The Learning-by-doing Effects in the Wind Energy Sector

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Introduction

How to control climate change and to spur green energy are among the most important challenges facing the world today. This research attempts to study the reason why governments subsidize green electricity. We know that the regulator can charge a Pigouvian tax on emissions that internalizes all damage from pollution. Nevertheless, countries have chosen subsidies to green electricity. The reasons often put forward are the learning by doing effects from the production of energy from renewable resources on the cost of future production. The main idea is that a critical mass of production has to be reached first, and then costs will be reduced thanks to R&D activities.

In this article, I review the recent environmental economics literature on the incentive mechanisms for energy from renewable sources, and the motivations for such supporting policies. Among renewable energies, I take into account wind power, that is growing at a rapid pace not only in Europe, but at a global level.

There is a long history of economic incentives in the European Union aimed at promoting the use of renewable resources. Policy instruments are usually divided into two classes: they can be either price-oriented or quantity-oriented. European countries differ in the scheme they adopt, but most of them rely basically on price-driven strategies. For instance, subsidies are directed to wind power and not to turbine producers. The reason for subsidizing wind energy is essentially that higher demand for wind electricity stimulates the turbine producer industry and it can be a spur to learning and reducing production costs.

In this study I investigate three reasons why an environmental policy of taxes and subsidies to wind power should be implemented by the government.

First I discuss the feasibility of charging firms that produce polluting emissions with a Pigouvian tax. There are some problems for governments to levy a Pigouvian tax both for difficulties in evaluating quantitatively the marginal damage from pollution to society and also due to lobbying activities by firms that use fossil fuel and attempt to achieve less regulation.

When Pigouvian taxes are not feasible, I consider instruments such as emission taxes and subsidies that may lead to Pareto-efficient levels of pollution.

Second, I consider an environmental policy to be implemented which comes from the "big push" literature, as in the paper by Murphy et al (1989). It focuses on the contribution of one firm to the market in a setting with imperfect competition and demand spillovers. One of the models presented in that paper takes into account investments in infrastructure; the example they consider is the possibility of building a railroad, which is particularly important for industrialization.

The link I find between the model presented by Murphy et al. and environmental policy may be understood if one thinks of "building a railroad" as "achieving a level of investment in wind power that will make green energy as competitive as fossil fuel due to investment and learning-by-doing spillovers." In the renewable energy sector, and more specifically in wind power, every firm benefits both from its own investment and from spillovers that come from the industry. With coordination of investment by the government, such as taxes and subsidies, it is possible to reach the 'good equilibrium' that is, to achieve an environmental big push through large-scale adoption of energy from renewable resources.

The article ends with the analysis of the learning by doing effects from the production of renewable energy, such as wind power, on the cost of future production, that is, cost reductions as technology become more mature.

Policy Analysis

I analyze three reasons why the government should implement the use of energy from renewable resources: the increase in polluting emissions from fossil fuels, learning by doing effects and the big push.

Tax versus Subsidy

Polluting emissions create a damage to society; without a price system, firms see a price of zero for pollution and it leads to the wrong amount of pollution. Since the "right level" of pollution will not emerge in a spontaneous way, the government must increase the cost of pollution by raising a tax, in order to reduce pollution generation. If pollution becomes more costly, the producer will produce less pollution. If the tax is at the optimal level, it is called a Pigouvian tax. The optimal amount of

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pollution is the amount that minimizes total costs from producing one more unit of pollution and total damages from pollution. Thus, the condition that marginal cost (or marginal saving) equals the marginal damage leads to the generation of the right amount of emissions. This is the main idea of the Pigouvian tax: "A Pigouvian fee is a fee paid by the polluter per unit of pollution exactly equal to the aggregate marginal damage caused by the pollution when evaluated at the efficient level of pollution. The fee is generally paid to the government" (Kolstad, 2000).

Note that the Pigouvian tax is also equal to the marginal cost from pollution generation at the optimal level of pollution. The difficulty for the government in levying a Pigouvian fee is that there are reasons why it is not feasible. First of all, it is not easy to do a quantitative evaluation of marginal damage. The number of activities and the number of people affected by pollution are so great that it is quite hard to estimate in money the damage from pollution. Moreover, the optimal tax level on polluting emissions is not equal to the marginal net damage that the polluting activity generates initially, but to the damage it would cause if the level of the activity had been adjusted to its optimal level (Baumol and Oates, 1971). If we are not at optimum, the Pigouvian tax will be neither the marginal cost of pollution nor the marginal damage from pollution. Basically we can say that in a perfect environment, like an economy in which there is perfect information and no constraints on government tax policy, only the Pigouvian tax is necessary to achieve efficiency.

If there are other distortions in the economy or limitation for the social planner, then other taxes and subsidies are needed to achieve efficiency.

Environmental Policy for Generating a Big Push

The other reason I consider for an environmental policy comes from the "big push" literature; here I consider the paper by Murphy et al (1989). It focuses on the contribution of one firm to the market size, in a setting with imperfect competition and demand spillovers. Such spillovers might lead to multiple equilibria and the economy might be in a bad equilibrium (no industrialization) if coordination of investments among sectors does not occur. The 'big push' amounts to moving from the bad to the good equilibrium, even if no sector could break even industrializing alone.

One of the models presented in that paper takes into account investments in infrastructure. Let us consider a large infrastructure project such as the building of a railroad, which is particularly important for industrialization because it significantly lowers production costs. The externalities from building the railroad are not captured by firms, but with coordination of investments we can move to the 'good' equilibrium', that is, the big push takes place. The authors assume that the railroad builder is a monopolist. There are mainly two reasons why the monopolist might decide not to build it. First, if he can't price discriminate among users, then he can't extract all the surplus generated by the railroad. Moreover, there is uncertainty about industrialization even if the railroad is built, and the monopolist might be afraid of ending up with a "white elephant".

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In the renewable energy sector, and more specifically in wind power as we will see in my model, every firm benefits both from its own investment and from the spillovers that come from the industry. These spillovers will lead to a reduction of costs and it is expected that green energy will be competitive with fossil fuel in the long run. Because of the uncertainty within the energy industry about the level of investment in renewables made by the firms themselves, it is possible that no one invests in the production of energy from renewable resources. With coordination of investment by the government, such as taxes and subsidies, it is possible to reach the 'good equilibrium', that is, to achieve an environmental big push through large-scale adoption of energy from renewable resources. With respect to externalities, the model I present can be seen as a "shortcut" when compared to Murphy et al. In the latter, resources invested by a firm go to the monopolist, who might build the railroad and then lower production costs for other firms; in the former, resources go directly to other firms. This means that the problem of no price discrimination is exacerbated (no pricing at all), while the 'white elephant' risk is not relevant: once investment takes place among all the firms in the green energy industry, the production cost is lowered and every firm can take advantage of it even without coordination. Note that if the other firms in the industry do nothing, the investing firm ends up with a "white elephant". Even with such a shortcut, the baseline of our model is precisely the same: "an industrializing sector essentially has the effect of reducing the total production costs of other sectors" (Murphy et al, 1989). Then we might think of taxes and subsidies as a tool box governments can employ to internalize environmental externalities, achieve coordination and reach the big push in the energy industry.

Learning by Doing

The last motivation I analyze for an environmental policy for the development of energy from renewable resources is represented by the experience curve. The future growth of the economics of energy from renewable resources is shown by the trend of experience gained; the learning curve relates the cumulative quantitative development of a product to the development of the specific costs.

On the existing literature on learning by doing, the paper by Petrakis et al. (1997) is an interesting work to study the effects of learning by doing in a competitive industry. Basically they show that learning by doing is compatible with perfect competition if the industry presents increasing marginal costs, and that the equilibrium outcome is socially efficient. More specifically, the point of departure of our study that explain the reasons for a policy in presence of learning by doing is the model proposed by Bläsi et al. (2007) focusing on the right subsidies in the presence of learning by doing in a competitive market. It develops a two-period model in which there are two types of electricity producers that are: producers of energy from fossil fuel generating polluting emissions, and producers from wind power. In this framework, the energy market is competitive, and also the market for wind turbines is competitive. The wind-turbine operators are heterogeneous because their productivity depends mainly on the location of the turbine; they buy turbines from turbine producers and these latter firms incur decreasing costs in the second period of production through learning. In the paper there is a distinction between pure private learning and learning spillovers; pure private learning means that costs in the second period are lower thanks to the quantity of energy produced by the firms themselves, while learning spillovers means that firms benefit also from the quantity produced by all the firms in the industry. They focus their analysis mainly on the wind turbine producers. Total learning that occurs in the upstream sector is the sum of private learning that comes from the turbines produced, and the spillovers from the quantity of turbines produced in the industry.

Note that in this study, they relate learning only to the quantity of turbines produced. The cost function of a firm that produces wind turbines depends on his own output and, in the second period, on total learning or experience. The cost function has positive and increasing marginal cost in output in each period and experience by the firm or by the industry will reduce marginal cost in the second period. Concerning a producer of energy from wind power, he faces a cost function that depends on the output and on a firm specific parameter that can be interpreted as the location of the turbine. We have that the cost function has positive and increasing marginal costs in output and in the location parameter. The total output in the electricity market comes from both fossil fuel and wind power. They first investigates the case in which economic incentives are given to the turbine's producers, so that the profit function of a typical turbine producer has an entry premium and an output subsidy. In this setting, the authors find that in a decentralized economy the optimal policy of the regulator, in order to implement first best consists of three instruments: a Pigouvian tax (equal to the marginal damage), an output subsidy per turbine and an entry premium for turbine producers. Both subsidies depend on the spillover coefficient. If there are no learning spillovers, the regulator should internalize externalities from polluting emissions by setting a Pigouvian tax; no subsidies are needed.

In reality, as we have seen before, it is hard to set taxes at Pigouvian level and in addition in several countries subsidies to wind turbine producers are not allowed. For these reasons, the authors study the second-best optimal subsidies when Pigouvian taxes and subsidies to turbine producers are ruled out. Subsidies are paid to producers of energy from wind power; the economic concept is that higher demand for wind turbines stimulate and accelerate learning by doing in the wind turbine industry, so that costs will be lower as learning proceeds. With only private learning among turbine producers, the authors eliminate subsidies from the turbine's producer profit and they consider an output subsidy on wind power. In this scenario, the interesting results are that, first, if the subsidy or the tax rate is raised in one period, the amount of energy produced from fossil fuels decreases in both periods; the quantity of wind power and the number of firms that produce wind energy increases in both periods. Moreover, while the price of electricity is unchanged because of the competitive market, an increase in the subsidy or in the tax rate leads to a higher price of wind turbines in the first period, and to a reduction of the price itself in the second period. This is because the higher demand of turbines can be satisfied at higher prices in the first period since turbine producers incur in increasing marginal costs. At the same time, higher demand stimulates learning and we will have both lower costs and lower prices in the second period.

When learning is private, the second-best optimal subsidy rate takes into account the marginal damage from polluting emissions from fossil fuel and the sub-optimal emission tax rate. They find out that the subsidy paid to firms that produce energy from wind power should be higher in the first period with respect to the second one. This is because increasing output in the wind industry today accelerates learning by doing and then decreases costs in the future. Moreover, they find that if marginal damage is constant, the quantity of energy generated by fossil fuel is higher than the one in the first best, and then environmental damage is higher than optimal, while the output of energy from wind power is equal to the first-best level.

In the presence of learning spillovers the authors obtain a subsidy that is equal to the marginal damage plus a term that comes from the externality generated by learning spillovers. In this case there is ambiguity in the paper since the authors don't know the sign of the term due to spillovers and so they can't sign the subsidy itself.

The paper by Bläsi et al. basically shows that the regulator has to take into account the learning effect to implement the first-best policy. In particular, when learning occurs, the regulator should tax polluting emissions and subsidize the production of turbines. There is some ambiguity on the sign of the subsidy to production of wind energy, but the paper is interesting and it is the point of departure of our work.

Conclusions

This study has explored the learning by doing effects from the production costs of wind power as a justification to the observed environmental policies.

When investments and production of wind energy generates learning externalities that help reduce costs of future production, the regulator should subsidize wind power to make it competitive in the energy industry. Firstly, I have analyzed the policies of the European Union to implement the use of wind power among EU member states and I have seen that these strategies are mainly price-driven. I have analyzed three reasons why governments should enforce the use of energy from wind power. these are the increase in polluting emissions from fossil fuels, learning by doing effects and the big push. In particular, since Pigouvian taxes are not feasible, the government has a tool box of instruments such as environmental taxes and subsidies to wind industry that would lead to Pareto-efficient levels of the polluting activities. I have shown that with coordination of investments that are taxes and subsidies, it might be possible to reach the 'good equilibrium', that is, to achieve an environmental big push through the large-scale adoption of energy from wind power and renewables in general. Then, the review shows that technological learning, that is, cost reductions as technology become more mature, are an important justification to the current European environmental and energy policies that strongly encourage the use of environmental-friendly technologies as renewable energy.