Raphael Bointner

ENERGY R&D EXPENDITURES AND PATENTS IN SELECTED IEA COUNTRIES

Raphael Bointner, Vienna University of Technology
Institute of Energy Systems and Electric Drives, Energy Economics Group – EEG
Gusshausstrasse 25-29/370-3, A-1040 Vienna, Austria
Phone +43(0)1-58801-370372, Fax +43(0)1-58801-370397, e-mail bointner@eeg.tuwien.ac.at

Overview

The long history of IEA and patent data offer a huge playground for scientific investigations of the energy innovation process. As part of my current research I present energy R&D expenditures and patents in four IEA countries in this paper. Calculations of the knowledge stock are followed by comparative innovation and patent shares.

Methods

The cumulative knowledge stock *(KS)* of energy technologies from 1974 to 2012 in selected IEA-countries *i* (Austria, Germany, Japan and United States) is broken-down among seven groups *k* defined by IEA (energy efficiency, fossil fuels, renewable energy, nuclear power, hydrogen and fuel cells, energy storage technologies, other cross-cutting technologies). This comprises the depreciated cumulative knowledge stock of the last period *(1 - δ) x KS (t-1)* and the R&D expenditures in period *t-x*. So, the cumulative knowledge stock *(KS)* is as follows

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

Klaassen 2005 and Kobos 2006 give a comprehensive overview of this methodology. In a second step and more specifically, five dedicated items *j* of the renewables group, namely solar heating and cooling, photovoltaic, wind energy, biofuels as well as hydroelectricity are subject to further investigation following the above mentioned methodology. Finally, comparative shares for R&D expenditures *(CIS)* derived from the knowledge stock and comparative shares of patents *(CPS)* are calculated as shown in formula (2), where *p* is the number of patents in country *i* in sector *j*; see Bointner 2012 and Walz 2008 for details on the methodology. Comparative shares for R&D expenditures *(CIS)* with *I* for innovation are derived in the same manner. *CIS* are an input to the innovation process while *CPS* are an output parameter, respectively.

$$CPS_{(Comparative\ Patent\ Share)} = 100 \times tanh\ ln \frac{\frac{p_{ij}}{\Sigma_i p_{ij}}}{\frac{\Sigma_j p_{ij}}{\Sigma_{ij} p_{ij}}} \qquad (2)$$

Results

The knowledge stock shows a high sensitivity regarding the depreciation *δ* in all countries whereas the time lag *x,* after which the R&D expenditures count for the knowledge stock in time *t*, has a negligible influence. With *δ = 0,1* and *x = 3* years, which seems to be appropriate in the given case of surrounding conditions, I derive quite suspenseful results for the four countries. Nuclear power counts for 44,4% of the total knowledge stock (see table 1) with a focus in Japan, while the German nuclear knowledge stock declined by more than 70% after its peak value in 1988. Although Japan's GDP (2010) is about 2/5 of US' GDP, Japan's total *KS* is slightly larger.

Table 1: Cum. knowledge stock (mil. €; 2010 prices and exc. rates) with δ =0,1 and x=3 by group and country

	Austria	Germany	Japan	United States	Total by group
energy efficiency	135,4	308,9	3.355,2	5.125,3	**8.924,9**
fossil fuels	10,4	357,3	2.764,6	5.961,5	**9.093,8**
renewable energy	136,5	984,9	1.480,2	3.983,4	**6.584,9**
nuclear power	35,4	2.261,9	22.125,3	6.135,4	**30.558,0**
hydrogen and fuel cells	12,2	123,5	848,1	1.138,7	**2.122,5**
energy storage technologies	48,2	142,7	890,8	1.675,6	**2.757,2**
cross-cutting technologies	43,2	534,1	615,0	7.530,1	**8.722,4**
Total by country	**421,3**	**4.713,3**	**32.079,2**	**31.550,0**	**68.763,8**

Table 2: Cum. knowledge stock of selected renewables (mil. €; 2010) with δ =0,1 and x=3 by country

	Austria	Germany	Japan	United States	Total by group
Solar heating and cooling	12,6	91,3	21,1	61,7	**186,7**
Photovoltaics	16,1	402,1	679,9	596,1	**1.694,3**
Wind energy	3,9	189,8	57,0	391,8	**642,5**
Biofuels (incl. liquids, solids and biogases)	91,1	103,1	265,6	1.670,9	**2.130,7**
Hydroelectricity	5,5	0,8	4,5	51,6	**62,3**
Total by country	**129,3**	**787,1**	**1.028,1**	**2.772,0**	**4.716,5**

The five selected technologies in table 2 count for 72% of the renewable energy knowledge stock whereat biofuels and photovoltaics take the lion's share. Surprisingly the Austrian biofuel knowledge stock is almost as large as the German one and its hydroelectricity knowledge is larger than German and Japanese together. By transforming the renewable *KS* of table 2 into *CIS* and computing *CPS* by using European Patent Office data we can learn about fields of strength and connections between R&D expenses and patents (see table 3).

Table 3: Comparative innovation and patent share (+100... strong field of strength, -100... no field of strength)

	Austria		Germany		Japan		USA	
	CIS	CPS	CIS	CPS	CIS	CPS	CIS	CPS
Solar heating and cooling	72	46	79	36	-58	-79	-52	1
Photovoltaics	-79	-85	34	-46	54	51	-47	-13
Wind energy	-91	-28	52	49	-72	-90	4	-6
Biofuels	42	22	-84	-8	-51	-37	28	21
Hydroelectricity	82	82	-99	-8	-80	-42	33	13

Conclusions

Though R&D expenditures and patents have several limitations (cf. Popp 2005 and Watanabe 2001), they seem to be a suitable proxy for determining the innovation process. Time series of the cumulative knowledge stock give insight in structural changes among time (e. g. a "solar peak" in the early 1980s due to the first oil crisis in all four countries and the tremendous decline of nuclear knowledge in Germany). Despite the nuclear debate after Fukushima, the nuclear knowledge stock is still the largest by far, whereas the renewable knowledge stock in those four countries is ranked 5th place, only. So, if policy makers go for a transition towards renewable energy lot more efforts have to be undertaken to create the needed know-how. However, even if doing so, R&D expenditures for decommissioning nuclear power and repositories are still needed over the next decades.

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