

INFLUENCE OF OIL PRICES ON INNOVATION IN RENEWABLE ENERGY SECTOR

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Abstract

In this study, oil prices' impact on innovation in renewable energy sector is analyzed. Using correlation-regression analysis, yearly average oil prices are taken as independent variables and patent counts as dependent variables. Patent counts act as proxy and indicator of innovation. For finding the consequent reaction and relationship, independent variables are lagged by one and two years. The study covers 1982-2010 period. Patent data is got from PATSTAT database for patents of European Patent Office (EPO). For the years of 1982 – 2010, firms that have applied to at least one solar (photovoltaic) patent are chosen for dataset. According to the analysis, oil prices have positive impact on innovation in renewable energy. In one year and two years periods companies' reaction regarding renewable energy innovation to oil prices are positively correlated, but in one year period this effect is greater.

Keywords: renewable energy sector, oil prices, solar energy, innovation, determinants of innovation

JEL Classification Codes: O31, O32, O33

Introduction

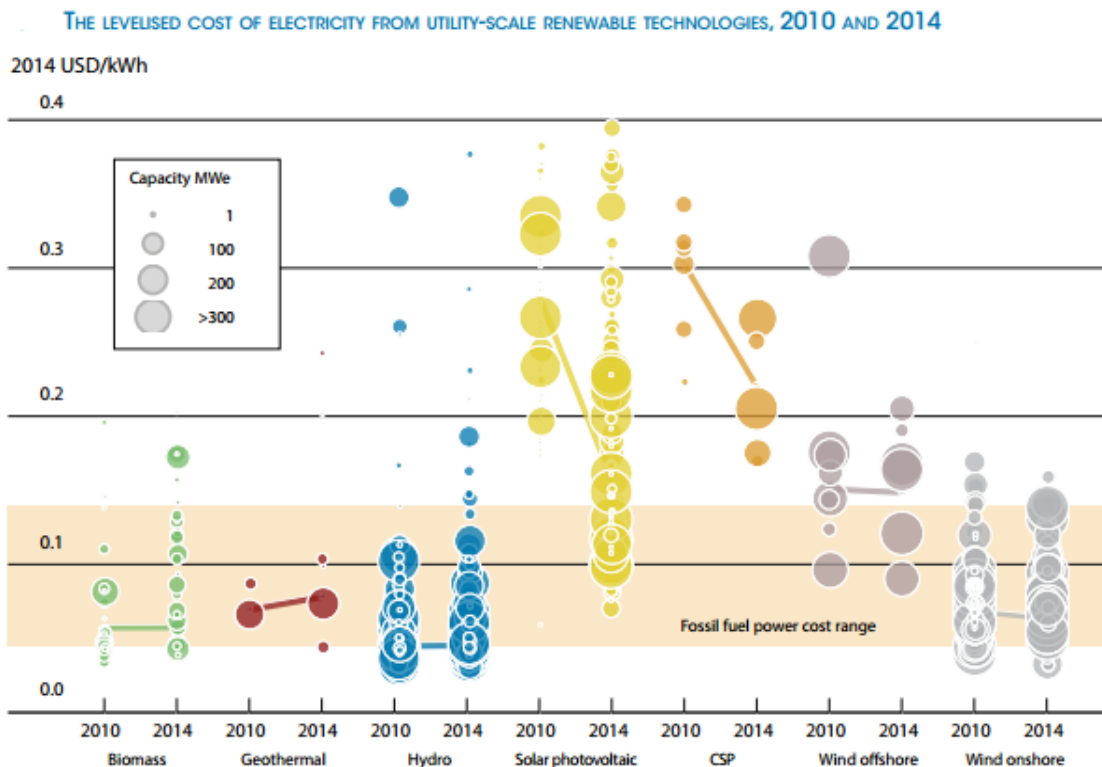
Renewable energy is an alternate source of energy which is naturally renewed, therefore doesn't deplete in contrast with conventional energy sources. As technology improves and count of people in the world rises, daily energy need of the world increases significantly. In such conditions governments and companies fulfill many activities to keep up with high demand for energy, and search for alternative and cheaper energy sources. But, costs of producing alternative energy are mainly higher than that of conventional energy.

Many years ago cost of alternative energy production was much higher, but important advances have been made in these renewable sectors. If we analyze what resulted in this, the answer will probably be the innovation.

Innovation is a broad category and defined as “the successful introduction into an applied situation of means or ends that are new to that situation” (Mohr, 1969, pp.112) [1].

Innovation is the remedy that can improve our life qualities, besides, innovation decreases costs in many industries, and renewable energy belongs to this group too. Innovation creates, endows wealth, comfort, reliability, quality.

If we look at cost of producing electricity from different resources, as shown in the graph below, the levelised cost of electricity from utility-scale renewable technologies has been decreased from 2010 to 2014. But, if we for example take solar photovoltaic and compare it to fossil fuel energy costs for producing electricity, we can see that, the solar energy costs more. So, new and more innovation is required for better competitiveness.



Source: IRENA Renewable Cost Database.
 Note: Size of the diameter of the circle represents the size of the project. The centre of each circle is the value for the cost of each project on the Y axis. Real weighted average cost of capital is 7.5% in OECD countries and China; 10% in the rest of the world.

Credit: RENEWABLE POWER GENERATION COSTS IN 2014; The International Renewable Energy Agency (IRENA) [2].

In another study, LAZARD finds that although conventional energy prices fall, costs in some renewable energy sectors (e.g. solar) has continued to shrink [3]. Decreasing costs can be a sign of more and new innovation despite of falling energy prices.

In general terms, relationship seem to exist between conventional energy prices and innovation in alternate energy sectors, and it seems to be positive correlation, but, as we noted, some studies find sometimes the costs in renewables continue to diminish in spite of decreasing oil prices. Simply, it seems logical that, as oil prices increase, companies need to shift to cheaper energy resources. If , say, 45 USD per barrel to generate electricity is much cheaper than some renewable energy sources, but when prices increase to 60 USD, then renewable energy sector's competitiveness chances increase and more and serious innovation is a good solution for cost shrinking.

In this research, I would like to shed light on possible relationship between oil prices and innovation in renewable energy sector.

Trends in renewable energy

According to OECD Factbook, In OECD (Organisation for Economic Co-operation and Development) countries, growth and development are more significant in renewable energy sector, which shows the importance and focus on this sector. Thus, between 1971-2014 total primary energy supply grew on average 1.0% yearly, but on the other hand this growth figure for renewable energy supply is 2.7%.

Among renewable energy sources hydro-power experienced the least growth rate (1.1%), while geothermal exposed 4.9%, biofuels and waste 2.9% growth rate yearly.

Governments stimulated development some renewable energy fields like solar and wind energy and they have achieved rapid growth.

During the discussed period total share of renewable energy in energy supply increased from 4.8% to 9.2%. But, while some countries get significant share of their energy from renewables (Iceland – 89.3%, Norway 43.5%), in some others (Japan, Korea) renewable energy sector contributed to total energy sector as low as 5% share [4].

According to UNEP's 10th "Global Trends in Renewable Energy Investment 2016", prepared by the Frankfurt School-UNEP Collaborating Centre for Climate & Sustainable Energy Finance and Bloomberg New Energy Finance, in 2015 investments in renewable sector became 286 billion dollars, which is about three

percent higher than in 2011. Custom energy sources gas-fired electricity and coal got less than half investment than solar, wind and other renewables.

In 2015 first time in the history, developing countries' investments in renewable energy sector left behind the developed countries and much of this was because of China [5].

These trends show the interest in renewable energy, and it is growing bigger each new year. Countries and companies look for ways to get more of their energy from renewable energy resources, and their investments are towards more and cost-efficient usage of renewable energy sources.

Factors that might stimulate innovation in renewable energy

There can be a lot of micro and macro level factors that stimulate or demotivate innovation. Energy prices being part of macro-level factors, it would be worthy to look at some such elements.

Henriques and Sadorsky correctly informs that, only little statistical research tries to find relationship between oil prices and financial gains and stability of renewable energy companies. Using vector auto regression model, they analyze correlation between stock prices of renewable energy companies and energy, technology stock prices and oil prices. According to their analysis, changes (shocks) to technology stock prices is more relevant to renewable energy companies' stock prices rather than changes in oil prices [6]. The hint is that, renewable energy sector represents the technological situation and is less influenced by other sectors including custom energy. Science is a solid base for innovation and improvements in science and technological environment, impact all sectors, as the newly invented finding many times can be applied to more than one sector. Technological changes themselves are influenced by investments, quantity and quality of scientists working on project, and technology stock prices can determine the financial situation, hardships and initiatives. Consequently, fall of stock prices can create financial hardships in technology related investments and all related sectors might be influenced, and in opposite, increases of stock prices can create money flow available for R&D and stimulate innovation. Here, I want to note that one of the most important elements in renewable energy innovation is the technological situation throughout the country or region, and new general scientific improvements impact the sector.

According to Cheon and Urpelainen, advances in technologies decrease costs of structural changes. Simultaneously such advances positively affect political

actions towards such changes. The study focuses on the relationship between oil prices and policymakers' and entrepreneurs' actions towards innovation in energy sectors. They use data such as public research and development expenditures and patents to gauge the relationship and findings support positive relationship [7]. Policymakers' actions are good reason that can determine renewable energy innovation. Many countries today try to focus on renewable energy more and governments have tools to motivate innovation and investments in these sectors. Dependence on oil creates instability and uncertainty regarding future and more risks. In contrast, renewable energy is something that countries and companies rely on long-term and such 'dependence' would not create similar risks. Governments through subsidies, creating knowledge hubs, helping universities, financing projects can direct innovation towards required fields.

When looking at policymakers' actions towards renewable energy from economic aspect, it is also important not to forget environmental benefits of alternative energy sector. Environmentalists and some representatives of governments focus on side-effects of custom energy and try to shift carbon-free energy sources. Here some might question why people just simply don't shift, but need innovation for this purpose. As noted above, costs are many times higher and innovation can decrease cost differences. Johnstone, Haščič and Popp study influences of environmental policies on renewable energy innovation. According to their analysis based on patent applications as determinant, various policy instruments have impact on innovation in renewable energy sector. Further, while broad-based environmental policies have special effect on innovation in areas which compete with custom energy sources, specific and targeted policies have effect on innovation in more costly renewable energy technologies [8]. Another important factor that can influence renewable energy innovation (alone or together with other drives) seems to be environmental policies.

According to Induced innovation theory, many economic factors, including input prices, market demand and etc. influence companies' focus on research activities. Lichtenberg analyzes effects of energy prices on research and development by United States companies and finds that, industries where price increases are witnessed more also show high tendency and growth in R&D expenditures [9]. R&D expenditures solely cannot determine innovation, as innovation is also dependent on many other factors, such as how innovation-open the sector or technology. For example, if we spend the same amount of money for

R&D on wood products and electronics, logically, electronics sector will encounter more innovation. However, it is clear that R&D spendings and innovation should be positively related. The study by Lichtenberg does analyze the energy prices' effect on innovation in the same sectors, but in this study, we want to see the influence on related/alternative sectors and whether such energy price increases also stimulate to shift to other sectors and consequent stimulation to invest in innovation (or R&D). Another interesting research is done by Crabb and Johnson. They gauge effects of oil prices in innovation in energy-efficient automotive technologies. Using patenting model, they confirm their hypothesis. They conclude that fuel prices' acquisition cost is important element in determining future level of innovation [10].

We noted the emphasis of science above, but how science or knowledge is available to inventor, to R&D people is an important element. Popp, one of the most great researchers in innovation field, uses patent data to measure energy prices' effect on innovations which are energy-efficient, therefore, demand less costs. His study shows that, prices have serious role in stimulating innovation, simulatenously, how available the knowledge to inventors and how qualified this knowledge is another considerable factor. However, an important finding here is that, eliminating quality of knowledge influences the results of study can be affected adversely [11]. This discussed element also looks through science, but this time not the current situation of knowledge and technology, but how easily company and independent researchers can get the knowledge. Some copyrighting restrictions, institutional difficulties might create obstacles people to get latest improvements in science. Therefore, besides technology, science and how it is accessible can determine innovation in renewable energy sector.

Some researches don't see the rate of innovation in a given sector to be related with energy prices. For example, Newell, Jaffe, & Stavins claims that, despite rate of innovation in total seems not to be dependent on energy prices, direction of innovation is related with changes in energy prices. Thus, when energy prices increase, it motivates innovation towards a direction in which capital costs are decreased and energy efficiency is achieved. Their study shows that, since 1973 year in more than twenty years rising prices in energy sector have resulted in improvements in energy-efficiency of new models. They also claim that, after labeling requirements for products came to scene, responsiveness and reaction of such innovation to energy prices increased significantly. However, many improvements for energy efficiency seem to be independent [12]. This argument

expresses its doubt about specific increase of rate of innovation, and it is very wise one. Thus, rather than investing heavily in your own sector, you can switch your innovation efforts to other cost effective and energy efficient sectors/inputs and this would support our argument too. A lot of time you can find substitutes, and as substitutes become more attractive or your current deal becomes rough, you are driven towards alternative sectors.

Hypothesis

After reviewing relevant studies, we can say that, various researches find influence of technology stock prices, political actions, quality of existing knowledge, environmental policies, price increases and etc. have impact on innovation in general and in renewable energy case. Sometimes complex set of factors influence altogether, and it becomes hard to determine factors which specifically influenced innovation in a given period. However, considering that increasing oil prices will result in rise in companies' and countries' energy input costs, therefore will create a need for alternative energy sources; and innovation is a good method for decreasing costs in alternative energy resources; furthermore, taking into account related research:

I hypothesize that, increasing oil prices positively influence innovation in renewable energy sector.

Empirical study

Method

I will use correlation-regression analysis to find relationship between oil prices and innovation in renewable energy sector.

Because renewable energy sector involves many fields (wind, solar, biofuel, geothermal and etc.) and therefore many and complex possible indicators exist, in my opinion, the best strategy would be choosing one of the fields and analyzing effects of oil prices on that sector. Thus, one field can actually represent the trends in renewable energy sector, considering that, they are all alternatives to custom energy sources and price increases of oil can make companies to shift to any or all of them as alternative sources and search for new measures to make them more cost competitive. Furthermore, the chosen field should be open to innovations, which mean that, innovation should be more clear to detect and patentable. I consider Solar Photo-voltaic to have these characteristics, therefore, patent applications' count (later "patent count") in this field can be a good indicator of innovation.

In this analysis, as independent variables average yearly oil prices from 1982 to 2010 and as dependent variables solar photo-voltaic (solar PV) patent counts of companies which have applied at least one solar PV patent in the given period are used.

The United States Patent and Trademark Office (USPTO) defines a patent as : “a property right granted by the government to an inventor to exclude others from making, using, offering for sale or selling the invention for a limited period of time in exchange for public disclosure of the invention when the patent is granted”. Patents can be granted for inventions, significant improvements or incremental innovations. In our case for measuring innovation, patents (patent counts) seem reasonable choice.

The logic here is that, price increases in companies in different sectors will result in search of other energy sources, they will shift to e.g. solar energy and will do more R&D, which will be accompanied with patents. But, here lag needs to be used. Thus, as an event or a process and its result cannot be present at the same time (at least in our example), and as the first causes (results in) the latter, innovation will be present in renewable energy sector some after rises in oil prices. Thus, after changes in oil prices, companies might start R&D process, start actions towards innovation and the results will be achieved after some period of time. A good method would be looking at oil prices in year N, and patent counts in years N+1, N+2.

Additionally, analyzed companies are not only renewable energy companies, but companies which have applied for at least one solar PV patent in the analyzed period. The reasons are: 1) we don't analyze the companies in renewable energy sector, but the sector itself. Companies doing other kind of business can have serious impact in this sector. 2) companies that use renewable energy as an alternative to custom energy are probably not renewable energy companies themselves, but various (all sectors) companies which need energy input in their operations. Therefore, as noted, companies involved in patents in solar PV are studied.

Historical oil prices are retrieved from the website of Illinois Oil and Gas Association (<http://www.ioga.com/history-of-crude-oil-prices>). Then, yearly average oil prices are calculated for the period between 1982-2010.

The Patent data is got from PATSTAT database for patents of European Patent Office (EPO).

Analysis

Below the yearly average oil prices and solar patent counts are shown.

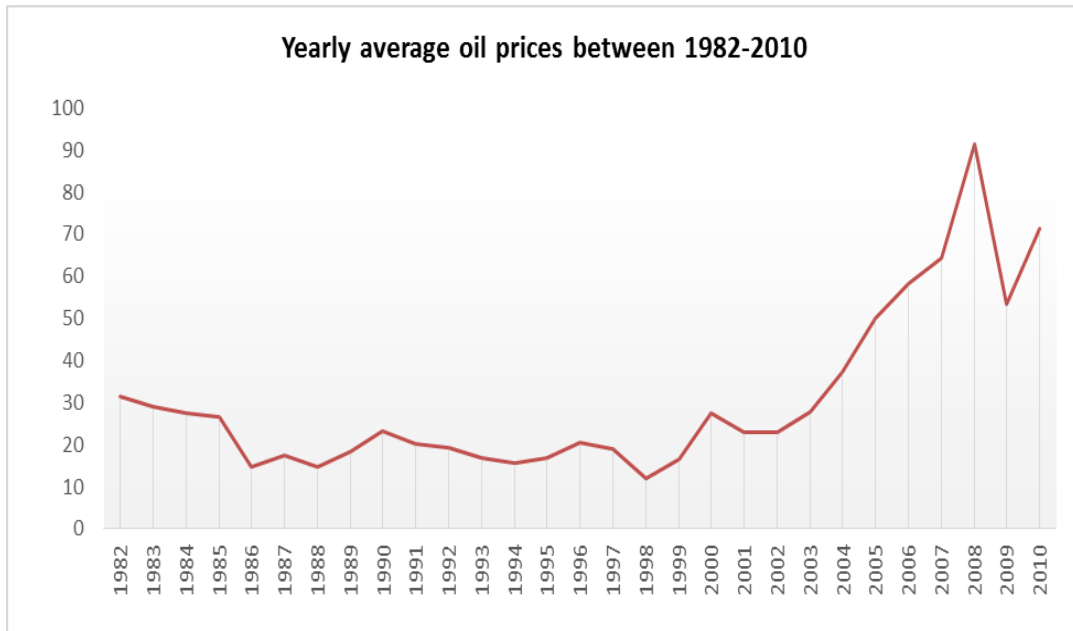
In the studied period the minimum yearly average oil price was 11,91 USD , which represents 1998 year. The maximum average price was 91,48 and it occurred in 2008.

Minimum yearly total patent count in solar photo voltaic sector was 57 (year: 1982), while the maximum being 1080 (year: 2009)

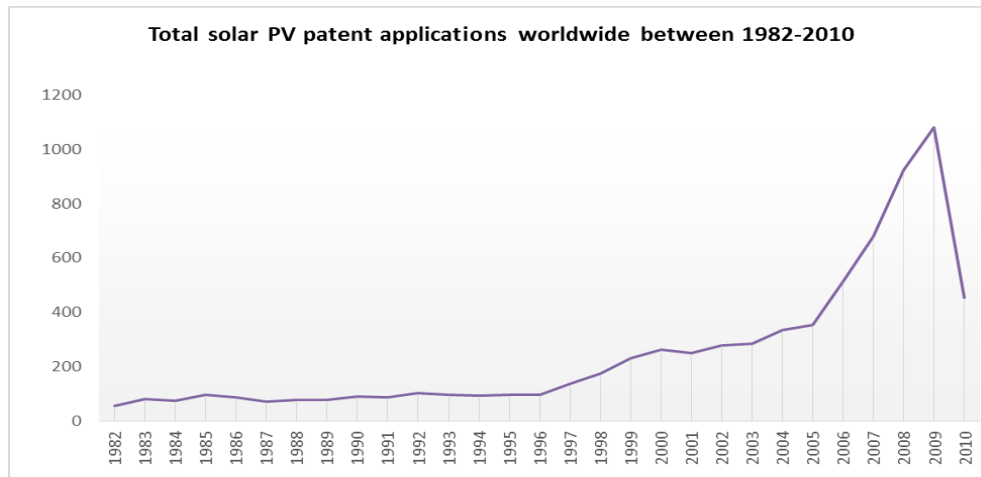
If we look at the numbers, we can see that, there is no chronologically stable increase. Because of some factors, the numbers sometimes increase, while sometimes shrink year-by-year. It will let us know, how patent counts react to oil prices.

Year	Av. Oil price	Year	Solar PV Patent Count
1982	31,55	1982	57
1983	29	1983	81
1984	27,5	1984	74
1985	26,5	1985	98
1986	14,64	1986	87
1987	17,5	1987	71
1988	14,87	1988	78
1989	18,33	1989	77
1990	23,19	1990	89
1991	20,19	1991	88
1992	19,25	1992	102
1993	16,74	1993	98
1994	15,66	1994	92
1995	16,75	1995	95
1996	20,46	1996	97
1997	18,97	1997	137
1998	11,91	1998	174
1999	16,55	1999	230
2000	27,4	2000	263
2001	23	2001	249
2002	22,81	2002	279
2003	27,69	2003	284
2004	37,41	2004	334
2005	50,04	2005	355
2006	58,3	2006	515
2007	64,2	2007	681
2008	91,48	2008	923
2009	53,5	2009	1080
2010	71,21	2010	455

And looking at historical graphs will give visual understanding, but, one thing should be noted that, indicators of the same year should not be compared, as we will use lag. The graphs are for informative purposes.



Graph 1. Prepared by the author based on information retrieved from the website of Illinois Oil and Gas Association



Graph 2. Prepared by the author based on information retrieved from database for patents of European Patent Office (EPO)

From the graphs above we can easily detect oil price increase in 2008 and the following rise in solar PV patent counts in 2009. Later, when oil prices fell down in 2009, solar PV patent counts decreased the following year - in 2010.

In this study, correlation-regression analysis will be done to find the relationship.

Dependent variables are yearly total solar PV patent application counts.

Independent variables are yearly average oil prices.

Firstly, all independent variables are lagged for 1 year to see the relationship of a given

year's oil price on innovation in renewable energy sector after one year.

Oil prices/ year = n	Solar patent counts/ year = n+1	a	b	a x b	a ²	b ²
31,55	81	2,428929	-175,643	-426,62395	5,899694	30850,4133
29	74	-0,12107	-182,643	22,1128316	0,014658	33358,4133
27,5	98	-1,62107	-158,643	257,171403	2,627873	25167,5561
26,5	87	-2,62107	-169,643	444,646046	6,870015	28778,699
14,64	71	-14,4811	-185,643	2688,30747	209,7014	34463,2704
17,5	78	-11,6211	-178,643	2076,0214	135,0493	31913,2704
14,87	77	-14,2511	-179,643	2560,10319	203,093	32271,5561
18,33	89	-10,7911	-167,643	1809,04605	116,4472	28104,1276
23,19	88	-5,93107	-168,643	1000,23283	35,17761	28440,4133
20,19	102	-8,93107	-154,643	1381,1264	79,76404	23914,4133
19,25	98	-9,87107	-158,643	1565,97497	97,43805	25167,5561
16,74	92	-12,3811	-164,643	2038,45497	153,2909	27107,2704
15,66	95	-13,4611	-161,643	2175,88605	181,2004	26128,4133
16,75	97	-12,3711	-159,643	1974,95319	153,0434	25485,8418
20,46	137	-8,66107	-119,643	1036,23533	75,01416	14314,4133
18,97	174	-10,1511	-82,6429	838,913546	103,0443	6829,84184
11,91	230	-17,2111	-26,6429	458,552117	296,221	709,841837
16,55	263	-12,5711	6,357143	-79,916097	158,0318	40,4132653
27,4	249	-1,72107	-7,64286	13,1539031	2,962087	58,4132653
23	279	-6,12107	22,35714	-136,84967	37,46752	499,841837
22,81	284	-6,31107	27,35714	-172,65288	39,82962	748,413265
27,69	334	-1,43107	77,35714	-110,7036	2,047965	5984,12755
37,41	355	8,288929	98,35714	815,275332	68,70634	9674,12755
50,04	515	20,91893	258,3571	5404,55462	437,6016	66748,4133
58,3	681	29,17893	424,3571	12382,2868	851,4099	180078,985
64,2	923	35,07893	666,3571	23375,0946	1230,531	444031,842
91,48	1080	62,35893	823,3571	51343,6693	3888,636	677916,985
53,5	455	24,37893	198,3571	4835,73462	594,3322	39345,5561
Mean= 29,12107143	Mean= 256,6428571			119570,761	9165,453	1848132,43

Correlation coefficient = $119570,761 / \sqrt{9165,453 \times 1848132,43} = 0,918716$

Also, it is worthy to look at correlation between oil prices and total solar PV patent application counts to see whether companies take immediate reaction to oil

prices' changes or they are keen to take more long term measures.

In the second correlation analysis all independent variables are lagged for 2 years.

Oil prices/ year = n	Solar patent counts/ year = n+2	a	b	a x b	a ²	b ²
31,55	74	3,331852	-189,148	-630,21361	11,10124	35777,0219
29	98	0,781852	-165,148	-129,12139	0,611292	27273,9108
27,5	87	-0,71815	-176,148	126,500466	0,515737	31028,1701
26,5	71	-1,71815	-192,148	330,138985	2,952033	36920,9108
14,64	78	-13,5781	-185,148	2513,96898	184,3661	34279,8368
17,5	77	-10,7181	-186,148	1995,16343	114,8787	34651,1331
14,87	89	-13,3481	-174,148	2324,55528	178,1731	30327,5775
18,33	88	-9,88815	-175,148	1731,89084	97,77547	30676,8738
23,19	102	-5,02815	-161,148	810,276763	25,28227	25968,7257
20,19	98	-8,02815	-165,148	1325,8338	64,45116	27273,9108
19,25	92	-8,96815	-171,148	1534,88195	80,42768	29291,6886
16,74	95	-11,4781	-168,148	1930,02936	131,7479	28273,7997
15,66	97	-12,5581	-166,148	2086,51306	157,7071	27605,2071
16,75	137	-11,4681	-126,148	1446,68565	131,5184	15913,3553
20,46	174	-7,75815	-89,1481	691,62454	60,18886	7947,39232
18,97	230	-9,24815	-33,1481	306,558985	85,52824	1098,79973
11,91	263	-16,3081	-0,14815	2,41602195	265,9557	0,02194787
16,55	249	-11,6681	-14,1481	165,082689	136,1457	200,170096
27,4	279	-0,81815	15,85185	-12,969163	0,669366	251,281207
23	284	-5,21815	20,85185	-108,80805	27,22907	434,799726
22,81	334	-5,40815	70,85185	-383,17731	29,24807	5019,98491
27,69	355	-0,52815	91,85185	-48,511385	0,27894	8436,76269
37,41	515	9,191852	251,8519	2314,98491	84,49014	63429,3553
50,04	681	21,82185	417,8519	9118,30121	476,1932	174600,17
58,3	923	30,08185	659,8519	19849,5657	904,9178	435404,466
64,2	1080	35,98185	816,8519	29391,8423	1294,694	667246,948
91,48	455	63,26185	191,8519	12136,9034	4002,062	36807,1331
Mean= 28,21814815	Mean=263,1481481			90820,9174	8549,109	1816139,41

Correlation coefficient = 90820,9174 / sqrt (8549,109 x 1816139,41) = 0,728871

Findings and discussion

The results show that, oil prices have positive influence on renewable energy sector innovation. The first finding is that, companies' direct reaction to oil prices seem to be higher in short term. Thus, when we analyze impact after one year, the correlation is 0,918. Therefore, companies positively react to oil prices. If oil prices increase in year n, then innovation (patents) increase in the following year and vice-versa. But if we make two years' lag, correlation coefficient decreases down to 0,728. It hints that, direct influence is mainly for short term and with time the relationship level shrinks between oil prices and discussed innovation.

The reason for short-term focus can be that companies always look for cheaper energy sources in short period and in real time. In real time business, they search for the cheapest energy input and if oil prices decrease, they again prefer to shift to

custom energy sources in the following time period (year).

Another reason can be governments' role. When oil prices increase, governments and policy makers start to stimulate renewable sector through subsidies, university-company cooperation, etc. But this becomes more influential in policy makers actions and plans in high energy price periods, and when prices go down ease and distraction starts again.

As noted this study represents the whole renewable energy sector, and it should again be noted that, there are many other factors that influence renewable energy companies' innovation. We analyzed oil prices' effect in general companies who can use both custom and renewable energy sources and the results showed that, companies innovativeness in alternate energy sector is related with oil prices, the reason of which might be inclination to shift back to oil based energy when prices go down. So it is possible they mainly behave tactically rather than strategically.

Regarding, how it affects companies' renewable energy policies in investments to innovation in 2 years' period, the relationship exists and is positive too. In long term, companies don't that seriously react to oil prices, and here the reason can be they want to insure themselves, and therefore dependence on oil prices decreases, so they try to keep innovation balance or to invest in more radical type of innovation. Although, low energy prices de-stimulate innovation somehow, it is not significant and companies understand the importance of alternate energy sector. Further research can be done using patent citations as indicator of innovation, which can shed light to more radical type innovation.

So, according to the results, when oil prices increase, companies are motivated to invest in renewable energy sector innovation, but tend to shift back to oil based energy when prices go down and their innovation level decreases in short term. However simultaneously, in the long term it is possible that, deeper (radical) innovation is achieved through years to decrease dependence from the oil price and its fluctuations, therefore relationship between prices and innovation levels decreases.

Conclusion

This paper analyzed relationship between oil prices and innovation in alternative energy sources – renewable energy.

The study showed that, oil prices influence innovation in renewable energy sector, and companies' reaction and response to changes of oil prices can be considered substantial.

Both in one year and two years periods companies react to oil prices on their

renewable energy policies, but in short term the effect is higher than 2 years' term.

As conclusion, although some other factors should be researched further – like patent history of companies (whether they keep their innovation levels) or government policies, renewable energy sector in terms of innovation seems to be influenced by oil prices.

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