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CONSEQUENCES OF ELECTRICITY RESTRUCTURING ON THE ENVIRONMENT: A SURVEY

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Consequences of electricity restructuring on the environment: A survey

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Summary: The aim of this paper is to assess theoretical consequences of restructuring electricity markets on the environment. We examine changes in potential behaviours in consumption-side as well as in supply-side. We show that restructuring and following access to competition is not neutral from an environmental standpoint. Deregulation could induce some negative externalities due to requirements in cost-efficiency. The principal result of this paper is the need of strong incentives in public policies to compensate the new short-term horizon in which energy sector's firms are evolving, particularly concerning R&D.

Keywords and phrases: Electricity restructuring, environment, greenhouse gas emissions, regulation, innovation.

JEL Classification Numbers: H50, Q28, Q48.

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1 Introduction and preliminary comments

The issue of deregulation has at length been debated, and today even if largely adopted, it is still contested. Considering the deregulation as an established fact, a new relevant topic is to know whether this process should lead to a better or a worse situation in terms of environment. The question is far from being obvious because of the multiplicity of factors to take into account. Two major difficulties emerge. First, sufficient time series do not exist to confirm or to invalidate theoretical assumptions and it is premature to make conclusive statements about the environmental impact of deregulation. Our aim will be here to put these assumptions into perspective with first observations in countries where liberalization is already well underway. Second, it appears also difficult to consider the pure effects of restructuring on the environment, without taking into account changes due to others factors, as general growth or technology advances.

Three kinds of actors can modify the level of emissions due to electricity generation: consumers (demand-side), generators (supply-side) and regulators by having an effect on the first two. To fulfil socially optimal environmental requirements, regulation can influence the quantity demanded, but also the quality desired by informed and educated consumers.

Concerning the supply-side, the need for competitiveness involves a drastic decline in non essential expenditures and an optimization of investment, principally the choice of the fuel mix. Then, R&D programs and demand-side-management (DSM) programs are declining, when not disappearing. In addition to the cost pressure, uncertainty leads producers to sub-optimal decisions. Uncertainty appears under different forms, from regulatory uncertainty, to technological or input price risks.

The second and third sections analyze potential consequences in the demand-side and the supply-side respectively. The fourth section explains the accentuating role of uncertainty on previously mentioned elements. The fifth section put the accent on the remaining major issue; we mean the underinvestment in energy R&D following deregulation. Section six concludes.

2 The Demand-Side

This section aims to present potential effects from restructuring in a consumer standpoint. Beyond an expected price effect, depending on price-elasticity, demand can also be influenced by demand-side-management programs and system reliability.

2.1 A basic price effect

Above all, deregulation is often expected to result in lower prices due to competition. The primary basic effect is then a higher demand, which could ceteris paribus lead to higher carbon emissions from electricity generation (Palmer, 1999). This possible increase may be due to both spatial and temporal arbitrages.

2.1.1 Interconnection and spatial considerations

Depending on initial situations, prices will not necessarily fall in all areas. For instance, if the local regulated utility is a low-cost supplier of electricity compared to its neighbours, prices could rise. The local utility would have, in this case, an incentive to serve more profitable customers in neighbourly areas and local demand should be completed by more high-cost suppliers. The latter could be utilities close to the initial area or new entrants (Burtraw et al. 2000). Fall in prices is then not a systematic consequence and emission levels may not increase in all regions. However, due to higher level in emissions from low-cost baseload generation, overall effect is expected to be negative.

2.1.2 On-peak and off-peak arbitrage

A symmetric argument can be found in time dimension. Deregulation allows utilities to create more precisely adapted contracts for individual or industrial customers to produce more widespread use of time-differentiated pricing of electricity (Palmer, 1999). In this framework, a shift of demand away from peak periods to off-peak periods could be expected. Consequences for the environment are related to the nature of baseload generation compared to peak generation. In France, for instance, such a shift would produce fewer emissions because of the nuclear baseload. In the United States, due to the coal-fired baseload generation, such a change would lead to a sensible increase of emissions.

2.2 Demand Side Management (DSM)

In order to reduce the total amount of electricity demanded, especially during peak periods, electric generators were required, prior to deregulation, to devote a portion of their revenues to DSM. A first motivation was that utilities were expected to be keenly aware of the characteristics of their consumers. Then revenues' allocation seemed to be better. But an observed consequence from the opening to competition seems to be the dramatic decline of these programs (York and Kushler, 2002). In the absence of a new policy initiative, the carbon emission savings attributable to past DSM and conservation efforts by utilities may be lost in a competitive market (Palmer, 1999).

DSM is a major issue in an environmental perspective. Power savings generally reduce production from marginal units, which is more polluting (diesel generation), with an evident positive consequence on the emission level. DSM often takes the form of demand response (DR) which refers to programs that encourage electricity customers to reduce demand or operate on-site generators during periods of high loads and/or high prices. If DR capacities were used to meet reserve requirements, significant emission reductions could result (Keith et al. 2004). But DR programs, and more generally DSM initiatives would be significantly improved by a greater price transparency. Today, only a negligible quantity of transactions occurring in spot and forward or futures markets are accessible to the public (Borenstein, 2002). Despite of arguments put forward by marketers, one can not help to think that electricians want to preserve their industry as an opaque one. Thus consumers often have no information about price formation and cannot operate any arbitrages.

2.3 Reliability and the Distributed Generation Question

Even if not obvious at first sight, reliability and carbon emissions are closely linked. Reliability is the product of resource adequacy and resource availability. Typically, regulators impose a required reserve margin - about 15 to 20% above peak load - for each utility, through contracts with others generators or through their own reserve capacity (see Cooke and Sangiovanni (2004), or Joskow and Tirole (2004) for a very more technical paper). Insufficiency in margin levels can lead to outages (Borenstein, 2002), which are extremely damageable for some very dependent industries (aluminium, micro-processors, and other high technologies). If customers are not supplied with safe and reliable power at a reasonable price, they have a strong incentive to invest in backup generation, often diesel generators, widely known as distributed generation (DG).

3 The supply-side

3.1 The issue of the optimal fuel mix

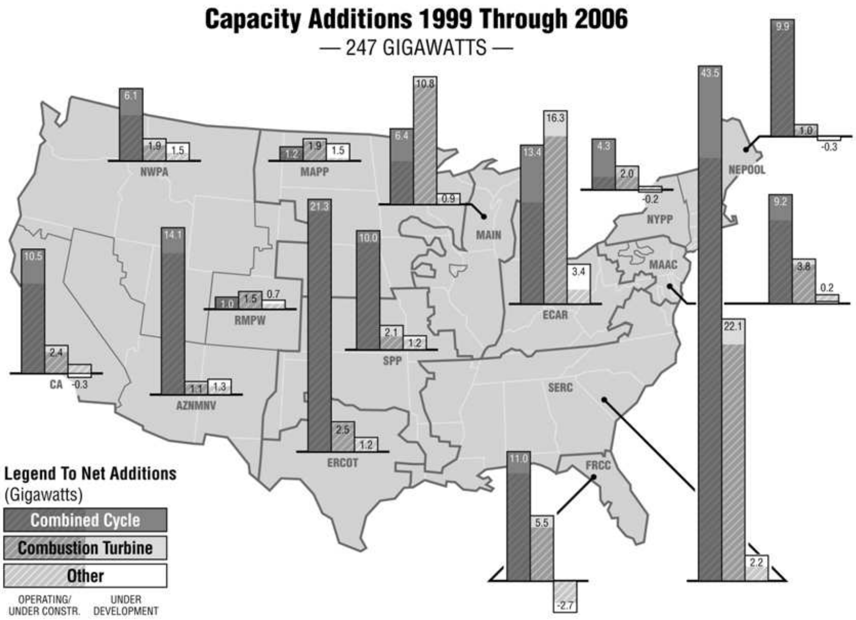
Independently from the growth of consumption, the first factor influencing emission level is the change in fuel mix. In a new competitive framework, generators have to reduce their costs (Dooley, 1998). Green (2004) assumes that competition in electricity markets today follows a price game, rather than a quantity game or Cournot competition. This is due to a better monitoring from the regulator (Green's paper analyzes the case of the previous British pool) and consequent fewer possibilities in capacity withholding (Wolak and Patrick, 1997). As a result, production costs become the decisive variable to compete.

In this context, electricity producers must adapt their fuel mix to enhance productive efficiency and remain competitive. In addition, present choices must be put in perspectives with future environmental decisions and features as flexibility or low-intensity in capital are crucial.

3.1.1 The gas miracle

Concerning natural gas, the most relevant example is the United Kingdom. Frequently labelled the "dirty man" of Europe from the 1950s to the 1980s, the UK had to solve the acid rain problem, imputed to coal-fired power stations (Villot, 1996). In 1990, coal is still used as 65% of power generation and the electricity supply industry accounted for more than 70% (Eikeland, 1998). Thus taking into account the environmental issue, natural gas has been the new choice of fuel, since the competitive reform process started in 1989. Remember that switch from coal to gas results in both a reduction in carbon emissions and a dramatic reduction in emissions of SO2. In fact, the principal pollutants from gas-fired plants are nitrogen oxides, which cause ozone pollution and act as a greenhouse gas (GHG), and carbon dioxide, a principal GHG. But overall, emissions from gas-fired generation facilities are significantly lower than from coal-fired generation.

In addition, qualities of gas for electricity production are numerous: high-efficiency, modularity and a very short lead-time for bringing these units online (Burtraw et al., 2000). Note that these features - essentially flexibility - are fundamental in a competitive environment. Consequently, when new entrants started to use cleaner combined cycle



Source: CATF, 2002

Figure 1: Planned capacity additions in the US (Clean Air Task Foce, 2002)

gas turbine (CCGT), National Power and PowerGen - the new privatized generation companies - were forced to respond with their own CCGT projects and the vast majority of new generating capacity are either natural gas-fired combined-cycle (baseload duty) or simple gas turbines (peak-load duty). Of course, another motivation was to get on with the 1992 Environment White Paper from the re-elected Conservative government of John Major, but competition remains the first and main motivation (Eikeland, 1998).

In the same way, market penetration of natural gas is particularly noteworthy. Figure I clearly show the US choice of gas to generate electricity. In California, Pennsylvania and Texas - more advanced states in terms of deregulation - between 1995 and 2001, more than 80% of the new generating capacity (91200 MW) were natural gas (Sverrisson et al., 2003).

At present, because of the volatility and the less availability of the resource, natural gas is a bit less interesting compared to other energy sources (American Gas Foundation, 2003). We will come back to this point later, in the next section.

3.1.2 The always competitive coal

A strong relationship exists between coal and electricity. Coal currently provides fuel for 37% of the world's electricity generation and power plants represent by far the largest group of coal end users, consuming 60% of the world-wide coal production to produce heat and generate electricity (APERC, 2000). Some countries (Germany, France or the UK) have a long history with coal dating back to the time of the Industrial Revolution. Further, coal displays several advantages in the deregulation and competitive framework.

First, in some regions coal is both abundant and relatively cheap to mine (open-pit mines). For instance, Victoria (Australia), the US or China have very large coal sectors due to the great availability of the resource. In these cases, the issue is different from European cases, where coal is no more economically extractable, independently from environmental considerations. Where coal is abundant, competition is a constant incentive to invest in coal-fired plant despite of the emissions.

Next, public policies sometimes have put other resources at a disadvantage compared to coal. In China, natural gas has been virtually ignored as fuel and considered as a by-product of oil production. The price has been historically regulated at levels allowing fertilisation on a small scale and no incentive exists to exploit the resource. Consequently, gas only constitutes 2% of fuel consumed in China (Williams, 1999). In the US, distortion in competition arises because of differentiated rules for older stations. In fact, older coal-fired plants benefit from an exemption from the New Source Review under the Clean Air Act. These plants are not supposed to install best available pollution control technology as other new stations have to do (York, 2003). Generators owning these old plants thus have an unfair competitive advantage. In Occidental Europe, distortion comes from social considerations (246000 employees for British Coal in March 1984 and 74000 in March 1991). These legitimate considerations were the source of multiple subsidies, which have contributed to the postponement of closure of many mines (Burtraw et al., 2000). In these three cases, consequences on the environment are obviously negative.

Finally, the short run outlook perfectly corresponds with the fired-coal generation (Lee and Darani, 1996). Considering how long this technology has been extended, coal plants are often both amortized and underutilized. Consequently, cost-based considerations are only almost from generators in a competitive framework which should entail an increase in emissions. In addition, because of relative short supply and price volatility of natural gas, coal becomes again relatively attractive, despite the environmental comparative disadvantage (see uncertainty section).

3.1.3 Prospects for nuclear generation

Penetration of nuclear is very heterogeneous through countries (cf. figure IV). In the US, about 20% of electricity is generated by nuclear. But some regions in the world do not use this technology because of a lack of know-how or the negative perception of population, often linked with the radioactive waste issue. Beyond the problem of acceptability, this led nevertheless Italy, Sweden (2010) or Germany (2030) to phase out nuclear generation in the near future; nuclear generation reveals some disadvantages in a competitive framework. Despite being a zero-emitting source of generation, and thus a comparative advantage under environmental regulation, nuclear power plants may not be able to recover their operating costs - fuel, operation, maintenance and safety requirements costs - (Bernow et al., 1998). In addition, nuclear generation is also a major source of potentially stranded costs on the eve of restructuring. For instance, the UK government sold in 1996 the eight most advanced nuclear plants for $2.2 billions, corresponding to the costs of all but one of the plants.

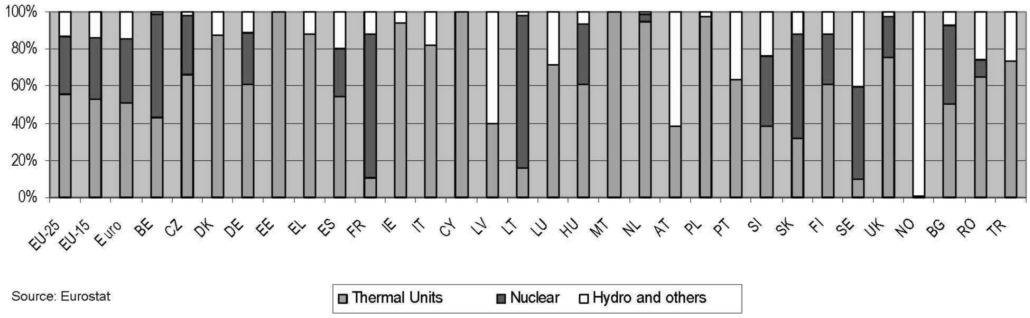


Figure 2: Contribution of the sources to the European production in 2003

This comparative disadvantage leads, for example in the US, to an early retirement of nuclear plants, leading meanwhile to a significant increase in emissions. Note however that some improvements are expected, inspired by competition, increasing efficiency in the surviving stations. Moreover some efficiency gains are already observed - nearly 10% in the US - allowing keeping nuclear plants on-line longer (Kushler et al., 2004). But no new nuclear project is planned - the French EPR project is an exception - leading to future potential increases in emissions compared to the present situation.

3.1.4 The future of renewables

As nuclear, renewables are zero-emitting emissions sources and thus incredible opportunities to fulfil environmental commitments (Lenssen and Flavin, 1996). Their development is however very variable through regions, depending on past public policies, development of technology and natural possibilities. Wind energy is an illustration. Absent in the great majority of countries, insignificant in the US - less than 1% -, the wind-powered electricity represents 4.7% in Germany and about 20% in Denmark. These differences remain due to the relative high-cost of green technologies compared to other sources, political support becoming an absolutely essential condition (Parker and Blodgett, 2002).

In some countries, "green power" service packages - a variable percentage of renewable-based electricity - are available to customers for a premium above the conventional market price (see the UK for example).This voluntary approach - in opposition to collective payment approach (in comparison with the two methods, see Wiser (2003)) - and following development of these packages is linked with the well-known problem of the willingness-to-pay (WTP). To by-pass the WTP issue, a renewable portfolio standard (RPS) approach can be carried out. The RPS requires that some percentage of total generation sold in a region comes from renewable sources, results depending on the chosen percentage.

More than other electricity sources, renewable development is a public decision problem. Due to the current higher generation costs (see table I), compared to fossil fuel sources (Glaser, 1999), renewables have to be integrated in a global policy for a sustainable development by means of direct or indirect subsidies (APERC, 2000). A new practice is particularly interesting from both environmental and reliability standpoints: Net metering. Net metering is the possibility of allowing customers with small renewable generating facilities that are interconnected with the local distribution company to sell all generation in excess of their own demand back to the grid at retail rates, effectively allowing the meter to run backwards. This provision creates an incentive for electricity consumers to install small-scale on-site renewable generation, thereby reducing the need for generation from conventional sources (Burtraw et al. 2000).

4 The key role of uncertainty

In this section, we explain how uncertainty influences decision from generators and industrial consumers. We show that market risk generally affects negatively agents' decisions in terms of environmental considerations. Investment is reduced or postponed due to the higher cost of capital and potential future stranded costs. Capacity margins are also reduced to enhance competitiveness leading to resort to DG. For industrial

Table 1: Cost Characteristics of New Electricity Generating Technologies

Technology	Capital Cost ($2001/kW)	Fixed O&M ($2001/kW-year)	Variable O&M ($2001 mills/kWh)	Heat Rate (Btu/kWh)	Real Levelized Fuel Cost (c/kWh)	Total Var. Cost (c/kWh)	Annual Real Levelized Capital Cost ($/kW-year)	Total fixed cost (c/kWh)	Assumed Capacity Factor (%)	Total Levelized fixed and variable cost (c/kWh)
Conventional Pulverized Coal	1,154	24.5	3.1	9,000	1.1	1.4	128	2.3	75%	**3.7**
Integrated Coal Gasification Combined Cycle	1,367	33.7	2.0	8,000	0.9	1.1	152	2.8	75%	**4.0**
Conventional Gas/Oil Combined Cycle	536	12.3	2.0	7,500	2.9	3.1	59	1.1	75%	**4.2**
Conventional Combustion Turbine	409	10.2	4.1	10,939	4.2	4.6	45	4.2	15%	**8.8**
Wind	1,003	26.1	0.0			0.0	111	5.2	30%	**5.2**
Solar Photovoltaic	3,915	10.1	0.0			0.0	434	25.3	20%	**25.3**
DG - Fuel Cells – 5 MW (*)	1,897	10 mills/kWh		6,426	2.5	3.5	210	3.2	75%	**6.7**
DG - IC Diesel – 500 kW (*)	508	5 mills/kWh		8,856	3.3	3.8	56	4.3	15%	**8.1**
DG - Gas Combustion Turbine - 500 kW (*)	619	9 mills/kWh		9,707	3.7	4.6	69	5.2	15%	**9.9**
Assumptions in calculating final energy cost (not from EIA):	Real Rate of Return is 12 percent									
	Inflation is 3 percent									
	30-year payback period									

Source of cost data: Energy Information Administration, 2003, except “Fuel Cell” and “IC Diesel” (*), which are based on data from Onsite Sycom Energy Corporation (2000). For those two technologies, fixed and variable O&M costs are shown combined. Therefore, “Fixed O&M” is included in “Total Variable Cost” and not under “Total Fixed Cost”.

Table 1: Production costs of different generating technologies

customers, confidence into the supply system is essential. Regulation, by improving reliability, can enhance the consumer’s confidence and then moderate emissions from DG units.

4.1 Uncertainty in Regulation and investment

We know since Dixit and Pindyck (1994), that uncertainty has a strong influence on investment, particularly when investors are risk averse. This is the case for instance concerning regulation uncertainty. When players do not know the rules, they prefer to wait. By postponing their investments, decisions are generally not optimal regarding the environment.

Optimal investment planning is a necessary condition to end up in an efficient electricity generation sector. Restructuring and competition could induce some changes in investment policy from generators, firstly owing to the threat of future stranded costs and secondly because of the uncertainties about next regulation rules.

The issue of stranded costs is a major one in a deregulation process. If prices decline under competition, the price no longer meets the required revenue to cover the remainder of the existing capital investment of the utility. Therefore, in countries that have not yet restructured, potential future stranded costs act as a brake in investment. Nevertheless, following Sverrisson et al. (2003), in the US, states that have restructured have shown that full stranded cost recovery is almost assured. If full compensation is guaranteed, then producers are - relatively - less reticent to invest in higher-intensive capital plants.

4.2 Reliability and confidence

As seen in the second section, reliability is a major issue when speaking about the environment. Uncertainty concerning the quality of supply leads to build private emergency capacity, when profits are very sensitive to outages. In order to avoid a too strong growth of distributed generation, regulator has to improve system quality and to choose sufficient margin levels (Joskow 2003).

Furthermore, increasing quality theoretically allows reducing additional capacity, because of the less probability of failures. This point must be noted when, as nowadays, sites available to build new plants on are relatively rare.

4.3 Volatility and Production Choices: The substitutability of inputs

At present, the risk of volatile natural gas prices (illustrated in figure II), which is far greater than in the case of coal, would tend to drive investment away from gas-fired

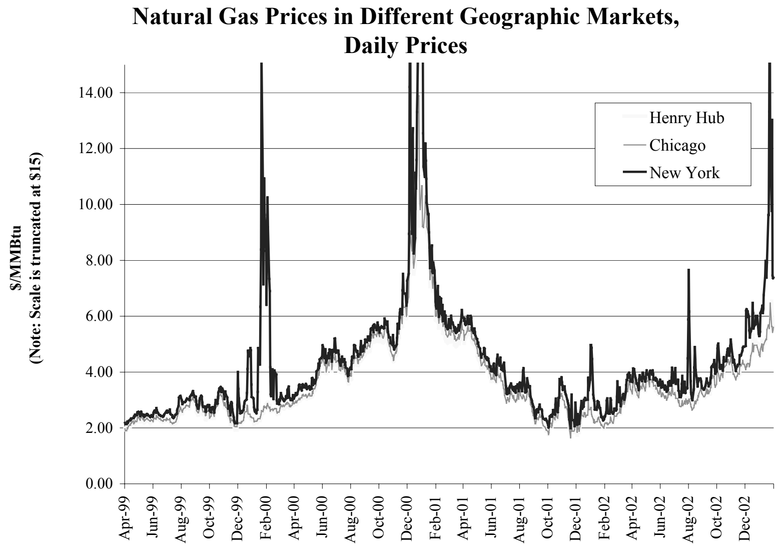


Figure 3: Natural gas prices in major US hubs

generation and slow the rate of entry of new gas combined cycle units. Paroush and Wolf (1992) have shown that for risk-averse decision-makers, volatility is a disadvantage for a particular input when compared to other substitutable inputs.

The American Gas Association report (2003) explains in an exhaustive manner why gas markets are more and more volatile and whether this volatility should go on or especially increases. Because of the natural gas volatility and if one assumes that economic actors are risk-averse, substitutable fuels become comparatively more competitive. As in the generation segment, investment could also be reduced in the upstream natural gas industry. This decline in gas production and possible lack in supply may in return increase tension in gas markets, and support volatility (Forbes and Zampelli, 2004).

5 The new challenge: Innovation and Competition in Energy

On the whole, R&D budgets have fallen because of their weight in final production cost. Empirically, competition has really a negative influence on R&D propensity to invest. Except for Japan and Switzerland, expenditures have been dramatically reduced from mid 1980s (Dooley, 1998): -88% for the UK, -74% for Germany and -75% for Italy (only -9% for the US). Even if those drastic cuts occurred principally in the nuclear domain, coal energy R&D has been cut back also. Consequences could be extremely serious considering stagnant position of coal in the US and growing reliance on coal in the Asia Pacific region (APERC, 2000).

In addition, Munari (2002) points out that, consequences are not only in terms of scale in R&D. An impact also exists concerning the composition and funding of R&D activities. Generally, companies reduce the allocation of resources to long-term activities and defined a more balanced allocation towards applied research and development. Concretely, an internal market among the research divisions and the operating units emerges. Companies now determine the economic viability of R&D by measuring its capacity to provide shorter-term innovations at a least cost.

Theoretically, Arrow (1962) showed fewer incentives to invest in R&D in a competition environment. Two solutions (or a mix) are then possible. First, fundamental research can be sustained by governments. But today, governments follow the trend. Many governmental energy R&D programs have shifted in focus from long-term (fundamental or system research) to short-term research (competitive research). It may not be as disastrous as it appears primarily. A number of technologies will underpin the next generation of energy power sources that already exist commercially, or are close to commercialisation. Second, if it is assumed that the global volume of R&D is insufficient, the desired amount could be reached by private research, but in a collusive framework, for example with joint-venture (for theoretical papers, see: D'Aspremont and Jacquemin 1988 or Kamien et al. 1992).

The ideal solution may be the Italian Ministry's one. Observing changes in focus of R&D due to the opening-up of the Italian electricity generation market to competition, government decided to create an independent research company owned not only by Enel (previous monopoly) but also by new generators. This new organization, widely based on the previous Enel R&D, is funded by a sort of R&D tax. The announced role is to be in charge of the entire "system research".

The issue of innovation is crucial because of its intergenerational impact. Facing emerging risk, as global warming, energy R&D cannot be neglected (Margolis and Kammen, 1999). In addition, it is well-known that only 10 "developed" countries contribute to 96% of the international energy innovation. Then, these countries are not only significant drivers for global research, they are the research. Consequently, spillovers from national under-investments may lead to a tragic and irreversible situation.

6 Concluding remarks: The role of regulation

In the field of environmental consequences of electricity restructuring, the only consensus is the expectation that prices will decrease and consumption should increase. Even this consensus may be doubtful if externalities are taken into account, and they should be in present policies. However, most studies appear to give pessimistic conclusions concerning the environment. These conclusions seem realistic even if changes in the fuel mix could lighten global effects (Geller and Kubo, 2000). Knowing expected effects from restructuring electricity and considering as essential the environmental issue, public policies have now to shift the emphasis of noticed trends (Biewald, 1997).

First by influencing demand level, because in a way one could say that the cleanest kWh is a non-produced kWh. As seen before, DSM programs have difficulties to emerge in competition and regulation has a role to play in this major issue, in particular when speaking about emerging economies. Figure III shows the trends in carbon and energy intensity in the US since 1970. Perhaps humanity could not afford the luxury of leaving new economies follow the path followed by our industrialized countries in the past, particularly considering growth rates observed in these new economies. Most economically developed countries have then to become models for developing ones and regulation may or should be a pertinent instrument (remember that the US was responsible for 23% of all energy-related carbon emissions world-wide).

Secondly by educating consumers and making them sensitive to the problem. This step is fundamental and takes place prior to any other measures. A change in mentalities would allow savings in power today, but also to adopt more severe proposals in the future.

Necessary too, measures for the supply-side have to direct the next generation towards cleaner fuels. In fact, even if regulation is often understood as a competition guarantor (Mansur 2004), its role is also to give strong incentives to improve the global pollution situation.

Firstly adapted rules are necessary concerning reliability. The issue remains that peak demand is being met in some part by many small diesel generators. The impact on pollutant emissions during peak load periods can then be significant. Due to the decline in reliability (Italy, US, Canada, Sweden and Denmark; see Cooke and Sangiovanni, 2004) more DG are coming online. Even if some of these units appear positively beneficial in the emission issue, when they combine heat and power (CHP) for instance, some of them are installed without concern for overall efficiency. Without taking into account the problem in a global manner emissions may increase.

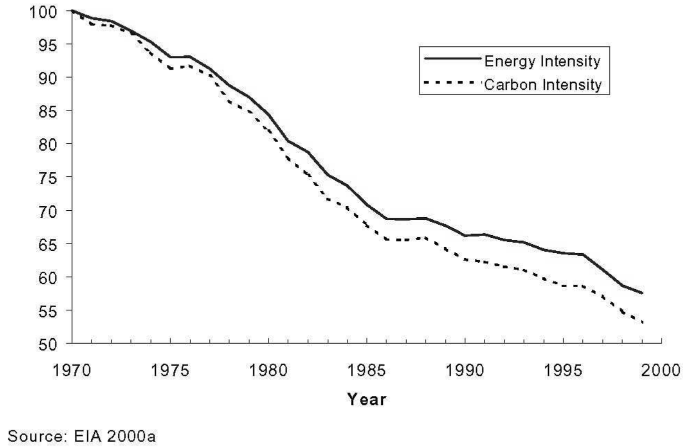


Figure 4: Carbon and energy intensity in the US (100 in 1970)

An optimal transportation cost should protect regions with a larger part of renewables from fired-coal regions (Palmer and Burtraw, 1997). In this case, low transportation costs may have a very negative impact on the environment. Note that a symmetric case exists when speaking about hydro-powered areas, which could supply more polluted areas (Quebec, Tasmania or Scandinavia (Amundsen and Tjøtta, 1999) are some examples). Thus pragmatism is the attitude to adopt because of the almost infinitely large range.

Decline observed in DSM budgets - voluntary approach - could be compensated by a tax to preserve improvements in energy efficiency, renewable energy and public benefit R&D. In the US, system benefit charges (SBC) have emerged during restructuring. A surcharge for each kWh of electricity has been implemented to encourage investment. Furthermore, Sverrisson et al. (2003) argue that restructuring led to higher SBC rates. Even if the analysis is partly biased, because restructured states were also less well-organized and had a need of efficiency, deregulation may have a positive effect on research. In addition, SBC avoids the not socially optimal free-riding behaviours.

Nevertheless, to fulfil environmental requirements at least cost, emissions trading (Dales, 1968) appear an efficient solution, compared to command and control schemes (Weitzman, 1974). Because of the scarcity of the resource, the fixed threshold is automatically achieved. A first success is the experience of the SO2 trading scheme in the US (Stavins 1998). In Europe, a similar system should be implemented at the beginning of 2005, but as for electricity and gas directives, delays might be required for a large majority of members. In addition, emissions trading currently deliver its first weaknesses. Recent studies have shown that exercise of market power may be enhanced by an emissions credits market.

But the major issue remains the question of energy R&D in a new deregulated environment. This single issue challenge the whole deregulation process in itself. In addition to relative negative consequences in terms of investment still observed in several newly liberalized network industries, an established negative result concerning innovation would lead undoubtedly to alterations concerning deregulation. Clearly, if energy R&D is not sufficiently stimulated, energy industry would contribute to unsustainability.

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