PRICE DISCRIMINATION, VERTICAL INTEGRATION AND DIVESTITURE IN NATURAL RESOURCE MARKETS

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Recent events have brought the market organization of natural resource industries to the national attention. This paper argues that vertical integration can occur in natural resource industries so as to enable the resource owner to effectively price discriminate between different users of the natural resource. Vertical divestiture would not bring about competition, but rather would remove the ability of the resource owner to price discriminate. By means of an example, this paper examines how various market participants would be affected by laws forcing vertical divestiture in such a market setting.

1. Introduction

Recent events have brought the market organization of natural resource industries to the national attention. Congress has considered proposals that would force the divestiture of vertical stages of production in certain natural resource industries. By means of an example, this paper examines how various market participants would be affected by such market reorganizations.

When a monopolist of an input faces several different customer groups, he would like to charge them different prices for the same good. With easily resalable goods (e.g., oil), it is often impossible for such price discrimination to persist since resale markets develop. In such cases, the monopolist can achieve his desired segmentation of the market by vertically integrating forward into some of the final goods market. For example, when there are only two final goods markets, the monopolist will integrate forward into the market which would be charged the lower price. By doing so, the monopolist can effectively price discriminate in the input market without worrying about resales. When vertical integration occurs for this reason, it is as if the different groups of demanders pay different prices for the input.

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1 Of course, the monopolist could integrate forward into both final goods markets and achieve the same result. Similarly, with several final good markets, the monopolist could either integrate forward into all of them or integrate forward into all but one, with that one being the market in which price of the resource will be highest.
case of oil, which can be used to produce either plastics or fuel, serves as an illustrative example: oil companies retail gasoline and sell oil to petrochemicals firms. (We have not analyzed whether monopoly power actually exists in oil.)

Earlier writers have addressed the question of how the behavior of a simple monopolist would differ from that of a competitive industry in a natural resource market. Special analysis of the natural resource market is necessary because simple propositions about static monopoly do not carry over to the dynamic natural resource problem [Stiglitz (1976)]. For example, restriction of output is simply not an important issue [Weinstein and Zeckhauser (1975)]. Instead, at issue is the different question of how a given stock of output will be allocated over time under competitive and monopolistic market structures. It is possible to construct realistic examples where competitive and monopoly behavior are identical [Stiglitz (1976)].

Comparisons of competition and monopoly in natural resource markets do not directly bear on the question of divestiture because, as argued above, vertically integrated companies are likely to behave more like discriminating than simple monopolists. Moreover, divestiture of vertical stages of production will not necessarily erode monopoly power but rather erode the ability to practice price discrimination. This suggests that the comparison of most policy relevance is between a simple and a discriminating monopolist in a natural resource market. Simple application of static results concerning a discriminatory monopolist do not necessarily carry over to the dynamic natural resource problem for the same reasons that explain why the static results concerning a simple monopolist do not carry over.

In this paper, we examine the effect of market structure on the prices that each group of demanders pay and on the total amount of the factor which each group receives over time. To illustrate our basic points, we use linear demand curves for each product market. We derive the equilibrium solution for the vertically integrated market structure (the discriminating monopolist), the pure monopolist (after divestiture occurs), and the competitive market structure. We compare the times of exhaustion of the derived demand for the two product industries, the prices each group pays, and the amount of natural resource the two industries obtain under the three different market structures. As argued above, the comparison between the discriminating and simple monopolist is likely to have the greatest policy significance.

2. Calculation of equilibria

Let there be two groups of demanders for the resource with demands, \( q_1 = a - b_1 p_1 \) (fuel producers) and \( q_2 = c - d_2 p_2 \) (plastics producers). We assume that \( a/b < c/d \). There is a finite amount of resource, \( \theta \), available at zero extraction cost. In order to focus attention on the price discrimination aspect
of vertical integration, we assume fixed coefficients production functions to avoid any distorting factor proportions resulting from monopoly power [see McKenzie (1951), Schmalensee (1973) and Warren-Boulton (1974)].

Case 1: The discriminating monopolist (D)

Through vertical integration, the monopolist is able to price discriminate. The discriminating monopolist (D) wishes to set prices \( p_1(t) \) and \( p_2(t) \) to maximize the present discounted value of profits. The Lagrangian for the monopolist is

\[
L_D = \int_0^{T_1^D} \left[ (a - bp_1^D) p_1^D e^{-\lambda_D t} - \dot{q}_1^D(t) \right] dt + \int_0^{T_2^D} \left[ (c - dp_2^D) p_2^D e^{-\lambda_D t} - \dot{q}_2^D(t) \right] dt + \lambda_D \theta,
\]

where \( T_1^D \) and \( T_2^D \) are the times beyond which demanders 1 and 2 desire no oil, \( r \) is the interest rate, and the value of \( \lambda_D \) is determined by the condition that no more oil can be sold than is in the ground. This last condition can be written as

\[
\int_0^{T_1^D} q_1^D(t) dt + \int_0^{T_2^D} q_2^D(t) dt = \theta. \tag{1}
\]

The optimal \( p_1^D, p_2^D, T_1^D \) and \( T_2^D \) satisfy (1) and

\[
p_1^D(t) = \frac{a}{2b} + \frac{\lambda_D}{2} e^{rt}, \quad p_2^D(t) = \frac{c}{2d} + \frac{\lambda_D}{2} e^{rt}, \tag{2}
\]

\[
T_1^D = \frac{1}{r} \ln \frac{a}{b \lambda_D}, \quad T_2^D = \frac{1}{r} \ln \frac{c}{d \lambda_D}. \tag{3}
\]

Under the assumption that \( a/b < c/d \), it is clear that \( p_1^D(t) < p_2^D(t), T_1^D < T_2^D \), and

\[
T_2^D - T_1^D = \frac{1}{r} \left[ \ln \frac{c}{d} - \ln \frac{a}{b} \right]. \tag{4}
\]

Case 2: The simple (non-discriminatory) monopolist (M)

Suppose that divestiture is required so that the owner of the resource can no longer practice price discrimination through vertical integration. In this

\[
T_2^D - T_1^D = \frac{1}{r} \left[ \ln \frac{c}{d} - \ln \frac{a}{b} \right].
\]
case, the demand curve relevant to the monopolist is the summation of the demands of the two groups in the market. The simple monopolist (M) seeks to set the common price for the resource, \( p^M(t) \), to maximize the present value of profits. The relevant Lagrangian is

\[
L_M = \int_0^{T_1^M} \left[ (a - b p^M(t)) p^M(t) e^{-\lambda_M t} - \lambda_M q_1(t) \right] dt + \int_0^{T_2^M} \left[ (c - d p^M(t)) p^M(t) e^{-\lambda_M t} - \lambda_M q_2(t) \right] dt + \lambda_M \theta.
\]

The optimal \( p^M(t) \) satisfies

\[
p^M(t) = \frac{a + c}{2(d + b)} + \frac{\lambda_M}{2} e^{\lambda_M t}, \quad t \leq T_1^M,
\]

\[
= \frac{c}{2d} + \frac{\lambda_M}{2} e^{\lambda_M t}, \quad t > T_1^M.
\]

(5)

The demand curve the monopolist faces is piecewise linear, causing marginal revenue to be discontinuous. The optimal price equation (5) is discontinuous at \( t = T_1^M \), to insure continuity of marginal revenue. The other optimal values are

\[
T_1^M = \frac{1}{r} \ln \left[ \frac{a}{b} - \frac{a + c}{2(d + b)} \right], \quad T_2^M = \frac{1}{r} \ln \frac{c}{d \lambda_M}.
\]

(6)

Notice that since \( a/b < c/d \) it follows that

\[
\frac{a + c}{d + b} > \frac{a}{b} \quad \text{and} \quad \frac{a + c}{b} - \frac{a + c}{2(d + b)} < \frac{a}{2b},
\]

and therefore from (6) and (4),

\[
T_1^M < \frac{1}{r} \ln \frac{a}{b \lambda_M}
\]

(7)

and

\[
T_2^M - T_1^M > \frac{1}{r} \left[ \ln \frac{c}{d} - \ln \frac{a}{b} \right] = T_2^D - T_1^D.
\]

(8)
Comparison of Cases 1 and 2

It is possible to prove (see appendix) that \( \lambda_D > \lambda_M \).\(^2\) In fig. 1 we graph the relevant price lines. [Recall that \( \frac{c}{d} > (a+c)/(d+b) > a/b \).] The prices faced by industry 2 demanders with the discriminating monopolist lie everywhere above those with the nondiscriminating monopolist. At least initially, and possibly over the entire range of interest, the prices faced by industry 1

\[
\begin{align*}
P^D_2 &= \frac{c}{2d} + \frac{\lambda_D}{2} e^{\rho t} \\
T^M_{2} &= \frac{a+c}{2(b+d)} + \frac{\lambda_{M}}{2} e^{\rho t}
\end{align*}
\]

(industry 2)

\[
\begin{align*}
P^D_1 &= \frac{a+b}{2b} + \frac{\lambda_{D}}{2} e^{\rho t} \\
T^M_{1} &= \frac{a+c}{2(b+d)} + \frac{\lambda_{M}}{2} e^{\rho t}
\end{align*}
\]

(industry 1)

Fig. 1. Price lines (\( \lambda_M < \lambda_D \)). The lines illustrate the following rules: \( T^M_2 < T^M_1 \), \( T^D_2 - T^D_1 < T^M_2 - T^M_1 \).

As drawn, \( T^M_1 < T^M_2 \), but the opposite (\( T^M_1 > T^M_2 \)) is possible.

\(^2\)As an illustration of how different static monopoly problems are from dynamic ones, notice that in a one period world, the shadow price of oil for discriminating and simple monopoly are identical in the case of linear demand curves when both groups of demanders receive the product.
demanders with the discriminating monopolist lie below those with the nondiscriminating monopolist. Moreover, the total amount of resource consumed by industry 1 rises with the discriminating monopolist, since industry 2 demanders face higher prices from the discriminating monopolist and consume less of the resource.

It follows from (3) and (6) that $T_2^D < T_1^M$. Therefore, the discriminating monopolist uses up the resource factor faster than does the non-discriminating monopolist. It is ambiguous whether $T_1^D$ exceeds $T_1^M$. It is unambiguous that under either discriminating or pure monopoly, industry 1 demanders voluntarily leave the market before industry 2 demanders, and that the interval during which only industry 2 demanders are satisfied is shorter with a discriminating monopolist than with a single monopolist.

\[
\begin{array}{|c|}
\hline
\text{Table 1} \\
\text{Comparisons of simple monopoly (M) to discriminating monopoly (D).}^* \\
\hline
\hline
\delta_D^* > \delta_M^* \ (\text{see fig. 1}) \\
\hline
T_1^D \geq T_1^M \\
T_2^D < T_2^M \\
T_2^D - T_1^D > T_2^M - T_1^M \\
\hline
p_1^D < p_1^M \ (\text{initially}) \\
\theta_1^D > \theta_1^M \\
\theta_2^D > \theta_2^M \\
\theta_2^D < \theta_2^M \\
\hline
\end{array}
\]

*Subscripts indicate industries; D and M indicate discriminating or pure monopolist; $T, P$ and $\theta$ refer to time, price and total oil consumed, respectively.

Industry 2 demanders are definitely better off in the non-vertically integrated market structure than in the vertically integrated one. With vertical integration, they obtain less of the resource and pay higher prices. Although it is not possible to prove that industry 1 demanders are better off in the vertically integrated market structure, it is clear that they obtain more resource, often at lower prices, than they would in a non-vertically integrated market. Finally, the monopolist is obviously worse off when he is not allowed to price discriminate. These results are summarized in table 1.

\[\text{Can we say whether society is better off or not after divestiture using discounted consumer surplus as a measure of social welfare? One's initial intuition suggests that society must be better off under discriminating monopoly since a discriminating monopolist does not overconserve as much as a simple monopolist. An offsetting feature to discriminating monopoly is that unlike simple monopoly different people face different shadow prices for the good. We have been unable to determine which effect will predominate. For specific cases numerical calculations can easily be performed to see whether society would gain or lose from divestiture.}\]
Earlier, we argued that the analysis bears on the question of divestiture in the oil industries. A reading of the engineering literature suggests that the reservation price for demanders of oil for plastics is likely to exceed that of demanders of oil for fuel since there are many substitute fuels. Therefore, we associate plastic (petrochemical) producers with industry 2 demanders, and the fuel producers with industry 1 demanders. The logic behind the price discrimination motive for vertical integration suggests that vertical integration should occur between industry 1 demanders and the oil firms. As the above analysis indicates, laws forcing divestiture would benefit the plastics industry; plastic producers would purchase more oil at lower prices.

Case 3: Competition (C)

How does the socially optimal policy, which coincides with the competitive solution [Hotelling (1932)] treat the industry 1 and industry 2 demanders? In competition (C), the price of the natural resource will rise exponentially at the interest rate, \( r \), so that \( p^C(t) = p_0 e^{rt} \). The initial price, \( p_0 \), is determined by the requirement that supply equal demand,

\[
\int_0^{T_1^C} (a - b p_0 e^{rt}) dt + \int_0^{T_2^C} (c - d p_0 e^{rt}) dt = \theta.
\]

The exhaustion times are easily calculated to be

\[
T_1^C = \frac{1}{r} \ln \frac{a}{b p_0}, \quad T_2^C = \frac{1}{r} \ln \frac{c}{d p_0}.
\]

Thus,

\[
T_2^C - T_1^C = \frac{1}{r} \left[ \ln \frac{c}{a} - \ln \frac{b}{d} \right].
\]

Curiously (11) says that in the competitive solution the time interval during which only industry 2 demanders consume the natural resource is identical to the corresponding time interval in the solution with a discriminating monopoly. Comparing (9) to (1) shows that \( p_0 > \lambda_0 \), from which it immediately follows from (10) and (3) that \( T_1^C < T_1^P \) and \( T_2^C < T_2^P \). As is

\footnote{We can rewrite (1) by substituting in the demand functions and the price equations to obtain

\[
\int_0^{T_1^P} \left( a - \frac{b \lambda_0}{2} e^{rt} \right) dt + \int_0^{T_2^P} \left( c - \frac{d \lambda_0}{2} e^{rt} \right) dt = \theta,
\]

or...}
typical in natural resource problems, the discriminating monopolist tends to overconserve resources — both groups of demanders are consuming positive amounts of resources, when at the corresponding times, the competitive solution has each consuming zero. Furthermore, since \( \lambda_D > \lambda_M \) it follows immediately from (6) and (3) that the simple monopolist overconserves to an even greater degree than the discriminating monopolist.

3. Conclusions

This paper has examined the consequences of forcing divestiture in a natural resource market where vertical integration is used as a means of price discrimination. Divestiture would remove the ability of an owner of natural resources to behave as a discriminating monopolist and would force him to behave as a simple monopolist. The conclusions are unchanged if we adopt the more realistic assumption that demand is growing exponentially over time [i.e., \( q_1 = (a - bP)e^{\theta t} \), and \( q_2 = (c - dP)e^{\delta t}, \delta < \theta \)]. Similarly all results hold when the number of product markets is increased.

Using these simple linear demand curves, or the somewhat more realistic, exponentially growing demand curves, is useful in developing our understanding of the effects of divestiture. The use of the extreme assumption of monopoly power in industries which may be oligopolistic is a simplification which is justifiable in that it helps to develop initial insights. While there are many issues associated with divestiture, this paper concentrated on the price discrimination effect of vertical integration. To the extent that such an effect is present in the oil industry (an issue we have not studied) our analysis suggests that plastic users will definitely gain from divestiture, oil owners will definitely lose, and fuel users may either gain or lose.

\[
\int_0^\theta (a - b\lambda_D e^\theta)\,dt + \int_0^\theta (c - d\lambda_D e^\theta)\,dt = 2\theta. \tag{1'}
\]

Compare (1') to

\[
\int_0^\theta (a - b\theta e^\theta)\,dt + \int_0^\theta (c - d\theta e^\theta)\,dt = \theta. \tag{9}
\]

Using the equation for \( T^S, T^C, T^P, T^F \) as functions of \( P_0 \) and \( \lambda_D \), it is clear that (15) and (9) are identical except (1') uses \( \lambda_D \), while (9) uses \( \theta \), and the right-hand side of (1') is twice that of (9). Totally differentiating (9), it follows that \( dP_0/d\theta < 0 \) (initial price is lower the larger is the initial stock of oil). Thus \( P_0 > \lambda_D \).

The tendency of a monopolist to overconserve has been pointed out by Hotelling (1932), Sojow (1974), Zeckhauser and Weinstein (1975), and Stiglitz (1976).
Appendix

In this appendix, we show $\lambda_D > \lambda_M$. The equation defining $\lambda_D$ is

$$
\frac{T_1^D}{r} \int_0^T (a - b p_1) \, dt + \frac{T_2^D}{r} \int_0^T (c - d p_2) \, dt = \theta,
$$

(A.1)

where

$$
\begin{align*}
  p_1 &= \frac{a}{2b} + \frac{\lambda_D}{2} e^{rt}, \\
  p_2 &= \frac{c}{2d} + \frac{\lambda_D}{2} e^{rt}, \\
  T_1^D &= \frac{1}{r} \ln \frac{a}{b \lambda_D}, \\
  T_2^D &= \frac{1}{r} \ln \frac{c}{d \lambda_D}.
\end{align*}
$$

Since $T_1, T_2, P_1, P_2$ are all functions of $\lambda$, we can denote the left-hand side of (A.1) as a function $F(\lambda)$. Eq. (A.1) implies that $\lambda_D$ solves

$$
F(\lambda) = \theta.
$$

(A.2)

Since $dp_1/d\lambda$ and $dp_2/d\lambda$ are positive and since demands depend negatively on price, it follows that $F'(\lambda) < 0$.

The defining equation for $\lambda_M$ is

$$
\frac{T_1^M}{r} \int_0^{T_1} (a - b p) \, dt + \frac{T_2^M}{r} \int_{T_1}^{T_2} (c - d p) \, dt + \frac{T_3^M}{r} \int_{T_2}^{T_3} (c - d p) \, dt = \theta,
$$

(A.3)

where

$$
\begin{align*}
  p &= \frac{a + c}{2b + d} + \frac{\lambda_M}{2} e^{rt} \quad \text{for} \quad t \leq T_1, \\
  &\quad = \frac{c}{2d} + \frac{\lambda_M}{2} e^{rt} \quad \text{for} \quad t > T_1,
\end{align*}
$$

$$
T_1^M = \frac{1}{r} \ln \left[ \frac{a}{b} - \frac{1}{2} \left( \frac{a+c}{b+d} \right) \right] \frac{2}{\lambda_M}, \quad T_2^M = \frac{1}{r} \ln \frac{c}{d \lambda_M}.
$$

We now calculate $F(\cdot)$ in (A.2) and relate it to the left-hand side of (A.3). Performing the indicated integration, we obtain

$$
F(\lambda) = \frac{a}{2r} T_1^D - \frac{b \lambda_D}{2r} [e^{rT_1^D} - 1] + \frac{c}{2} T_2^D - \frac{d \lambda_D}{2r} [e^{rT_2^D} - 1],
$$

with $T_1^D$ and $T_2^D$ defined below (A.1) as functions of $\lambda$. 
Calculating the value of the left-hand side of (A.3), we obtain

\[
K_1 T_1^M - \frac{b \lambda_M}{2r} (e^{r T_1^M} - 1) + K_2 T_2^M - \frac{c \lambda_M}{2r} [e^{r T_1^M} - 1] + \frac{c}{2} (T_2^M - T_1^M)
\]

\[
- \frac{d \lambda_M}{2r} (e^{r T_1^M} - e^{r T_1^M}),
\]

where

\[
K_1 \equiv a - \frac{1}{2} b \frac{a+c}{b+d}, \quad K_2 \equiv c - \frac{1}{2} d \frac{a+c}{b+d}.
\]

Rewriting the above, we obtain

\[
[K_1 + K_2 - \frac{c}{2}] T_1^M - \frac{b \lambda_M}{2r} [e^{r T_1^M} - 1] + \frac{c}{2} T_2^M - \frac{d \lambda_M}{2r} [e^{r T_1^M} - 1].
\]

Note that

\[
K_1 + K_2 - \frac{c}{2} = \frac{1}{2} a,
\]

\[
T_1^M(\lambda) = T_1^D(\lambda) + \frac{1}{r} \ln \left[ \frac{a}{b} \left( \frac{a+c}{b+d} \right)^2 \lambda \right], \quad \text{or}
\]

\[
T_1^M(\lambda) = T_1^D(\lambda) + \frac{1}{r} K_3,
\]

where

\[
K_3 = \ln \left[ \frac{1 - \frac{1}{2} \frac{b}{a} \frac{a+c}{b+d} \lambda}{a b + d} \right]^2.
\]

Using these substitutions, we can rewrite the LHS of (A.3) as

\[
\frac{a}{2} T_1^D + \frac{a}{2} \frac{1}{r} K_3 - \frac{b \lambda_M}{2r} [e^{r T_1^M} \cdot e^{K_3} - 1] + \frac{c}{2} T_2^M - \frac{d \lambda_M}{2r} (e^{r T_2^M} - 1).
\]

Thus expression is a function of \( \lambda \) through the functions \( T_1^D(\lambda) \) and \( T_2^M(\lambda) \). [Notice that \( T_2^M(\lambda) \equiv T_2^D(\lambda) \).]
Rewrite the above as

\[
\frac{a}{2r} K_3 - \frac{b\lambda_M}{2r} \left[ e^{rT} [e^{K_3} - 1] \right] + F(\lambda),
\]

or using the definition of \( T_1^D \),

\[
\frac{a}{2r} K_3 - \frac{b\lambda_M}{2r} \left[ \frac{a}{b\lambda_M} [e^{K_3} - 1] \right] + F(\lambda),
\]

or

\[
\frac{a}{2r} [K_3 - e^{K_3} + 1] + F(\lambda).
\]

Notice that

\[
\frac{a}{2r} (K_3 - e^{K_3} + 1) < 0 \quad \text{for all } K_3 \neq 0.
\]

Therefore the defining equation of \( \lambda_M \) can be written as

\[
N + F(\lambda_M) = 0, \quad \text{for } N < 0,
\]

or

\[
F(\lambda_M) = -N. \tag{A.4}
\]

Comparing (A.4) to (A.2) and using \( F'(\lambda) < 0 \), the result \( \lambda_M < \lambda_D \) follows.

References


