12th IAEE European Energy Conference

Energy challenge and environmental sustainability

September 9-12, 2012 in Venice, Italy
Ca' Foscari University of Venice

Welcome to Venice  Conference venue  Who should attend  Travel information

The Conference Objectives

Recent events - such as the conflicts within several North African and Middle East oil and gas-exporting countries, and the nuclear disaster in Japan - have added elements of uncertainty in the already complex evolution of the energy situation in the world and in Europe in particular. Security of supply, geopolitical aspects and environmental problems are once more at the forefront. The Conference aims at providing a forum for an analysis of the new developments and a new vision of the future.

No better stage can be imagined for this discussion than the magic and fragile environment of one of the most beautiful cities in the world.

The first plenary sessions of the 12th IAEE European Energy Conference will therefore be dedicated to the evolution of demand and to the new energy markets less dependent on major commodities.

A debate will follow on how to deal with climate change through better regulation of CO2 emissions and what opportunities Europe can get from these new regulations. The last sessions of the Conference will deal with energy security in a geopolitical context that is getting more and more complex and difficult in all the main areas of the world.

Besides these main topics the 12th IAEE Conference will also discuss all the issues related to the environmental change and its new perspectives, such as energy efficiency, developing renewable sources, biofuels and sustainable transportation. 8 plenary and 50 concurrent sessions will be organized by the AIEE - together with the International Association for Energy Economics - IAEE in cooperation with Fondazione Eni Enrico Mattei and Ca' Foscari University of Venice.
Raphael Bointner
ENERGY R&D EXPENDITURES AND PATENTS IN SELECTED IEA COUNTRIES

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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 \((1 - \delta) \times KS_{(t-1)}\) and the R&D expenditures in period \(t-x\). So, the cumulative knowledge stock \((KS)\) is as follows

\[
KS_{(t)} = (1 - \delta) \times KS_{(t-1)} + RD_{(t-x)}
\]

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.

\[
CPS_{(Comparative Patent Share)} = 100 \times \tanh \ln \frac{p_{ij}}{\sum p_{ij}}
\]

Results
The knowledge stock shows a high sensitivity regarding the depreciation \(\delta\) 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 \(\delta = 0.1\) 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 \(\delta = 0.1\) and \(x = 3\) by group and country

<table>
<thead>
<tr>
<th>Group</th>
<th>Austria</th>
<th>Germany</th>
<th>Japan</th>
<th>United States</th>
<th>Total by group</th>
</tr>
</thead>
<tbody>
<tr>
<td>energy efficiency</td>
<td>135.4</td>
<td>308.9</td>
<td>3,355.2</td>
<td>5,125.3</td>
<td>8,924.9</td>
</tr>
<tr>
<td>fossil fuels</td>
<td>10.4</td>
<td>357.3</td>
<td>2,764.6</td>
<td>5,961.5</td>
<td>9,093.8</td>
</tr>
<tr>
<td>renewable energy</td>
<td>136.5</td>
<td>984.9</td>
<td>1,480.2</td>
<td>3,938.4</td>
<td>6,584.9</td>
</tr>
<tr>
<td>nuclear power</td>
<td>35.4</td>
<td>2,261.9</td>
<td>22,125.3</td>
<td>6,135.4</td>
<td>30,558.0</td>
</tr>
<tr>
<td>hydrogen and fuel cells</td>
<td>12.2</td>
<td>123.5</td>
<td>848.1</td>
<td>1,138.7</td>
<td>2,122.5</td>
</tr>
<tr>
<td>energy storage technologies</td>
<td>48.2</td>
<td>142.7</td>
<td>890.8</td>
<td>1,675.6</td>
<td>2,757.2</td>
</tr>
<tr>
<td>cross-cutting technologies</td>
<td>43.2</td>
<td>534.1</td>
<td>615.0</td>
<td>7,350.1</td>
<td>8,722.4</td>
</tr>
<tr>
<td>Total by country</td>
<td>421.3</td>
<td>4,713.3</td>
<td>32,079.2</td>
<td>31,550.0</td>
<td>68,763.8</td>
</tr>
</tbody>
</table>

Table 2: Cum. knowledge stock of selected renewables (mil. €; 2010) with \(\delta = 0.1\) and \(x = 3\) by country

<table>
<thead>
<tr>
<th>Group</th>
<th>Austria</th>
<th>Germany</th>
<th>Japan</th>
<th>United States</th>
<th>Total by group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solar heating and cooling</td>
<td>12.6</td>
<td>91.3</td>
<td>21.1</td>
<td>61.7</td>
<td>186.7</td>
</tr>
<tr>
<td>Photovoltaics</td>
<td>16.1</td>
<td>402.1</td>
<td>679.9</td>
<td>596.1</td>
<td>1,694.3</td>
</tr>
<tr>
<td>Wind energy</td>
<td>3.9</td>
<td>189.8</td>
<td>57.0</td>
<td>391.8</td>
<td>642.5</td>
</tr>
<tr>
<td>Biofuels (incl. liquids, solids and biogases)</td>
<td>91.1</td>
<td>103.1</td>
<td>265.6</td>
<td>1,670.9</td>
<td>2,130.7</td>
</tr>
<tr>
<td>Hydroelectricity</td>
<td>5.5</td>
<td>0.8</td>
<td>4.5</td>
<td>51.6</td>
<td>62.3</td>
</tr>
<tr>
<td>Total by country</td>
<td>129.3</td>
<td>787.1</td>
<td>1,028.1</td>
<td>2,772.0</td>
<td>4,716.5</td>
</tr>
</tbody>
</table>
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)

<table>
<thead>
<tr>
<th></th>
<th>Austria</th>
<th>Germany</th>
<th>Japan</th>
<th>USA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solar heating &amp; cooling</td>
<td>72 46 CIS 79 36 CND 54 51 CND 54 51</td>
<td>79 36 CND 54 51 CND 54 51</td>
<td>-58 -79 -52 1</td>
<td>-91 -28 52 49 -72 -90 4 6</td>
</tr>
<tr>
<td>Photovoltaics</td>
<td>-79 -85 CND 34 -46 CND 54 51 CND 54 51</td>
<td>-84 52 49 -8 -51 -37 28 21</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wind energy</td>
<td>-91 -28 52 49 -72 -90 4 6</td>
<td>22 -84 -8 52 49 -8 -51 -37 28 21</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Biofuels</td>
<td>42 22 -99 -8 52 49 -8 -51 -37 28 21</td>
<td>82 82 -99 -8 52 49 -8 -51 -37 28 21</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hydroelectricity</td>
<td>82 82 -99 -8 52 49 -8 -51 -37 28 21</td>
<td>82 82 -99 -8 52 49 -8 -51 -37 28 21</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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.

References