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Energy R&D in Private and State-owned Utilities: An Analysis of the Major World Electric Companies*

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Abstract

The last two decades have witnessed a staggering decline of R&D investment in the fields of energy and electricity. This paper contends that this widespread phenomenon is mainly ascribable to the processes of liberalisation and privatisation of electricity markets which have induced electric utilities to dramatically reduce R&D expenditures. However, a closer inspection to recent data concerned with ten major electric companies of the world shows that not all of them behaved in the same way. The drop of research expenditures was particularly strong among the private or newly-privatised companies, while those that remained under public control did not reduce R&D efforts. Moreover, the choice of maintaining an adequate level of R&D was not at odds with the goal of increasing company profits.

According to these findings and to the widely recognised need of a surge of energy R&D, radical policy measures seem necessary. Along with an R&D obligation for private electric utilities, also an extension of public ownership or the introduction of public-private partnerships should be seriously taken into account.

Keywords: Energy R&D, Electric utilities, Public and private enterprises.

JEL codes: L33, L94, O30.

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"For some people the case against the liberalised electricity model will never be proved. There will always be a market design error that can be fixed to solve the problems, while any problems with a publicly owned monopoly are inevitably insoluble […]. But when supply security can no longer be guaranteed, politicians will be forced to act […] Prices may have to rise for a backlog of investment, skills lost because of short-term cost-cutting will have to be recreated and governments will have to abandon their denigration of publicly owned companies and get on with their job of managing them properly." (Thomas, 2006a, p. 1982).

1. Introduction

Within the most developed areas of the world R&D investment in the field of energy/electricity has declined dramatically over the last decades. Although even public research efforts have been reduced, the key area of concern rests on the behaviour of the electricity supply industry. Investment in energy R&D by US utilities fell by 72% between 1990 and 2004. Over the same period, the electric companies of the EU reduced R&D expenditures by 62% while in Japan the decrease, although remarkable, has been less pronounced.

Such a huge research drop is mainly, if not entirely, attributable to the processes of liberalisation and privatisation of electricity markets launched during the 1990s. The latter have increased the competitive pressure to cut costs and those concerned with R&D have been particularly vulnerable. In particular, electric utilities have abandoned the long-term research projects concerned with fundamental and general-purpose technologies.

These choices are at odds with the increasing need of funding an adequate level of basic or long-term R&D aimed at guaranteeing the future supply of cheaper and cleaner energy, a crucial goal for addressing the problem of climate changes and fostering a sustainable economic development. According to a team of energy experts appointed by the European Commission (Advisory Group on Energy, 2005), in order to achieve the above goal the energy R&D funding should be restored, in real terms, to the levels of 25 years ago (i.e. increased by a factor of four). This implies that not only governments but also utilities have to radically change their behaviour with respect to energy R&D.

This paper shows that the above requirement is less stringent for the (few) electric companies that are still publicly owned. In effect, looking at the recent R&D performance of the major electric providers of the world, it emerges that all the privately owned companies have dramatically reduced their R&D efforts, while those under public control have not followed the same path. It must be added that public companies, although maintaining a positive attitude towards R&D, have increased their profit margins more than private companies.

The paper is organised as follows.

The first section illustrates the staggering decrease of R&D expenditures in energy and electricity experienced in the US, EU and Japan over the period 1990-2004. After showing that the R&D decline is mainly due the behaviour of energy/electric companies (most of which already private, others privatised during the period considered), it is argued that these corporate choices have been induced by the process of electricity reform.

A second and more extended section is based upon an analysis of the R&D expenditures, sales and profits of ten major electric power companies of the world over the period 2000-07: six are located in Europe, three in Japan and one in Canada. The main finding is that the only companies that did not reduce R&D investment are three state-owned enterprises: Electricité de France, the Sweden-based Vattenfall and Hydro-Québec in Canada. Moreover, in terms of operating margins (i.e. the gross profits generated by the production and distribution of electricity), the same public companies achieved the best performance.

The above findings suggest that the R&D drop experienced by many of the largest electric companies of the world is a typical market failure – or, to put it another way, an unintended consequence of the privatisation and liberalisation processes – and, as such, it calls for urgent and radical policy measures. These are discussed in the final section of the paper. A first possibility is that of fostering R&D and innovation by extending the regulation of electricity markets. However, in light of the strategic role played by the energy sector and looking at the experience of state-owned utilities, also an extension of public ownership or the introduction of new forms of public-private partnership should be seriously taken into account.

2. The declining R&D in the energy/electricity sector: evidence and explanations

From 1990 to 2004, the most advanced economies of the world have experienced a dramatic reduction of the R&D expenditures devoted to energy or electricity (see Table 1). Although part of the blame should be put on public organizations, the decline of energy R&D is mainly due to the behaviour of the electricity supply industry in which private companies have played a dominant role. The gap engendered by electric utilities is so huge that, even assuming a radical change of policies, governmental bodies could hardly fill it[1].

Table 1 - R&D expenditures in energy/electricity

	Levels				Percentage changes		
	1990	1995	2000	2004	1990-95	1995-2000	2000-04
*US energy R&D investment (millions of US dollars at 2002 prices)**							
Public	3550	3400	3050	3350	-4.23	-10.29	9.84
Private	3520	2050	1480	990	-41.76	-27.80	-33.11
Total	7070	5450	4530	4340	-22.91	-16.88	-4.19
*EU R&D expenditures in electricity (millions of Euros at 2004 prices)***							
Government	2651	1966	1936	1916	-25.84	-1.53	-1.03
Electricity supply industry	2818	2519	1935	1063	-10.61	-23.18	-45.06
Total	5469	4485	3871	2979	-17.99	-13.69	-23.04
*R&D expenditures in Japanese electricity industry (billions of yens)****							
	175	205	168	140	17.14	-18.05	-16.67

* Source: Nemet and Kammen (2007). ** Source: ERMInE (2008). *** Source: Jamasb and Pollit (2008).

In the US, total investment in energy R&D declined by almost 39% in real terms. Over the entire period considered, the reduction of public investment was relatively modest (thanks to an inversion occurred since 2000), while private energy companies diminished their R&D expenditures by 72%. One thing to be noticed is that the reduction of private R&D, although continuous, was particularly strong during 1990-95 (see also Blumstein and Wiel, 1998).

In the EU, the overall R&D expenditures related to electricity (always expressed at constant prices)[2] declined by 45.5%. Although less severe than that experienced in the US, such a dramatic drop has been mainly due to the behaviour of electric companies, whose R&D investment diminished by 62%. Comparing the records of the US and EU electric utilities over time, it can be seen that the

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[1] Aside from the budget constraints that limit the extent of governments' intervention, it should be stressed that, also in the energy and electricity sectors, public R&D is not a substitute for but a complement of business R&D. An excess of public over business research could reduce the effective exploitation of new pieces of knowledge and discoveries.
[2] The EU data are taken from the research project titled ERMinE (Electricity Research Road Map in Europe) funded by the European Commission under the 6th Framework Programme.

latter started to significantly reduce their R&D efforts not during the period 1990-95 but in the subsequent years and, particularly, after 2000.

Moving to Japan, the only available data refer to the R&D expenditures recorded in the domestic electricity industry composed of private companies. Being expressed at current prices they are not strictly comparable to the previous figures. In any case, it is possible to infer that the R&D cuts of Japanese companies have been less pronounced than those experienced in the US and EU. Moreover, the reduction of R&D efforts began in 1995, while during the early 1990s the Japanese electricity industry recorded increasing research expenditures.

The different timing and extent of the R&D reduction by the energy/electricity utilities of the countries considered are clearly associated with the processes of electricity reform undertaken by the different countries[3]. These processes have been based on different combinations of policies aimed at restructuring, deregulating, liberalising and, in the EU, privatising the electricity market (Jamasb and Pollitt, 2008). As Box 1 illustrates, the first country emanating an act that opened the door to the electricity reform was the US in 1992, while the crucial legislation changes in Japan and the EU occurred in 1995 and 1996.

Obviously, the reform processes have been implemented in the subsequent years and, still nowadays, are far from being completed. For instance, not all the US states have deregulated or significantly restructured the electricity market. Similarly, the timing and extent of electricity liberalisation has been quite different across EU countries, and in some cases the electricity companies are still state-owned. Finally, the Japanese process of liberalisation has been very gradual and cautious with a view of preserving a stable domestic supply of electricity.

In spite of the above qualifications, it is possible to say that the very emanation of acts announcing the market reform brought about deep changes in the behaviour of electric utilities. As Dooley points out "Even though a handful of countries have substantially completed the deregulation process, utilities in countries that are transitioning to a deregulated market or are simply considering deregulating their markets are behaving in much the same way as fully deregulated utilities. That is, even if they are not yet in a competitive environment, the fear of finding themselves in a deregulated market and unprepared for competition is causing utilities to act in substantially the same way as if they were deregulated." (Dooley, 1998, p. 550).

[3] The negative effect on R&D engendered by the reforms of electricity markets is supported not only by the aggregate figures of Table 1 but also by firm-level data. By means of a regression analysis concerned with 134 US electric utilities examined over the period 1990-2001, Sanyal (2007) finds that the dummy variable for deregulation (taking the value of 1 when a US state passed an order for retail competition) exerts a negative and significant impact on company expenditures devoted to environmental research.

Box 1: Processes of electricity reform

Deregulation in the United States

In the US, the major electricity providers are private (or investor-owned) companies which, for a long time, had a dominant position in their own regional market. As a consequence, they were strictly regulated by state authorities. A substantial step towards electricity deregulation was undertaken with the **Energy Policy Act of 1992** which liberalized the wholesale market for electricity to non-utility generators. Vertically integrated utilities, operating in both electricity generation and transmission, were required to act as common carriers and open up their transmission lines to other power producers. The latter requirement was **implemented in 1996** by the Federal Energy Regulatory Commission (FERC) with Orders 888 and 889. To be stressed is that the 1992 Act and the FERC orders applied at federal level, so that the different states were free to open to competition their internal markets. California and Rhode Island were the first states taking advantage of this opportunity in 1996, and by 1998 other 22 states (especially in New England) had passed some form of utility-restructuring legislation.

Liberalisation and privatisation in the European Union

In the EU, the **Electricity Market Directive of 1996** defined the minimum requirements for market liberalisation. It established that electricity production had to be opened to competition as of **February 1999**, while the retail competition was established more gradually. In 2003, a second Directive further promoted competition by fostering and regulating the access to electricity networks.

Both directives were silent on the need of private ownership, so that different Member States have chosen different paths. In Germany, the major electricity companies were already private (totally or partially) before the reform. The most extensive privatization process has taken place in the UK since the early 1990s, while in Italy, starting from 1999, the state-owned monopolist (Enel) has been partially privatised. Instead, in France and other EU countries (such as Greece, Ireland and the Nordic Countries) the incumbent electricity companies are still under public control.

Liberalisation in Japan

Since 1971, the Japanese electricity market is segmented in ten regional areas in which distinct private companies operate as monopolists. A partial process of liberalisation was launched with the **1995 Amendment of the Electricity Utilities Law**, which opened to competition the wholesale generation market. After that, a step by step approach has been followed: a retail competition limited to large customers was introduced in 2000 and the scope of liberalisation was further expanded in 2005. The Japanese model of liberalisation aims at increasing competition and transparency while maintaining the vertical integration of generation, transmission, and distribution in order to guarantee a stable supply of electricity.

Sources: Ardoin and Grady (2006); FINERGY (2003); TEPCO (2004).

Unfortunately, among the corporate changes generated by the mere announcement of electricity reform there has been the dramatic drop of research expenditures. This is the reason why the US electric utilities started to significantly undercut their R&D investment before those based in the EU and Japan. Clearly, the extent of R&D cuts has been influenced by the effective implementation of electricity reform. This could explain the relatively lower cuts undertaken by the Japanese industry, as well as their increase in the EU industry after 2000.

Why the processes of electricity reform have been accompanied by a staggering reduction of the R&D performed by electric utilities? The main and broad motivation is that all the above processes have increased the competitive pressure to cut costs and those required to sustain the R&D departments of electric companies have been particularly vulnerable. Accordingly, the latter have abandoned both the research projects that were judged less essential to their operations and those that could have generated some benefits only in the medium and long run.

Moreover, the privatisation of state-owned utilities has induced the managers to increase short-term profits and dividends for shareholders at the expense of long-term investments with uncertain outcomes, such as those devoted to R&D. However, since in the US and Japan most of the electric companies were already private before the reform, the explanation based on privatisation should be limited to the electric utilities of some European countries only (see Box 1). For those located in other countries one has to focus on the role played by the processes of restructuring, deregulation and liberalisation (Jamasb and Pollitt, 2008).

The restructuring of electricity markets (such as the vertical unbundling of generation, transmission and distribution) reduces, in principle, the size of the companies and, then, the level of R&D expenditures. The problem is that the overwhelming majority of electric utilities have dramatically reduced not only the level of R&D but also its intensity on total sales. It should be stressed that the electric one has never been an R&D-intensive sector; however, before the 1990s a typical electric utility spent around 1% of its sales on R&D (Dooley, 1988) while over the 2000s the average research intensity reduced to about 0.3% (see the next section).

With respects to the role of deregulation and/or liberalisation, the resulting increasing competition in electricity markets should, in principle, push the companies to be more engaged in R&D with a view of gaining competitive advantages. This does not necessarily imply an increase of the overall research efforts because the same companies are also induced to refocus their R&D on short-term and business-oriented goals[4] at the expense of public-interest[5] and long-term projects. Nevertheless,

[4] Due to the liberalisation of telecommunications, similar changes of R&D strategy have been implemented by the telecom companies too (Calderini and Garrone, 2001) which, albeit to a lower extent, have reduced their overall R&D expenditures during the early 2000s (Sterlacchini, 2006).

although this shift of the balance is undisputable and even justifiable, it is difficult to explain why total R&D expenditures should exhibit a staggering decrease, as it happened with most electric utilities.

According to Jamasb and Pollitt (2008, p. 998), "liberalisation has transformed electricity from a public service to a commodity which is technically homogenous". With a limited potential for product differentiation, prices tend to converge and profit margins mainly depend on cost savings. In this context, the reduction of R&D expenditures becomes an effective means to enhance short-term profits. Thus, within a liberalised market for electricity the scope for short-term R&D is limited while long-term research projects are not only too risky but, having some characteristics of public goods, cannot be fully appropriated by private companies. As Thomas (2006b, p. 12) puts it "If electricity is made a competitive activity, the 'free-rider' problem becomes serious and money spent on R&D and training is discretionary spending that can be, and generally is, saved and distributed as extra profits". The problem is that the efficiency of this particular sector, crucial for guaranteeing a sustainable development, can be effectively improved mainly through basic R&D and radical innovations in the field of energy sources. Unfortunately, these are the activities that private deregulated companies, obsessed by the imperative of increasing shareholder value[6], are unwilling to perform at a socially desirable level.

It should be noticed that, in spite of the staggering reduction of energy R&D, some advocates of the liberalisation process do not share any policy concern. A report on energy markets predisposed by a Dutch research institute (CPB, 2006, p. 31) contends that "R&D expenditure may have been either inefficiently high or ill-directed before liberalisation, when it was carried out by intransparently regulated public utilities, which did not necessarily act as profit-maximisers". Similarly, in an interview published in 1993 by the *Financial Time*, a chief executive of the British electric utility CEGB argued that, especially within the former state-owned monopolies, R&D laboratories often acted in relative isolation from the markets as if they were pseudo-universities "engaged in pure academic activity" (cf. Munari et al., 2002, p. 48). Thus, we should not be worried about the drop of energy R&D because electric utilities have simply (and rightly) abandoned wasteful and useless research activities which, in the past, could be carried out only thanks to the absence of competition.

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[5] According to Blumstein and Weil (1998), public-interest R&D includes the areas of health, safety, environment, energy efficiency, and pre-commercial technical information.

[6] Fostered by the deregulation of financial markets, which began in the US during the 1980s, the ideology of maximising shareholder value has "encouraged the top managers to align their own interests with external financial interests rather than with the interests of the productive organizations over which they exercised control" (Lazonick and O'Sullivan, 2000; p. 27). The same authors provide some examples of important high-tech companies that, in the late 1990s, spent more on stock repurchases than on R&D. Deregulated and privatised electric companies seem to have embraced the above ideology with particular enthusiasm.

The above argument is unconvincing for many reasons. Firstly, due to the inherent uncertainty of long-term R&D activities, it is extremely difficult to establish ex ante what projects are worth to be pursued. Secondly, the idea that public managers are particularly prone to finance useless research projects (from both a private and public point of view) is based on anecdotal evidence rather than a sound empirical basis. As the next section will show, also for electric companies, a sustained level of research expenditures is not associated with lower profits and, then, should be not viewed as a waste of money. Finally, and most importantly, the disruption of monopolies could justify a certain reduction of R&D investment but not a drop ranging from 60 to 70% in fifteen years. In conclusion, there are enough counter-arguments pointing to the fact that a decline of energy R&D of the magnitude observed in the last two decades is a clear sign of dynamic inefficiency.

In launching the electricity reform, the policy makers of most countries have not taken into account this kind of market failure[7] and the negative consequences of that are evident nowadays, when the generalised and strong need of cheaper, cleaner and safer sources of energy is undermined by the inadequate level of innovative activities.

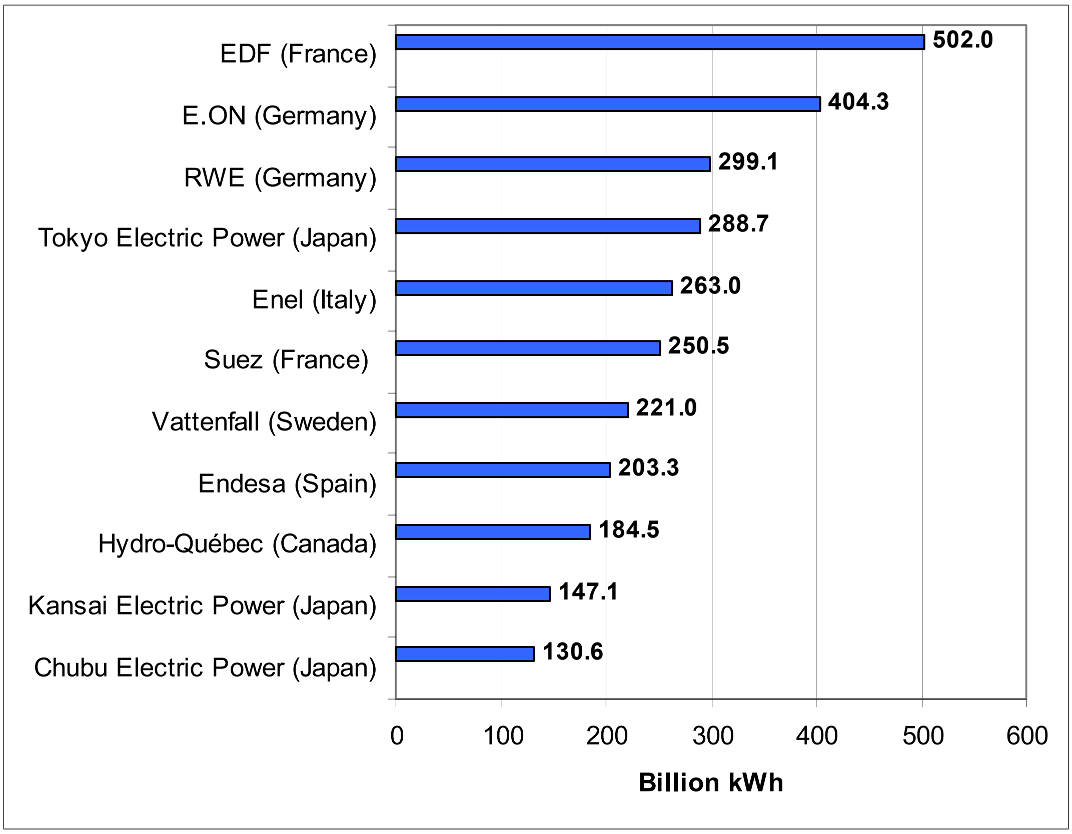
3. R&D in private and public electric utilities

This section is based on company data concerned with the major world electric power companies. Figure 1, taken from the 2006 Annual Report of the Tokyo Electric Power Company (TEPCO), illustrates the 2005 sales (expressed in billion kWh) of the eleven largest electricity producers and distributors of the world.

The first three companies are European (EDF, E.ON and RWE) while the fourth is the Japanese TEPCO; the next four companies with more than 200 billion kWh are all based in Europe, followed by the Canadian Hydro-Québec and two, relatively smaller, Japanese companies.

[7] The Japanese government can be seen as a partial exception. In 1985, one year after the opening of competition in Japanese telecommunication services, the Nippon Telegraph and Telecom Corporation (NTT) was established as a joint-stock company and begun to be partially privatised in 1986. "In order to guarantee that the effort in research activities would not be weakened by the partial privatisation, the 1984 Corporation Law, a special law defined for the privatised company, explicitly obliged NTT to undertake R&D and disseminate the results, considering the public nature of the business and its close relationship to national interest and public policies" (Munari et al., 2002; p. 45). Although, to my knowledge, there has not been a similar requirement for private electric companies, the 1984 Corporation Law is quite illuminating about the attitude of Japanese policy makers towards long-term goals. This is confirmed by the gradual process of liberalisation of electricity market (see Box 1).

Figure 1 – Sales of the major world electric power companies (fiscal year 2005)



Source: Tokyo Electric Power Company, Annual Report 2006 (www.tepco.co.jp).

Due to the higher level of geographical fragmentation of the market, none of the US electric utilities has a size similar to that of the companies included in Figure 1. In fact, the largest company located in the US is the Florida Power & Light company which, in 2005, recorded 105 billion kWh of electricity sales, followed by the Georgia Power Corporation with less than 90 billion kWh. For this reason and also because we found that both companies do not provide any information on R&D expenditures in their recent annual reports, the US electric utilities are excluded from the analysis. This also applies to the UK electricity companies; in fact, due to the advanced process of liberalisation, none of them records an amount of electricity sales comparable to that of the largest European companies[8].

3.1 R&D performance across companies and company types

Data on sales and R&D expenditures of the major electricity companies of the world are taken from the consolidated group accounts provided by the ultimate parent companies in their

[8] To be added is that, among the major players in the UK electricity markets, there are many foreign companies (such as EDF, RWE and E.ON) which, instead, are taken into account.

audited annual reports. For sales, the usual accounting definition of total sales net of taxes and shares of joint ventures and associated companies is used. The R&D figure is the company cash spending indicated in the annual report and, as such, it should only include that funded and performed by the company itself. Such a figure derives from the accounting definition of R&D established by international standards and based on the OECD 'Frascati' manual.

The company data, collected and harmonised over the period 2000-2007, refer to the utilities whose principal line of business is the provision of electricity. Although many companies are also active in other services such as gas and water supply, most of them can be classified as incumbent electricity operators in their respective national or regional markets. In addition, some of them are also present in foreign liberalised markets (the major example of which is the UK electricity market). A partial exception is that of Suez, a France-based multinational, which derives about 40% of its revenues from environmental services not related to energy. In this case, only the energy sales are taken into account and, since the R&D expenditures of the company are not broken down by line of business, only 60% of them are considered.

For all the electric companies included in Figure 1 but Endesa, I was able to collect consistent data on net sales and R&D expenditures over the years 2000-2007. Unfortunately, aside from those concerned with the last years, the previous annual reports of Endesa do not include information on R&D expenditures, so that the Spanish company had to be neglected. It should be added that in October 2007 Endesa was taken over by the Italian Enel which, as a consequence, became the second most important electric utility in Europe.

The R&D performance of the major electricity companies of the world over the period 2000-07 or, for the Japanese companies, the fiscal years 2001-08 (ending on March 31st) is illustrated in Table 2. For the companies based in countries outside the Euro zone, sales and R&D figures are converted into Euros by applying an exchange rate constant over time. This procedure, adopted to compare the levels of R&D expenditures, does not affect the R&D changes and intensities of the companies that use different currencies, while it could produce minor biases when their figures are added to or compared with those of the companies located in the Euro area.

The last column of Table 2 shows the percentage changes of the variables considered which, to limit the effect of annual volatility, are computed between the first and the last biennium.

Table 2 – Sales and R&D expenditures of electric companies (€ million at current prices)

	2000	2001	2002	2003	2004	2005	2006	2007	Change 2000-01/ 2006-07
Electricité de France*									
Sales	34424	38153	44643	44919	46928	51051	58932	59637	63.37
R&D expenditures	379	418	432	381	425	402	389	375	-4.14
R&D/Sales (%)	1.1	1.1	0.97	0.85	0.91	0.79	0.66	0.63	-41.32
Enel (Italy)									
Sales	25109	28781	29977	31427	31011	34059	38513	43673	52.51
R&D expenditures	124	100	100	40	20	20	22	29	-77.25
R&D/Sales (%)	0.49	0.35	0.33	0.13	0.06	0.06	0.06	0.07	-85.33
E.ON (Germany)									
Sales	41575	37273	37059	46364	49103	56399	64091	68731	68.45
R&D expenditures	103	92	69	69	55	24	27	37	-67.18
R&D/Sales (%)	0.25	0.25	0.19	0.15	0.11	0.04	0.04	0.05	-80.6
RWE (Germany)									
Sales	41000	50336	46633	43875	42137	39487	42554	42507	-6.87
R&D expenditures	101	108	87	78	78	55	73	74	-29.67
R&D/Sales (%)	0.25	0.21	0.19	0.18	0.19	0.14	0.17	0.17	-25.01
Suez - Energy (France)									
Sales	19586	26374	24242	26635	29334	30400	33140	34777	47.77
R&D expenditures	113	156	75	53	61	62	64	73	-48.89
R&D/Sales (%)	0.58	0.59	0.31	0.20	0.21	0.20	0.19	0.21	-65.39
Vattenfall (Sweden)**									
Sales	3375	7349	10759	11921	11823	13184	14462	15297	177.5
R&D expenditures	61	66	52	51	60	69	81	108	49.14
R&D/Sales (%)	1.81	0.89	0.48	0.43	0.51	0.53	0.56	0.71	-53.17
Hydro-Québec (Canada)***									
Sales	15994	17601	18214	16006	14569	15257	15637	17274	-2.04
R&D expenditures	140	144	150	139	122	134	137	139	-2.82
R&D/Sales (%)	0.88	0.82	0.82	0.87	0.84	0.88	0.88	0.80	-0.74
	2001°	**2002°**	**2003°**	**2004°**	**2005°**	**2006°**	**2007°**	**2008°**	**Change 2001-02/ 2007-08**
Tokjo Electric Power°°									
Sales	37768	37498	35333	34864	36253	37749	37947	39357	2.71
R&D expenditures	410	345	290	266	252	258	240	279	-31.28
R&D/Sales (%)	1.09	0.92	0.82	0.76	0.7	0.68	0.63	0.71	-33.14
Kansai Electric Power°°									
Sales	18497	19045	18784	18245	18772	18525	18649	19317	1.13
R&D expenditures	211	219	196	167	165	150	150	141	-32.47
R&D/Sales (%)	1.14	1.15	1.04	0.91	0.88	0.81	0.8	0.73	-33.16
Chubu Electric Power°°									
Sales	16182	16010	15631	15092	15323	15447	15901	17475	3.68
R&D expenditures	152	144	132	126	115	120	102	101	-31.2
R&D/Sales (%)	0.94	0.9	0.84	0.84	0.75	0.77	0.64	0.58	-33.46

**= the R&D intensity in 2000 was set equal to that in 2001.*
***= the exchange rate to convert Vattenfall data is 0.1065 euro per Swedish kronor and constant over time.*
****= the exchange rate to convert Hydro-Québec data is 0.714 euro per Canadian dollar and constant over time.*
°= fiscal year ending on March 31st.
°°= the exchange rate to convert the data of Japanese companies is 0.13922 euro per yen and constant over time.

Table 2 (follows)

	2000	2001	2002	2003	2004	2005	2006	2007	Change 2000-01/ 2006-07
Total companies									
Sales	253510	278421	281275	289348	295253	311557	339826	358045	31.20
R&D expenditures	1794	1791	1583	1370	1354	1294	1285	1355	-26.36
R&D/Sales (%)	0.71	0.64	0.56	0.47	0.46	0.42	0.38	0.38	-44.00
European companies									
Sales	165070	188266	193313	205141	210336	224580	251692	264622	46.13
R&D expenditures	881	939	815	672	699	632	656	696	-25.72
R&D/Sales (%)	0.53	0.5	0.42	0.33	0.33	0.28	0.26	0.26	-49.29
European private companies*									
Sales	127271	142764	137911	148301	151585	160345	178298	189688	36.27
R&D expenditures	441	455	331	240	214	161	186	213	-55.47
R&D/Sales (%)	0.35	0.32	0.24	0.16	0.14	0.10	0.10	0.11	-67.44
Japanese companies									
Sales	72446	72554	69748	68201	70348	71720	72497	76149	2.51
R&D expenditures	773	708	618	559	533	528	492	520	-31.61
R&D/Sales (%)	1.07	0.98	0.89	0.82	0.76	0.74	0.68	0.68	-33.29
Private companies**									
Sales	199717	215318	207659	216502	221933	232065	250795	265837	24.48
R&D expenditures	1214	1163	949	799	747	689	678	733	-40.64
R&D/Sales (%)	0.61	0.54	0.46	0.37	0.34	0.30	0.27	0.28	-52.43
Public companies***									
Sales	53793	63103	73616	72846	73320	79492	89031	92208	55.04
R&D expenditures	580	628	634	571	607	605	607	622	1.74
R&D/Sales (%)	1.08	1.00	0.86	0.78	0.83	0.76	0.68	0.67	-34.58
Private/Public companies R&D	2.09	1.85	1.50	1.40	1.23	1.14	1.12	1.18	

**= Enel, E.ON, RWE and Suez.*
***= Enel, E.ON, RWE and Suez plus the Japanese companies.*
****= Electricité de France, Vattenfall and Hydro-Québec.*

Starting from the European electric companies, it can be seen that Enel, E.ON[9], RWE and Suez have experienced a staggering decrease of research expenditures at current prices. The R&D change ranges from minus 30% of RWE to minus 77% of Enel.

All the above companies but Enel were already private (mostly, as in the case of RWE, or entirely) before the introduction of electricity reform. Instead, Enel was partially privatised starting from 1999. The Italian Government has remained the major shareholder of the company by maintaining 30% of its shares and leaving a free-float of 70%. Thus, in principle, Enel could be viewed as a company under public control. In practice, this has not been the case and, since the early 2000s, the

[9] The consolidated group accounts of E.ON documented a much higher level of R&D expenditures during the years 2000-02. However, about 80% of them were performed by a chemical division that was deconsolidated in 2003. Accordingly, for the sake of consistency, the R&D expenditures of E.ON for 2000-02 have been adjusted by subtracting those attributable to the chemical division.

strategic choices of the company have not been either objects of political discussion or governmental approval. Therefore, free from effective public control, Enel has acted as a private utility with the only limitation of being regulated by the Italian Regulatory Authority for Electricity and Gas (which co-determines the prices for households and small customers and the conditions of access to the liberalised electricity market). Being the only example of a newly privatised electric utility, the fact that Enel has recorded the largest reduction of R&D investment among the companies considered in this paper is worth of an in-depth investigation.

Before being privatised Enel funded and carried out the R&D needed by the Italian electric system. Most of it referred "to the general innovation of the system in a long run perspective, to the improvement of environmental impact, of the quality and of security of the electric system" (cf. Eurolectric, 2003; Section 4.5: Italy; p. 29). Such a definition coincides with that of public-interest R&D (see footnote 5). With the electricity liberalisation and privatisation of 1999, public-interest R&D was separated from competitive R&D. The Liberalisation Decree of March 16th 1999 stated that system related research activities had to be included among the general charges of the electric system. A subsequent decree established that public-interest R&D had to be financed by means of a levy from electricity bills and that CESI (an already existing corporation providing technical services to Enel) was temporarily in charge of conducting this kind of research. As a consequence, Enel transferred to CESI all the related facilities and personnel and, thus, reduced dramatically its R&D expenditures between 2000 and 2003 (cf. Table 2). In 2006 a new decree fixed the rules for selecting the projects eligible to the funds raised for public-interest R&D, so that CESI was no more the sole responsible of such a task. According to the Italian Regulatory Authority for Electricity and Gas, in 2007 the above funds amounted to € 58 million (cf. Autorità per l'Energia Elettrica e il Gas, 2009). By adding the R&D expenditures of Enel in the same year (see Table 2) one gets € 87 million, while in 1998, i.e. before the privatisation, Enel alone spent € 181 million. In conclusion, the transition from a monopolistic electricity market based on public ownership to a liberalised market dominated by a newly privatised company had important negative consequences in terms of the overall investment in electricity R&D. More specifically, the lesson arising from the Italian experience is that the introduction of a regulation system in which almost all the burden of public-interest R&D is passed to consumers via price increases cannot guarantee an adequate amount of funds, able to compensate the reduction of research efforts by the former state-owned companies.

The above conclusion is supported by the cases of Electricité de France (henceforth EDF) and Vattenfall, i.e. the two European utilities that have remained under public control (80% of the former's shares are held by the French government while the latter is entirely owned by the Swedish state).

Table 2 shows that EDF has reduced its R&D investment from 2000-01 to 2006-07 by only 4%. Having recorded a remarkable growth of total sales the R&D intensity of the company has diminished from 1.1 to 0.65. In any case, with about € 380 million, EDF is the world electric utility that spends more on R&D and accounts for more than a half of the overall research expenditures recorded by the six European companies considered in this paper. About 1950 people (1.2% of the company employees) are occupied in R&D departments[10] in which different long-term projects are carried out. Although particularly concerned with nuclear technologies, the R&D carried out by EDF covers a wide spectrum of energy-related projects. According to the 2007 report, more than € 100 million (out of 375) are devoted to activities concerned with environmental protection, such as energy efficiency, renewable sources and local impacts of climate change.

The other European public utility is the Swedish Vattenfall which, as documented in Table 2, has experienced a staggering increase of total sales, especially from 2000 to 2002. The triplication of the company size in a time span of two years is entirely due to numerous European acquisitions, particularly concentrated in Germany after the liberalisation of that market. As a consequence, it is not surprising that such an expansion has not been accompanied by an similar increase of R&D investment. However, while maintaining a constant level of R&D until 2004, Vattenfall is the only company among those included in Table 2 that remarkably augmented its research expenditures in the subsequent years. Due to this 'anomalous' behaviour, the Swedish utility is currently the second European company (after EDF) in terms of R&D expenditures, while in 2000 it ranked last. Similarly to EDF, Vattenfall research activities are mainly concentrated on nuclear technologies (with particular emphasis on the treatment and storage of nuclear waste), followed by projects concerned with the reduction of CO_2 emissions and renewable energy.

It should be stressed that the recent surge of consciousness with respect to energy efficiency and the reduction of carbon emissions has affected not only the behaviour of state-owned utilities but, though with a lower extent, that of the private ones. This seems particularly the case of RWE which, according to the most recent annual reports, has raised and is planning to further increase the research efforts in these fields[11]. This is also visible in Table 2: in effect, after the marked reduction

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[10] To emphasise the huge amount of human resources engaged in research activities by EDF, it suffices to say that in 2007 the R&D employees of RWE and E.ON were, respectively, 270 and 190.

[11] According to the 2007 Annual Report of RWE (Section 1.9: Innovation) "The Energy sector is in need of innovation. Secure, affordable and climate-friendly power supplies will be impossible without technological progress. Therefore, RWE is stepping out its research and development. We will significantly increase spending in this field in the years

of the first period, the R&D expenditures of RWE have augmented in the years 2006-07. Although the levels of the early 2000s have been not recovered, this change of strategy is worth to be mentioned. It must be added that in 2007 also the other European private companies have spent on R&D more than in the previous two years. However, the changes are too small for saying that we are in the presence of a reversing trend, similar to that announced by RWE.

Moving out of Europe, the 9th largest electricity provider of the world (and the first in terms of hydroelectric generation) is Hydro-Québec. Established in 1944 as a public company by the government of Québec, Hydro-Québec became the unique electricity operator of the province after the 1963 nationalisation of the electricity sector. Having resisted the attempts of privatisation that started during the 1980s, the company is still under full governmental control[12]. However, the public ownership has not impeded Hydro-Québec to substantially reform its governance, organisation and operations in line with the institutional and competitive evolution of electricity markets (Bernier and Simard, 2007). Hydro-Québec is the only electric utility of North America operating, since long time, a large scale research centre (the *Institut de recherche d'Hydro-Québec*); in 1988, the latter was coupled with another R&D laboratory (the *Laboratoire des technologies de l'énergie*). The research activities of the company are evenly distributed among the different phases of a typical electric operator (generation, transmission and distribution) and also long-term strategic projects are funded. As shown by Table 2, also during the 2000s, the company has kept almost intact the capability of its research centres. In fact, after the up and down between the biennia 2001-02 and 2003-04, the amount of R&D expenditures in the last years has reached almost the same level of 2000. However, aside from these small variations, the most important finding that must be emphasised is that, among those considered in this paper, Hydro-Québec is the only electric utility that has maintained a constant share of research expenditures on total sales (about 0.85) so that, in 2006-07, it ranks first in terms of R&D intensity (while in 2000-01 it was fifth). Finally, in order to stress the importance of the company in the Canadian system of research and innovation, it should be added that, in 2007-08, Hydro-Québec ranked 19th among the Canada's top 100 corporate R&D spenders (while it was 25th in 2005-06)[13].

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ahead. We want to pave the way for a new method of generating electricity from coal, involving the capture of carbon dioxide emissions and their storage under ground".

[12] There have been numerous proposals of privatising Hydro-Québec, but all of them have received little support from the public opinion. Thus, Québec has not followed the same path of Ontario which, in 2002, introduced an electricity reform based on deregulation and privatisation. Both processes failed and the Ontario government was compelled to re-establish a strict regulation of electricity prices (cf. OECD, 2004). That of Ontario is not the only case in which the electricity reform ended up in a failure (see Thomas, 2006b).

[13] See the list of Canada's Top 100 Corporate R&D Spenders provided by RE$EARCH Infosource Inc. (http://www.researchinfosource.com/top100.shtml).

The final group of utilities examined in this paper includes the three most important electric power companies of Japan. In spite of the recent measures of liberalisation (see Box 1 in Section 2), the Japanese electricity market is still geographically segmented in many areas served by incumbent companies. The Tokyo Electric Power Company (TEPCO) operates in the Tokyo metropolitan area, which accounts for about one-third of Japan's population and 40% of national GDP. This explains why TEPCO total sales are more than twice those recorded by the second and third electricity company of the country: Kansai Electric Power, based in the Osaka area, and Chubu Electric Power, located in the Nagoya area. Using balance sheet data for the fiscal years ending on March 31st, Table 2 shows that, over the period 2001-2008, the Japanese companies followed an almost identical path. Total sales recorded a modest increase in nominal terms, while the research investment constantly declined from 2001 to 2008 (with the only exception of TEPCO in 2008). The fact that, over the entire period considered, the three companies have reduced their R&D expenditures by almost the same and remarkable percentage (slightly above 30%) is a clear signal of a strongly symmetric behaviour. This common attitude towards R&D induces one to infer that the process of electricity liberalisation (which, in Japan, has been intensified since 2000) has raised the pressure for cost reductions and, then, pushed the companies to progressively cut research expenditures.

In spite of the marked drop of expenses, it should be stressed that the R&D intensity on total sales recorded by the Japanese companies remains, at the end of the period, significantly above the average arising from the ten biggest electric companies of the world (see the second part of Table 2, which compares the performance of different company groupings). In particular, the Japanese utilities have an intensity of research expenditures (68%) largely above that of their European counterparts (26%). However, being private, the companies based in Japan should be compared with the private or privatised utilities of Europe: by doing so, the gap becomes huge since the latter have reduced R&D expenditures by 55% (versus 32% in Japan) and the R&D intensity by 67% (versus 33%). This confirms that the Japanese path towards electricity liberalisation has been more gradual than that followed in Europe, where, being coupled with privatisation processes, it has induced the private (or privatised) utilities to halve their R&D investment in a time span of eight years. In any case, the Japanese companies share with the rest of private corporations a negative trend in terms of R&D efforts.

Instead, the only group of utilities showing a slight increase of R&D expenditures is composed of the three state-owned companies considered in this study: EDF, Vattenfall and Hydro-Québec. It must be noticed that, in terms of R&D intensity, public companies experienced a reduction similar to that recorded by the Japanese companies (this is due to the fact that the sales of EDF and, especially, Vattenfall grew much faster than those of their Japanese counterparts). Instead, when state-owned utilities are compared with all the private ones (both Japanese and European), the R&D intensity gap in favour of the former increased remarkably over time. The last row of Table 2 shows that, while in 2000-01 the amount of R&D expenditures by private companies was about two times bigger than that of public companies, in 2006-07 the R&D of the former was only 15% above that of the latter. In short, without the positive contribution of state-owned utilities, the decline of corporate R&D in energy/electricity would have been much more severe than it has been during the last years.

3.2 Is less R&D conducive to more profits?

Having established that, among the major electric utilities of the world, publicly-owned companies have been the only ones that did not reduce R&D investment, an important question that arises is whether such a behaviour could be ascribed to the fact that public utilities, as opposed to private ones, do not have a strong need to increase profits by means of cost reductions. To address this issue, I compared across the ten electric companies considered in this paper the changes in profitability with those in terms of R&D expenditures and intensity.

As a measure of profitability I took the EBITDA margin on total sales with the former standing for "Earnings Before Interest, Taxes, Depreciation and Amortisation", an indicator that is widely used, especially in stock-market analyses, to evaluate a company's ability to generate profits. For Hydro-Québec and the Japanese companies EBITDA figures were not provided in the annual reports so that I used the Operating Income margin on total sales[14]. In both cases what is evaluated is not the net income (i.e. the amount of 'final profits') earned by the company but the gross income generated by its activities (only the typical ones when Operating Income is considered).

For analysing the relationship with the changes in profitability, I did not use the contemporaneous changes in research investment and intensity but those delayed by two years. In this way I tried to rule out the possibility that the decision to reduce (augment) R&D could be 'caused' by a reduction (increase) of profits. So, the variations of R&D expenditures and intensity are computed from 2000-01 to 2004-05 while those concerned with profitability are measured between 2002-03 and 2006-07 (again, biennia are chosen for reducing annual volatility).

Table 3 – Changes in R&D expenditures, R&D intensity and profitability

	R&D expenditures			R&D intensity on sales			EBITDA margin on sales*		
	2000-01	2004-05	Change	2000-01	2004-05	Change	2002-03	2006-07	Change
Electricité de France	399	414	3.76	1.10	0.85	-22.92	24.93	24.74	-0.78
ENEL	112	20	-82.15	0.42	0.06	-85.36	26.81	21.89	-18.37
E.ON	98	40	-59.49	0.25	0.08	-68.75	20.55	18.20	-11.40
RWE	105	67	-36.36	0.23	0.16	-29.62	17.42	17.72	1.71
Suez-Energy	134	62	-54.12	0.58	0.20	-64.64	16.23	16.39	0.99
Vattenfall**	66	65	-2.27	0.69	0.52	-24.78	25.81	32.13	24.49
Hydro-Québec	142	128	-9.85	0.85	0.85	0.43	38.30	44.31	15.71
Tokyo Electric Power	377	255	-32.38	1.00	0.69	-31.19	11.61	10.73	-7.62
Kansai Electric Power	215	158	-26.58	1.15	0.85	-26.11	12.25	11.57	-5.51
Chubu Electric Power	148	117	-20.62	0.92	0.76	-16.95	14.65	13.06	-10.83

* For the Japanese companies and Hidro-Québec the figures refer to the Operating Income margin on sales. Moreover, for the former companies the figures refer to the fiscal years subsequent to those indicated ending on March 31st.
**The initial figures for R&D expenditures and intensity refer to 2001-02. This is done for reducing the drop in R&D intensity due to the company acquisitions in 2001-2002.

For all the companies, Table 3 reports the initial and final levels and, then, the rates of change of the variables under consideration. The EBIDTA margin changes are plotted in Figures 2 and 3 against, respectively, the variation of R&D expenditures and that of the R&D intensity on total sales. In both cases, a clear positive relationship emerges. Although the findings are quite similar, I shall comment only the picture depicted in Figure 3 also because, in this case, both the profitability and R&D indicator are expressed as ratios on total sales.

A big deal of the positive relationship is due to the performance of two of the three public companies considered, i.e. Vattenfall and Hydro-Québec which are characterised by above average changes in both R&D intensity and, especially, profitability. The three (private) Japanese companies do not conform well to the rule, but their closeness clearly indicates that the symmetric behaviour in terms of R&D is associated with similar variations in profitability. Finally, it should be noticed that, even when only the (four) private European companies are taken into account, the relationship between the variations of R&D intensity and EBITDA margin remains positive.

Although the R&D variable is inserted with a lag, I do not claim that those described in the above graphs should be interpreted as causal relationships. Obviously, the small number of observations and the limited length of time that have been considered do not allow one to draw such a strong conclusion. Moreover, the results could have been different if another measure of profitability (e.g. net instead of gross income) was chosen.

[14] EBIDTA is defined as operating revenue minus operating expenses plus other revenues, while Operating Income does not take into account other revenues.

Figure 2 – Changes in R&D expenditures and EBITDA margin

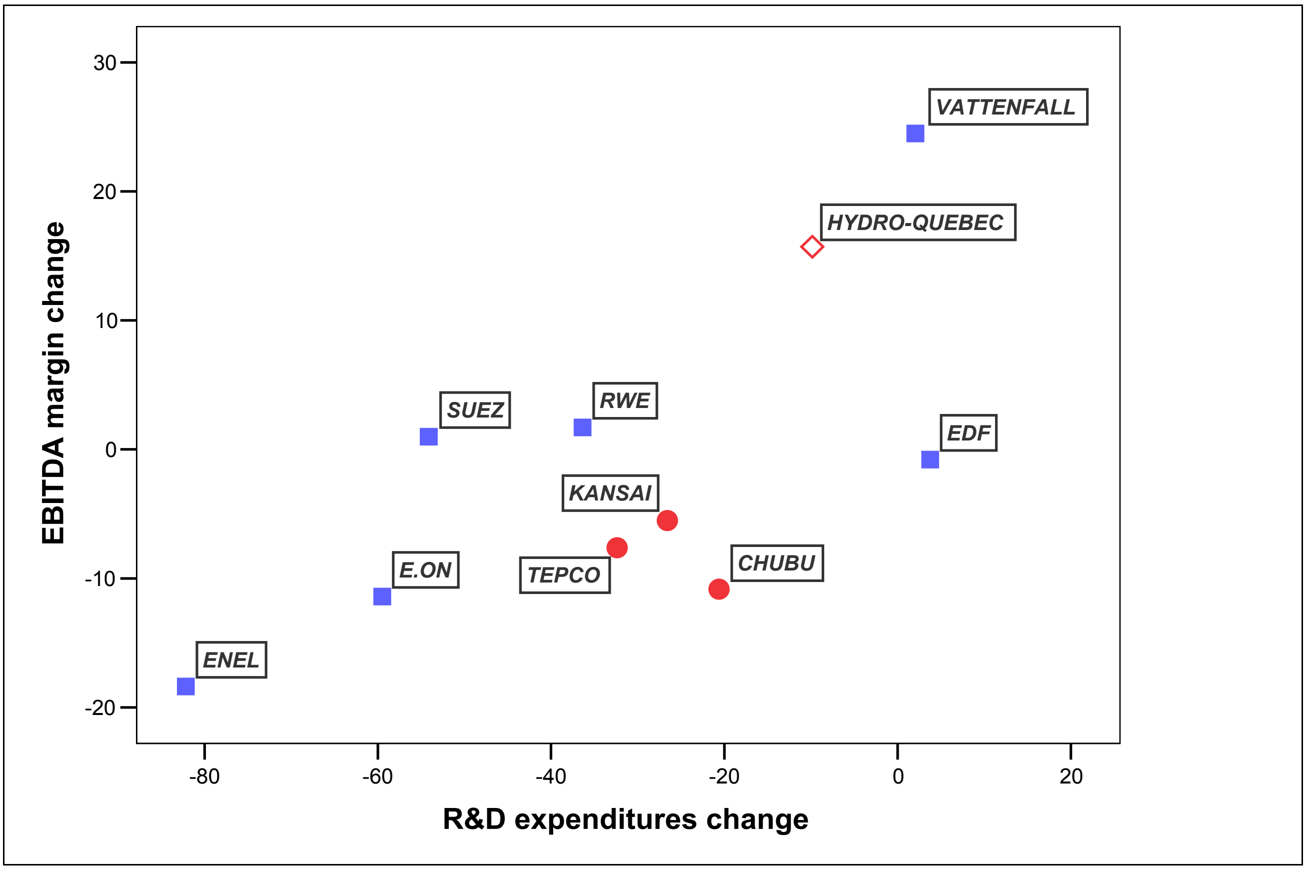
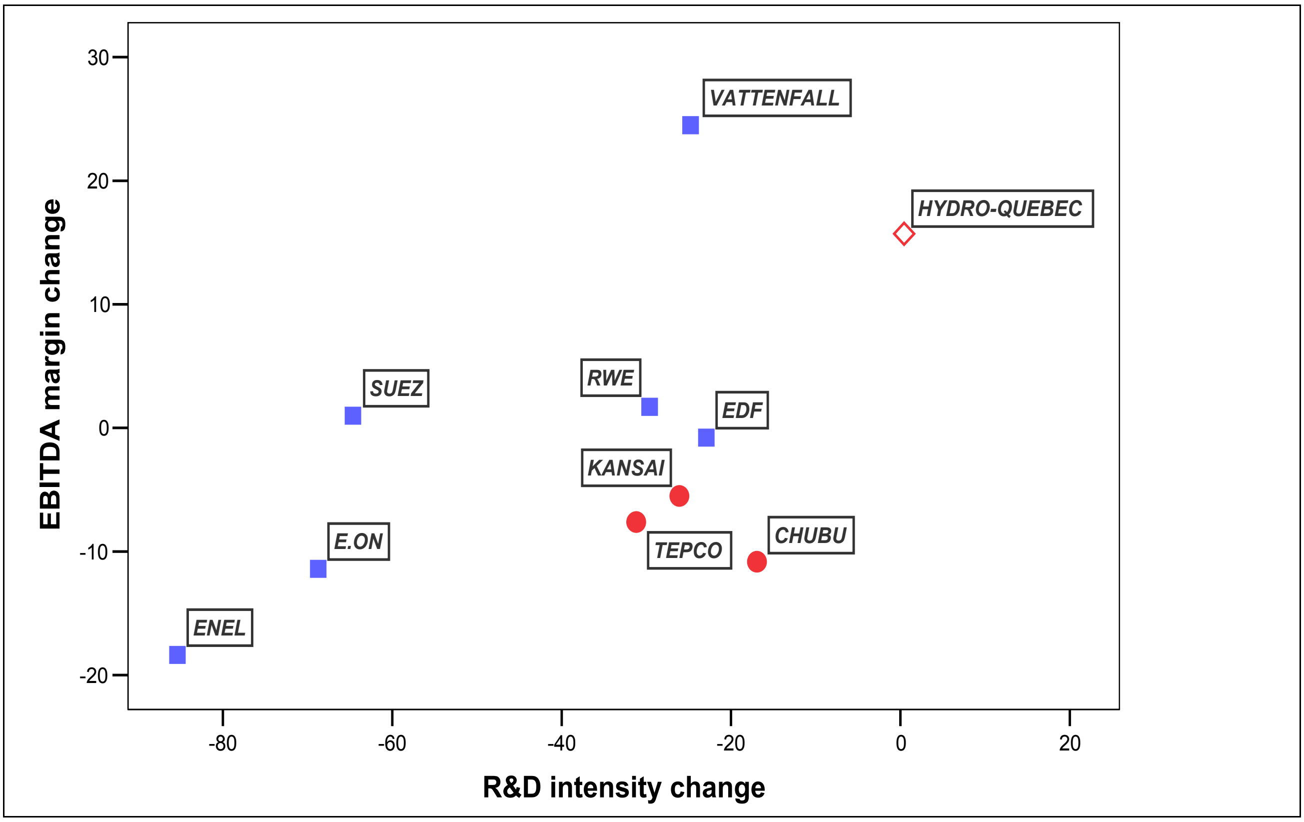


Figure 3 – Changes in R&D intensity and EBITDA margin



According to the above arguments, one cannot be certain that an increase of R&D efforts by electric utilities would bring about more profits. However, what clearly emerges from the recent performance of the major electric utilities of the world is that a drop of research expenditures is not associated with better outcomes in terms of profitability. To put it another way, it is possible to conclude that the positive attitude of state-owned companies towards R&D has not hampered their capability to earn a remarkable amount of profits.

4. Concluding remarks and policy considerations

This paper has stressed that the staggering decline of R&D investment in the field of energy/electricity recorded during the last two decades has been mainly due to the behaviour of electric utilities and that the cuts of corporate R&D have been mainly induced by the reforms of electricity markets (liberalisation and, in some European countries, privatisation of state-owned companies). However, a closer inspection to recent data concerned with ten major electric companies of the world has shown that not all of them behaved in the same way. The drop of research expenditures was dramatic among the private or newly-privatised companies, while those that remained under public control did not reduce their R&D efforts. Moreover, we found that the choice of maintaining an adequate level of R&D was not at odds with the goal of increasing company profits. These findings have relevant policy implications.

The most important one is that, without a radical change in the behaviour of electric utilities, it will be impossible to mobilise the huge amount of R&D funds required to guarantee the safer, cheaper and cleaner sources of energy that the entire world urgently needs. As mentioned in the introduction, some experts contend that the current investment in energy R&D should be increased by a factor of four (cf. Advisory Group on Energy, 2005). Accordingly, along with a surge of the contribution given by the public sector and other industries closely linked to the generation and distribution of electricity (such as the providers of electric equipment), the electric utilities should re-build the research capacity that they have lost during the last twenty years.

For achieving this ambitious goal there are two main options: either to impose a more effective regulation on electric utilities or to extend the presence of public companies or public-private partnerships. At a first sight, the former could be viewed as the less demanding solution because it does not imply a direct governmental intervention aimed at (re)taking the ownership and control of the major electric companies or establishing new entities under substantial public control. However, in the current setting of electricity markets, the regulatory option cannot be easily implemented and, in any case, would impose a non-negligible restriction on the behaviour of private companies.

The need of ascribing to the regulators of public utilities the task of promoting innovation and R&D also in presence of liberalised markets has been discussed, among others, by Blumstein and Wiel (1998), Feneyrol (2002), and Thomas (2004). Before the liberalisation, many regulatory bodies established that regulated utilities could pass to consumers, via prices increases, a portion of the R&D costs undertaken to perform long-term, public-interest research projects. This scheme cannot be applied to fully competitive markets simply because the final price of electricity is not set (or co-determined) by a regulation authority. At the same time, traditional policies based on tax credits and public subsides could be ineffective in boosting private R&D spending to the levels recorded before the electricity reform and with particular reference to long-term projects.. As a consequence, the only viable option seems that of establishing a mandatory scheme, i.e. a sort of R&D obligation for the incumbent electric companies. However, since most of the outcomes of long-term R&D are likely to become public goods, some of the research costs should be borne by the rest of market players. This means that, along with the R&D obligation for the incumbent operators, a system of compulsory levies from the revenues of all the other electric companies should be established. Obviously, these additional costs will give rise to higher prices but, in presence of competitive markets, it is unlikely that all the burden of public-interest R&D will be passed to consumers.

Aside from the inherent difficulties of implementing the above scheme (see, for example, Thomas, 2004), the main obstacle to a mandatory regulation for R&D is of political nature. In fact, governments should recognise that the electricity reform has undermined the dynamic efficiency of the sector and, as a consequence, intervene to limit the freedom of private companies. Interestingly, however, not all the governments should paid such a political price: in fact, since state-owned companies have not diminished their research efforts, the governments that have maintained the full control of the incumbent electric companies are not subject to the same pressure of increasing corporate R&D and, then, do not need to introduce a specific obligation.

So, looking at the international experience and considering the difficulties in establishing a mandatory regulation, governments should seriously take into consideration the option of re-taking the control of the major electric utilities or that of establishing, by means of public-private partnerships, new companies or agencies having the main task of performing long-term R&D in the fields of energy and electricity. Obviously, to make viable the option of public-private entities, the private participation should be not voluntary but mandatory.

In short, if one acknowledges that the decline in energy R&D is a market failure that must be urgently addressed, there seems to be no alternatives to some kinds of public intervention that will reduce the degrees of freedom of private enterprises. As a consequence, whether an R&D obligation to private companies would be preferable to the public control of state-owned or mixed companies should be not evaluated on the basis of political or ideological beliefs but in terms of economic convenience and effectiveness. Although such a demanding cost-benefit analysis goes beyond the scope of the present paper, it is possible to contend that there are no theoretical and practical reasons for assuming that the option of public ownership should be inferior to that of a mandatory regulation.

As a final consideration, it must be stressed that, in this paper, the re-appraisal of public electric companies has been exclusively based on their positive attitude towards R&D. Albeit important, it could be argued that the need of reversing the negative trend of energy R&D is not enough for introducing a radical counter-reform of electricity markets. However, what is suggested here is not the return to the old framework based on public monopolies, but the recourse to publicly-owned companies with a view of achieving an adequate investment in long-term, public-interest R&D that fully competitive markets, composed of private companies only, cannot guarantee. The experience of some countries (such as France and Sweden in Europe, as well as Québec in Canada) suggests that large state-owned utilities can mobilise an adequate amount of resources for R&D without generating inefficiencies and impeding to open the electricity markets to substantial forms of competition.

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