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## A note on resource use, substitute production, and governmental intervention

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A Note on Resource Use,  
Substitute Production,  
and Governmental Intervention

Florian | Sauter-Servaes

Serie A - Nr. 146

DISKUSSIONSBEITRÄGE

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Resource markets have traditionally been a wide field for governmental activities. Except for some notable contributions, for instance by Burness (1976), Sweeney (1977) and by Dasgupta and Heal (1979), the effects of such interventions on the intertemporal allocation of an exhaustible non-renewable resource have not been examined in the literature. Furthermore, the analysis has been restricted to the pure theory of exhaustion, where there is no substitute for the resource.

In this paper an attempt will be made to analyse the question of how governmental interventions will influence the transition from an exhaustible nonrenewable resource to a substitute that can be produced by means of a backstop technology.

Three different kinds of governmental intervention will be taken into consideration: (1) The imposition of a sales tax on the resource, (2) subsidies for the substitute, and (3) the imposition of a minimum price for the resource. As reference case we will use the price and quantity paths in competitive equilibrium without governmental actions. So let us first review those briefly.

Consider an exhaustible resource whose finite stock is known and can be extracted at no cost. The size of this stock will be denoted with  $S$ , the rate of extraction of the resource at time  $t$  with  $x_t$ , and the price at which the resource is sold at time  $t$  with  $p_t$ . If the market rate of interest is  $r > 0$ , then the fundamental principle of the economics of exhaustible resources, the Hotelling Rule, tells us that in competitive equilibrium the price of the resource must rise at the market rate of interest, i.e.

$$(1) \quad \frac{\dot{p}_t}{p_t} = r$$

Now we assume the existence of a so called backstop technology that allows the production of a perfect substitute for the exhaustible resource in unlimited quantities at constant unit costs  $\bar{p}$ . We further assume that the substitute is competitively supplied, i.e. nobody holds a patent for the backstop technology.

In this situation the Hotelling Rule still applies except for one modification. In competitive equilibrium the price of the resource must rise at the market rate of interest as long as the resource has not been exhausted; however, there is now a ceiling for the resource price. If it rises above  $\bar{p}$  (the competitive price for the substitute), the substitute will take over the market and the resource cannot be sold any longer. Thus, in competitive equilibrium the resource stock must be exhausted just in that point of time  $T$ , when the resource price reaches the level  $\bar{p}$ . In order to insure this, the initial price of the resource  $p_0$  must be set properly. The resulting price path for a competitive equilibrium is depicted in Figure 1. It is easy to see that the cumulated discounted profit derived from the resource stock amounts to  $p_0 \cdot S$ .

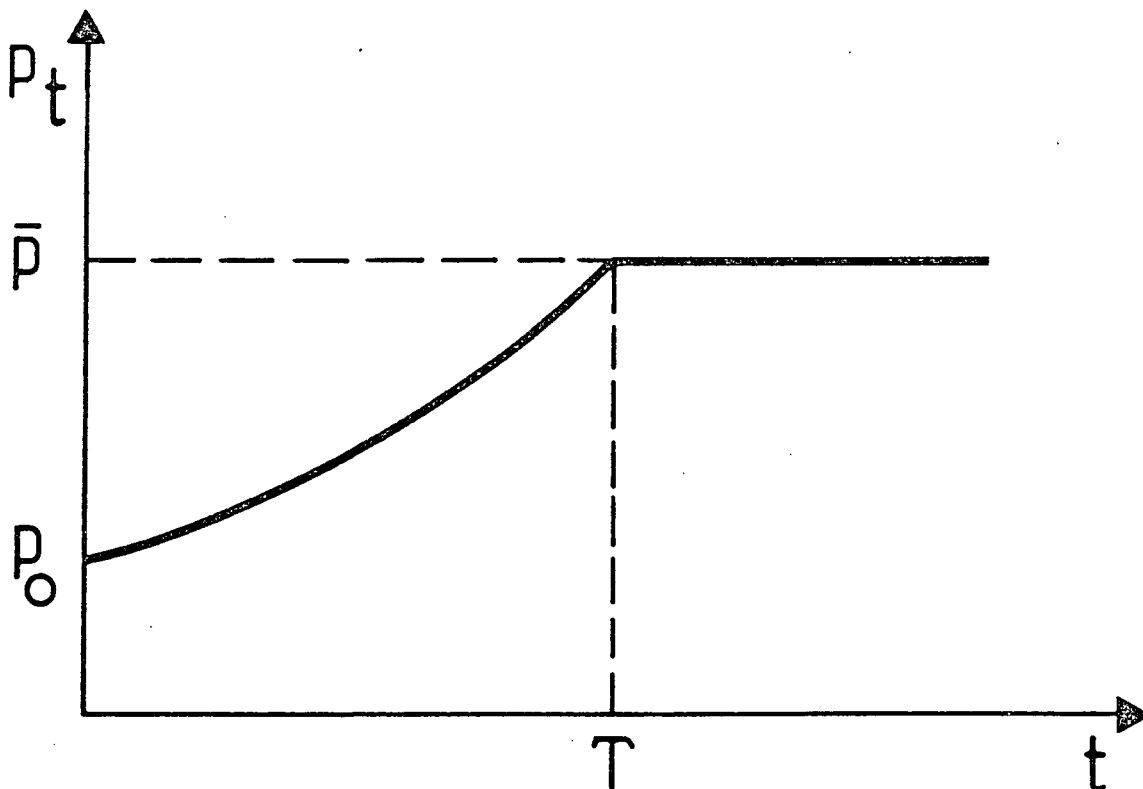


Figure 1

All this is well known and has been stated in greater detail for instance by Nordhaus (1973) and Dasgupta and Stiglitz (1976).

The purpose of this paper is to demonstrate the effects of governmental interventions in the resource market. Taxation, price regulations, and subsidies are the most common governmental actions with respect to resource markets.

Let us first consider the effects of a sales tax on the resource. We assume that no direct governmental action is taken towards the substitute. If we denote the sales tax per unit of resource at time  $t$  with  $\theta_t$  and remember that the resource extraction is costless, we see that the price of the resource splits into two parts, the so called scarcity rent  $\pi_t$  and the sales tax  $\theta_t$ ; that is

$$(2) \quad p'_t = \pi_t + \theta_t \quad .^1)$$

In our first case without taxation, price and scarcity rent were, of course, identical. Now the Hotelling Rule for a competitive equilibrium requires that the scarcity rent rise at the market rate of interest. Therefore in competitive equilibrium we have

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<sup>1)</sup>  $p'_t$  denotes the resource price with taxation in contrast to the resource price without taxation,  $p_t$ .

$$\begin{aligned}
 (3) \quad \frac{\dot{p}'_t}{p'_t} &= \frac{\dot{\pi}_t}{\pi_t} \cdot \frac{\pi_t}{\pi_t + \theta_t} + \frac{\dot{\theta}_t}{\theta_t} \cdot \frac{\theta_t}{\pi_t + \theta_t} \\
 &= r \cdot \frac{\pi_t}{\pi_t + \theta_t} + \frac{\dot{\theta}_t}{\theta_t} \cdot \frac{\theta_t}{\pi_t + \theta_t},
 \end{aligned}$$

and we see that the price path in competitive equilibrium is not altered by taxation, if the sales tax  $\theta_t$  increases at the rate  $r$ . For then (3) implies

$$(4) \quad \frac{\dot{p}'_t}{p'_t} = r \cdot \frac{\pi_t}{\pi_t + \theta_t} + r \cdot \frac{\theta_t}{\pi_t + \theta_t} = r,$$

which in turn makes it necessary that  $p'_0 = p_0$  (otherwise the resource stock would not be exhausted just at the moment when  $p'_t$  reaches  $\bar{p}$ ).

This type of taxation reduces the cumulated discounted profit derived from the resource stock by  $\theta_0 \cdot S$  and leaves  $\pi_0 \cdot S = p_0 \cdot S - \theta_0 \cdot S$  to the resource owners. This shows that the tax is paid by the resource suppliers and cannot be charged to the consumers. Therefore an exponentially rising sales tax (at the rate  $r$ ) can be viewed as a tax on the profits of the resource owners.

If the sales tax is constant in time, i.e.  $\dot{\theta}_t = 0$  for all  $t$ , (3) reduces to

$$(5) \quad \frac{\dot{p}'_t}{p'_t} = r \cdot \frac{\pi_t}{\pi_t + \theta_t} < r,$$

which implies that the price of the resource increases at a slower rate than it does without taxation. For a better characterization of the price path  $p'_t$  we shall rule out some conceivable paths.

Assume  $p'_0 \leq p_0$ . Because of (5) this implies  $p'_t < p_t$  for all  $0 < t \leq T$ . Assuming a regular demand function for the resource, we get  $x'_t > x_t$  for all  $0 < t \leq T$ , implying

$$\int_0^T x'_t dt > \int_0^T x_t dt = S,$$

which is impossible. So we can state:

$$(6) \quad p'_0 > p_0.$$

Using a similar argument it can be shown that  $p'_t \geq p_t$  for all  $t \leq T$  would lead to a contradiction. Now we have sufficient information about the competitive equilibrium price path under the assumption of a constant sales tax  $\theta$  to compare its graph with the price path in case of no taxation. This is done in Figure 2.

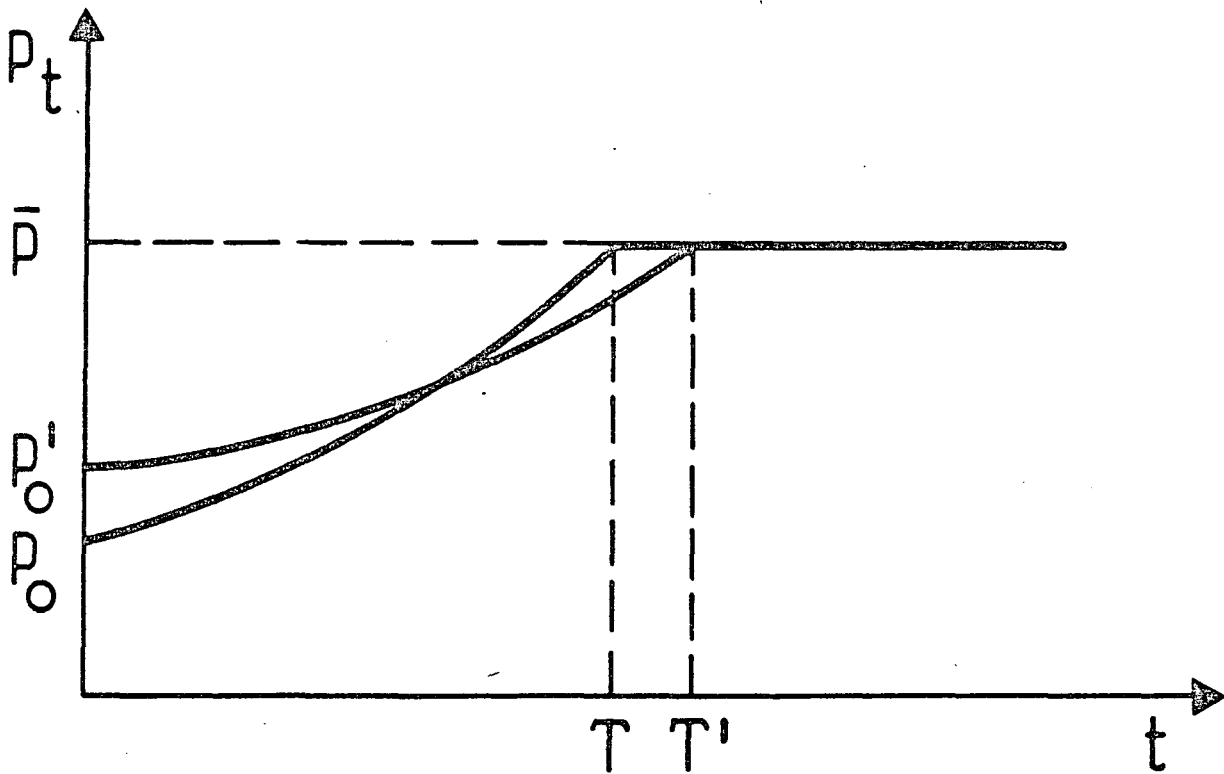


Figure 2



Thus a constant sales tax implies that the resource price will initially be higher than without taxation for a certain length of time. Afterwards it will be lower until the resource is exhausted. The date of exhaustion is retarded by the constant sales tax (that is  $T' > T$ ); in this sense, the constant sales tax has a resource conserving effect.

Furthermore we have  $\pi_T = p'_T - \theta < p_T = \bar{p}$  and therefore

$\pi_0 < p_0$  because  $\frac{\dot{\pi}_t}{\pi_t} = \frac{\dot{p}_t}{p_t} = r$ . This implies that a con-

stant sales tax decreases the cumulated discounted profit derived from the resource stock, so that at least part of the tax is not charged to the consumers.

At this point it should be noted that all these observations are independent of the size of the resource stock. The changes in resource extraction caused by governmental actions will always have the same characteristics no matter how large or small the resource stock is.

As an alternative governmental intervention in the resource market, let us now analyse an indirect intervention that influences the resource extraction via subsidies of the substitute. We consider the simplest form of subsidy by supposing that it lowers the competitive price of the substitute from  $\bar{p}$  to  $\bar{\bar{p}} < \bar{p}$ . It is easy to see (by means of indirect proof) that this subsidy changes the price path for the resource in competitive equilibrium as depicted in Figure 3.

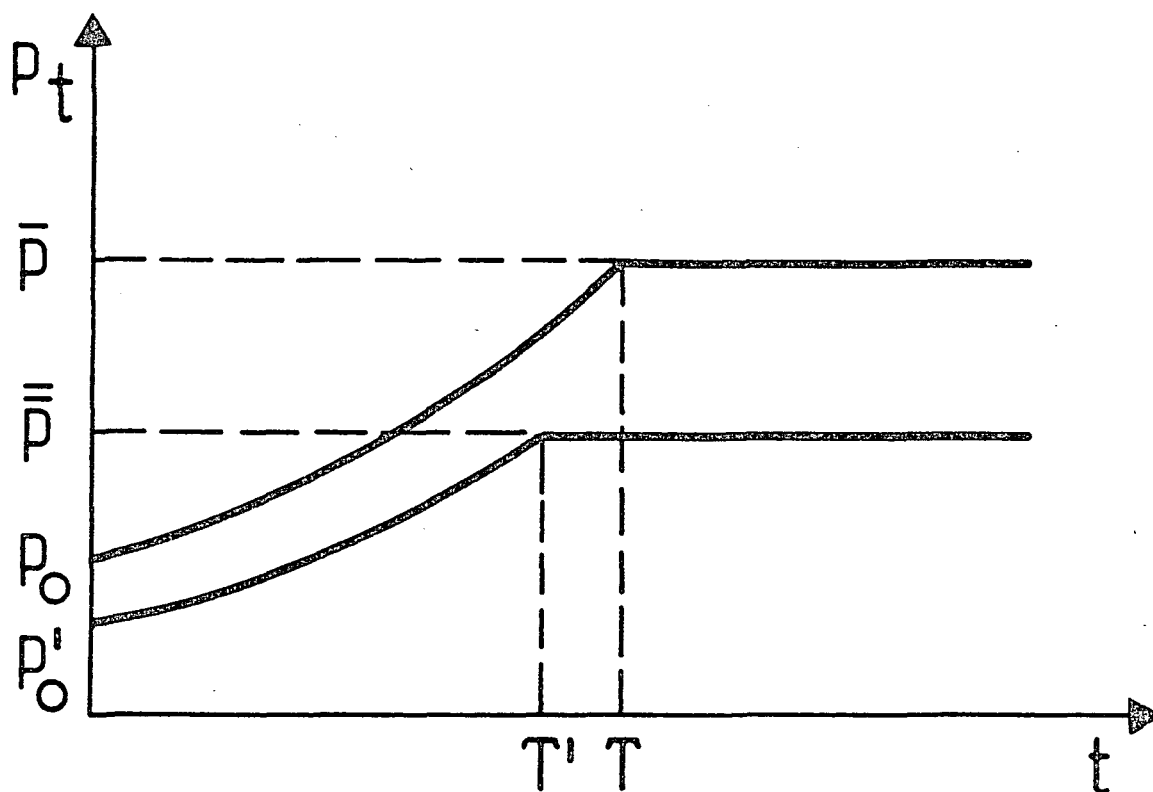


Figure 3

Subsidies that lower the price of the substitute also decrease the resource price, which is equivalent to a higher rate of utilization of the resource. The date of exhaustion of the resource,  $T'$ , is thus moved closer to the present by the subsidies. Cumulated discounted profits derived from the resource stock decrease by  $S \cdot (p_0 - p_0')$ , whereas cumulated discounted consumers' rent increases.

Finally, we want to assume that the government imposes price regulations on the resource market in the form of a minimum price,  $\underline{p}$ , for the resource. If  $\underline{p} \leq p_0$ , there is, of course, no effect on the equilibrium price path for the resource, and if  $\underline{p} \geq \bar{p}$ , the resource will not be extracted at all, since it cannot compete with the substitute, which is assumed to be unaffected by the price regulation. So we can concentrate on the relevant case,  $p_0 < \underline{p} < \bar{p}$ .

As the government sets the minimum price  $\underline{p}$ , resource suppliers realize that the Hotelling equilibrium price path has become infeasible, because if the resource price increased at the market rate of interest, it would hit the substitute price,  $\bar{p}$ , before the resource stock had been depleted. Thus a resource deposit becomes a relatively unprofitable capital asset, and the resource owners try to sell it as fast as possible. This leads to an excess supply on the resource market, which keeps the resource price at its minimum level  $\underline{p}$ . There it remains until the resource stock has been reduced to a size  $\underline{S}$  for which  $\underline{p}$  is the initial price in intertemporal competitive equilibrium. From  $t_1$  on, the resource price rises at the rate  $r$ . It reaches  $\bar{p}$ , just when the resource stock is exhausted. This price path is illustrated in Figure 4.

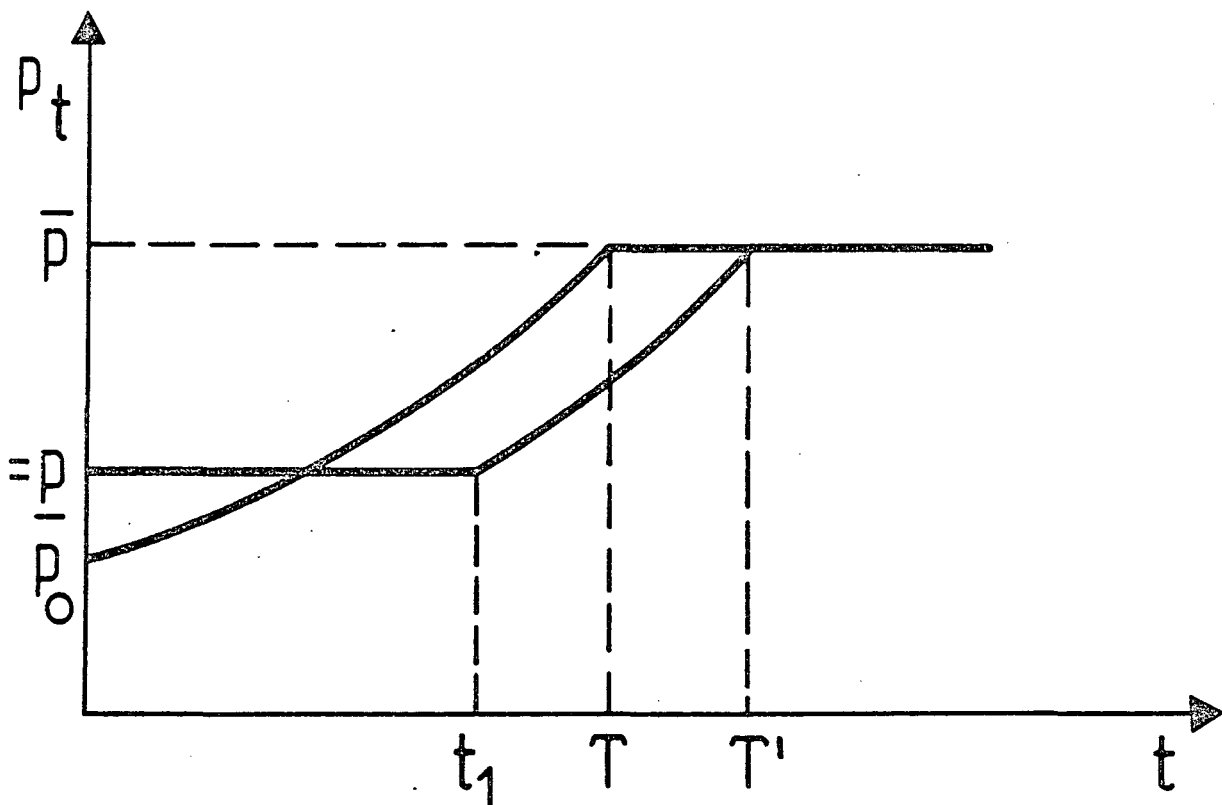


Figure 4

In Figure 4 it can be seen that the imposition of a minimum price for the resource has effects similar to those implied by the imposition of a constant sales tax for the resource. Again the introduction of the substitute is retarded by the governmental action and the initial loss of consumers' rent caused by the higher price  $\underline{p}$  is partly made up for by the lower price in the time interval  $(t_1, T')$ .

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