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THE RENEWABLE ENERGY KNOWLEDGE STOCK – A NEW APPROACH

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(1) Overview

Insight on the cumulative energy knowledge stock is essential for understanding the energy innovation process and policies on energy innovation. As part of my current research, I present a new approach for measuring the cumulative knowledge in the energy sector, including public R&D expenditures as well as patent data. To demonstrate this new method, I apply it to estimating the Austrian renewable energy knowledge stock.

(2) Methods

The cumulative knowledge stock $(KS_{R\&D})$ of energy technologies from 1974 to 2013 in IEA-countries i is broken-down among seven groups k defined by IEA (2012). This comprises the depreciated cumulative knowledge stock of the last period $(1 - \delta) \times KS_{(t-1)}$ and the R&D expenditures in period t-x. So, the cumulative knowledge stock (KS) is as follows

$$KS_{R\&D\ (t)\ i,k} = (1 - \delta) \times KS_{R\&D\ (t-1)\ i,k} + RD_{(t-x)\ i,k} \qquad (1).$$

Klaassen et al. (2005) and Kobos et al. (2006) give a comprehensive overview of this methodology. In this paper, i is limited to Austria and k to renewable energy. In a second step and more specifically, seven dedicated items j of the renewables group, namely solar heating and cooling, photovoltaic, wind energy, biomass, heat pumps, hydroelectricity as well as other renewables are subject to further investigation following the above mentioned methodology. The cumulative patent stock (KS_{PAT}) of energy technologies can be derived in a similar manner, by using the Y02 classification scheme for renewable energy technologies from 1980 to 2012. For simplicity, the patent depreciation was fixed to ten per cent, according to a patent time span of ten years. Thus, the cumulative patent stock is calculated as follows

$$KS_{PAT\ (t)\ i,k} = (1 - \delta) \times KS_{PAT\ (t-1)\ i,k} + PAT_{(t)\ i,k} \qquad (2).$$

where PAT denotes the number of Patents in year t. A more sophisticated method shown by Popp (2001) was neglected to be coherent with formula (1) above. However, calculating the cumulative knowledge stock based on R&D expenditures and on patents are both limited. R&D expenditures as well as patents underestimate the cumulative knowledge stock. For instance, R&D expenditures cannot capture knowledge spillovers, while intellectual property rights do not include secret and implicit knowledge (cf. Watanabe 2001, Popp 2006, Johnstone et al. 2010, Indinger and Katzenschlager 2012, Wiesenthal et al. 2012). Nelson (2009) founds that different measures count different aspects of knowledge and "*it is doubtful that any single indicator is an adequate measure*." To overcome these limitations - gaining more information - I combine both, patents and R&D expenditures to calculate the cumulative knowledge stock using a new approach as follows

$$KS_{(t)i,k} = \sqrt{{KS_{(t)i,k,R\&D}}^2 + {KS_{(t)i,k,PAT}}^2} \qquad (3).$$

This will be demonstrated using public energy R&D expenditures and patent data. As one of the next steps private R&D expenditures derived in cooperation with Statistics Austria will be incorporated, too (Table 1).

(3) Results

Table 1: *Austrian public and industrial R&D expenditures in 2009 in thousand EUR; industrial R&D expenditures were estimated in cooperation with Statistics Austria*

Energy Sector	Industrial R&D	Public R&D	Total by group
Solar Heating and Cooling	4.269	3.006	7.275
Photovoltaic	9.906	5.415	15.321
Wind Energy	10.987	739	11.726
Biomass (incl. liquids, solids and biogas)	69.922	20.777	90.699
Heat pumps	3.113	121	3.234
Hydroelectricity	25.429	1.859	27.288
Other renewables	n. a.	1.931	1.931
Renewables total	**123.626**	**33.848**	**157.474**
Fossil fuels	65.303	514	65.817

Private energy R&D expenditures play an important role in the knowledge stock. Breyer et al. (2010) and Wiesenthal et al. (2012) provided similar approaches to capture private energy R&D investments. Wiesenthal et al. (2012) found that about 56% of the 3.32 billion EUR SET-Plan priority R&D investments in 2007 were financed by private companies. But having a look on certain energy technologies, the ratio of public to private R&D investments varies tremendously, mainly depending on the level of maturity, the involved capital cost and the economic expectations (Table 1). Investigations on the total knowledge stock by applying formula (3) show a high dependency on the assumptions on the R&D expenditures per patent. According to WIPO (2012) and own calculations, 1.1 mil. EUR can be derived for Austria, which may overestimate the real R&D value. Thus, I use a world average of 0.45 mil. EUR for estimating the patent knowledge stock as shown in Figure 1.

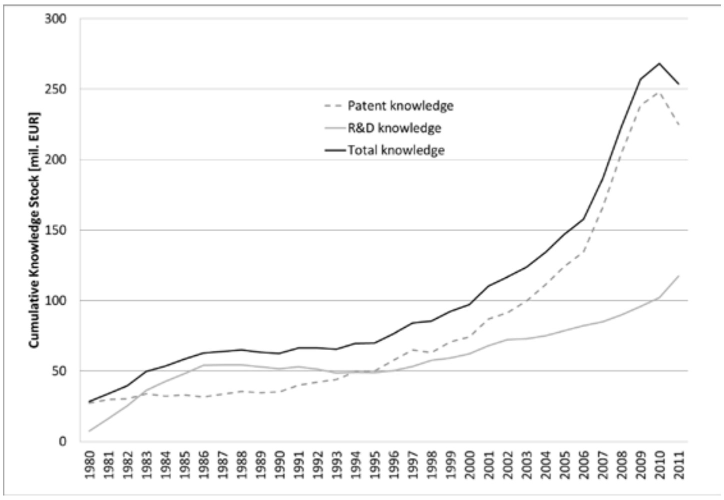

Figure 1: *Cumulative Renewable Energy Knowledge Stock of Austria induced by (a) public R&D expenditures (mil. €; 2011 prices and exc. rates; knowledge depreciation 10%, time lag 3 yrs) and (b) renewable energy patents (0.45 mil. € R&D expenditures per patent; knowledge depreciation 10%) [Own illustration, based on IEA (2012), WIPO (2012) and data from the Austrian Patent Office (2013)]*

(4) Conclusions

R&D expenditures as well as patents do not illustrate the whole knowledge stock, as they are facing several limitations as discussed above. As shown, further research is needed on capturing reliable time series of private energy R&D expenditures and the R&D expenditures per patent to exploit the full potential of the presented approach. Taking these issues into account, this new approach may provide better results on the total knowledge stock, which may become essential for modelling innovation, energy scenarios and policy making. However, we have to keep in mind that there is no true value of knowledge. Knowledge is always related to estimations and indicators, which calls for additional empirical studies.

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