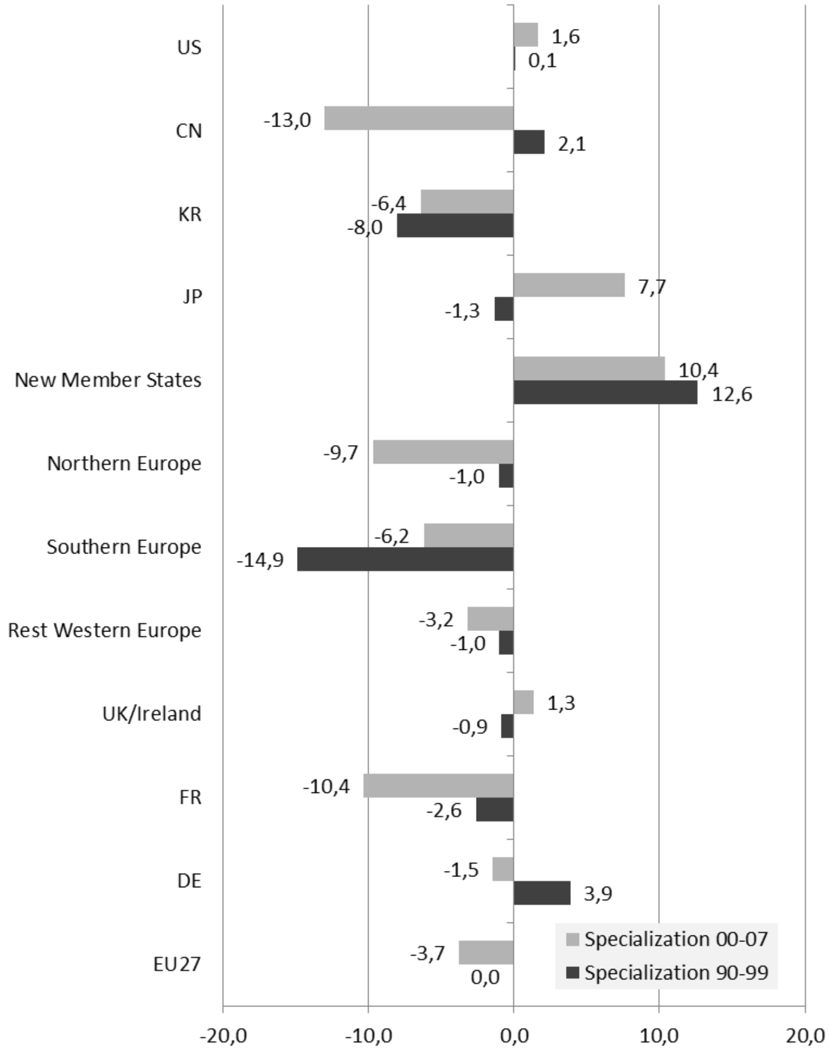
$$RPA_{kj} = 100 * \tanh \ln [(P_{kj}/\Sigma j\ Pkj)/(\Sigma_k P_{kj}/\Sigma_{kj} P_{kj})]$$

with P_{kj} indicating the number of patent applications of country k in the technology field j. It is bounded between -100 and +100. Positive values indicate that the technology has a higher weight in the portfolio of the country than its weight in the world (all applications from all countries at EPO). Negative values then indicate specializations below the average.

All WIPO Green Inventory classified patent applications at the EPO

We start by considering the population of “green patent applications” at the EPO (Table 16). The EU27 was responsible for 44 percent of all “green” patent applications at the EPO between 1990 and 1999. The share reduced to 39 percent between 2000 and 2007. Within Europe Germany was the major contributor to the “green” patenting activity with a share of 17 percent of all “green” patent applications at the EPO. The reduction of the share of Europe in the global production of green patents came along with an increase of the contribution by Japan (from 18 percent to 21 percent), Korea (from 1 to 2 percent) and China (from 0 to 1 percent). The average annual growth rates in “green patenting” was 7 percent between 1990 and 1999 and has reduced to 4 percent between 2000 and 2007. The strongest growth can be found for the new EU member states, China and South Korea. With regard to the specialization index Figure 3 displays the specialization in “green” patenting for selected regions for the two considered time periods. From 1990 to 1999 European patent applications at the EPO as a whole were specialized to the same degree as the entire population of “green” applications at the EPO. Compared to this average specialization Germany was slightly specialized in “green” patenting. The strongest specialization could be found for the new member states with a specialization of +12.6. In 2000-2007 Europe as a whole has lost its specialization in green patenting, with all countries besides UK/Ireland and the new member states exhibiting a negative specialization. The countries specialized above average in “green” patenting in 2000-2007 are the new member states, Japan, the United States and UK/Ireland. When narrowing down the “green patents” to the triadic “green patents” (Table 17) however, this impression changes: The positive relative specialization of the new member states turns negative, the specialization of the United States and UK/Ireland, as well as to some degree Japan, fades. At the same time Germany now exhibits an above average specialization in "green" patenting[3]. Interpreting triadic patents as a correlate for patent quality, we find that, while exhibiting a strong specialization and growth, "green" patenting by the new member states does not (yet) come along with an increase in high quality.

Figure 3 **Specialization index for WIPO Green Inventory classified patent applications**



[3] Overall, triadic patenting by the United States has dropped significantly between the two observed time periods, while overall US patenting has increased. See Table 15 for details. The reasons behind this may be a drop in the quality of US patents or a change in patent application strategies (particularly with respect to Japan) by US companies.

"Alternative Energy" patent applications at the EPO

Turning to the green patents classified as alternative energy patents by the WIPO (Table 18) we find slightly higher growth than for the overall green patents with a 9 percent average growth rate for 1990-1999 and a seven percent average growth rate for 2000-2007. With respect to specialization we find EU27 to be slightly below average in 1990-1999 and exacly at the average in 2000-2007. Germany moves from a specialization below the average to +2 in 2000-2007. The countries least specialized in alternative energy patenting are the United States and the rest of Western Europe.

"Green Transportation" patent applications at the EPO

Green patenting in the area of "green transportation" (Table 20) is mainly driven by the EU27 countries (38 percent in 1990-1999 and 35 percent in 2000-2007), Japan (29 and 36 percent) and the United States (25 and 19 percent).The average annual growth rate was high in 1900-1999 with 11 percent and has dropped to 7 percent in 2000-2007. The highest relative specialization can be found for Japan and Southern Europe, followed by France.

"Energy Storage" patent applications at the EPO

Table 22 displays the development of energy storage patenting across the world. While growth was high between 1990 and 1999 (8 percent) it slowed down in 2000 to 2007 (3 percent). The regions most specialized above average in 2000-2007 are the rest of Western Europe (+42), South Korea (+35), the new member states (+23), and the United States (+13).

"Green Waste Management" patent applications at the EPO

In the area of waste management growth also slowed down from an average annual growth rate of 4 percent to 1 percent in 2000-2007 (Table 24). The EU27 states are highly specialized in waste management patenting with a specialization indicator of +10 in 2000-2007. The comparison countries United States, China, South Korea and Japan all exhibit a below-average specialization in this field.

"Green Agriculture" patent applications at the EPO

Table 26 displays the development of "green agriculture" patenting across the world. We find Germany and the United States to be specialized above average while all other considered regions can be found below average. When narrowing down the analysis to triadic patents the degree of specialization of Germany increases even more, while the degree of specialization of the Unites States drops.

"Green Administration" patent applications at the EPO

About half of all "green administration" patents originated from the United States in 1990-1999, which then exhibited an above-average degree of specialization of +21. Northern Europe, though only patenting 5% of the overall “green administration” patents was even more specialized with a specialization index of +40. The specialization of the Eu27 countriess as a whole was considerably below average with a value of -21, with Germany even reaching -50 (Table 28). After a very high average annual growth rate of 24 percent from 1990 to 1999, growth slowed down to 4 percent in 2000-2007. During this time period the Unites States lost part of their relative specialization while UK/Ireland, the rest of Western Europe, the new member states and most considerable China and Japan have increased their degree of specialization in “green administration”.

“Nuclear Power” patent applications at the EPO

With only two percent of nuclear power patent applications make up the smallest share of “green” patent applications at the EPO. The highest degree of specialization can be found for the EU27 countries and here particularly for France with a specialization of +55 from 2000-2007.

4. SME and Young Firms Contribution to Patenting in Sustainable Energy Fields - The Case of Germany

4.1 Dataset

The core question of this paper is to which extent small and young firms contribute to the development of sustainable technologies. To investigate this question, characteristics of the applicants such as size and age are necessary. This information can be retrieved by linking the patent database with a firm database. ZEW has established this link for Germany using the Mannheim Enterprise Panel (MUP) and PATSTAT. The Mannheim Enterprise Panel is a panel database of firms located in Germany. The panel is based on data produced by Creditreform, Germany’s largest credit rating agency. Creditreform provides this data on a half-yearly basis since 2000. The database comprises about 3.1 million firms per year which is virtually the population of active companies in Germany. The matching of the Mannheim Enterprise Panel to the patent database PATSTAT has been executed via a heuristic match of the names and addresses of the companies to the names and addresses of the patent applicants. The result of the algorithm was a list of potential assignments of firm names to patent applicants, which then was checked manually. As a result, we have a comprehensive panel of firms located in Germany covering the period 2000 to 2007.[4] The dataset includes both firm characteristics and yearly EPO patent information.

[4] The Manheim Enterprise Panel provides data since 2000 while PATSTAT covers patent applications up to 2007. Patent applications for 2008 are not completely covered yet.

We use the database for analyses at the patent level as well as the firm level with a special focus on firm size and age. For this purpose, the firms are divided into four size classes according to the number of employees and whether the firm is part of an enterprise group. The classification corresponds to the categories regarding staff headcount by the European Commission[5]. Micro enterprises employ fewer than 10 persons. Small firms have between 10 and 49 employees and medium-sized firms between 50 and 249 employees. Firms with 250 or more employees are defined as large firms. If a firm belongs to an enterprise group it is classified as a large firm. Firms up to eight years old are defined as young firms. Firm size is missing for 25 percent of the firm-year observations. Thus, 2 percent of the patent applications cannot be classified according to the applicant's size. An overview of the firm-level dataset regarding firm size, age and year of observation is presented in Table 32 in the appendix.

In a first step we look at the patent applications at the EPO by firms located in Germany and present firm characteristics of the applicants. This analysis is based on 149.474 patent applications[6]. These patent applications have been made at the EPO between 2000 and 2007 by 13.709 different applicants located in Germany. The applicants are classified as private firms; information on firm size and age as well as IPC codes of the patent applications are available. In a second step, we analyze the probability of green patenting at the firm level.

12.921 patent applications (8.6%) are green patent applications (WIPO Green Inventory classified patent applications). The share of green patents is constant over the two time periods 2000-2003 and 2004-2007. 36.593 of all patent applications (24%) are triadic patents. The share of green triadic patents is slightly higher than the share of green patents in all patent applications. One in ten triadic patent applications linked to a green technology (10.3%).

4.2 Analyses at patent level

Figure 4 displays the share of patents applied by SMEs and young firms in all patent applications of German firms at the EPO. We find SMEs to be responsible for about 15% of all patent applications. This is the same for the WIPO Green Inventory classified patents (green patents).). Around half of patent applications of SMEs are made by young firms (firms up to 8 years old).

Micro firms, i.e. firms with less than 10 employees, play an important role. About one half of all patent applications by SMEs are filed by micro firms (Table 34).

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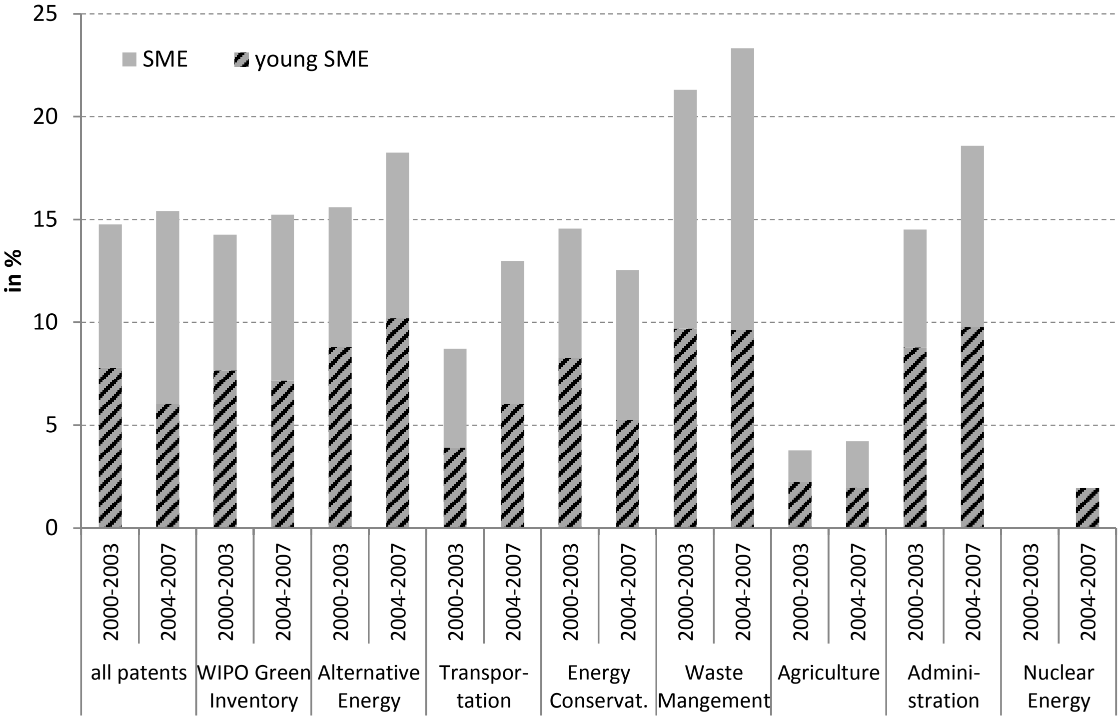
[5] http://europa.eu/legislation_summaries/enterprise/business_environment/n26026_en.htm

[6] A patent is counted several times if it has been applied for by multiple firms. The number of unique patents is 142.026. The difference between the 176.829 applications retrieved from the country level analysis is due to the fact that we only consider applications by German firms in this part of the analysis, ignoring applications by individuals as well as by universities and research institutes.

The share of patents applications of SMEs varies with technology class. While in waste management the share of SMEs is relatively high, SMEs are less active in transportation, agriculture and particularly nuclear power generation, where no patent is filed by SMEs between 2000 and 2003 and only 2 patents are filed by SMEs between 2004 and 2007.

The share of young SMEs in all SMEs patent applications is 53 for all patent applications between 2000 and 2003 and reduces to 39 percent in 2004 to 2007. In the green patenting area the share of young SMEs in all SMEs patent applications is also 53 in 200-2003, but reduces less strongly to 46% in 2004 to 2007.

Figure 4 **Share of patents applied by SMEs and young firms in all patent applications of German firms at the EPO, by field and time period**

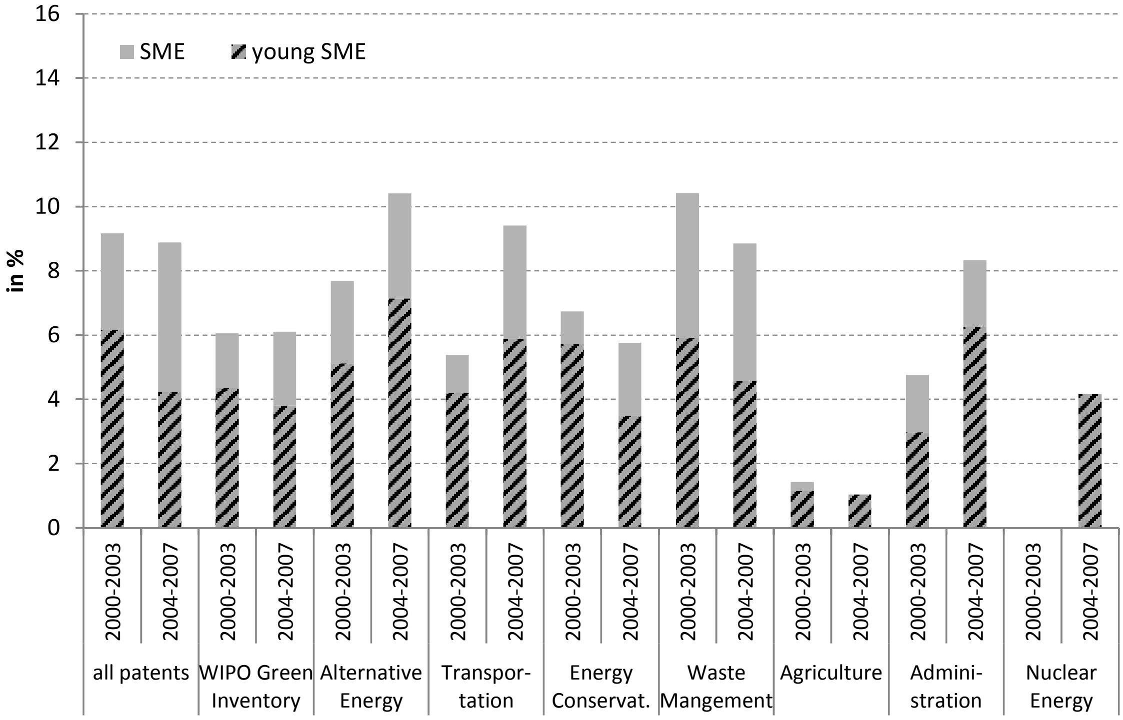


The relative contribution of SMEs to more valuable patent applications (measured by triadic patent applications) is smaller than their contribution to all patent applications at the EPO.

Figure 5 shows that while the SME share in overall patenting is 15 percent it is only about 9 percent in the population of triadic patents. This is even more severe for green patent applications, where the SME share is only 6 percent. This low share is to a large extent driven by the very low SME participation in agriculture and nuclear power patenting. In triadic patents, none of the technology areas considered reaches an SME share considerably above the average across all patents.

To summarize, we find the relative contribution of SMEs to green patenting to be similar to their overall contribution to patenting. When controlling for the value of the patents, the contribution of SMEs to green patents even decreases below their contribution across all technology areas.

Figure 5 **Share of triadic patents applied by SMEs and young firms in all triadic patent applications of German firms at the EPO, by field and time period**



4.3 Analyses at firm level

In a first step we provide descriptive insights into the importance of green patenting by investigating the likelihood and intensity of applying for green patents. Secondly, we analyze effect of firm size and age regarding the probability of patenting in a multivariate context.

4.3.1 Descriptive analyses

Overall, patenting is a rare event. The probability of applying for a patent in a year is 0.15 percent.[7] The likelihood that a firm applies for a green patent is around 0.02 percent. The probability of patent applications increases with firm size. While 0.04 percent of micro firms apply for patents, almost 5 percent of large firms apply for patents - which is still rather low in absolute terms. Around 60 percent of the micro firms with patent applications are young firms. The share is slightly lower for all patent applications (58%) than for green patent applications (61%).

Table 6 **Share of firms with patent applications at the EPO (in percent)**

	Probability of applying for a…	
Size class	patent	green patent
micro	0.04	0.00
small	0.24	0.03
medium	1.52	0.12
large	4.68	0.81
total	0.15	0.02

If we compare the distribution of firms with patent applications, large firms are relatively more important for green patent applications than for all patent applications. 61 percent of firms with green patent applications are large while this share is 49 percent regarding firms with any patent applications.

Table 7 **Distribution of firms with patent applications at the EPO by size class (in percent)**

Size class	Patent application	Green patent application
micro	21.3	19.5
small	14.4	11.2
medium	15.5	8.5
large	48.8	60.9
total	100.0	100.0

In a next step we consider the intensity of patenting given that a firm applies for patents at all. The 2 left columns in Table 8 show the average number (and median) of patent applications given that a firm patents. On average, a patenting firm in a given year applies for 5.3 patents. The median however is 1, which reveals the highly skewed distribution. Differentiating between

[7] The probability of patent applications for firms with missing size information is 0.02. If we also consider these firms, the overall probability of applying for a patent decreases to 0.12 percent. The probability of applying for a green patent remains 0.02.

size classes we find, as expected, large firms to have the highest average number of patents. The differences between medium, small and micro firms are very small, with micro firms even having a higher average number of patents than small firms. When turning to the probability of applying for a green patent (column 3), given at least one patent application, large firms have the highest likelihood of having a green patent among their patent applications (17.4%). Interestingly, micro firms have the second highest probability of applying for a green patent. Conditional on applying for green patents the number of green patents is 3.3 on average, 4.6 for large firms, 1.4 for medium-sized firms and 1.2 for small and micro firms. These descriptive statistics indicate that within the population of patenting firms large firms are both more likely to have green patents and to have a higher average number of patents and green patents. Within the SMEs however, there is relatively little variation within the three size classes, with micro firms performing at least as good as or even better than small and medium sized firms.

Table 8 **Probability and intensity of patent application per firm**

	Conditional on applying for patents			Conditional on applying for green patents	
	Number of patent applications		Probability of green patent applications	Number of green patent applications	
Size class	Mean	Median		Mean	Median
micro	1.6	1	12.7	1.2	1
small	1.4	1	10.8	1.2	1
medium	1.7	1	7.6	1.4	1
large	9.3	2	17.4	4.6	1
total	5.3	1	13.9	3.3	1

4.3.2 Multivariate analyses

In order to check for the effect of firm size and age on green patent applications we estimate the probability of green patent applications conditional on applying for a patent and controlling for other firm characteristics such as sector, year, firm's credit rating and previous patenting activities. We pool the firm-year observations in the multivariate analysis. We apply a probit model with sample selection (Heckprobit). Applying for a patent and applying for a green patent may be affected by unobserved heterogeneity reflected in the correlation of the error terms of the latent selection equation (likelihood of applying for any patent at all) and the latent outcome equation (applying for green patent). In that case both equations might contain some common omitted variable and the error terms would be correlated. Using a probit model with sample selection we can take into account this unobserved heterogeneity and correct the estimation procedure. In a first stage we estimate the probability of applying for a patent application in general. In the second stage, the dependent variable is a dummy variable indicating that the firm applies for a green patent. As exclusion restriction we use the credit rating of a company as well as a dummy variable for those firms for which we do not observe the rating. These variables are included as explanatory variables in the selection equation but not in the outcome equation. The economic rationale for this is that, while the solvency of a firm should matter for its general decision to file a (costly) patent, it is not expected to have an impact on the technology classes covered by the patent. We test for independence of the two equations and reject independence, such that the use of a selection model is appropriate.

We use the following variables in our multivariate analysis:

- Patent application: dependent variable in the first stage, indicating whether the firm has applied for at least one patent in the given year
- Green patent application: dependent variable in the first stage, indicating whether the firm has applied for at least one “green” patent (using the WIPO Green Inventory definition) in the given year
- Ln(patent stock)$_{t-1}$: natural logarithm of lagged patent stock calculated with a depreciation rate of 15%. A patent stock of zero is replaced by the minimum value
- Ln(patent stock WIPO)$_{t-1}$: natural logarithm of lagged green patent stock calculated with a depreciation rate of 15%. A patent stock of zero is replaced by the minimum value
- Credit rating: rating variable defined by Creditreform going from 100 (best) to 600 (worst) rating
- Missing credit rating: Dummy variable for missing rating information
- Micro_young: Micro firms up to 8 years, dummy variable
- Micro_old: Micro firms older than 8 years, dummy variable
- Small_young: Small firms up to 8 years, dummy variable
- Small_old: Micro firms older than 8 years, dummy variable
- Medium_young: Medium-sized firms up to 8 years, dummy variable
- Medium_old: Medium-sized firms older than 8 years, dummy variable
- Large: Large firms. We do not differentiate by age here as large firms often appear in our database as young firms due to the new establishment of holding-type subsidiaries. As these are not young in the technological sense, and large firms are generally older than 8 years, we pool large firms in a single category.
- Industry dummies: 14 industry dummies
- Year dummies

Overall we have an unbalanced panel of 18,320,727 firm-year observations, covering the years 2000-2007, and including 3,492,634 different firms. Table 9 provides descriptive statistics for the variables used in the multivariate analysis.

Table 9 **Descriptive statistics**

Variable	All firms (Mean)	Only firms with patent application (Mean)
Dependent variables		
Patent application (d)	0.002	
Green patent application (d)		0.139
Explanatory variables		
Micro_young (d)	0.462	0.122
Micro_old (d)	0.416	0.090
Small_young (d)	0.025	0.053
Small_old (d)	0.067	0.091
Medium_young (d)	0.003	0.025
Medium_old (d)	0.012	0.130
Large (d)	0.015	0.489
Ln(patent stock WIPO)$_{t-1}$		-3.187
Ln(patent stock)$_{t-1}$	-4.198	0.024
Credit rating	342.928	
Missing credit rating (d)	0.206	
Sector: non-high-tech manufacturing (d)	0.074	0.272
Sector: cutting-edge technology manufacturing (d)	0.005	0.090
Sector: high-technology manufacturing (d)	0.010	0.199
Sector: technology-intensive services (d)	0.056	0.128
Sector: other knowledge-intensive services (d)	0.051	0.015
Sector: other business-oriented services (d)	0.066	0.041
Sector: consumer-oriented services (d)	0.168	0.036
Sector: energy/mining (d)	0.007	0.007
Sector: construction (d)	0.156	0.023
Sector: wholesale and retail trade (d)	0.284	0.118
Sector: transportation and storage (d)	0.043	0.004
Sector: financial and insurance activities (d)	0.038	0.004
Sector: activities of head office, act. of holding companies (d)	0.026	0.060
Sector: agriculture, forestry, fishing (d)	0.017	0.002
Year: 2000 (d)	0.107	0.120
Year: 2001 (d)	0.114	0.117
Year: 2002 (d)	0.119	0.117
Year: 2003 (d)	0.124	0.120
Year: 2004 (d)	0.129	0.121
Year: 2005 (d)	0.133	0.130
Year: 2006 (d)	0.136	0.135
Year: 2007 (d)	0.137	0.139
No. of observations	18,320,727	27,662

Notes: (d) dummy variable. Credit rating and missing credit rating serve as exclusion restriction.

Table 10 provides the estimation results of the probit model with sample selection. We cluster the standard errors at the firm level as one firm can appear in several years. Table 10 shows the determinants of applying for a green patent, conditional on having applied for any patent at all, which is the result of the second stage. We find that, compared to the reference category "large firm", all other size classes have a lower likelihood of applying for a green patent. We do however find that, within each size class, the negative effect is less strong for the younger firms. This may hint at younger SMEs having an advantage in the generation of green patents.

We further find the lagged patent stock and the lagged green patent stock to positively affect the likelihood of applying for a green patent in a given year. This result indicates that prior R&D activities, particularly in the green technology area are a strong determinant of current green patenting. With respect to differences across industries we find firms in the sectors cutting-edge technology manufacturing, high-technology manufacturing, technology-intensive services, other knowledge-intensive services, other business-oriented services, energy/mining, construction and activities of head office and holding companies to be more likely to apply for green patents than firms in the reference sector non-high-tech manufacturing.

Table 11 displays the estimation results for the selection equation. The probability of applying for a patent decreases with firm size. Compared to the reference category, which is a large firm, all other firm sizes are less likely to apply for a patent. We do again find that, within each size class, the negative effect is less strong for the younger firms. This shows that younger firms within the SMEs seem to be having an advantage in the generation of patents in general.

The lagged patent stock has a positive and significant effect on the likelihood to apply for a patent, indicating that past R&D activities are a strong driver of current patenting. We find a worsening of the credit rating to reduce the likelihood of patenting, which can be explained by credit constrained firms having fewer resources to do R&D and to pay for patent applications. The positive impact of the dummy indicating a missing credit rating is due to the fact that we set the rating for this firm to the worst possible rating in order to be able to include them into the estimation. The industry dummies show the expected pattern: Compared to the reference category of non-.high-tech manufacturing, the sectors cutting-edge technology manufacturing, high-technology manufacturing as well as technology-intensive services have a significantly higher likelihood of applying for patents, while firms active in all other sectors have a significantly lower likelihood.

Table 10 **Estimation results: outcome equation (probit model with sample selection, 2nd stage)**

Variable	Green patent application (dummy variable) Coefficient	Std. error
Micro_young	-0.391***	0.045
Micro_old	-0.488***	0.050
Small_young	-0.226***	0.047
Small_old	-0.268***	0.040
Medium_young	-0.111*	0.064
Medium_old	-0.250***	0.037
Ln(patent stock WIPO)$_{t-1}$	0.294***	0.010
Ln(patent stock)$_{t-1}$	0.088***	0.019
Sector: cutting-edge technology manufacturing	0.117***	0.042
Sector: high-technology manufacturing	0.105***	0.034
Sector: technology-intensive services	0.235***	0.035
Sector: other knowledge-intensive services	0.230***	0.077
Sector: other business-oriented services	0.144***	0.053
Sector: consumer-oriented services	-0.066	0.056
Sector: energy/mining	0.806***	0.094
Sector: construction	0.175***	0.067
Sector: wholesale and retail trade	-0.067*	0.038
Sector: transportation and storage	-0.026	0.127
Sector: financial and insurance activities	-0.102	0.172
Sector: activities of head office, act. of holding companies	0.107**	0.048
Sector: agriculture, forestry, fishing	0.150	0.186
Year: 2001	-0.029	0.037
Year: 2002	-0.094**	0.038
Year: 2003	-0.082**	0.038
Year: 2004	-0.086**	0.037
Year: 2005	-0.121***	0.037
Year: 2006	-0.014	0.036
Year: 2007	-0.059	0.036
Constant	-1.018***	0.077
rho	0.601	
LR test of independent equations (rho = 0): chi2(1)	61.65***	
Wald chi2 (28 d.f.)	4,375.10***	
No. of observations	18,320,727	
No. of censored observations	18,293,065	
No. of uncensored observations	27,662	

Notes: *** (**,*) indicates a significance level of 1% (5%, 10%). Standard errors are clustered at firm level. Reference categories: large firm; year: 2000; sector: non-high-tech manufacturing.

Table 11 **Estimation results: selection equation (probit model with sample selection, 1nd stage)**

Variable	Patent application (dummy variable) Coefficient	Std. error
Micro_young	-0.681***	0.012
Micro_old	-0.789***	0.012
Small_young	-0.294***	0.015
Small_old	-0.471***	0.012
Medium_young	-0.123***	0.023
Medium_old	-0.205***	0.013
Ln(patent stock)$_{t-1}$	0.413***	0.002
Sector: cutting-edge technology manufacturing	0.266***	0.018
Sector: high-technology manufacturing	0.199***	0.013
Sector: technology-intensive services	0.133***	0.011
Sector: other knowledge-intensive services	-0.274***	0.019
Sector: other business-oriented services	-0.214***	0.015
Sector: consumer-oriented services	-0.419***	0.015
Sector: energy/mining	-0.249***	0.033
Sector: construction	-0.444***	0.015
Sector: wholesale and retail trade	-0.244***	0.010
Sector: transportation and storage	-0.624***	0.035
Sector: financial and insurance activities	-0.644***	0.041
Sector: activities of head office, act. of holding companies	-0.105***	0.019
Sector: agriculture, forestry, fishing	-0.452***	0.043
Year: 2001	-0.047***	0.011
Year: 2002	-0.072***	0.011
Year: 2003	-0.065***	0.011
Year: 2004	-0.068***	0.012
Year: 2005	-0.043***	0.011
Year: 2006	-0.040***	0.011
Year: 2007	-0.039***	0.011
Exclusion variable: credit rating	-0.001***	0.000
Exclusion variable: missing credit rating	0.390***	0.022
Constant	-0.465***	0.017
No. of observations	18,320,727	

Notes: *** (**,*) indicates a significance level of 1% (5%, 10%). Standard errors are clustered at firm level. Reference categories: large firm; year: 2000; sector: non-high-tech manufacturing.

5. Conclusion

In this study we have concentrated on sustainable patenting as an indicator for inventions in sustainable technologies. We have applied a definition introduced by the World Intellectual Property Organization (WIPO 2013) that classifies patents in a Green Inventory Scheme, defining seven sustainable technology fields.

In the first step we analyzed the overall developments in sustainable patenting at the European Patent Office. We find the share of green patent applications in all patent applications at the EPO to be rather constant over time, varying between 8 and 10 percent. In 2007, the most active areas among the green technologies are alternative energy production with 26% of all green patent applications, energy storage (21%), and waste management (19%, Table 4). Administration, agriculture/forestry and transportation contribute between 8 and 14 percent to green patent applications at the EPO. Patent applications within the area of nuclear power generation are negligible (1%). With regard to specialization we find Germany to be slightly specialized in "green" patenting from 1990-1999. The strongest specialization could be found for the new member states with a specialization of +12.6. In 2000-2007 Europe as a whole has lost its specialization in green patenting, with all countries besides UK/Ireland and the new member states exhibiting a negative specialization. The countries specialized above average in "green" patenting in 2000-2007 were the new member states, Japan, the United States and UK/Ireland. When narrowing down the "green patents" to the triadic "green patents" (Table 17) however, this impression changes: The positive relative specialization of the new member states turns negative, the specialization of the United States and UK/Ireland, as well as to some degree Japan, fades. At the same time Germany now exhibits an above average specialization in "green" patenting. Interpreting triadic patents as a correlate for patent quality, we find that, while exhibiting a strong specialization and growth, "green" patenting by the new member states has not (yet) come along with an increase in high quality.

The second step linked sustainable growth to the "entrepreneurial" economy by examining to which degree small and young firms are driving sustainable patenting. We find SMEs to be responsible for about 15% of all patent applications. This is the same for the WIPO Green Inventory classified "green" patents. Around half of patent applications of SMEs are made by young firms. About one half of all patent applications by SMEs are filed by micro firms. When narrowing down the analysis to triadic patents, we find the contribution of SMEs to decrease to about 9% of all patent applications. The contribution to green patenting is even lower with only 6 percent of all green patents coming from SMEs.

In the third step of the analysis, based on the link of German firm data to patent applications at the European Patent Office, we analyzed at the firm level whether small and young firms are more or less likely to file sustainable patents than other firms. The results show that large firms are significantly more likely to file both patents in general and green patents. We do find that, for micro, small and medium size firms, the negative effect on patenting compared to the reference category of a large firm is less strong for the younger firms. This effect exists both for the generation of patents in general and the generation of green patents. Therefore there does not seem to be a particular advantage for small or young firms in producing sustainable, green patents.

In summary this study shows that, while green patents are an important field as such, making up about 9 percent of all patent applications at the EPO, the role of SMEs in this field should not be overrated. SMEs make up about 15 percent of all green patent applications, but only 6 percent of the more valuable, triadic green patent applications. These shares are similar to the contribution of SMEs to overall patenting, such that we cannot find a particular advantage of SMEs in the generation of sustainable, green technologies. We find green patenting at the firm level to be driven mainly by firm size and prior experience in patenting and particularly green patenting. This indicates that green innovations are the result of an experienced innovation regime rather than being driven by young entrepreneurs.

This study contributes to the ongoing innovation policy discussion on how to best promote smart and sustainable growth. It provides policymakers with the insight that neither small nor young firms are at an advantage in the production of sustainable green innovation, such that policies aimed at the promotion of these innovations should best target the broad population of firms.

Future studies may want to take a closer look at the particular characteristics of “green” patents in order to classify them along the notions of an incremental or radical innovation or somewhere in between.

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Annex

Table 12 **Country Classification**

Region	**Assigned country**
EU27	all EU-27 countries
France (FR)	France
Germany (DE)	Germany
UK/Ireland	Ireland United Kingdom
Rest Western Europe	Austria Belgium Luxembourg Netherlands
Northern Europe	Denmark Finland Sweden
Southern Europe	Greece Italy Portugal Spain
New Member States	Bulgaria Czech Republic Hungary Poland Romania Slovakia Estonia Latvia Lithuania Malta Slovenia Cyprus
Japan (JP)	Japan
China (CN)	China
USA (US)	USA
South Korea (KR)	South Korea
World	all countries

Note: Malta and Cyprus are part of the group “New Member States” (instead of “Southern Europe”) due to their entry into the EU in 2004.

Table 13 **Triadic WIPO Green Inventory classified patent applications at the EPO, by year and technology class**

	Technology						
Year	Alternative Energy	Transportation	Energy Storage	Waste Management	Agriculture	Administration	Nuclear Energy
1990	405	100	549	515	315	103	122
1991	367	102	549	496	269	80	112
1992	401	114	432	504	237	78	109
1993	349	119	545	468	202	84	103
1994	372	124	566	567	220	143	80
1995	402	143	523	533	263	121	67
1996	426	163	545	516	273	172	63
1997	445	177	591	548	259	185	43
1998	567	196	654	562	235	225	54
1999	612	250	768	584	246	332	50
2000	796	277	902	716	261	753	46
2001	766	267	865	608	285	594	55
2002	779	273	855	556	239	427	52
2003	747	290	863	550	246	361	54
2004	711	269	835	551	328	323	55
2005	710	262	731	536	315	223	45
2006	879	253	726	592	336	253	61
2007	885	285	819	553	349	249	61

Source: EPO Worldwide Patent Statistical Database (PATSTAT). Calculations by ZEW

Table 14 **Total patent applications at the EPO**

	Total patents					
	Sum 1990-1999	Sum 2000-2007	Share 1990-1999	Share 2000-2007	Growth 1990-1999	Growth 2000-2007
EU27	327,419	420,345	0.44	0.42	0.06	0.02
DE	141,331	176,829	0.19	0.18	0.07	0.02
FR	54,163	62,513	0.07	0.06	0.04	0.02
UK/Ireland	35,639	38,768	0.05	0.04	0.04	0.01
Rest Western Europe	37,396	56,851	0.05	0.06	0.07	0.04
Southern Europe	28,402	39,956	0.04	0.04	0.06	0.04
Northern Europe	29,163	41,946	0.04	0.04	0.13	0.03
New Member States	1,325	3,481	0.00	0.00	0.10	0.14
JP	135,513	174,710	0.18	0.18	0.04	0.02
KR	4,752	28,012	0.01	0.03	0.27	0.21
CN	580	7,332	0.00	0.01	0.28	0.36
US	228,374	271,905	0.30	0.27	0.06	0.00
World	750,398	994,184	1.00	1.00	0.06	0.02

Source: EPO Worldwide Patent Statistical Database (PATSTAT). Calculations by ZEW

Table 15 **Total triadic patent applications at the EPO**

	Total triadic patents					
	Sum 1990-1999	Sum 2000-2007	Share 1990-1999	Share 2000-2007	Growth 1990-1999	Growth 2000-2007
EU27	95,784	114,045	0.42	0.45	0.04	0.02
DE	41,239	45,616	0.18	0.18	0.05	0.00
FR	16,462	18,295	0.07	0.07	0.03	0.04
UK/Ireland	9,642	10,230	0.04	0.04	0.00	0.04
Rest Western Europe	12,418	22,117	0.05	0.09	0.06	0.04
Southern Europe	5,203	6,519	0.02	0.03	0.00	0.07
Northern Europe	10,527	10,715	0.05	0.04	0.11	0.02
New Member States	293	552	0.00	0.00	0.02	0.19
JP	52,288	72,571	0.23	0.28	0.04	0.05
KR	2,144	12,110	0.01	0.05	0.24	0.20
CN	236	1,810	0.00	0.01	0.32	0.29
US	64,257	32,551	0.28	0.13	-0.01	-0.10
World	230,439	255,863	1.00	1.00	0.02	0.02

Source: EPO Worldwide Patent Statistical Database (PATSTAT). Calculations by ZEW

Table 16 **Total WIPO Green Inventory classified patents**

	Total WIPO Green Inventory classified patents							
	Sum 90-99	Sum 00-07	Share 90-99	Share 00-07	Specialization 90-99	Specialization 00-07	Growth 90-99	Growth 00-07
EU27	26901	34733	0.44	0.39	0	-4	0.06	0.04
DE	12699	15399	0.21	0.17	4	-1	0.05	0.04
FR	4190	4431	0.07	0.05	-3	-10	0.04	0.03
UK/Ireland	2871	3601	0.05	0.04	-1	1	0.06	0.03
Rest Western Europe	3003	4762	0.05	0.05	-1	-3	0.09	0.06
Southern Europe	1651	3121	0.03	0.03	-15	-6	0.08	0.12
Northern Europe	2340	3020	0.04	0.03	-1	-10	0.11	0.03
New Member States	146	399	0.00	0.00	13	10	0.15	0.20
JP	10800	18776	0.18	0.21	-1	8	0.10	0.04
KR	324	2176	0.01	0.02	-8	-6	0.53	0.22
CN	50	489	0.00	0.01	2	-13	0.59	0.36
US	18810	25433	0.31	0.28	0	2	0.08	0.01
World	61654	89547	1.00	1.00	0	0	0.07	0.04

Source: EPO Worldwide Patent Statistical Database (PATSTAT). Calculations by ZEW

Table 17 **Triadic WIPO Green Inventory classified patents**

	Triadic WIPO Green Inventory classified patents							
	Sum 90-99	Sum 00-07	Share 90-99	Share 00-07	Specialization 90-99	Specialization 00-07	Growth 90-99	Growth 00-07
EU27	8197	9779	0.43	0.42	1	-3	0.04	0.03
DE	3825	4459	0.20	0.19	5	3	0.05	0.02
FR	1453	1362	0.08	0.06	3	-9	0.00	0.04
UK/Ireland	831	934	0.04	0.04	2	0	0.02	0.05
Rest Western Europe	981	1782	0.05	0.08	-2	-5	0.11	0.04
Southern Europe	296	478	0.02	0.02	-16	-9	0.07	0.09
Northern Europe	785	714	0.04	0.03	-5	-14	0.13	0.01
New Member States	26	49	0.00	0.00	3	-1	0.53	0.38
JP	4246	7320	0.22	0.31	-1	4	0.08	0.07
KR	139	1091	0.01	0.05	-11	-1	0.82	0.31
CN	19	155	0.00	0.01	-3	-3	#DIV/0!	0.42
US	5147	3052	0.27	0.13	-2	1	-0.01	-0.07
World	19139	23335	1.00	1.00	0	0	0.03	0.03

Source: EPO Worldwide Patent Statistical Database (PATSTAT). Calculations by ZEW

Table 18 **Total Alternative Energy Patents**

	Alternative Energy							
	Sum 90-99	Sum 00-07	Share 90-99	Share 00-07	Specialization 90-99	Specialization 00-07	Growth 90-99	Growth 00-07
EU27	5380	8848	0.41	0.39	-3	0	0.08	0.09
DE	2624	4058	0.20	0.18	-1	2	0.09	0.07
FR	834	1084	0.06	0.05	-3	-1	0.11	0.06
UK/Ireland	468	835	0.04	0.04	-12	-4	0.10	0.14
Rest Western Europe	563	1008	0.04	0.04	-6	-8	0.11	0.12
Southern Europe	323	899	0.02	0.04	-4	6	0.09	0.25
Northern Europe	537	851	0.04	0.04	3	5	0.14	0.12
New Member States	31	113	0.00	0.01	0	5	0.36	0.40
JP	2808	5619	0.21	0.25	9	7	0.14	0.04
KR	60	702	0.00	0.03	-7	11	#DIV/0!	0.45
CN	15	149	0.00	0.01	15	8	#DIV/0!	0.40
US	3742	5361	0.28	0.24	-3	-8	0.07	0.05
World	13151	22596	1.00	1.00	0	0	0.09	0.07

Source: EPO Worldwide Patent Statistical Database (PATSTAT). Calculations by ZEW

Table 19 **Triadic Alternative Energy Patents**

	Triadic Alternative Energy Patents							
	Sum 90-99	Sum 00-07	Share 90-99	Share 00-07	Specialization 90-99	Specialization 00-07	Growth 90-99	Growth 00-07
EU27	1814	2593	0.42	0.41	-1	-1	0.08	0.05
DE	818	1156	0.19	0.18	-3	-2	0.13	0.00
FR	388	435	0.09	0.07	7	7	0.07	0.12
UK/Ireland	149	299	0.03	0.05	-10	8	0.23	0.20
Rest Western Europe	184	289	0.04	0.05	-8	-22	0.14	0.09
Southern Europe	67	158	0.02	0.03	0	9	0.19	0.20
Northern Europe	203	240	0.05	0.04	6	10	0.16	0.11
New Member States	5	16	0.00	0.00	-9	9	#DIV/0!	#DIV/0!
JP	1089	2038	0.25	0.32	5	2	0.10	0.08
KR	26	366	0.01	0.06	-8	10	#DIV/0!	0.44
CN	6	57	0.00	0.01	15	14	#DIV/0!	0.62
US	1021	636	0.23	0.10	-6	-11	-0.01	-0.02
World	4346	6272	1.00	1.00	0	0	0.05	0.05

Source: EPO Worldwide Patent Statistical Database (PATSTAT). Calculations by ZEW

Table 20 **Total Transport Patents**

	Transport							
	Sum 90-99	Sum 00-07	Share 90-99	Share 00-07	Specialization 90-99	Specialization 00-07	Growth 90-99	Growth 00-07
EU27	1535	2423	0.38	0.35	-4	-5	0.12	0.05
DE	675	1097	0.16	0.16	-8	-5	0.15	0.06
FR	253	425	0.06	0.06	-1	11	0.19	0.08
UK/Ireland	117	157	0.03	0.02	-9	-21	0.14	0.23
Rest Western Europe	151	188	0.04	0.03	-6	-21	0.16	0.09
Southern Europe	189	389	0.05	0.06	27	15	0.19	0.10
Northern Europe	137	150	0.03	0.02	-9	-24	0.30	0.09
New Member States	14	17	0.00	0.00	16	-30	#DIV/0!	#DIV/0!
JP	1188	2454	0.29	0.36	13	15	0.16	0.08
KR	47	126	0.01	0.02	38	-23	#DIV/0!	0.24
CN	7	75	0.00	0.01	14	21	#DIV/0!	0.86
US	1012	1290	0.25	0.19	-6	-10	0.10	0.08
World	4089	6911	1.00	1.00	0	0	0.11	0.07

Source: EPO Worldwide Patent Statistical Database (PATSTAT). Calculations by ZEW

Table 21 **Triadic Transport Patents**

	Transport							
	Sum 90-99	Sum 00-07	Share 90-99	Share 00-07	Specialization 90-99	Specialization 00-07	Growth 90-99	Growth 00-07
EU27	485	683	0.33	0.31	-11	-12	0.14	0.01
DE	224	350	0.15	0.16	-10	-6	0.17	0.05
FR	75	127	0.05	0.06	-24	-8	0.12	0.18
UK/Ireland	31	37	0.02	0.02	-21	-42	0.21	0.60
Rest Western Europe	67	68	0.05	0.03	3	-17	0.26	0.11
Southern Europe	24	79	0.02	0.04	2	16	#DIV/0!	0.22
Northern Europe	61	20	0.04	0.01	-6	-55	0.43	0.35
New Member States	3	3	0.00	0.00	25	-27	#DIV/0!	#DIV/0!
JP	571	1127	0.38	0.52	18	20	0.21	0.05
KR	26	65	0.02	0.03	43	-29	#DIV/0!	0.19
CN	2	16	0.00	0.01	-1	-9	#DIV/0!	#DIV/0!
US	311	154	0.21	0.07	-5	-15	0.03	0.02
World	1488	2176	1.00	1.00	0	0	0.11	0.02

Source: EPO Worldwide Patent Statistical Database (PATSTAT). Calculations by ZEW

Table 22 **Total Energy Storage Patents**

	Energy Storage							
	Sum 90-99	Sum 00-07	Share 90-99	Share 00-07	Specialization 90-99	Specialization 00-07	Growth 90-99	Growth 00-07
EU27	6088	7997	0.40	0.37	3	2	0.07	0.04
DE	2720	3564	0.18	0.16	3	2	0.07	0.05
FR	976	888	0.06	0.04	1	-17	0.01	0.07
UK/Ireland	650	666	0.04	0.03	17	13	0.07	0.01
Rest Western Europe	806	1639	0.05	0.08	16	42	0.16	0.06
Southern Europe	384	617	0.03	0.03	-26	-29	0.08	0.13
Northern Europe	528	531	0.03	0.02	2	5	0.22	0.01
New Member States	24	91	0.00	0.00	-33	23	0.51	0.36
JP	3329	5393	0.22	0.25	-12	-15	0.11	0.03
KR	73	910	0.00	0.04	-36	35	0.49	0.35
CN	6	125	0.00	0.01	-57	-27	#DIV/0!	0.60
US	4799	5457	0.32	0.25	10	13	0.06	-0.01
World	15227	21666	1.00	1.00	0	0	0.08	0.03

Source: EPO Worldwide Patent Statistical Database (PATSTAT). Calculations by ZEW

Table 23 **Triadic Energy Storage Patents**

	Energy Storage							
	Sum 90-99	Sum 00-07	Share 90-99	Share 00-07	Specialization 90-99	Specialization 00-07	Growth 90-99	Growth 00-07
EU27	2114	2628	0.37	0.40	5	10	0.07	0.01
DE	823	1043	0.14	0.16	-2	-1	0.09	0.05
FR	340	259	0.06	0.04	7	-17	0.02	0.05
UK/Ireland	212	194	0.04	0.03	25	23	0.04	0.08
Rest Western Europe	421	943	0.07	0.14	21	58	0.19	0.02
Southern Europe	92	85	0.02	0.01	0	-42	0.02	0.11
Northern Europe	218	93	0.04	0.01	-3	18	0.31	0.02
New Member States	8	13	0.00	0.00	-18	14	#DIV/0!	#DIV/0!
JP	1531	2100	0.27	0.32	-15	-21	0.08	0.03
KR	33	451	0.01	0.07	-45	35	#DIV/0!	0.37
CN	2	36	0.00	0.01	-53	-13	#DIV/0!	#DIV/0!
US	1756	934	0.31	0.14	17	29	0.00	-0.08
World	5722	6595	1.00	1.00	0	0	0.05	0.01

Source: EPO Worldwide Patent Statistical Database (PATSTAT). Calculations by ZEW

Table 24 **Total Waste Management Patents**

	Waste Management							
	Sum 90-99	Sum 00-07	Share 90-99	Share 00-07	Specialization 90-99	Specialization 00-07	Growth 90-99	Growth 00-07
EU27	10329	9411	0.52	0.46	11	10	0.03	0.00
DE	4983	3922	0.25	0.19	14	7	0.01	-0.02
FR	1549	1391	0.08	0.07	8	22	0.05	0.01
UK/Ireland	1020	955	0.05	0.05	8	18	0.05	0.00
Rest Western Europe	1177	1208	0.06	0.06	5	-11	0.05	0.05
Southern Europe	635	918	0.03	0.05	10	20	0.06	0.08
Northern Europe	891	881	0.04	0.04	11	24	0.03	0.03
New Member States	74	136	0.00	0.01	36	20	0.37	0.13
JP	2775	3989	0.14	0.20	-19	-10	0.08	0.03
KR	97	260	0.00	0.01	1	-48	#DIV/0!	0.07
CN	18	88	0.00	0.00	38	-13	#DIV/0!	0.65
US	5175	4852	0.26	0.24	-8	-2	0.03	0.00
World	19969	20353	1.00	1.00	0	0	0.04	0.01

Source: EPO Worldwide Patent Statistical Database (PATSTAT). Calculations by ZEW

Table 25 **Triadic Waste Management Patents**

	Waste Management							
	Sum 90-99	Sum 00-07	Share 90-99	Share 00-07	Specialization 90-99	Specialization 00-07	Growth 90-99	Growth 00-07
EU27	2671	2194	0.50	0.47	13	7	0.03	-0.02
DE	1220	934	0.23	0.20	20	10	0.04	-0.05
FR	558	379	0.11	0.08	24	31	0.02	0.01
UK/Ireland	266	233	0.05	0.05	13	23	0.07	-0.04
Rest Western Europe	276	269	0.05	0.06	-15	-37	0.08	0.07
Southern Europe	91	123	0.02	0.03	3	30	0.04	0.21
Northern Europe	251	240	0.05	0.05	9	51	0.05	0.09
New Member States	10	16	0.00	0.00	15	26	#DIV/0!	#DIV/0!
JP	943	1403	0.18	0.30	-18	-2	0.07	0.07
KR	44	140	0.01	0.03	16	-34	#DIV/0!	0.11
CN	7	30	0.00	0.01	50	8	#DIV/0!	0.58
US	1179	486	0.22	0.10	-14	-13	-0.02	-0.05
World	5293	4660	1.00	1.00	0	0	0.02	0.00

Source: EPO Worldwide Patent Statistical Database (PATSTAT). Calculations by ZEW

Table 26 **Total Agriculture Patents**

	Total Agriculture Patents							
	Sum 90-99	Sum 00-07	Share 90-99	Share 00-07	Specialization 90-99	Specialization 00-07	Growth 90-99	Growth 00-07
EU27	4153	3634	0.48	0.41	-4	-5	0.01	0.03
DE	2417	2213	0.28	0.25	5	12	0.00	0.06
FR	488	338	0.06	0.04	-14	-25	0.02	0.00
UK/Ireland	545	372	0.06	0.04	9	-5	0.04	-0.02
Rest Western Europe	350	308	0.04	0.03	-17	-23	0.10	0.04
Southern Europe	178	219	0.02	0.02	-19	-25	0.13	0.10
Northern Europe	156	154	0.02	0.02	-38	-38	0.11	-0.01
New Member States	20	32	0.00	0.00	-20	-26	0.57	0.18
JP	1086	725	0.12	0.08	-5	-36	-0.02	0.04
KR	58	49	0.01	0.01	13	-35	1.21	0.42
CN	6	37	0.00	0.00	-12	-1	#DIV/0!	0.49
US	2593	3306	0.30	0.38	6	20	0.03	0.06
World	8725	8798	1.00	1.00	0	0	0.01	0.04

Source: EPO Worldwide Patent Statistical Database (PATSTAT). Calculations by ZEW

Table 27 **Triadic Agriculture Patents**

	Triadic Agriculture Patents							
	Sum 90-99	Sum 00-07	Share 90-99	Share 00-07	Specialization 90-99	Specialization 00-07	Growth 90-99	Growth 00-07
EU27	1395	1487	0.55	0.63	4	13	-0.01	0.08
DE	939	1105	0.37	0.47	21	35	0.00	0.11
FR	132	107	0.05	0.05	-29	-25	0.01	0.46
UK/Ireland	165	128	0.07	0.05	11	3	0.02	0.07
Rest Western Europe	87	69	0.03	0.03	-18	-29	0.10	0.17
Southern Europe	41	37	0.02	0.02	-2	-23	0.31	0.12
Northern Europe	26	36	0.01	0.02	-58	-48	#DIV/0!	0.27
New Member States	5	6	0.00	0.00	3	-17	#DIV/0!	#DIV/0!
JP	299	214	0.12	0.09	-17	-48	0.01	0.06
KR	28	21	0.01	0.01	13	-49	0.74	0.12
CN	3	13	0.00	0.01	-1	-7	#DIV/0!	#DIV/0!
US	538	263	0.21	0.11	-2	3	-0.02	-0.11
World	2519	2359	1.00	1.00	0	0	-0.02	0.05

Source: EPO Worldwide Patent Statistical Database (PATSTAT). Calculations by ZEW

Table 28 **Total Administration Patents**

	Total Administration Patents							
	Sum 90-99	Sum 00-07	Share 90-99	Share 00-07	Specialization 90-99	Specialization 00-07	Growth 90-99	Growth 00-07
EU27	2036	5273	0.29	0.31	-21	-13	0.17	0.06
DE	538	1669	0.08	0.10	-50	-39	0.22	0.07
FR	408	692	0.06	0.04	2	2	0.19	0.05
UK/Ireland	289	903	0.04	0.05	-18	10	0.22	0.11
Rest Western Europe	325	817	0.05	0.05	7	14	0.18	0.13
Southern Europe	139	396	0.02	0.02	-1	-3	0.31	0.13
Northern Europe	327	731	0.05	0.04	40	37	0.30	0.02
New Member States	11	67	0.00	0.00	-16	4	#DIV/0!	1.00
JP	923	2596	0.13	0.15	3	26	0.29	0.09
KR	38	288	0.01	0.02	-9	45	#DIV/0!	0.18
CN	6	85	0.00	0.00	10	7	#DIV/0!	0.49
US	3355	7159	0.48	0.42	21	5	0.29	-0.01
World	6958	17063	1.00	1.00	0	0	0.24	0.02

Source: EPO Worldwide Patent Statistical Database (PATSTAT). Calculations by ZEW

Table 29 **Triadic Administration Patents**

	Triadic Administration Patents							
	Sum 90-99	Sum 00-07	Share 90-99	Share 00-07	Specialization 90-99	Specialization 00-07	Growth 90-99	Growth 00-07
EU27	411	852	0.27	0.27	-30	-36	0.17	0.10
DE	115	202	0.08	0.06	-60	-70	0.75	0.11
FR	97	107	0.06	0.03	8	-13	0.16	0.03
UK/Ireland	42	116	0.03	0.04	-36	-17	0.31	0.30
Rest Western Europe	57	254	0.04	0.08	4	41	0.93	0.50
Southern Europe	18	34	0.01	0.01	-14	-16	#DIV/0!	#DIV/0!
Northern Europe	80	134	0.05	0.04	61	41	0.46	0.20
New Member States	2	6	0.00	0.00	-18	-9	#DIV/0!	#DIV/0!
JP	348	1203	0.23	0.38	28	55	0.25	0.31
KR	6	126	0.00	0.04	-45	58	#DIV/0!	0.99
CN	2	21	0.00	0.01	4	7	#DIV/0!	#DIV/0!
US	652	747	0.43	0.23	29	31	0.19	-0.08
World	1523	3183	1.00	1.00	0	0	0.17	0.04

Source: EPO Worldwide Patent Statistical Database (PATSTAT). Calculations by ZEW

Table 30 **Total Nuclear Power Patents**

	Total Nuclear Power Patents							
	Sum 90-99	Sum 00-07	Share 90-99	Share 00-07	Specialization 90-99	Specialization 00-07	Growth 90-99	Growth 00-07
EU27	785	382	0.52	0.42	24	13	0.00	0.02
DE	268	131	0.18	0.14	34	17	0.02	0.21
FR	291	153	0.19	0.17	47	55	-0.02	0.10
UK/Ireland	68	19	0.04	0.02	3	-38	0.30	-0.09
Rest Western Europe	30	25	0.02	0.03	-36	-24	#DIV/0!	#DIV/0!
Southern Europe	33	19	0.02	0.02	4	-5	#DIV/0!	#DIV/0!
Northern Europe	95	35	0.06	0.04	12	-5	0.23	0.12
New Member States	0	1	0.00	0.00	#ZAHL!	-50	#DIV/0!	#DIV/0!
JP	151	144	0.10	0.16	-13	2	0.12	0.12
KR	3	15	0.00	0.02	-41	-1	#DIV/0!	#DIV/0!
CN	0	0	0.00	0.00	#ZAHL!	#ZAHL!	#DIV/0!	#DIV/0!
US	553	299	0.36	0.33	-12	-11	-0.10	0.12
World	1523	909	1.00	1.00	0	0	-0.05	0.02

Source: EPO Worldwide Patent Statistical Database (PATSTAT). Calculations by ZEW

Table 31 **Triadic Nuclear Power Patents**

	Triadic Nuclear Power Patents							
	Sum 90-99	Sum 00-07	Share 90-99	Share 00-07	Specialization 90-99	Specialization 00-07	Growth 90-99	Growth 00-07
EU27	378	219	0.47	0.51	24	27	0.01	0.05
DE	108	58	0.13	0.13	24	31	0.33	0.05
FR	161	104	0.20	0.24	46	70	0.06	0.30
UK/Ireland	37	12	0.05	0.03	22	-11	0.49	-0.08
Rest Western Europe	18	12	0.02	0.03	-23	-42	#DIV/0!	#DIV/0!
Southern Europe	9	7	0.01	0.02	-5	15	#DIV/0!	#DIV/0!
Northern Europe	46	27	0.06	0.06	4	17	#DIV/0!	0.14
New Member States	0	1	0.00	0.00	#ZAHL!	9	#DIV/0!	#DIV/0!
JP	74	41	0.09	0.10	-38	-53	0.03	0.36
KR	2	9	0.00	0.02	-16	-27	#DIV/0!	#DIV/0!
CN	0	0	0.00	0.00	#ZAHL!	#ZAHL!	#DIV/0!	#DIV/0!
US	332	128	0.41	0.30	-2	10	-0.16	0.24
World	803	428	1.00	1.00	0	0	-0.08	0.04

Source: EPO Worldwide Patent Statistical Database (PATSTAT). Calculations by ZEW

Table 32 **Descriptive statistics of the firm-level dataset**

	No. of observations	Percent
Size class		
micro	16,408,006	88
small	1,702,008	9
medium-sized	284,218	2
large	292,158	2
Sum	*18,686,390*	*100*
Age class		
old	9,497,936	51
young	9,188,454	49
Sum	*18,686,390*	*100*
Year		
2000	2,006,280	11
2001	2,127,489	11
2002	2,226,682	12
2003	2,320,763	12
2004	2,415,479	13
2005	2,485,925	13
2006	2,537,167	14
2007	2,566,605	14
Sum	*18,686,390*	*100*

Table 33 **Patent applications at the EPO in given fields by firms located in Germany, by firm size and age (absolute number)**

(Number of applications)		2000-2003					2004-2007				
		<10	10-49	50-249	>249	*Sum*	<10	10-49	50-249	>249	*Sum*
all patents	young	3,788	1,226	771	885	*6,670*	2,631	1,152	744	491	*5,018*
	old	1,423	1,421	2,336	62,458	*67,638*	1,967	1,770	3,306	63,105	*70,148*
	Sum	*5,211*	*2,647*	*3,107*	*63,343*	*74,308*	*4,598*	*2,922*	*4,050*	*63,596*	*75,166*
WIPO Green Inventory	young	340	98	53	68	*559*	280	109	76	57	*522*
	old	143	140	141	5,440	*5,864*	173	167	184	5,452	*5,976*
	Sum	*483*	*238*	*194*	*5,508*	*6,423*	*453*	*276*	*260*	*5,509*	*6,498*
Alternative Energy	young	95	24	22	28	*169*	102	47	14	40	*203*
	old	40	32	37	1,327	*1,436*	57	47	25	1,269	*1,398*
	Sum	*135*	*56*	*59*	*1,355*	*1,605*	*159*	*94*	*39*	*1,309*	*1,601*
Transportation	young	15	1	1	4	*21*	11	4	4	0	*19*
	old	7	12	2	394	*415*	9	6	7	275	*297*
	Sum	*22*	*13*	*3*	*398*	*436*	*20*	*10*	*11*	*275*	*316*
Energy Conservat.	young	108	19	16	18	*161*	49	17	23	5	*94*
	old	28	31	50	1,462	*1,571*	26	36	62	1,481	*1,605*
	Sum	*136*	*50*	*66*	*1,480*	*1,732*	*75*	*53*	*85*	*1,486*	*1,699*
Waste Management	young	91	38	12	12	*153*	97	16	38	19	*170*
	old	59	54	56	1,134	*1,303*	71	73	71	1,185	*1,400*
	Sum	*150*	*92*	*68*	*1,146*	*1,456*	*168*	*89*	*109*	*1,204*	*1,570*
Agriculture	young	8	8	0	14	*30*	13	6	0	0	*19*
	old	6	3	2	678	*689*	9	7	6	933	*955*
	Sum	*14*	*11*	*2*	*692*	*719*	*22*	*13*	*6*	*933*	*974*
Administration	young	57	19	5	3	*84*	39	21	3	0	*63*
	old	19	24	10	787	*840*	24	14	19	526	*583*
	Sum	*76*	*43*	*15*	*790*	*924*	*63*	*35*	*22*	*526*	*646*
Nuclear Energy	young	0	0	0	0	*0*	1	0	0	0	*1*
	old	0	0	0	62	*62*	0	0	0	51	*51*
	Sum	*0*	*0*	*0*	*62*	*62*	*1*	*0*	*0*	*51*	*52*

Table 34 **Patent applications at the EPO in given fields by firms located in Germany, by firm size and age (share in %)**

(Share of applications)		2000-2003					2004-2007				
		<10	10-49	50-249	>249	*Sum*	<10	10-49	50-249	>249	*Sum*
all patents	young	5	2	1	1	9	4	2	1	1	7
	old	2	2	3	84	91	3	2	4	84	93
	Sum	7	4	4	85	100	6	4	5	85	100
WIPO Green Inventory	young	5	2	1	1	9	4	2	1	1	8
	old	2	2	2	85	91	3	3	3	84	92
	Sum	8	4	3	86	100	7	4	4	85	100
Alternative Energy	young	6	1	1	2	11	6	3	1	2	13
	old	2	2	2	83	89	4	3	2	79	87
	Sum	8	3	4	84	100	10	6	2	82	100
Transportation	young	3	0	0	1	5	3	1	1	0	6
	old	2	3	0	90	95	3	2	2	87	94
	Sum	5	3	1	91	100	6	3	3	87	100
Energy Conservat.	young	6	1	1	1	9	3	1	1	0	6
	old	2	2	3	84	91	2	2	4	87	94
	Sum	8	3	4	85	100	4	3	5	87	100
Waste Management	young	6	3	1	1	11	6	1	2	1	11
	old	4	4	4	78	89	5	5	5	75	89
	Sum	10	6	5	79	100	11	6	7	77	100
Agriculture	young	1	1	0	2	4	1	1	0	0	2
	old	1	0	0	94	96	1	1	1	96	98
	Sum	2	2	0	96	100	2	1	1	96	100
Administration	young	6	2	1	0	9	6	3	0	0	10
	old	2	3	1	85	91	4	2	3	81	90
	Sum	8	5	2	85	100	10	5	3	81	100
Nuclear Energy	young	0	0	0	0	0	2	0	0	0	2
	old	0	0	0	100	100	0	0	0	98	98
	Sum	0	0	0	100	100	2	0	0	98	100

Table 35 **Triadic patent applications at the EPO by firms located in Germany, by firm size and age (number)**

(Number of applications)		2000-2003					2004-2007				
		<10	10-49	50-249	>249	*Sum*	<10	10-49	50-249	>249	*Sum*
all patents	young	790	280	119	294	1,483	416	198	116	131	861
	old	139	155	289	17,265	17,848	258	200	346	15,597	16,401
	Sum	929	435	408	17,559	19,331	674	398	462	15,728	17,262
WIPO Green Inventory	young	60	20	9	25	114	36	16	14	19	85
	old	9	12	14	1,897	1,932	15	12	13	1,611	1,651
	Sum	69	32	23	1,922	2,046	51	28	27	1,630	1,736
Alternative Energy	young	19	8	3	13	43	12	12	0	11	35
	old	1	7	7	528	543	7	1	3	290	301
	Sum	20	15	10	541	586	19	13	3	301	336
Transportation	young	6	0	1	2	9	3	1	1	0	5
	old	1	1	0	156	158	3	0	0	77	80
	Sum	7	1	1	158	167	6	1	1	77	85
Energy Conservat.	young	30	1	3	4	38	4	2	11	2	19
	old	3	1	2	550	556	1	4	6	456	467
	Sum	33	2	5	554	594	5	6	17	458	486
Waste Management	young	9	9	3	4	25	15	0	1	7	23
	old	3	7	6	314	330	4	7	4	312	327
	Sum	12	16	9	318	355	19	7	5	319	350
Agriculture	young	0	4	0	6	10	5	0	0	0	5
	old	1	0	0	341	342	0	0	0	478	478
	Sum	1	4	0	347	352	5	0	0	478	483
Administration	young	3	2	0	0	5	1	1	1	0	3
	old	1	1	1	160	163	1	0	0	44	45
	Sum	4	3	1	160	168	2	1	1	44	48
Nuclear Energy	young	0	0	0	0	0	1	0	0	0	1
	old	0	0	0	30	30	0	0	0	23	23
	Sum	0	0	0	30	30	1	0	0	23	24

Table 36 **Triadic patent applications at the EPO by firms located in Germany, by firm size and age (share in %)**

(Share of applications)		2000-2003					2004-2007				
		<10	10-49	50-249	>249	*Sum*	<10	10-49	50-249	>249	*Sum*
all patents	young	4	1	1	2	8	2	1	1	1	5
	old	1	1	1	89	92	1	1	2	90	95
	Sum	5	2	2	91	100	4	2	3	91	100
WIPO Green Inventory	young	3	1	0	1	6	2	1	1	1	5
	old	0	1	1	93	94	1	1	1	93	95
	Sum	3	2	1	94	100	3	2	2	94	100
Alternative Energy	young	3	1	1	2	7	4	4	0	3	10
	old	0	1	1	90	93	2	0	1	86	90
	Sum	3	3	2	92	100	6	4	1	90	100
Transportation	young	4	0	1	1	5	4	1	1	0	6
	old	1	1	0	93	95	4	0	0	91	94
	Sum	4	1	1	95	100	7	1	1	91	100
Energy Conservat.	young	5	0	1	1	6	1	0	2	0	4
	old	1	0	0	93	94	0	1	1	94	96
	Sum	6	0	1	93	100	1	1	3	94	100
Waste Management	young	3	3	1	1	7	4	0	0	2	7
	old	1	2	2	88	93	1	2	1	89	93
	Sum	3	5	3	90	100	5	2	1	91	100
Agriculture	young	0	1	0	2	3	1	0	0	0	1
	old	0	0	0	97	97	0	0	0	99	99
	Sum	0	1	0	99	100	1	0	0	99	100
Administration	young	2	1	0	0	3	2	2	2	0	6
	old	1	1	1	95	97	2	0	0	92	94
	Sum	2	2	1	95	100	4	2	2	92	100
Nuclear Energy	young	0	0	0	0	0	4	0	0	0	4
	old	0	0	0	100	100	0	0	0	96	96
	Sum	0	0	0	100	100	4	0	0	96	100

Project Information

Welfare, Wealth and Work for Europe

A European research consortium is working on the analytical foundations for a socio-ecological transition

Abstract

Europe needs change. The financial crisis has exposed long-neglected deficiencies in the present growth path, most visibly in the areas of unemployment and public debt. At the same time, Europe has to cope with new challenges, ranging from globalisation and demographic shifts to new technologies and ecological challenges. Under the title of Welfare, Wealth and Work for Europe – WWWforEurope – a European research consortium is laying the analytical foundation for a new development strategy that will enable a socio-ecological transition to higher levels of employment, social inclusion, gender equity and environmental sustainability. The four-year research project within the 7th Framework Programme funded by the European Commission was launched in April 2012. The consortium brings together researchers from 33 scientific institutions in 12 European countries and is coordinated by the Austrian Institute of Economic Research (WIFO). The project coordinator is Karl Aiginger, director of WIFO.

For details on WWWforEurope see: www.foreurope.eu

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Institute for Financial and Regional Analyses	GEFRA	Germany
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ICLEI - Local Governments for Sustainability	ICLEI	Germany
Institute of Economic Research Slovak Academy of Sciences	IER SAVBA	Slovakia
Kiel Institute for the World Economy	IfW	Germany
Institute of World Economics, RCERS, HAS	KRTK MTA	Hungary
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