Lecture notes electricity market support schemes

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Abstract

The purpose of this short note is to complement the lecture on electricity market support schemes (Lectures 7–8).

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1 Introduction

The purpose of this short note is to complement the lecture on electricity market support schemes (lecture 8). We describe the basic market reactions to incentives, and provide the efficient way of achieving the policy target. Then, we discuss the distortions arising from subsidy schemes.

2 The model

2.1 Technologies

The total output is Q (measured, for example, in MWh). The output coming from the renewables is denoted by Q_R, and the output from fossils is Q_F. For simplicity, we assume that these are the only two technologies, so that $Q = Q_R + Q_F$.

The two technologies have cost functions $C_R(Q_R)$ and $C_F(Q_F)$, respectively. Both are strictly convex and increasing: $C_j'(Q_j) > 0, C_j''(Q_j) > 0, j = R, F$. The cost of producing the total Q is given by

$$C(Q) = \min_{Q_R, Q_F} \Big\{ C_R(Q_R) + C_F(Q_F) : Q = Q_R + Q_F \Big\}$$

Throughout the note we focus on interior allocations, $Q_R > 0, Q_F > 0$.

2.2 Consumers

Consumers choose how much to demand output Q given the price of the output, denoted by P. Thus, consumers solve

$$\max_{Q} \Big\{ U(Q) - PQ \Big\}$$

where $U(Q)$ measures how the consumer side values consumption, satisfying $U'(Q) > 0, U''(Q) < 0$. The consumer takes the price as parametrically given but through the optimality condition

$$U'(Q) = P$$

we can consider how the consumer responses to price changes, $dQU''(Q) = dP$. This defines demand, that is, a relationship between prices and quantities:

$$\frac{dQ}{dP} = \frac{1}{U''(Q)} < 0.$$

2.3 Producers

We assume perfect competition: so producers take the price of output as given and then decide how much to produce,

$$\max_{Q} \left\{ PQ - C(Q) \right\}.$$

For any given $P > 0$, the optimal choice requires

$$P = C'(Q)$$

where $C(Q)$ is the cost aggregate (recall the definition of $C(Q)$). Note this outcome shows how the total production is chosen, not yet the division between renewables and fossil outputs. This division must minimize costs as follows: fix a given Q and then note that the costs are minimized by choosing Q_F such that

$$-C'_R(Q - Q_F) + C'_F(Q_F) = 0$$
$$\Rightarrow$$
$$C'_R(Q_R) = C'_F(Q_F)$$

Note that it also follows that

$$C'(Q) = C'_R(Q_R) = C'_F(Q_F)$$

because a marginal increase in Q is optimal to allocate between the two technologies such that the marginal costs are equalized.

2.4 Market equilibrium

We have now seen that consumers follow the rule $U'(Q) = P$ and producers the rule $P = C'(Q)$, together with the cost minimization rule $C'_R(Q_R) = C'_F(Q_F)$. Taking together, we obtain

$$U'(Q) = C'_R(Q_R) = C'_F(Q_F).$$

The market thus equalizes the marginal costs. This outcome is efficient; it would not be possible to find another Q and its division Q_R, Q_F achieving a higher consumer side gain, or leading to a lower cost for a given total output.

3 Limit on fossil output

We consider first a policy target that limits the use of fossil fuels: $Q_F \leq \overline{Q}_F$ where $\overline{Q}_F$ is a given fixed total fossil output cap. The producer problem is now

$$\max_Q \Big\{ PQ - C(Q) \Big\}$$
$$\text{subject to: } Q_F \leq \overline{Q}_F$$

Let us write the Lagrangian, denoted by L, for the problem as follows:

$$L = PQ - C(Q) + \lambda(\overline{Q}_F - Q_F)$$
$$= PQ - \Big((C_R(Q - Q_F) + C_F(Q_F)\Big) + \lambda(\overline{Q}_F - Q_F)$$

We have two choices (Q, Q_F) and so the following two necessary conditions

$$P - C'_R(Q - Q_F) = 0$$
$$C'_R(Q - Q_F) - C'_F(Q_F) - \lambda = 0$$

where λ is the shadow price of the constraint. It measures how much the producer would earn more if the limit $\overline{Q}_F$ was marginally relaxed.

Taken together, we see that the fossil producers set their marginal cost plus the shadow value equal to the output price:

$$P = C'_F(Q_F) + \lambda$$

Note that λ not a fixed constant but must be found as part of the market equilibrium. For example, if $\overline{Q}_F$ is sufficiently increased, it is no longer binding and then $\lambda = 0$: the producers behave as in the previous section. λ can be interpreted as a market price for rights to produce with fossil fuels, arising in the market for such rights. The policy maker only needs to decide how many rights are printed and then these are traded. Alternatively, λ could be a tax on fossil fuels. Then, each producer would pay $C'_F(Q_F)$ for a marginal increase in output and also the tax λ.

The outcome described in this section is an efficient way to reach the limit on fossil fuel use.

4 Subsidy: feed-in tariff

We consider next the same target $Q_F \leq \overline{Q}_F$ but assume that the policy maker subsidizes the renewable energy to reach the target. This may seem awkward but the actual policies work this way, that is, the alternative technology is subsidized to reduce the use of the fossil fuels. The subsidy works such that the policy maker sets the output price for renewables, denoted by $\overline{P}$. The idea is to set a price high enough so that the share of renewables increases, replacing fossils. Thus, the term *feed-in tariff* used by practitioners. The money for the subsidy may come from the government budget. The producer faces now two prices: the market price P as before and the subsidy price $\overline{P}$. The producer's problem is now

$$\max_{Q_F, Q_R} \Big\{ P Q_F + \overline{P} Q_R - C_F(Q_F) - C_R(Q_R) \Big\}.$$

Quite simply, we have the following two optimality conditions:

$$P - C'_F(Q_F) = 0$$
$$\overline{P} - C'_R(Q_R) = 0.$$

This is a bit tricky policy objective but, ideally, the subsidized price $\overline{P}$ should be set such that renewables crowd out fossils to the extent that the target $Q_F = \overline{Q}_F$ is reached. Since price equals marginal utility, we have

$$P = U'(Q_R + \overline{Q}_F) = C'_F(\overline{Q}_F) < C'_F(\overline{Q}_F) + \lambda$$

where λ comes from the previous section describing the efficient implementation of the target. We observe that for the subsidized price to reach the same target, the output price must be inefficiently low. This makes intuitive sense: the subsidy drives the fossil out from the market by flooding the market with supply. The total efficiency could be increased by, for example, setting price λ on fossils.