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IS IT POSSIBLE TO MOVE THE COPPER MARKET?

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1. INTRODUCTION

In recent years, the question whether and to what extent a large supplier (or a cohesive group of suppliers) could effectively move the world copper market has attracted increasing attention among industry and market observers in Chile[1].

In this paper we address this question in a general context without going into the specifics of copper other than recognizing that this mineral like many others are typically traded in both forward and spot markets. Based on the model developed by Liski and Montero (2003a), we will describe the equilibrium properties of a market for a depletable resource stock in which there is a supplier with a large fraction of the total original stock and a fringe of competitive suppliers with the remaining of the stock.

The literature on the economics of exhaustible resources was pioneered by Hotelling (1931), who provided a complete characterization of the equilibrium path when all the stock is either in competitive hands or in the hands of one agent. A vast literature has followed including several papers extending the Hotelling model to the case in which there is a large stockholder that acts as a leader and a fringe of price-taker suppliers with rational expectations (e.g., Salant, 1976; Newbery, 1981).[2] These papers found that the large stockholder always can move the market by shifting today's production towards later periods.

In our paper we revisit the leader-fringe literature but drop the assumption that all sales are done exclusively through the spot market (i.e., flow sales). We open up the players' action space by allowing forward contracting and/or stock transactions (e.g., sale or purchase of a copper mine). Under this more realistic setting, we find that the leader suffers from the very possibility of signing forward contracts (or engaging in stock sales) making his problem closely resemble that of a durable-goods monopoly (e.g., Coase, 1972, Bulow, 1980): the leader constantly wants to revise its sales strategy as time progresses. In fact, we show that in a

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1 Chile produces about a third of the world's copper mine production. See Meller (2002) for more.

2 Most of these papers has been motivated by the market structure observed in the oil market.

three-period setting the leader loses all its ability to move the market.

The rest of the paper is organized as follows. In the next section we develop a three-period simple example to introduce the problem and some of our results. Without providing a formal derivation,[3] in Section 3 we explain how the results of the simple example extend to the more general case. We discuss areas for future research in Section 4.

2. An Example

Consider the following three-period example. The demand for, say, copper (coming from numerous price-taker consumers) in each period is $p_t = a - bq_t$, where p_t is the spot price and q_t is the total amount consumed at t=1,2,3. For the numerical exercise we will use a = 10 and b=1. The size of the initial stock is $S_0 = 10$. We will assume that a fraction α of this stock is in the hands of one strategic player that attempts to move the market (we will use the index "m" to refer to this large stockholder). The remaining fraction of the initial stock, $1 - \alpha$, is in the hands of a fringe of competitive suppliers (we will use the index "f" to refer to the fringe). There are no extraction costs and the discount rate is r = 0.5. We assume that both fringe members and consumers have rational expectations.

Let us first compute the market equilibrium when $\alpha = 0$ or α 1. When $\alpha = 0$ the equilibrium price path must satisfies Hotelling's arbitrage condition that $p_{t+1} = (1 + r)\, p_t$ (recall that there are no extraction costs). Imposing this condition together with the exhaustion condition that all the stock is to be consumed within the three periods solves for the equilibrium path which is shown in the first column of Table 1. On the other hand, when all the stock is in the hands of the leader, i.e., $\alpha = 1$, the relevant arbitrage condition changes to $mr_{t+1} = (1 + r)\, mr_t$ where $mr_t = a - 2bq_t$ is marginal revenue.[4] Notice that because the demand elasticity (in absolute terms) increases with price, the monopoly price path grows at rate lower than the discount rate r, as shown in the second column of the table.

The equilibrium solution when the leader (i.e., large stockholder) and the fringe coexists, i.e., $0 < \alpha < 1$, is more involved. The leader's problem is to chose a sales path that maximizes its revenues subject to agents' beliefs. For instance, in equilibrium we cannot have fringe members selling along a price path that is increasing a rate either lower or higher than r.

If we assume that transactions can be made only in the spot market, then the market price will be realized on a period-by-period basis. Players must form rational price expectations which can be found by backward induction. The equilibrium must satisfy the exhaustion condition together with the following two arbitrage conditions: (i) $p_{t+1} = (1 + r)\, p_t$ must hold for any two subsequent periods

3 The formal derivation can be found in Liski and Montero (2003a).

4 During the writing this paper we came to realize that also the monopoly solution may suffer from time consistency problems when forward contracting is possible. We look at that problem in Liski and Montero (2003b).

in which the fringe sells (ii) $mr_{t+1}^{m} = (1+r)\, mr_{t}^{m}$ must hold for any two subsequent periods in which the leader sells;[5] where $mr_t^m = a - bq_t^f - 2bq_t^m$ and q_t^f and q_t^m are the amounts sold by the fringe and leader, respectively, at t. In this Nash-Cournot equilibrium, as commonly referred to in the literature (e.g., Salant, 1976: Newbery, 1981),[6] we observe that it is optimal for the leader to let the fringe exhaust first and be the only one selling at t=3 (see column 3 in Table 1). Although at t=3 units are sold at a lower price in present value terms (which explains the fringe's absence), at the margin the leader receives the same revenue for these units that for those sold at t=1 and 2. Thus, the leader moves the market by shifting sales to the third period (they are more than three times larger than under the competitive case) in exchange of an increase in today's prices. Note that the fringe benefits from the presence of the leader.

TABLE 1
EQUILIBRIUM PATHS FOR DIFFERENT MARKET STRUCTURES

	Competitive $\alpha = 0$	Monopoly $\alpha = 1$	Nash-Cournot $\alpha = 0.6$	Deviation $\alpha = 0.6$
p_1	4.211	6.053	4.674	4.674
p_2	6.316	6.579	7.011	6.234
p_3	9.474	7.368	8.316	9.093
q_1^f	5.789	-	3.6	3.6
q_2^f	3.684	-	0.4	2.989
q_3^f	0.526	-	0	0
q_1^m	-	3.947	1.726	1.726
q_2^m	-	3.421	2.589	0.777
q_3^m	-	2.632	1.684	0.907

If we now open up the contract space to include forward contracting and/or stock transactions, which are quite common in these markets, the Nash-Cournot equilibrium is no longer an equilibrium in the sense that it suffers from a time-consistency problem that contradicts consumers' and fringe's rational expectations. In this example, by forward contracting we mean that in period t=1 the leader and fringe member not only sell their supply for period t=1 but also offer

5 Note that consumers are passive here. They only come to the spot market in every period.

6 Newbery (1981) explains that if extraction costs are positive the Nash-Cournot solution may be time inconsistent. He argues, however, that the time consistent solution is very similar to the Nash-Cournot solution.

delivery contracts for period t=2 and t=3.[7] In fact, if consumers believe that the equilibrium price will follow the Nash-Cournot path discussed above, they should be willing to buy their expected demand through forward contracts whose pricing follows the expected spot price (the leader can always break the indifference in favor of its contracts using small discounts).

Having contracted its second-period sales, the leader has effectively put this part of his stock in competitive hands. Whatever happens to the price in the second-period spot market, the leader's revenue is already secured. This implies that the leader himself has an incentive to bring part of the production that was originally allocated to the third period to the second period. The reason is that the marginal revenue from selling more than the contracted amount in the second period spot market jumps up at the moment the original supply becomes contracted. As shown in the fourth column of Table 1, the leader's optimal deviation at t=2 causes the second-period price to drop from 7.011 to 6.234 imposing losses on both competitive suppliers (that did not sign forward contracts) and consumers that signed period-2 forward contracts.

It is important to emphasize that if the leader could credibly communicate (i.e., commit) that he will stay away from forward transactions or stock transactions, the Nash-Cournot solution would be the equilibrium of the game. But there are several reasons that make it difficult for the leader to do so. Forward transactions are very common in these markets. Although some of these transactions are for hedging reasons,[8] it would be hard for any consumer to distinguish out of the total volume of forward contracts how much is related to hedging and how much to strategic behavior.

Even if we do not consider hedging, fringe members have incentives to sell forward in anticipation of a leader's move that may leave them worse off ex-post. Any fringe member that assigns a tiny probability to the possibility that the leader (or any other fringe member) will not stick to spot transactions wants to be the first in selling a forward contract or its entire stock in anticipation of any price collapse (as illustrated by the drop of p_2. Since consumers have no means to tell apart the origin of contracts (if they do, the leader will use brokers or some fringe members to mask himself), at the moment fringe members put forwards in the market, consumers will no longer believe that the original path (i.e., Nash-Cournot path) will be fulfilled.[9]

7 The leader may decide not to offer contracts for t=3 without changing the results. If it does it can always buy back part of these contracts at t=2 (possibly after paying some previously agreed fee). This is so because third period contract holders cannot do arbitrage since they cannot sell t=3 deliveries earlier. Only the leader can bring t=3 deliveries to periods t=1 and 2 because he has the stock.

8 We do not have uncertainty in our model to justify heding but we can let the demand be subject to temporary shocks creating some price variation.

9 Best-price provisions compensating forward contract holders for future price cuts are neither likely to work here (Butz, 1990). Besides we do not see them in these markets, it would be hard to enforce such provisions in a context in which price changes are in large part exogenous to the leader due to the presence of other suppliers and genuine uncertainty.

The Nash-Cournot equilibrium with no forward contracting thus appears little realistic. Hence, in this paper we look for the equilibrium of the game in which agents expect that some level of forward contracting may prevail in equilibrium (note that this is not the same as imposing an exogenous amount of contracting). In this equilibrium we must have the leader maximizing profits given (the correctly perceived) expectations of buyers and the fringe, and these agents, in turn, are expecting (correctly) that the leader will so behave. This implies that in equilibrium there cannot be revisions or losses by contract holders.

The equilibrium of the game is obtained by backward induction as follows. Consider for a moment that the leader only signs t=2 contracts and let q_3^m be the leader' spot sale at t=3 at price p_3. If the equilibrium is to be any different from the competitive equilibrium the fringe cannot be selling at t = 3. Assuming that the fringe' stock is such that it sells at 1 and 2,[10] the equilibrium price path must satisfy

$$(1) \qquad p_1 = \frac{p_2}{1+r} > \frac{p_3}{(1+r)^2}$$

Thus, for the leader to not have incentives to deviate by making an unexpected spot sale at t = 2, we must have

$$(2) \qquad mr_3^m \geq (1+r)\, p_2$$

where $mr_3 = a - 2bq_3^m = p_3 - bq_3^m$.

Conditions (1) and (2), however, cannot simultaneously hold for $q_3^m \geq 0$.[11] Hence, the equilibrium solution cannot be anything but the competitive equilibrium with both the fringe and the leader selling in all three periods at prices rising at the discount rate r. Only competitive pricing rules out the leader's deviation incentives.

Since in equilibrium consumers and fringe members correctly anticipate the leaders' deviation incentives (i.e., the use of forward contracting for surplus extraction purposes), the very possibility of signing contracts destroys the leader's credibility, and with it, its ability to move the market. We say the "very possibility'' because in equilibrium we can observe any level of contracting from zero to full contracting. In fact, if there is no contracting, it is not difficult to show that the leader has no incentives to deviate at t = 2 from the competitive path. If the leader deviates and withholds some output at t=2 with the intention of closing the price gap between periods 2 and 3, the presence of the fringe assures that the new price path (i.e., off-the-equilibrium path) cannot depart from the competitive level. Since along the equilibrium path the fringe supplies at t=3 , a price rise at t=2 would move

10 If α =0.7, for example, the fringe sells everything at t=1 in the Nash-Cournot solution.

11 Note that if the leader has also contracted its third period, $q_3^m = 0$ and the "no-deviation" condition becomes $p_3 \geq (1 + r)\, p_2$ (some small fee from buying back part of the contracted deliveries may need to be added to p_3).

an even larger fraction of fringe' sales to the third period. If, on the other hand, the leader deviates and supplies extra output at t=2 with the idea of opening the price gap between periods 2 and 3, fringe members (and consumers) will arbitrate and keep prices along the competitive path as well.

3. Building Reputation

The possibility of forward contracting or stock transacting makes the leader's problem very similar to that of a durable goods monopoly in that the leader has incentives to revise its sales strategy as time goes by. In the example above we showed that is not possible to simultaneously have forward activity (at least in expectations) and the leader exercising market power,[12] while it can be demonstrated (by backward induction) that the durable-goods monopolist can still reap some monopoly profits in a three-period setting (Bulow, 1982).

The durable good monopolist may also fail to charge prices above marginal costs if he can move several times before the last sale, i.e., if the time interval between successive periods of the game is arbitrarily small. Because the durable-goods monopolist is always tempted to sell additional output as the game progresses, when the time interval approaches zero, consumers expect the monopolist to flood the market "in the twinkling of an eye", and hence, they will decline to buy at prices much above marginal cost (this is the Coase (1972) conjecture).

Ausubel and Deneckere (1989) argue, however, that as the time interval becomes arbitrarily small it is possible to have the durable-goods monopoly charging nearly static monopoly prices in a subgame perfect equilibrium. The equilibrium consist of a main (observed) path and a punishment path. The punishment path exhibits Coasian dynamics. The main path, on the other hand, starts with a price equal the static monopoly price and descend at an arbitrarily slow pace. As the time interval approaches zero, adherence to the main path becomes subgame perfect, because (by the Coase conjecture) the punishment becomes increasingly severe.

In Liski and Montero (2003a), we use the same "reputational equilibria" concept of Ausubel and Deneckere (1989) and ask whether the leader is able sustain the commitment solution, which here coincides with Nash-Cournot path described above, in subgame perfect equilibrium. Taken the (perfect) rational expectation equilibrium illustrated in the example of Section 2 as our punishment path, we find that the leader not always can build reputation as to sustain the Nash-Cournot path. If its original stockholding is below a certain threshold, the amount of the stock that the leader leaves for sales in the latter periods is so small that other players correctly anticipate that as soon as they start moving along the Nash-Cournot path the leader would deviate. If the leader's original stock is above

12 Note that this does not occur in a two period model in which the fringe sells only in the first period and the leader sells in both periods.

the threshold, adherence to the Nash-Cournot path becomes subgame perfect because now the punishment is more severe in the sense that reversion to the competitive equilibrium affects a larger remaining stock.

4. Conclusions and Future Research

Minerals such as oil and copper are traded in both spot and forward markets. We find that the latter significantly reduces the ability of a large supplier to exercise market power. The reason is that forward contracting creates a time inconsistency problem that in the presence of agents with rational expectations (for both consumers and remaining suppliers) may prevent this large supplier from moving the market.

There are several interesting directions for future research. One of them is the implementation of an empirical test for a specific mineral such as copper. This would bring new elements to the model (e.g., extraction costs that are stock dependent) with no trivial implications to the market equilibrium. It would also be interesting to explore the implications on the equilibrium solution of asymmetric information regarding the size of the leader's initial stock. Since the leader is better informed about his stock, a large stockholding leader may need to signal his size to separate from a smaller stockholding leader. Following Lewis and Schmalensee (1980), a third research avenue is to extend our model to an oligopolistic environment with a few large stockholders.

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