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ECO-INNOVATION AND FIRM GROWTH: DO GREEN GAZELLES RUN FASTER? MICROECONOMETRIC EVIDENCE FROM A SAMPLE OF EUROPEAN FIRMS

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Eco-innovation and firm growth: Do green gazelles run faster? Microeconometric evidence from a sample of European firms[1]

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ABSTRACT. This paper investigates the impact of eco-innovation on firms' growth processes, with a special focus on gazelles, i.e. firms' showing higher growth rates than the average. In a context shaped by more and more stringent environmental regulatory frameworks, we posit that inducement mechanisms stimulate the adoption of green technologies, increasing the derived demand for technologies produced by upstream firms supplying eco-innovations. For these reason we expect the generation of green technologies to trigger sales growth. We use firm-level data drawn from the Bureau van Dijk Database, coupled with patent information obtained from the OECD Science and Technology Indicators. The results confirm that eco-innovations are likely to augment the effects of generic innovation on firms' growth, and this is particularly true for gazelles, which actually appear to run faster than the others.

Keywords: Gazelles, Eco-Innovation, firms' growth, Inducement mechanisms, derived demand, WIPO Green Inventory.

JEL Classification Codes: L10, L20, O32, O33, Q53, Q55.

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1 Introduction

The relationship between innovation and firm growth patterns has received increased attention in the last year (Audrestch et al., 2014). The main theoretical grounds rest upon Schumpeter's argument according to which firms can enjoy better performances in the market by bringing about innovation through the creative destruction process (Schumpeter, 1942).

More recently the policy debate about the importance of innovation has become more and more focused on the capacity to reconcile economic and environmental performances through the generation, adoption and diffusion of eco-innovations. Such new technologies have indeed been identified as a means of restoring the competitiveness of advanced countries which has been harmed by the economic crisis. Their emergence is indeed supposed to bring about new jobs and new perspectives for economic growth.

These arguments are based on the well-known Porter's hypothesis (Porter and van der Linde, 1995), according to which innovations aiming at improving firms' environmental performances may also yield positive effects on firms' economic performances due to the enhancement of products and processes, which is engendered by the adoption of the innovation[2].

However, most of the empirical analyses carried out at both the micro and macro-economic level, has focused on the determinants of eco-innovations, while relatively little attention has been paid to their effects on economic and financial performances. In other words the beneficial effects of eco-innovations were somehow considered as an assumption motivating the enquiry into the very mechanisms of their generation. Notable exceptions can be found in Marin (2014), who proposes an extension of the Crepon-Duguet-Mairesse (CDM) model to investigate the effects of eco-innovation on productivity growth for a sample of Italian firms. Rexhauser and Rammer (2013) use instead the German CIS 2009 to investigate the effects of different types of environmental innovations on the profitability of German firms, while Lanoie et al. (2011) propose a framework to investigate the complete causality chain from environmental

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[2] According to the assumptions on the effect of regulations, the Porter Hypothesis can be split into a "narrow" a "weak" and into a "strong" version (Jaffe and Palmer, 1997). This hypothesis remains controversial in its empirical investigation (see, for instance, Lanoie et al., 2011).

regulatory stringency to environmental and financial performance, through environmental innovation, by means of a survey on 4,200 facilities in seven OECD countries.

This paper aims at contributing this less explored field of enquiry, by analysing the effects of eco-innovations on firms' growth processes. In particular, we put together different strands of analysis comprising the studies focusing on eco-innovations and the literature that analyses the determinants of firms growth, moving from the well-known Gibrat's law to get to the investigation of a peculiar type of firms called high-growth firms (HGFs) or 'gazelles'. These latter have been recently object of renewed policy interest due to their role in the creation of new jobs and hence in sustaining economic development of regions and countries. A report by the Europe INNOVA Sectoral Innovation Watch (Mitusch and Schimke, 2011), points to the importance of eco-innovation to realize a sustainable innovative development and trigger firms' growth. Environmental innovations can be thus strategic for gazelles. We qualify this argument, by emphasizing that producing eco-innovations in markets that are more and more shaped by strict environmental regulations, is likely to yield returns in terms of higher sales growth rates.

The empirical analysis is carried out on a sample of more than 400,000 firms located in Germany, France, Italy, Spain and Sweden, over the time span 2002-2011. Our results show that on average firms producing eco-innovations are characterized by higher growth rates than those generating generic innovations. Moreover when we focus on HGFs, we find that green gazelles, i.e. gazelles generating environmental innovations, actually run faster than the other gazelles. Our results are robust to different specifications, and in particular to the implementation of least absolute deviation (LAD) estimators, which are better suited to empirical contexts in which the distribution of the dependent variable is close to a Laplace one.

The rest of the paper is organized as it follows. Section 2 outlines the theoretical framework underpinning the empirical analysis. Section 3 describes the dataset, the methodology and the variables. In section 4 we present the results of the econometric estimations and of the robustness checks. Finally Section 5 concludes, by emphasizing the implications in terms of industrial and environmental policy.

2 Firms' growth and the generation of eco-innovations

The understanding of the relationship between the generation of eco-innovation[3] and firms' growth is grounded on the very notions of induced innovation and derived demand. The inducement hypothesis in the domain of environmental economics points to the moderating role played by regulation on the generation of green technologies. Stringent policies are conceived as an additional cost increasing firms' production costs by changing the relative factor prices. This stimulates firms to commit resources to introduce innovations aimed at reducing the increased cost, e.g. emission-saving technologies. The relevance of these mechanisms has been investigated either by using patent data to test whether regulation affected knowledge generation (e.g. Lanjouw and Mody, 1996; Brunnermeier and Cohen 2003; Jaffe and Palmer, 1997; Popp, 2006) or by using survey data to test whether regulation pushes and/or pulls environmental innovations (e.g. Frondel et al, 2008; Horbach et al., 2012, Rennings and Rammer, 2011; Rennings and Rexhäuser, 2011; for a review see Del Rio, 2009). In both cases, the results provide support to the idea that regulation triggers innovation through a genuine mechanism of creative response *à la* Schumpeter (1947).

However, although the distinction between the different phases of generation, adoption and diffusion of innovation is more and more blurred, it is worth stressing that polluting firms under a stringent regulation may be willing to adopt green technologies, but they do not always have the necessary competences to generate them. In such cases, the environmental pressures (both in strong and in weak regulatory frameworks) can engender a *derived demand* for green technologies. This translates into increased production of eco-innovations to confront with increased demand by firms operating in downstream sectors. Following the interplay between price-inducement and derived demand-pull mechanisms, the generation of new technologies is likely to be triggered by the derived demand of polluting firms for technologies that improve their environmental performances (Ghisetti and Quatraro, 2013).

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[3] There are different definitions of eco-innovations. As noted by Kemp (2010: p. 398) "The absence of a common definition led the European Commission to fund two projects on measuring eco-innovation: Measuring Eco-Innovation (MEI) and Eco-Drive. The eco-innovation definition of the Eco-Drive is «a change in economic activities that improves both the economic performance and the environmental performance». The definition of MEI is «the production, assimilation or exploitation of a product, production process, service or management or business method that is novel to the organisation (developing or adopting it) and which results, throughout its life cycle, in a reduction of environmental risk, pollution and other negative impacts of resources use (including energy use) compared to relevant alternatives»".

The interplay between the classical inducement mechanism and the derived demand-pull dynamics (Schmookler, 1954) provides therefore the main underpinning to the relationship between the production of eco-innovations and higher sales' growth rates. The grafting of the literature on firms' growth onto the analysis of eco-innovations can be far reaching in this respect. Moving from the seminal contribution by Gibrat (1931), a large number of studies has enquired into the dynamics of firms' growth and its possible determinants (Sutton, 1997; Geroski, 1999; Bottazzi and Secchi, 2006; Cefis et al., 2007; Acs and Mueller, 2008; Lotti, Santarelli and Vivarelli, 2009; Coad, 2007 and 2009; Lee, 2010; Parker et al., 2010; Bottazzi et al., 2011; Coad and Hölzl, 2011).

Among the studies that deal explicitly with innovation/growth links at firm level, many are inspired by Mansfield (1962), which was the first rigorous empirical assessment of the complex relationship between growth and innovation at the firm level. Positive links are also found by Scherer (1965), Mowery (1983), and Geroski and Machin (1992). Innovation is assumed to be 'good' for growth and survival, insofar as firms are able to capture the value from innovation (Nelson and Winter, 1982; Teece, 1986). More recently, a new wave of empirical studies have rejuvenated the interest in the impact of innovation on firms' growth (Cainelli et al., 2006; Coad and Rao, 2008; Cassia and Colombelli, 2008; Cassia et al., 2009; Colombelli et al., 2013). These studies provide some general evidence in favour of a positive and significant relation between firm innovation and firm growth. This finding is consistent across the use of different proxies for innovation. Yet, no studies systematically investigating the impact of green technologies on firms' growth can be identified.

The interaction between inducement and derived demand-pull provides a valuable theoretical framework to investigate the links between eco-innovations and firms' growth. In this perspective it is worth mentioning that some studies frame the investigation of the determinants of growth in terms of differential effects on HGFs (Colombelli and Quatraro, 2014; Colombelli et al., 2014; Coad and Rao, 2008 and 2010; Hoelzl, 2009). The interest in gazelles derives from Birch's (1979, 1981) contributions that maintain that these gazelles are the main source of job creation in the economic system (Henrekson and Johansson; 2010). The analysis of the contribution of eco-innovation to exceptionally high growth rates can help understanding the conditions that can make firms gazelles in the wake of the so-called '20-20-20' targets. In so doing further channels through which they contribute to the dynamics of aggregate economic growth can be devised, helping policymakers to design targeted supporting policy measures (Nightingale and Coad, 2014).

In view of the arguments outlined so far, we are now able to refine our working hypotheses.

The increasingly stringent regulatory framework concerning the sustainability of production processes is likely to engender a creative response in polluting firms, which are more and more willing to adopt technologies improving their environmental performances, and in particular lowering their polluting emissions. This inducement dynamics implies a surge in the derived demand for eco-innovations, so that firms producing green technologies are likely to experience increasing growth rates. Coeteris paribus, for the same token, gazelles producing green technologies are expected to run faster than other gazelles producing generic innovations.

3 Data, Variables and Methodology

3.1 The Dataset

The analysis of the relationship between eco-innovation and firms' growth has been carried out by relying on two data sources. Balance sheet data have been drawn from the Bureau van Dijk (BVD) ORBIS database (July 2012). The ORBIS database also contained information about firms' patenting activity, assigning patent numbers to BVD id numbers. This information has been matched with the OECD RegPat Database (July 2014) in order to assign priority years and technological classes to each patent.

Firm-level data have been extracted by focusing on firms operating in manufacturing sectors (NACE rev. 2 "C" section) and in six European countries, i.e. France, Italy, Germany, Spain, United Kingdom and Sweden. The first available year for balance sheet data in ORBIS is 2002. Since we used the 2012 release, we decided to take the time span 2002-2010 in order to rule out the risk of incomplete data in the last available year. As an outcome of this selection, the initial dataset comprised 953,479 firms[4].

We then dropped from the dataset the records for which information on sales was missing, as well as those not reporting the sector classification. We were left then with an unbalanced panel of 456,240 firms. Tables 1 and 2 provide the country and sector distribution of sampled firms before and after the cleaning for missing information.

>>>INSERT TABLES 1 AND 2 ABOUT HERE <<<

3.2 The variables

The empirical analysis employs dependent and the explanatory variables that are implemented by exploiting the dataset described in the previous section. In what follows we provide the details concerning the construction of each variable.

3.2.1 The dependent variable

Consistently with the basic research question underlying this study, the dependent variable used in the empirical estimations is the growth rate of deflated sales for each firm. Actually there are different available alternatives to the measurement of growth involving the use of assets, employment or sales (see Coad and Hoelzl (2011) for a discussion of the pros and cons of each proxy). However, the theoretical discussion carried out in Section 2 directly points to the use of sales growth, insofar as the main link between eco-innovation and growth is expected to be channelled by the derived-demand pull dynamics.

In order to proceed with the analysis, we define sales growth rates as follows:

$$Growth_{i,j,k,t} = \ln\left(X_{i,j,k,t}\right) - \ln\left(X_{i,j,k,t-1}\right) \qquad (1)$$

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[4] It is worth stressing that the distribution by size class shows an important weakness of the ORBIS database as for more than 18 million companies no information about employment is available. This is due to the fact that employment is not a mandatory variable in balance sheet data. Moreover, ORBIS is based on data collected by national Chambers of Commerce, i.e. concerning companies that are registered and hold a VAT. This implies that small firms are likely to be underrepresented. However, for the purposes of this paper this drawback is not too problematic, as patenting behavior is also biased towards larger firms.

Where X is measured in terms of sales of firm *i* in country *j* and sector *k* at time *t*. Following previous empirical works (Bottazzi et al, 2011; Coad, 2010), the growth rates distributions have been normalized around zero in each year by removing means as follows:

$$s_{i,j,k,t} = Growth_{i,j,k,t} - \frac{1}{N}\sum_{i=1}^{n} Growth_{i,j,k,t} \tag{2}$$

Where N stands for the total number of firms in country *j* and sector *k* at time *t* in the sample. This procedure effectively removes average time trends common to all the firms caused by factors such as inflation and business cycles.

Figure 1 shows the distribution of firms' growth rates. As evidenced by the figure, the empirical distribution of the growth rates for our sample seems closer to a Laplacian than to a Gaussian distribution. This is in line with previous studies analysing the distribution of firm growth rates (Bottazzi et al. 2007; Bottazzi and Secchi 2006; Castaldi and Dosi 2009).

>>>INSERT FIGURE 1**Errore. L'origine riferimento non è stata trovata.** ABOUT HERE<<<

Such evidence suggests that standard regression estimators, like ordinary least squares (OLS), assuming Gaussian residuals may perform poorly if applied to these data. To cope with this, a viable and increasingly used alternative consists of implementing the least absolute deviation (LAD) techniques, which are based on the minimization of the absolute deviation from the median rather than the squares of the deviation from the mean. We will provide further details in Section 3.3.

3.2.2 Explanatory variables

A first explanatory variable aims at controlling for firm size. For this reason we include in the regression the natural logarithm of firms' sales at time t-1 ($SALES_{i,t-1}$). We also control for firms age by taking the logarithm of the difference between the year of the observation and the year birth reported in the dataset ($AGE_{i,t-1}$).

Our focal explanatory variables concern firms' innovation efforts, and in particular eco-innovations. To this purpose we use patent statistics to derive a measure of firms' stock of technological knowledge. It is worth emphasizing that we made each patent 'last' three years in order to cope with the intrinsic volatility of patenting behaviour. This means that a patent application submitted by firm i say in 2003, will also be assigned to same firm in 2004 and 2005.

Firms' **knowledge stock** ($KSTOCK_{i,t}$)has been then computed by applying the permanent inventory method to patent applications. We calculated it as the cumulated stock of past patent applications using a rate of obsolescence of 15% per annum:

$$KSTOCK_{i,t} = \dot{h}_{i,t} + (1-\delta)KSTOCK_{i,t-1} \qquad (3)$$

Where $\dot{h}_{i,t}$ is the flow of patent applications and δ is the rate of obsolescence. The choice of the rate of obsolescence raises the basic issue as to which is the most appropriate value. There are indeed a number of studies moving from Pakes and Schankerman (1989) and Schankerman (1998) that attempted to estimate the patent depreciation rate. However, for the scope of this paper we follow the established body of literature based on Hall et al. (2005) that applies to patent applications the same depreciation rate as the one applied to R&D expenditures (see for example McGahan and Silverman 2006, Coad and Rao 2006, Nesta 2008, Laitner and Stolyarov 2013, Rahko 2014).

The calculation of the knowledge stock is a crucial step for the appreciation of the effects of eco-innovation. The latter are detected by building an indicator variable ($GREEN_{i,t}$) which is equal to 1 if the firm *i* has produced at least one patent that can be labelled as 'green' at time *t*, 0 otherwise.

Patents were then labelled as *environmental* on the basis of the World Intellectual Property Organization "WIPO IPC green inventory", an International Patent Classification that identifies patents related to the so-called "Environmentally Sound Technologies" and scatters them into their technology fields (Tab. A1), with the *caveat* that it is not the only possible classification of green technologies and, as with other available classifications, it presents some drawbacks (Costantini et al., 2013)[5].

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[5] Although interesting, it is out of the scope of the current work to systematically test for the differences that may arise from the choice of classification. We selected the WIPO IPC green inventory since it is currently a wide and well established classification of green technologies. The OECD has indeed also developed the OECD Indicator of Environmental Technologies (OECD, 2011), based on the International Patent Classification (IPC), which features

Table 3 provides a summary of variables definitions as well as their main descriptive statistics.

>>> INSERT TABLE 3 ABOUT HERE <<<

3.3 Methodology

The baseline specification to model firms' growth as a function of firm innovation follows the original logarithmic representation in Gibrat's Law:

$$\ln\left(X_{i,t}\right)=\lambda_1+\lambda_2\ln\left(X_{i,t-1}\right)+\beta Z_{i,t-1}+\sum\omega_j+\sum\psi_t+\varepsilon_{i,t} \tag{4}$$

where $X_{i,t}$ and $X_{i,t-1}$ represent sales (deflated) for firm *i* at time *t* and *t-1*, respectively, while $Z_{i,t-1}$ is a vector of explanatory variables for firm i at time t-1. ω_j and ψ_t represent a set of industry[6] and time dummies, controlling respectively, for macroeconomic and time fluctuations. Transforming Equation (1), we obtain an alternative specification of Gibrat's Law as follows:

$$\begin{aligned} Growth_{i,t} &= \lambda_1+\lambda_2\ln\left(X_{i,t-1}\right)+\beta_1 KSTOCK_{i,t-1}+\\ &+\beta_2(GREEN_{i,t}\times KSTOCK_{i,t})+\beta_3 AGE+\sum\psi_t+\varepsilon_{i,t} \end{aligned} \tag{5}$$

Equation (2) can be estimated using traditional panel data techniques implementing the fixed effects estimator, by removing industry-specific effects as by definition they are accounted for by firm-level fixed effects. The effects of generic innovation on firms' growth are captured by the coefficient β_1, while β_2 allows us to appreciate the differential effects of eco-innovations on

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seven environmental areas, i.e. (a) general environmental management, (b) energy generation from renewable and non-fossil sources, (c) combustion technologies with mitigation potential, (d) technologies specific to climate change mitigation, (e) technologies with potential or indirect contribution to emission mitigation, (f) emission abatement and fuel efficiency in transportation, and (g) energy efficiency in buildings and lighting. At the same time, the European Patent Office (EPO) is working on completing its own system of classification (ECLA) to assign each patent a green tag, depending on the environmental aim of each patent. So far, EPO allows tagging technologies for adaptation or mitigation to climate change (Y02), in terms of buildings (Y02B), energy (Y02E), transportation (Y02T) and capture, storage sequestration or disposal of GHG (Y02C). More recently, Costantini et al. (2013) have pointed to the shortcomings of classification methods based on efforts to collect IPCs potentially related to green technologies in one place. Focusing on the biofuels sector, they show that the WIPO Green Inventory is likely to overestimate the number of patents to be assigned due to the fact that IPCs are not specifically designed to identify this narrow and very specific domain. Clinical analysis based on keyword search and validations from experts are likely to yield finer grained classifications. Nonetheless, due to the wide scope of our analysis which encompasses many kinds of green technologies, we will rely on the WIPO Green Inventory.

[6] The industrial context is important because innovation is 'industry context specific' (Dosi, 1988). Thus, we need to control for industry effects.

firms' growth. Actually, when $GREEN_{i,t} = 1$, β_2 adds β_1 and the effect of $KSTOCK_{i,t}$ is augmented accordingly.

However, as noted in section 3.2.1, the kernel density plot of the dependent variable reveals that its distribution seems closer to a Laplacian than to a Gaussian one. For this reason traditional linear estimators like the standard fixed effects may perform poorly.

To cope with this, a viable and increasingly used alternative consists of implementing the least absolute deviation (LAD) techniques, which are based on the minimization of the absolute deviation from the median rather than the squares of the deviation from the mean. The equation to be estimate becomes the following:

$$\begin{aligned} Growth_{i,t} &= \lambda_1 + \lambda_2 \ln\left(X_{i,t-1}\right) + \beta_1 KSTOCK_{i,t-1} + \\ &+ \beta_2 (GREEN_{i,t} \times KSTOCK_{i,t}) + \\ &+ \beta_3 AGE + \sum \omega_i + \sum \mu_i + \sum \psi_t + \varepsilon_{i,t} \end{aligned} \tag{6}$$

In which we reintroduce industry dummies ω_j and add country dummies μ_j. Following Coad (2010), we do not include individual dummies in the analysis. Since we are dealing with rates rather than levels of growth, in our view any firm-specific components have been mostly removed. We follow the large literature on analysis of firm growth rates which states that the non-Gaussian nature of growth rate residuals is a more important econometric problem and deserving of careful attention.

4 Empirical results

The results of the fixed effects estimations of the relationship between eco-innovation and firms' growth are reported in table 4. Columns (1) and (2) show the results obtained by running the estimations on the whole dataset. Column (1) only includes $KSTOCK_{t-1}$ as focal regressor besides the other controls. This allows us to position our results with respect to previous empirical papers on the topic. Actually, the figures appear to be quite in line with the other studies as the coefficient of $KSTOCK_{t-1}$ is positive and highly significant. The commitment of resources to innovation activities, as proxied by the outcome variable represented by firms' patents stock, on average is associated to increasing growth rates.

>>> INSERT TABLE 4 ABOUT HERE <<<

Column (2) includes the interaction between $KSTOCK_{t-1}$ and $GREEN_{t-1}$, i.e. the dummy variable that takes value 1 if the firm *i* has applied at least one green patent at time *t*, 0 otherwise. These coefficients provide information on the extent to which the impact of innovation activities on firms' growth is augmented by the fact that some of the firms' patent involved green technologies. The coefficient is positive and significant, supporting the idea that out of innovating firms, those producing green technologies are likely to benefit from a higher impact of innovation activities on their performances. In other words, growing firms' sales are associated with innovation efforts, but this link is amplified when the innovative this activity concerns eco-innovations. This result is in line with our main working hypothesis according to which firms generating green technologies are favoured by the increasing derived demand of downstream firms that creatively respond to the more and more stringent environmental regulatory frameworks. These latter indeed raise production costs for polluting firms, in such a way that the commitment of resources to adopt green technologies is offset by the reduction of production costs due to the compliance with environmental regulations.

Now we turn our attention to the difference between HGFs and non-HGFs. There are different definitions of HGFs in the literature, and the OECD provides its own 'institutional' definition. In this paper we attempt to stand as closer as possible to the information conveyed by the data, rather than following other aprioristic definitions. For this reason we calculated the average annual growth rate of each firm over the observed time span, and then we labelled a firm as HGF if its average annual growth rate was in the uppermost decile of the distribution.

Columns (3) and (4) provide the results of the estimations carried out on the subset of HGFs identified through the procedure we just described. The results are quite in line with previous estimations. Actually the coefficient of $KSTOCK_{t-1}$ is still positive and highly significant in both models. Moreover, if one looks at the coefficient of the interaction, it is again positive and significant. Once again, innovation is associated to higher growth rates even for HGFs, and the relationship is even greater if their technological activity involves the generation of green technologies. Columns (5) and (6) provides the estimation results for the subsample of non-HGFs. The difference from HGFs is clearly evident. Actually, neither $KSTOCK_{t-1}$ nor the interaction variable seem to be characterized by a significant coefficient, although positive. This would imply that the results on the whole sample are actually driven by HGFs.

In order to gain a more comprehensive understanding of the effects of eco-innovation we implement another set of estimations by including the dummy variable $GREEN_{t-1}$ alone, instead of interacting it with $KSTOCK_{t-1}$. The results are shown in Table 5.

>>>INERT TABLE 5 ABOUT HERE <<<

The interpretation of the coefficient of the dummy is straightforward, as it implies a change in the intercept of the regression line, and hence its shift. The first column reports the results of the estimation carried out on the full sample. Consistently with the other regressions, the coefficient of $KSTOCK_{t-1}$ is positive and statistically significant. The dummy $GREEN_{t-1}$ also is characterized by a positive and significant coefficient, which denotes an upwards shift of the regression line. The interpretation is that innovation is related to higher firms' growth rates, and that for each level of innovative activity, those firms that produce green technologies on average show higher growth rates. This allows us to further qualify our argument, in that eco-innovation not only enhances the link between innovative activities and firms' growth, but also provides a sort of comparative advantage to innovative firms, allowing them to be characterized by higher growth rates than other innovative firms not involved in the generation of green technologies.

Column (2) shows the results of the estimation carried out on the subset of the HGFs. The results are once again pretty consistent with what we discussed so far. The coefficient of $KSTOCK_{t-1}$ is positive and significant, and the same applies to the coefficient of $GREEN_{t-1}$. If we look at column (3), reporting the results of the regressions concerning the non-HGFs, we observed that both the coefficient of $KSTOCK_{t-1}$ and that of $GREEN_{t-1}$ are not significant. Taken together, the evidence provided by these two columns once again suggests that the results of the overall estimations are driven by the dynamics concerning HGFs. We are therefore able now to provide an answer to the question raised in the title, i.e. 'do green gazelles run faster'? Yes, they do. Actually the generic result according to which the generation of green technologies i) enhances the effects of innovation on firms' growth, and ii) provides a comparative advantage translating into higher growth rates (on average), seem to hold for HGFs and not to hold for the other firms.

By way of robustness check, in Table 6 we provide the results for a subset of econometric estimations obtained by implementing the LAD estimator with boostrapped standard errors. This step is necessary in that we have already observed in Section 3 that the dependent variable is characterized that resembles much more a Laplace than a Gaussian.

>>> INSERT TABLE 6 ABOUT HERE <<<

The first set of results concerns the HGF subsample. Column (1a) reports the coefficients for the baseline model, i.e. the one including only $KSTOCK_{t-1}$. As anticipated, in this step we do not include for firm-level dummies as most of the individual effects are removed by taking the normalized log-difference of sales as a dependent variable. However, besides time dummies we also include country and industry dummies (calculated on the basis of the 2 digit NACE rev. 2 classification). The results seem to be robust to the change of estimator, as $KSTOCK_{t-1}$ is still characterized by a positive and significant coefficient. Column (1b) reports instead the model also including the interaction between $KSTOCK_{t-1}$ and $GREEN_{t-1}$. The coefficient of the interaction variable is still positive and significant, and the same applies to that of $KSTOCK_{t-1}$ alone. Finally column (1c) includes the dummy variable $GREEN_{t-1}$ instead of the interaction variable. Once again the results are in line with the previous estimations. All in all we can conclude that the eco-innovation seems to contribute the growth process of HGFs in such a way that ‘green gazelles’ are supposed to run faster than other HGFs.

The second set of regressions provides instead evidence about the relationship between innovation, and eco-innovation, and growth rates of firms that cannot be included in the HGF subsample. Column (2a) shows the coefficients yield by estimating the baseline model. The main difference with the previous estimations is that now the lagged value of *SALES* is not significant. On the contrary AGE_{t-1} is characterized by a negative and significant coefficient. The coefficient of $KSTOCK_{t-1}$ is positive and significant, suggesting that increasing growth rates are associated with higher levels of innovative activity. In column (2b) we include the interaction term between $KSTOCK_{t-1}$ and $GREEN_{t-1}$. While the evidence on the other regressors is substantially unchanged, the coefficient on the interaction term is not significant for the subsample of non-HGF firms. This result confirm the one obtained with the linear fixed effects estimations in Table 4. Firms’ growth is associated with higher level of innovations. This holds both for gazelles and for non-HGFs. However, when we look at the differential effects of eco-innovation green-gazelles seem to run faster than their non-green counterparts, while eco-innovation does not yield any significant effect on the relationship between innovation and growth rates for non-HGFs. Finally, column (2c) shows the results obtained by including the $GREEN_{t-1}$ dummy alone, rather than interacted with $KSTOCK_{t-1}$. The results in this case deviate from the evidence gathered in the previous tables, as the dummy is characterized by a positive and significant coefficient. This would suggest that while the fact of producing eco-innovation does not affect the impact of innovations on firms growth for HGFs, on average producing eco-innovation is associated with higher levels of growth.

5 Conclusions

There is growing interest at the policy level about the importance to use regulation as a means to induce firms to lower their polluting emissions and improving the efficiency of their production processes at the same time. Moving from the seminal contribution by Porter and van der Linde (1993), a large body of policy measure for the environment have been aiming at coupling the improvement of firms' environmental and economic performances (and productivity in particular). These benefits are supposed to show up due the increasing firms' efforts to adopt eco-innovations in their production processes. However a rather less debated of this normative environment concerns the spread of the effects of inducement mechanisms along the value chain.

In this paper we have hypothesized that actually the derived demand for eco-innovation by downwards firms is likely to positively affect the performances, and sales in particular, of upwards firms producing and supplying eco-innovations. In this direction specific attention has been devoted to a peculiar kind of firms, i.e. HGFs or gazelles, in view of their rather undisputed contribution to the process of economic growth. In view of this, our econometric estimations of the determinants of firms' growth provided support to the idea that eco-innovation positively affects firms' growth processes. Moreover we show that actually this generic result is driven by HGFs rather than non-HGFs. This allows us to draw the conclusion that innovation plays a key role in the growth process of HGFs, and that 'green gazelles' that is HGFs producing green technologies are i) much more affected by innovation and ii) are characterized on average by higher growth rates.

Green gazelles run faster than the others. This bears important policy implications, calling for increasing attention to the systemic character of technology and environmental policies (Crespi and Quatraro, 2013 and 2015). Actually it is quite evident how the effects of environmental policies pushing firms' to adopt green technologies engender a bandwagon effect in the economy, which spreads also along the value chain. At the same time, technology policies promoting the development of specific technological areas should be coordinated with environmental policies in such a way that firms' producing new technologies are given the necessary incentives to produce 'green technologies' to anticipate the increasing demand from downstream firms. Also, the case for 'competent' public procurement of innovation also emerges. Public expenditure is indeed key to the development of strategic technological fields, and once again the coordination with other technology and environmental policies may prove to be crucial to display positive effects on environmental and economic performances not only of firms, but of the economy as a whole in the medium and long term.

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Table 1 - Country distribution of sampled firms

	Full Sample		Cleaned Sample	
Country	Freq.	Percent	Freq.	Percent
DE	223,301	23.87	83,31	18.26
ES	186,501	19.94	115,706	25.36
FR	129,815	13.88	122,205	26.79
UK	197,191	21.08	450	0.10
IT	141,949	15.17	132,538	29.05
SE	56,722	6.06	2,031	0.45
Total	935,479	100.00	456,240	100.00

Source: our elaboration on Bureau Van Dijk Orbis Data.

Table 2 - Sector Distribution of Sampled Firms

Nace rev. 2	Definition	Full Sample		Cleaned Sample	
		Freq.	Percent	Freq.	Percent
10	Manufacture of food products	109,052	11.66	55,598	12.19
11	Manufacture of beverages	14,144	1.51	7,237	1.59
12	Manufacture of tobacco products	311	0.03	106	0.02
13	Manufacture of textiles	30,29	3.24	13,859	3.04
14	Manufacture of wearing apparel	33,809	3.61	17,493	3.83
15	Manufacture of leather and related products	16,362	1.75	10,202	2.24
16	Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials	47,887	5.12	20,351	4.46
17	Manufacture of paper and paper products	12,227	1.31	6,173	1.35
18	Printing and reproduction of recorded media	63,827	6.82	29,288	6.42
19	Manufacture of coke and refined petroleum products	1,394	0.15	539	0.12
20	Manufacture of chemicals and chemical products	24,279	2.60	11,647	2.55
21	Manufacture of basic pharmaceutical products and pharmaceutical preparations	4,977	0.53	2,137	0.47
22	Manufacture of rubber and plastic products	34,298	3.67	18,465	4.05
23	Manufacture of other non-metallic mineral products	44,431	4.75	23,576	5.17
24	Manufacture of basic metals	13,659	1.46	7,116	1.56
25	Manufacture of fabricated metal products, except machinery and equipment	156,227	16.70	83,907	18.39
26	Manufacture of computer, electronic and optical products	39,06	4.18	16,488	3.61
27	Manufacture of electrical equipment	29,244	3.13	13,883	3.04
28	Manufacture of machinery and equipment n.e.c.	75,857	8.11	38,673	8.48
29	Manufacture of motor vehicles, trailers and semi-trailers	14,062	1.50	6,563	1.44
30	Manufacture of other transport equipment	12,552	1.34	4,814	1.06
31	Manufacture of furniture	44,028	4.71	21,224	4.65
32	Other manufacturing	64,119	6.85	21,623	4.74
33	Repair and installation of machinery and equipment	49,383	5.28	25,278	5.54
Total		935,479	100.00	456,240	100.00

Source: our elaboration on Bureau Van Dijk Orbis Data.

Table 3 – Variables definition and descriptive statistics

Variables	Definition	N	Max	Min	Mean	St. Dev.
$S_{i,t}$	Normalized firms' growth rates	2030552	9.091	-11.252	0.021	0.221
$SALES_{i,t-1}$	Logarithm of firms' sales level	2366794	10.424	-3.542	0.042	1.090
$AGE_{i,t-1}$	Logarithm of firms' age	2429568	5.974	0.000	3.212	0.459
$KSTOCK_{i,t-1}$	Firms' knowledge capital stock (PIM on patent applications)	2045318	11.331	0.000	0.064	0.443
$GREEN_{i,t-1}$	Dummy variable = 1 if the firm has applied At least one green patent at time t	2431033	1.000	0.000	0.003	0.057

Table 4 – Econometric results (I), fixed effects estimations

	Overall		HGFs		Non-HGFs	
	$S_{i,t}$	$S_{i,t}$	$S_{i,t}$	$S_{i,t}$	$S_{i,t}$	$S_{i,t}$
SALES$_{i,t-1}$	-0.4821***	-0.4821***	-0.6513***	-0.6513***	-0.4866***	-0.4866***
	(0.0006)	(0.0006)	(0.0020)	(0.0020)	(0.0007)	(0.0007)
AGE$_{i,t-1}$	0.1169***	0.1170***	-0.1006***	-0.0998***	0.0988***	0.0988***
	(0.0039)	(0.0039)	(0.0209)	(0.0209)	(0.0035)	(0.0035)
KSTOCK$_{i,t-1}$	0.0183***	0.0179***	0.0125***	0.0111***	0.0014	0.0015
	(0.0011)	(0.0012)	(0.0042)	(0.0042)	(0.0011)	(0.0011)
GREEN$_{i,t-1}$ × ***KSTOCK***$_{i,t-1}$		0.0025*		0.0081*		-0.0004
		(0.0013)		(0.0047)		(0.0013)
Time dummies	YES	YES	YES	YES	YES	YES
Cons	-0.3374***	-0.3377***	0.5447***	0.5424***	-0.3145***	-0.3145***
	(0.0118)	(0.0118)	(0.0598)	(0.0598)	(0.0108)	(0.0108)
N	1981248	1981248	192243	192243	1789005	1789005
AIC	-1.4739e+06	-1.4739e+06	68133.1226	68131.4696	-1.8749e+06	-1.8749e+06
BIC	-1.4738e+06	-1.4738e+06	68244.9543	68253.4678	-1.8747e+06	-1.8747e+06

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 5 – Econometric results (II), fixed effects estimations

	(Overall)	(HGF)	(Non-HGF)
	$S_{i,t}$	$S_{i,t}$	$S_{i,t}$
SALES$_{i,t-1}$	-0.4821***	-0.6514***	-0.4866***
	(0.0006)	(0.0020)	(0.0007)
AGE$_{i,t-1}$	0.1170***	-0.0997***	0.0988***
	(0.0039)	(0.0209)	(0.0035)
KSTOCK$_{i,t-1}$	0.0177***	0.0106**	0.0013
	(0.0012)	(0.0042)	(0.0011)
GREEN$_{i,t-1}$	0.0192***	0.0530***	0.0049
	(0.0043)	(0.0151)	(0.0043)
Time Dummies	YES	YES	YES
Cons	-0.3378***	0.5421***	-0.3146***
	(0.0118)	(0.0598)	(0.0108)
N	1981248	192243	1789005
AIC	-1.4739e+06	68119.8644	-1.8749e+06
BIC	-1.4738e+06	68241.8626	-1.8747e+06

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 6 – Econometric results (III), LAD estimations

	HGF			NON-HGF		
	(1a)	(1b)	(1c)	(2a)	(2b)	(2c)
	$S_{i,t}$	$S_{i,t}$	$S_{i,t}$	$S_{i,t}$	$S_{i,t}$	$S_{i,t}$
$SALES_{i,t-1}$	-0.0195***	-0.0195***	-0.0194***	0.0002	0.0002	0.0002
	(0.0005)	(0.0006)	(0.0005)	(0.0001)	(0.0002)	(0.0002)
$AGE_{i,t-1}$	-0.0270***	-0.0271***	-0.0271***	-0.0089***	-0.0089***	-0.0089***
	(0.0012)	(0.0014)	(0.0013)	(0.0002)	(0.0002)	(0.0002)
$KSTOCK_{i,t-1}$	0.0117***	0.0108***	0.0109***	0.0039***	0.0039***	0.0036***
	(0.0008)	(0.0010)	(0.0008)	(0.0003)	(0.0004)	(0.0004)
$GREEN_{i,t-1} \times KSTOCK_{i,t-1}$		0.0028*			0.0004	
		(0.0018)			(0.0009)	
$GREEN_{i,t-1}$			0.0108***			0.0063**
			(0.007)			(0.0031)
Country dummies	YES	YES	YES	YES	YES	YES
Industry dummies	YES	YES	YES	YES	YES	YES
Time dummies	YES	YES	YES	YES	YES	YES
Cons	0.2789***	0.2787***	0.2784***	0.0700***	0.0699***	0.0699***
	(0.0309)	(0.0263)	(0.0267)	(0.0027)	(0.0015)	(0.0014)
N	192243	192243	192243	1789005	1789005	1789005

Bootstrapped Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Figure 1 – Kernel Distribution, Firms' Normalized Growth Rates

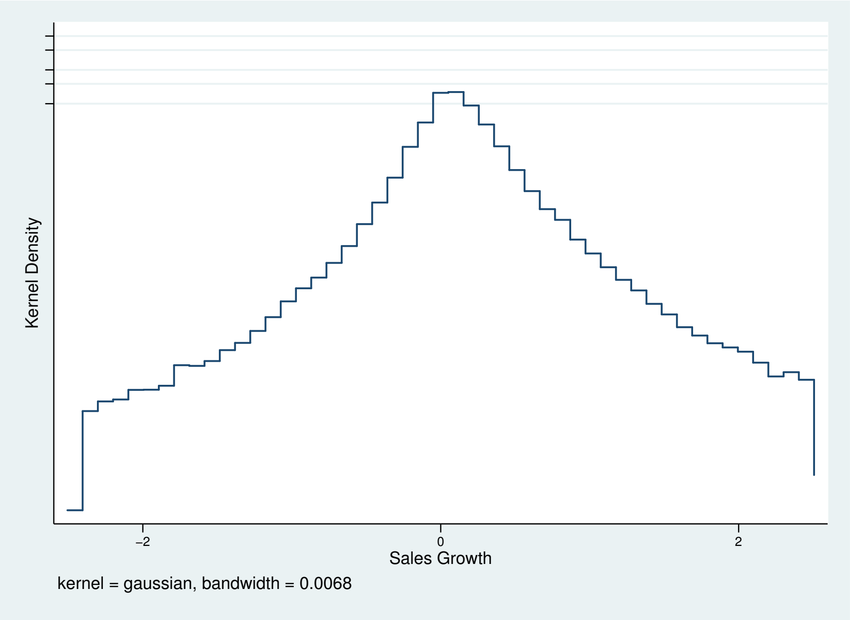

Table A1 – WIPO IPC Green Inventory

TOPIC	IPC
ALTERNATIVE ENERGY PRODUCTION	
Bio-fuels	
Solid fuels	C10L 5/00, 5/40-5/48
Torrefaction of biomass	C10B 53/02
	C10L 5/40, 9/00
Liquid fuels	C10L 1/00, 1/02, 1/14
Vegetable oils	C10L 1/02, 1/19
Biodiesel	C07C 67/00, 69/00
	C10G
	C10L 1/02, 1/19
	C11C 3/10
	C12P 7/64
Bioethanol	C10L 1/02, 1/182
	C12N 9/24
	C12P 7/06-7/14
Biogas	C02F 3/28, 11/04
	C10L 3/00
	C12M 1/107
	C12P 5/02
From genetically engineered organisms	C12N 1/13, 1/15, 1/21, 5/10, 15/00 A01H
Integrated gasification combined cycle (IGCC)	C10L 3/00
	F02C 3/28
Fuelcells	H01M 4/86-4/98, 8/00-8/24, 12/00-12/08
Electrodes	H01M 4/86-4/98
Inert electrodes with catalytic activity	H01M 4/86-4/98
Non-activeparts	H01M 2/00-2/04 , 8/00-8/24
Within hybridcells	H01M 12/00-12/08
Pyrolysis or gasification of biomass	
	C10B 53/00
	C10J
Harnessing energy from manmade waste	
Agricultural waste	C10L 5/00
Fuel from animal waste and crop residues	C10L 5/42, 5/44
Incinerators for field, garden or wood waste	F23G 7/00, 7/10
Gasification	C10J 3/02, 3/46
	F23B 90/00
	F23G 5/027
Chemicalwaste	B09B 3/00
	F23G 7/00
Industrial waste	C10L 5/48
	F23G 5/00, 7/00
Using top gas in blast furnaces to power pig-iron production	C21B 5/06
Pulp liquors	D21C 11/00
Anaerobic digestion of industrial waste	A62D 3/02
	C02F 11/04, 11/14
Industrial wood waste	F23G 7/00, 7/10
Hospital waste	B09B 3/00
	F23G 5/00
Landfill gas	B09B
Separation of components	B01D 53/02, 53/04, 53/047, 53/14, 53/22, 53/24
Municipal waste	C10L 5/46
	F23G 5/00
Hydroenergy	
Water-power plants	E02B 9/00-9/06
Tide or wave power plants	E02B 9/08
Machines or engines for liquids	F03B
	F03C
Using wave or tide energy	F03B 13/12-13/26
Regulating, controlling or safety means of machines or engines	F03B 15/00-15/22
Propulsion of marine vessels using energy derived from water movement	B63H 19/02, 19/04
Ocean thermal energy conversion (OTEC)	F03G 7/05
Wind energy	F03D
Structural association of electric generator with mechanical driving motor	H02K 7/18
Structural aspects of wind turbines	B63B 35/00
	E04H 12/00
	F03D 11/04
Propulsion of vehicles using wind power	B60K 16/00
Electric propulsion of vehicles using wind power	B60L 8/00
Propulsion of marine vessels by wind-powered motors	B63H 13/00
Solar energy	
Photovoltaics (PV)	
Devices adapted for the conversion of radiation energy into electrical energy	H01L 27/142, 31/00-31/078 H01G 9/20
	H02N 6/00

TOPIC	IPC
Using organic materials as the active part	H01L 27/30, 51/42-51/48
Assemblies of a plurality of solar cells	H01L 25/00, 25/03, 25/16, 25/18, 31/042
Silicon; single-crystal growth	C01B 33/02
	C23C 14/14, 16/24
	C30B 29/06
Regulating to the maximum power available from solar cells	G05F 1/67
Electric lighting devices with, or rechargeable with, solar cells	F21L 4/00
	F21S 9/03
Charging batteries	H02J 7/35
Dye-sensitised solar cells (DSSC)	H01G 9/20
	H01M 14/00
Use of solar heat	F24J 2/00-2/54
For domestic hot water systems	F24D 17/00
For space heating	F24D 3/00, 5/00, 11/00, 19/00
For swimming pools	F24J 2/42
Solar updraft towers	F03D 1/04, 9/00, 11/04 F03G 6/00
For treatment of water, waste water or sludge	C02F 1/14
Gas turbine power plants using solar heat source	F02C 1/05
Hybrid solar thermal-PV systems	H01L 31/058
Propulsion of vehicles using solar power	B60K 16/00
Electric propulsion of vehicles using solar power	B60L 8/00
Producing mechanical power from solar energy	F03G 6/00-6/06
Roof covering aspects of energy collecting devices	E04D 13/00, 13/18
Steam generation using solar heat	F22B 1/00
	F24J 1/00
Refrigeration or heat pump systems using solar energy	F25B 27/00
Use of solar energy for drying materials or objects	F26B 3/00, 3/28
Solar concentrators	F24J 2/06
	G02B 7/183
Solar ponds	F24J 2/04
Geothermal energy	
Use of geothermal heat	F01K
	F24F 5/00
	F24J 3/08
	H02N 10/00
	F25B 30/06
Production of mechanical power from geothermal energy	F03G 4/00-4/06, 7/04

TOPIC	IPC
Other production or use of heat, not derived from combustion, e.g. natural heat	F24J 1/00, 3/00, 3/06
Heat pumps in central heating systems using heat accumulated in storage masses	F24D 11/02
Heat pumps in other domestic- or space-heating systems	F24D 15/04
Heat pumps in domestic hot-water supply systems	F24D 17/02
Air or water heaters using heat pumps	F24H 4/00
Heat pumps	F25B 30/00
Using waste heat	
To produce mechanical energy	F01K 27/00
Of combustion engines	F01K 23/06-23/10
	F01N 5/00
	F02G 5/00-5/04
	F25B 27/02
Of steam engine plants	F01K 17/00, 23/04
Of gas-turbine plants	F02C 6/18
As source of energy for refrigeration plants	F25B 27/02
For treatment of water, waste water or sewage	C02F 1/16
Recovery of waste heat in paper production	D21F 5/20
For steam generation by exploitation of the heat content of hot heat carriers	F22B 1/02
Recuperation of heat energy from waste incineration	F23G 5/46
Energy recovery in air conditioning	F24F 12/00
Arrangements for using waste heat from furnaces, kilns, ovens or retorts	F27D 17/00
Regenerative heat-exchange apparatus	F28D 17/00-20/00
Of gasification plants	C10J 3/86
Devices for producing mechanical power from muscle energy	F03G 5/00-5/08
TRANSPORTATION	
Vehicles in general	
Hybrid vehicles, e.g Hybrid Electric Vehicles (HEVs)	B60K 6/00, 6/20
Control systems	B60W 20/00
Gearingstherefor	F16H 3/00-3/78, 48/00-48/30
Brushless motors	H02K 29/08
Electromagnetic clutches	H02K 49/10
Regenerative braking systems	B60L 7/10-7/22
Electric propulsion with power supply from force of nature, e.g. sun, wind	B60L 8/00
Electric propulsion with power supply external to vehicle	B60L 9/00
With power supply from fuel cells, e.g for hydrogen vehicles	B60L 11/18
Combustion engines operating on gaseous fuels, e.g hydrogen	F02B 43/00
	F02M 21/02, 27/02

TOPIC	IPC
Power supply from force of nature, e.g. sun, wind	B60K 16/00
Charging stations for electric vehicles	H02J 7/00
Vehicles other than rail vehicles	
Drag reduction	
	B62D 35/00, 35/02
	B63B 1/34-1/40
Human-powered vehicle	B62K
	B62M 1/00, 3/00, 5/00, 6/00
Rail vehicles	B61
Drag reduction	B61D 17/02
Marine vessel propulsion	
Propulsive devices directly acted on by wind	B63H 9/00
Propulsion by wind-powered motors	B63H 13/00
Propulsion using energy derived from water movement	B63H 19/02, 19/04
Propulsion by muscle power	B63H 16/00
Propulsion derived from nuclear energy	B63H 21/18
Cosmonautic vehicles using solar energy	B64G 1/44
ENERGY CONSERVATION	
Storage of electrical energy	B60K 6/28
	B60W 10/26
	H01M 10/44-10/46
	H01G 9/155
	H02J 3/28, 7/00, 15/00
Power supply circuitry	H02J
With power saving modes	H02J 9/00
Measurement of electricity consumption	B60L 3/00
	G01R
Storage of thermal energy	C09K 5/00
	F24H 7/00
	F28D 20/00, 20/02
Low energy lighting	
Electroluminescent light sources (e.g. LEDs, OLEDs, PLEDs)	F21K 99/00
	F21L 4/02
	H01L 33/00-33/64, 51/50
	H05B 33/00
Thermal building insulation, in general	E04B 1/62, 1/74-1/80, 1/88, 1/90
Insulating building elements	E04C 1/40, 1/41, 2/284-2/296
For door or window openings	E06B 3/263
For walls	E04B 2/00

TOPIC	IPC
	E04F 13/08
For floors	E04B 5/00
	E04F 15/18
For roofs	E04B 7/00
	E04D 1/28, 3/35, 13/16
For ceilings	E04B 9/00
	E04F 13/08
Recovering mechanical energy	F03G 7/08
Chargeable mechanical accumulators in vehicles	B60K 6/10, 6/30
	B60L 11/16
WASTE MANAGEMENT	
Waste disposal	B09B
	B65F
Treatment of waste	
Disinfection or sterilisation	A61L 11/00
Treatment of hazardous or toxic waste	A62D 3/00, 101/00
Treating radioactively contaminated material; decontamination arrangements therefor	G21F 9/00
Refuse separation	B03B 9/06
Reclamation of contaminated soil	B09C
Mechanical treatment of waste paper	D21B 1/08, 1/32
Consuming waste by combustion	F23G
Reuse of waste materials	
Use of rubber waste in footwear	A43B 1/12, 21/14
Manufacture of articles from waste metal particles	B22F 8/00
Production of hydraulic cements from waste materials	C04B 7/24-7/30
Use of waste materials as fillers for mortars, concrete	C04B 18/04-18/10
Production of fertilisers from waste or refuse	C05F
Recovery or working-up of waste materials	C08J 11/00-11/28
	C09K 11/01
	C11B 11/00, 13/00-13/04
	C14C 3/32
	C21B 3/04
	C25C 1/00
	D01F 13/00-13/04
Pollution control	
Carbon capture and storage	B01D 53/14, 53/22, 53/62
	B65G 5/00
	C01B 31/20
	E21B 41/00, 43/16

TOPIC	IPC
	E21F 17/16
	F25J 3/02
Air quality management	
Treatment of waste gases	B01D 53/00-53/96
Exhaust apparatus for combustion engines with means for treating exhaust	F01N 3/00-3/38
Rendering exhaust gases innocuous	B01D 53/92
	F02B 75/10
Removal of waste gases or dust in steel production	C21C 5/38
Combustion apparatus using recirculation of flue gases	C10B 21/18
	F23B 80/02
	F23C 9/00
Combustion of waste gases or noxious gases	F23G 7/06
Electrical control of exhaust gas treating apparatus	F01N 9/00
Separating dispersed particles from gases or vapours	B01D 45/00-51/00
	B03C 3/00
Dust removal from furnaces	C21B 7/22
	C21C 5/38
	F27B 1/18
	F27B 15/12
Use of additives in fuels or fires to reduce smoke or facilitate soot removal	C10L 10/02, 10/06
	F23J 7/00
Arrangements of devices for treating smoke or fumes from combustion apparatus	F23J 15/00
Dust-laying or dust-absorbing materials	C09K 3/22
Pollution alarms	G08B 21/12
Control of water pollution	
Treating waste-water or sewage	B63J 4/00
	C02F
To produce fertilisers	C05F 7/00
Materials for treating liquid pollutants	C09K 3/32
Removing pollutants from open water	B63B 35/32
	E02B 15/04
Plumbing installations for waste water	E03C 1/12
Management of sewage	C02F 1/00, 3/00, 9/00
	E03F
Means for preventing radioactive contamination in the event of reactor leakage	G21C 13/10
AGRICULTURE / FORESTRY	
Forestry techniques	A01G 23/00
Alternative irrigation techniques	A01G 25/00
Pesticide alternatives	A01N 25/00-65/00
Soil improvement	C09K 17/00
	E02D 3/00
Organic fertilisers derived from waste	C05F
ADMINISTRATIVE, REGULATORY OR DESIGN ASPECTS	
Commuting, e.g., HOV, teleworking, etc.	G06Q
	G08G
Carbon/emissions trading, e.g pollution credits	G06Q
Static structure design	E04H 1/00

NUCLEAR POWER GENERATION	
Nuclear engineering	G21
Fusion reactors	G21B
Nuclear (fission) reactors	G21C
Nuclear power plant	G21D
Gas turbine power plants using heat source of nuclear origin	F02C 1/05