KNOWLEDGE SPILLOVERS FROM RENEWABLE, CLEAN, AND SMART ENERGY TECHNOLOGIES

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Overview

Mitigation of climate change requires a switch from fossil fuels to renewable energy sources, such as intermittent wind and solar production technologies. However, an increasing share of intermittent electricity production poses challenges to electric power systems. Intermittent energy production causes more and frequent demand-supply mismatches and thus a need of flexibility to the power grid. Many of solutions to increase flexibility, such as demand side management measures, integration of energy storage system or systemic innovations, require information and communications technologies (ICT). Hence, it is expected that new smart energy innovations that combine renewable energy solutions together with ICT solutions are becoming more valuable.

In this paper we investigate the value of renewable, clean and smart energy innovations by using patent citation data. We use patent citations as indicator of knowledge spillovers generated by patents. We study whether smart energy inventions that are co-classified both as an energy technology and information and communications technology receive more citations than pure energy technology inventions. Moreover, we compare different renewable energy and combustion technologies to assess whether there are differences in the value of inventions between energy technology sectors.

Methods

We use the patent citation data from the World Patent Statistical database (PATSTAT) and utilize the fixed effects Poisson pseudo-maximum likelihood regression model. Our estimation equation is

$$C_i = \exp\left(\alpha_{ICT} \cdot ICT_i + \beta_T \cdot T_i + \gamma_T \cdot ICT_i \times T_i + \delta \cdot X_i + \varepsilon_i\right), \qquad (1)$$

where C_i is the number of forward citations received by invention i, ICT_i is a dummy variable indicating whether energy invention i is also characterized as ICT invention, T_i is the energy technology of invention i, X_i is a vector of controls: triadic patent, granted patent, patent family size, year of earliest filing, cumulative number of inventions in a given technology field, patent office, and inventor country. ε_i is the error term. In our estimations we are particularly interested in coefficient estimates of ICT_i, T_i, and their interactions, i.e., α_{ICT}, β_T, and γ_T.

Results

Based on our esitmations, smart energy inventions receive on average 1.31 – 1.36 times more citations from all patents when compared to pure energy inventions. For citations from ICT patents the effect is even higher: smart energy patents receive on average 11.87 – 15.08 times more citations from ICT patents than pure energy inventions. In Table A we have approximated the effect of ICT on patent counts. The first row of Table A shows the sample means of received citations conditional on invention being non-ICT invention, and thus $ICT_i = 0$. In the second row we have calculated the incidence rate ratios (IRR) of coefficient α_{ICT}. The third row gives approximations of the average citation counts for pure energy inventions if all these inventions would have been smart energy inventions. Hence, the mean number of citations from all patents received by pure energy inventions would have increased from 4.09 citations to 5.56 citations, if these inventions would have been smart energy inventions. Moreover, for citations from ICT patents the mean citation would have increased from 0.23 to 3.46 citations (from all ICT patents).

PV and wind energy patents are the most cited technology fields from renewable technologies. Table B presents incidence rate ratios of different technologies with respect to non-ICT combustion apparatus inventions. Smart energy PV inventions receive on average 2.3 times more citations from all patents than pure combustion apparatus inventions and 2.3/2.1 = 1.1 times more citations than pure energy PV inventions (column 1). Wind energy inventions have fairly similar coefficient estimates as PV inventions.

Differences are much higher when we investigate incidence rate ratios of the model, where we count only citations from ICT patents (column 3). For instance, smart PV inventions receive on average 46.7 times more citations from ICT patents than non-ICT combustion apparatus inventions and 46.7/11.6 = 4.0 times more citations than non-ICT-PV inventions. Smart energy wind inventions receive on average 60.9 times more citations from ICT patents than non-ICT combustion apparatus inventions.

Since older patents have had more time to be cited we have modeled also citation counts only within five year window after the first filing of a patent. Columns 2 and 4 in Table B present direct (and relative) incidence rate ratios of citations within a five year window. The IRRs get qualitatively similar results as the model where all citations are counted. However, levels of incidence rate ratios based on models, which count citations only within five year window, are lower than those of based on all citations.

Table A. *Estimation results: Mean and expected citation counts (without self-citations).*

	From all patents		From ICT patents	
	All citations	Within 5 years	All citations	Within 5 years
Mean $(C_i \mid ICT_i = 0)$	4.09	1.67	0.23	0.13
IRR, $\exp(\alpha_{ICT})$	1.36	1.31	15.08	11.87
$E[\text{Mean}(C_i \mid ICT_i = 0 \rightarrow 1)]$	5.56	2.20	3.46	1.56
Mean $(C_i \mid ICT_i = 1)$	7.34	3.60	3.01	1.70

Table B. *Incidence rate ratios of technology coefficients of the Poisson fixed effects regression with respect to combustion apparatus inventions. Dependent variable: Forward citations without self-citations.*

	From all patents		From ICT patents	
	All citations	Within 5 years	All citations	Within 5 years
Solar thermal	1.4	1.2	2.9	1.5
Photovoltaic	2.1	1.7	11.6	5.4
Wind	1.9	1.4	5.9	3.1
Combustion CCMT	1.3	1.0	2.5	1.4
Combustion apparatus	1	1	1	1
Solar thermal - ICT	2.0	1.4	35.9	14.7
Photovoltaic - ICT	2.3	2.1	46.7	24.4
Wind - ICT	2.3	1.8	60.9	27.6
Combustion CCMT - ICT	1.4	1.1	38.1	16.2
Combustion apparatus - ICT	1.3	1.4	19.5	14.2

Conclusions

From the societal point of view, innovation actions are more valuable the more knowledge spills over from new inventions. However, large knowledge spillovers reduce private firms' incentives to invest in R&D actions and investments of clean energy technologies. Public policies are thus called for to support these actions. However, there are many open questions related to supporting renewable energy: what policy instruments to use, where and which technologies should be supported and to what extent? Our results provide new insights for policy makers when deciding support policies on energy technology R&D activities.

Citation counts are one measure of knowledge spillovers. Based on our estimation results, smart energy inventions that are co-classified both as energy and ICT technologies receive more citations than pure energy inventions. PV and wind energy patents are the most cited technology fields from renewable technologies. Our results imply that when technologies are converging, as it is the case with new energy technologies, the knowledge spreads widely also to other fields of technology. Hence, supporting renewable energy R&D is a recommended policy option, not only for supporting the development of renewable energy technologies narrowly but supporting the development of clean and reliable energy markets more widely.