Mergers in exhaustible resource industries
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(Preliminary version)

Abstract
We examine the profitability and welfare implications of horizontal mergers and acquisitions (M&A) within exhaustible resource industries, which account for a large proportion of M&A activity worldwide. We model an exhaustible resource industry as a multi-period framework where firms compete in quantities in each period. Each firm is assumed to own a limited stock of the resource and, therefore, faces a constraint on the cumulative extraction over time. We show that, for an intermediate range of total stock, more mergers are profitable than under standard Cournot without stock constraints. At the same time, such mergers reduce consumer surplus and total surplus within our theoretical framework.

JEL Classifications:

Keywords: exhaustible resources, horizontal mergers, endogenous mergers, dynamic games, antitrust policy.

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1 Introduction

This paper examines the private and social incentives to merge firms in exhaustible resource industries. Exhaustible resource sectors constitute a large proportion of GDP in many economies\(^1\), and has a long history of mergers and acquisitions (M&A) activity starting with Standard Oil’s acquisitions in the early 1900’s. The volume of M&A has been consistently higher in exhaustible sectors relative to many other sectors, and has experienced a spate of mega-mergers starting in the late 1990’s, including the mergers of BP and Amoco (1998, $63 billion), Exxon and Mobil (1999, $74.2 billion), Total Fina and Elf Aquitaine (1999, $54.2 billion), Chevron and Texaco (2001, $45 billion), Royal Dutch Petroleum and the Shell Group (2004).\(^2\) Exhaustible resource sectors require a specific merger analysis to take into account the fact that the cumulative extraction over time of each firm is limited by its stock. This paper develops a theoretical framework to address the following questions. Why is there so much M&A activity in exhaustible resource sectors? Given that firms are heterogeneous in terms of their privately owned resource stocks, which mergers are likely to emerge in equilibrium. Are these mergers desirable from a social welfare perspective?

In order to address these questions, we develop a multi-period Cournot framework, where firms compete in the quantities of resource extracted in each period, and where the accumulative extraction of each firm is limited by its resource stock. In a standard Cournot oligopoly without restrictions on the quantities produced in each period, most mergers are not profitable (see, for example, Salant, Switzer and Reynolds (SSR), 1983; Gaudet and

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\(^1\)For example, exhaustible resource sectors, including oil, gas and minerals and mining, accounted for about 10% of Canadian GDP annually during 2008-2012, according to Statistics Canada.

\(^2\)The global value of M&A in the oil sector rose from $88.99 billion in 1997 and $66.6 billion in 1998 to $372 billion in 2007 and $339 billion in 2008. (See Kumar, 2012, for further details). Consider also, for example, Canada, where, in recent years, exhaustible resource extraction industries have seen rising volumes of M&A. According to the data provided by the Canadian Competition Bureau, during 2012 to 2013, about 20% of the 330 mergers that were reviewed by the Bureau were in this sector, with 16% of mergers being realized in oil and gas extraction industries. The highest value merger transactions in Canada in 2012 were realized in the oil and gas extraction industry in the form of cross-border acquisitions, according to Macleans and Blake Canadian Lawyers, including the C$15-billion acquisition of Nexen by China’s CNOOC and the C$5.5-billion acquisition of Progress Energy Resources by Malaysia’s Petronas.
The basic intuition driving this result is as follows. Given that the best response functions of firms in terms of quantities are strategic substitutes in the Cournot model, when the merger participants decrease quantity, the non-merging firms respond by increasing their output levels, thereby mitigating the increase in market power of the merger participants. In this paper we ask whether this result carries over to exhaustible resource industries where stocks are finite.

We assume that each firm owns a limited stock of the resource and, therefore, faces a constraint on the cumulative extraction over time. The total stock denotes the aggregate stock across all firms in the industry. We show that, for an intermediate range of total stock, more mergers are profitable than under the standard Cournot model without stock constraints. For sufficiently small stocks of the resource, each firm exhausts its stock within a single period regardless of a merger, such that a merger does not affect profits. As stocks tend to infinity, the equilibrium approaches the standard Cournot case, where mergers are not profitable unless a very large proportion of the industry merges (see SSR, 1983; Gaudet and Salant, 1991). The novel intuition generated by our framework is as follows. For an intermediate range of stocks, we show that the merger participants prolong their extraction over more periods than in the equilibrium without any merger. By doing so, in period 1, the merger participants are able to jointly reduce production without the outsiders responding with an increase in production, given their stock constraints. This enables the merged firm to gain market power in period 1 by delaying some production to future periods. Thus, we show that more mergers are profitable in exhaustible resource industries. At the same time, such mergers reduce consumer surplus and total surplus within our theoretical framework.

In the existing literature, papers have characterized exhaustible resource markets either as cartel versus fringe or as oligopolies. Within the former category, some studies model the cartel and the fringe moving simultaneously (see, for example, Salant, 1976; Ulph and Folie, 1980; Lewis and Schmalensee, 1980; Pindyck, 1978; Benchekroun and Withagen, 2012), and

\[3^3\text{As shown in SSR, in a Cournot oligopoly with } n \text{ identical firms, linear demand and constant marginal cost, a merger is only profitable if it involves at least 80\% of the industry.}\]
others model the cartel as a Stackelberg leader (see, for example, Gilbert, 1978; Groot, Withagen and de Zeeuw, 1992, 2003). Papers that model exhaustible resource markets as oligopolies include Loury (1986), Polasky (1996), Salo and Tahvonen (2001), Eswaran and Lewis (1985), and Hartwick and Brolley (2008). None of these papers analyze mergers in the presence of individual constraints on the cumulative extraction.

Our paper contributes to this literature by developing a multi-period Cournot oligopoly model where each firm faces an individual constraint on the cumulative extraction. Within this setup, we first analyze the profitability and welfare effects of mergers of an exogenously given merger within an industry consisting of identical firms. We then allow heterogeneity across firms in terms of resource stocks and determine the merger pattern that emerges endogenously in equilibrium. We also analyze which firm has the greatest incentive to acquire the others, and show that this depends on the degree of asymmetry in resource stocks across firms.

Most of the oligopoly models of exhaustible resource markets use open-loop strategies (see, for example, Salant, 1976, 1982; Loury, 1986; Gaudet and Long, 1994; Benchekroun, Halsema and Withagen, 2009, 2010). However, the equilibrium derived using open-loop strategies may not be subgame perfect and in the case of the leader-follower framework, the equilibrium may be time-insconsistent (see, for example, Karp and Newberry, 1991; Groot, Withagen and de Zeeuw, 1992, 2003). Another set of papers have used closed-loop strategies to characterize exhaustible resource markets. In an effort to derive analytical solution, these papers have relied on specific functional forms or assumptions such as iso-elastic demand and zero extraction cost (Eswaran and Lewis, 1985; Reinganum and Stokey, 1985; Benchekroun and Long, 2006), economic abandonment where the resource is not exhausted in full (Salo and Tahvonen, 2001), and an exogenous fixed time horizon (Hartwick and Brolley, 2008). A few papers use closed-loop strategies without relying on these functional forms or assumptions, such as, Polasky (1996), Benchekroun and Gaudet (2003), and Wan and Boyce (2014) which offers, in a two period model, a full characterization of the duopolistic equilibrium in the
case of Cournot and Stackelberg games. Our paper generalizes the basic setup in Wan and Boyce (2014) by allowing for more than two periods and more than two firms, and explicitly models mergers and acquisitions.

We proceed as follows. Section 2 presents the model. Section 3 presents the analysis regarding the profitability and welfare implications of mergers for identical stocks across firms. Section 4 examines the case where stocks are heterogeneous across firms. Section 5 provides our concluding remarks.

2 The Model

Consider the set of \( N = \{1, ..., n\} \) Cournot oligopolists indexed by \( i \). Each firm possesses resource stock \( S_i \). There exist multiple periods. In the benchmark model, we restrict our analysis to the range of stocks such that all firms choose to exhaust their stocks within two periods.

In each period, the inverse demand function is given by:

\[
p_t = A - Q_t
\]

where \( A > 0 \) and \( Q_t \) is total production of all firms in period \( t \). Each firm has a constant marginal cost of production, \( c \), and a discount factor, \( \beta \). In order to present the main results as clearly as possible, we begin by focusing on the case with identical firms, that is, \( S_i = S, \forall i \).

Let each firm’s production be denoted by \( q_{it} \) in period \( t \). In the two period version of the model, firm \( i \) produces \( q_{i1} \) in period 1 and \( q_{i2} = S_i - q_{i1} \) in period 2.

The scenario without any mergers:

Let the profits of firm \( i \) in period \( t \) be given by \( \pi_{it} \). The discounted profits over two periods

\footnote{In Section 4.1, we show that the main results carry over to cases with asymmetric stocks across firms.}
of firm $i$ is, thus, given by $\pi_{i1} + \beta \pi_{i2}$, where

$$
\pi_{i1} \equiv (A - q_{i1} - (n - 1)q_{j1})q_{i1} - cq_{i1} \quad \text{for all } i, j \in N \quad (2)
$$

$$
\pi_{i2} \equiv (A - (S - q_{i1}) - (n - 1)(S - q_{j1}) - c)(S - q_{i1}) \quad \text{for all } i, j \in N \quad (3)
$$

Within this setup, if the resource stocks of firms are sufficiently large, the model converges to a standard Cournot oligopoly. In order to highlight the effect of the stock contraints on firm behaviour, we, therefore, assume that the stocks are sufficiently small, that is, less than $\bar{S}$ as specified in Assumption 1 below, such that, in the pre-merger equilibrium, all firms choose to exhaust their stocks completely within the first period. For all firms to deplete their entire stocks within one period, that is, $q_{i1} = S \forall i$, the marginal profit from producing in period 1 must be greater than the marginal profit from producing in period 2, that is,

$$
\frac{\partial (\pi_{i1} + \beta \pi_{i2})}{\partial q_{i1}} \bigg|_{q_{i1}=q_{j1}=S} > 0. \quad (4)
$$

We have that

$$
\frac{\partial (\pi_{i1} + \beta \pi_{i2})}{\partial q_{i1}} = A - c - 2q_{i1} - (n - 1)q_{j1} + \beta ((A - (S - q_{i1}) - (n - 1)(S - q_{j1}) - c)(-1) + (S - q_{i1}))
$$

It follows that

$$
\frac{\partial (\pi_{i1} + \beta \pi_{i2})}{\partial q_{i1}} \bigg|_{q_{i1}=q_{j1}=S} = (1 - \beta)(A - c) - (n + 1)S
$$

Thus, (4) is satisfied iff $0 < S < \bar{S} \equiv \frac{(1 - \beta)(A - c)}{n + 1}$. This leads to Assumption 1.

**Assumption 1:** We assume that the stock of each firm, $S$, satisfies the following condition:

$$
0 < S < \bar{S} \equiv \frac{(1 - \beta)(A - c)}{n + 1}.
$$

**The scenario with a merger:**

Within this setup, consider an exogenously given merger of $m$ firms, where $1 < m < n$, that occurs at the beginning of period 1. The merger participants belong to the set $M \subset N$. The rivals of the merged firm that do not participate in the merger are referred to as "outsiders", etc.
and belong to the set \( O = N \setminus M \). The post-merger equilibrium may be characterized as follows. Let the merged entity’s profits in period \( t \) be given by \( \pi_M \) and quantity of resource extracted in period \( t \) be given by \( q_M \). Let outsider \( i \)’s profits in period \( t \) be given by \( \pi_i \) and quantity of resource extracted in period \( t \) be given by \( q_i \). The discounted profits over two periods of the merged entity is, thus, given by \( \pi_M \), where

\[
\pi_M \equiv (A - q_M - (n - m)q_i - c)q_M \quad \text{for } i \in O
\]  

(5)

\[
\pi_M \equiv (A - (mS - q_M) - (n - m)(S - q_i) - c)(mS - q_M) \quad \text{for } i \in O
\]  

(6)

Outsider \( i \)’s discounted profits over two periods is given by \( \pi_i + \beta \pi_i \), where

\[
\pi_i \equiv (A - q_M - q_i - (n - m - 1)q_j - c)q_i \quad \text{for } i, j \in O
\]  

(7)

\[
\pi_i \equiv \left( A - (mS - q_M) - (S - q_i) \right) (S - q_i) \quad \text{for } i, j \in O
\]  

(8)

If the merger is realized, one of two possible outcomes may arise in equilibrium, depending on the resource stock, \( S \).

**Case 1**: All firms, that is, the merged entity and the outsiders, deplete their entire stocks within one period.

**Case 2**: The merged entity splits production over two periods while the outsiders deplete their entire stocks within one period.

As per Assumption 1, if there is no merger, all firms deplete their entire stocks within one period. Under Case 1, this also carries over to the scenario if the merger is realized. Thus, in Case 1, the equilibria extraction levels with and without the merger are identical. Case 1 occurs when the following conditions are satisfied:

\[
\frac{\partial (\pi_M + \beta \pi_M)}{\partial q_M}\bigg|_{q_M = mS, q_i = S} > 0
\]  

(9)

\[
\frac{\partial (\pi_i + \beta \pi_i)}{\partial q_i}\bigg|_{q_M = mS, q_j \neq i = S} > 0
\]  

(10)
We have that (9) and (10) are only satisfied if the following holds:

\[ 0 < S < \hat{S} \equiv \frac{(1 - \beta) (A - c)}{n + m} < \bar{S} \]  

(11)

**Lemma 1:** For any \( m \in \{2, ..., n\} \), we have the following:

(i) For \( 0 < S < \hat{S} \), the merged entity and the outsiders deplete their entire stocks within one period.

(ii) For \( \hat{S} < S < \bar{S} \), the merged entity splits production over two periods while the outsiders deplete their entire stocks within one period.

**Proof:** We show that under Assumption 1, that is, when we restrict our attention to values of \( S \) within the range \( 0 < S < \hat{S} \), Cases 1 and 2 provide an exhaustive list of possible cases. From (9), (10) and (11), it follows that for \( 0 < S < \hat{S} \), Case 1 is realized in equilibrium. This completes the proof for Lemma 1(i). For \( \hat{S} < S < \bar{S} \), it must be that Case 2 is realized in equilibrium since the outsiders have no incentive to delay their extraction to more than one period. Recall that there are no synergies from the merger within the context of this model, since the marginal cost of production remains \( c \) regardless of the merger. Therefore, the only incentive to merge is to gain market power by raising the resource price. Given that the firms play \( \text{à la Cournot} \) in each period, the firms’ best response functions are strategic substitutes. Thus, when the merger participants attempt to raise price by decreasing output in period 1, the outsiders have an incentive to increase output in period 1. It follows that since the outsiders were exhausting their entire stock within one period in the absence of a merger under Assumption 1, they will do so also in Case 2 with the merger. This ensures that the outsiders have no incentive to delay their extraction to more than one period, and completes the proof for Lemma 1(ii). □

Lemma 1 has clear implications for the profitability and welfare impact of an exogenously given merger within this context.
3 Profitability and welfare effect of an exogenously given merger

Let the profitability of a given merger be denoted by the difference between the profit of the merger entity if the merger is realized, and the joint equilibrium profits of the merger participants if the merger is not realized.

**Proposition 1:** For any $m \in \{2, ..., n\}$, there exists an intermediate range of resource stock, $\hat{S} < S < \bar{S}$, such that a merger of $m$ firms is profitable, with this range expanding in $m$.

**Proof:** In the absence of any merger, let the profit of each firm, under Assumption 1, be given by:

$$\bar{\pi}_{i1} = S (A - c - Sn) \quad \forall i$$

and no profits are realized in period 2. From Lemma 1 (ii), it follows that for $\hat{S} < S < \bar{S}$, the merged entity splits production over two periods while the outsiders deplete their entire stocks within one period. If the merger is realized, we have

$$q_{M1} = \frac{(1 - \beta) (A - c) - S (n - m - 2m\beta)}{2(\beta + 1)}$$

and

$$\pi_{M1} + \beta \pi_{M2} = \frac{1}{4} (\beta + 1)^{-1} \begin{pmatrix} -S^2 (2mn + 4mn\beta - m^2 - n^2) \\
+(c - A)^2 (\beta - 1)^2 + 2S (A - c) (m - n + 3m\beta + n\beta) \end{pmatrix}$$

The profitability of a merger of $m$ firms is given by

$$\pi_{M1} + \beta \pi_{M2} - m\bar{\pi}_{i1} = \frac{1}{4} (\beta + 1)^{-1} (c - A + Sm + Sn + A\beta - c\beta)^2 > 0$$

Moreover, since $\hat{S}$ is decreasing in $m$, and $\bar{S}$ does not vary with $m$, it follows that the range $\hat{S} < S < \bar{S}$ is expanding in $m$.
Proposition 1 provides a sharp contrast to the case of a standard Cournot model without resource stock contraints, as depicted by SSR. Within a similar setting to ours, that is, with linear demand and constant marginal cost, SSR shows that unless 80% of the industry participates in a given merger, the merger is not profitable. By contrast, Proposition 1 shows that in the presence of stock constraints, even the smallest merger (of two out of \( n \) firms, where \( n \) may be arbitrarily large) is profitable for an intermediate range of \( S \). This is because, unlike in the SSR model, where outsiders respond to the merger by increasing output and mitigating the merger participants’ gain in market power, in this model, under Assumption 1, the outsiders do not change their output levels in period 1 due to the merger. As per Lemma 1, within the range \( 0 < S < \hat{S} \), the outsiders exhaust their stocks within one period regardless of the merger. This allows greater merger-induced market power than in the SSR model.

For sufficiently small values of \( S \), the merger participants do not find it profitable to postpone extraction to a second period. For \( 0 < S < \hat{S} \), Case 1 is realized such that the merger is not profitable since it does not affect equilibrium profits. As \( S \to \infty \), the model converges to SSR. Thus, our novel result is relevant for intermediate ranges of the stock, \( \hat{S} < S < \bar{S} \), for which we show that more mergers are profitable than in the SSR framework.

Next, we examine the welfare implications of a given merger within our framework.

**Proposition 2:** For \( \hat{S} < S < \bar{S} \), cumulative consumer surplus over time is lower due to the merger than it would be in the absence of the merger.

**Proof:** For \( \hat{S} < S < \bar{S} \), the resource price is higher in period 1 due to the merger than it would be in the absence of the merger. This follows directly from Lemma 1 (ii). Also, part of the consumer surplus is postponed from period 1 to 2. Assuming that consumer have a positive discount rate, this implies that the cumulative consumer surplus over time is lower due to the merger than it would be in the absence of the merger.

Thus, although more mergers are profitable under the resource constraints, these mergers occur for market power, and harm consumers.
Example 1: For $A = 1$, $n = 10$, $c = 0$ and $\beta = 0.9$, we illustrate Propositions 1-2.

Figure 1: Profitability of merger

In line with Proposition 1, Figure 1 illustrates that even a merger of two firms is profitable for a range of $S$. This range expands as the size of the merger, $m$, increases. Below $\hat{S}|_{m=10}$, no mergers are profitable (not even a merger to monopoly) since all firms exhaust their resources within one period regardless of whether the merger is realized.

Figure 2: Merger-induced change in consumer surplus
In line with Proposition 2, Figure 2 illustrates that consumer surplus decreases as a result of a merger. The larger the merger, that is, the greater is $m$, the greater the decrease in consumer surplus due to the larger merger-induced increase in market power of the merger participants.

The effect of a given merger on total surplus, that is, the sum of producer and consumer surplus, is ambiguous since producer surplus increases at the expense of consumer surplus. In our example, total surplus decreases due to a given merger, as illustrated in Figure 3.

These results imply that antitrust authorities should be concerned by mergers in exhaustible resource industries with intermediate stock levels. While more mergers are profitable in such industries than among standard Cournot oligopolists facing no stock restrictions, these mergers impose a loss of consumer surplus and of total surplus.\(^5\)

\(^5\)For example, Exxon’s acquisition of Mobil (1999) led to approximately 9000 job losses representing 7 percent of the group’s workforce around the world. The Chevron-Texaco merger (2001) led to approximately 4000 job losses representing 7 percent of the group’s workforce around the world. See Kumar (2012) for further details.
4 Heterogeneous resource stocks

Next, we determine whether the results presented in the previous section carry over to cases where the resource stock is heterogeneous across firms. Allowing for asymmetry across firms also enables us to address further questions about the equilibrium pattern of mergers. For example, which mergers are most likely to emerge in equilibrium? Which firm (the largest or the smallest) has most incentive to acquire the other firms? Does this depend on the degree of asymmetry? For analytical tractability, we present the case of three firms with different stocks. The three firm case with two periods is sufficient to generate the new insights that we wish to highlight within this context.

Consider three firms, 1, 2 and 3, with $S_1 > S_2 > S_3$. The pre-merger discounted profits over two periods of firm $i$ is given by $\pi_{i1} + \beta \pi_{i2}$, where

$$\pi_{i1} = (A - c - q_{11} - q_{21} - q_{31})q_{i1}$$

$$\pi_{i2} = (A - c - S_1 + q_{11} - S_2 + q_{21} - S_3 + q_{31})(S_i - q_{i1})$$

All firms deplete their stocks within one period in the absence of any merger iff

$$\frac{\partial (\pi_{i1} + \beta \pi_{i2})}{\partial q_{i1}}|_{q_{i1}=S_1,q_{21}=S_2,q_{31}=S_3} > 0$$

From (12) and (13), it follows that:

$$\frac{\partial (\pi_{i1} + \beta \pi_{i2})}{\partial q_{i1}} = (A - c - q_{11} - q_{21} - q_{31}) - q_{i1}$$

$$+ \beta ((A - c - S_1 + q_{11} - S_2 + q_{21} - S_3 + q_{31})(-1) + (S_i - q_{i1}))$$

with

$$\frac{\partial (\pi_{i1} + \beta \pi_{i2})}{\partial q_{i1}}|_{q_{i1}=S_1,q_{21}=S_2,q_{31}=S_3} = (A - c - S_1 - S_2 - S_3) - S_i + \beta ((A - c)(-1))$$
From (15), it follows that (14) is only satisfied if the following holds.

\[ 2S_i + S_j + S_k < (1 - \beta)(A - c) \]  \hspace{1cm} (16)

According to (16), all firms deplete their entire stocks within one period in the absence of any merger if either the profit margin, \((A - c)\), is sufficiently high or the discount factor, \(\beta\), is sufficiently low.

**Assumption 2:** We assume that the stocks of each firm satisfy the following condition:

\[ 2S_i + S_j + S_k < (1 - \beta)(A - c). \]

Assumption 2 implies that, as in the case with identical firms, the range of stocks are such that all firms deplete their stocks within one period in the absence of any merger.

Without loss of generality, consider the merger of firms \(i\) and \(j\). Let the profits of the merged entity and the outsider in period \(t\) be denoted by \(\pi_{M_i}\) and \(\pi_{k_t}\) respectively, where

\[ \pi_{M1} = (A - c - q_{M1} - q_{k1})q_{M1} \]  \hspace{1cm} (17)

\[ \pi_{M2} = (A - c - S_i - S_j + q_{M1} - S_k + q_{k1})(S_i + S_j - q_{M1}) \]  \hspace{1cm} (18)

and

\[ \pi_{k1} = (A - c - q_{M1} - q_{k1})q_{k1} \]  \hspace{1cm} (19)

\[ \pi_{k2} = (A - c - S_i - S_j + q_{M1} - S_k + q_{k1})(S_k - q_{k1}) \]  \hspace{1cm} (20)

As in the symmetric case, there arise two possible cases post-merger.

**Case 1:** All firms deplete their entire stocks within one period iff

\[ \frac{\partial (\pi_{M1} + \beta \pi_{M2})}{\partial q_{M1}}|_{q_{M1}=S_i+S_j,q_{k1}=S_k} > 0 \]  \hspace{1cm} (21)

\[ \frac{\partial (\pi_{k1} + \beta \pi_{k2})}{\partial q_{k1}}|_{q_{M1}=S_i+S_j,q_{k1}=S_k} > 0 \]  \hspace{1cm} (22)
From (19) and (20), it follows that:

\[
\frac{\partial (\pi_{M1} + \beta \pi_{M2})}{\partial q_{M1}} = (A - c - q_{M1} - q_{k1}) - q_{M1} \\
+ \beta ((A - c - S_i - S_j + q_{M1} - S_k + q_{k1}) (-1) + (S_i + S_j - q_{M1}))
\]

with

\[
\frac{\partial (\pi_{M1} + \beta \pi_{M2})}{\partial q_{M1}}_{|q_{M1}=S_i+S_j,q_{k1}=S_k} = (A - c - (S_i + S_j) - S_k) - (S_i + S_j) + \beta ((A - c) (-1))
\]

(23)

From (23), we have that (21) and (22) are only satisfied if

\[(1 - \beta) (A - c) > 2S_i + 2S_j + S_k \]

(24)

Case 2: The merged firm splits production over two periods while the outsider depletes its entire stocks within one period. This occurs iff

\[2S_i + S_j + S_k < (1 - \beta) (A - c) < 2S_i + 2S_j + S_k \]

(25)

**Lemma 2:** For any \( m \in \{2, 3\} \), we have the following:

(i) For \((1 - \beta) (A - c) > 2S_i + 2S_j + S_k\), the merged entity and the outsiders deplete their entire stocks within one period.

(ii) For \(2S_i + S_j + S_k < (1 - \beta) (A - c) < 2S_i + 2S_j + S_k\), the merged entity splits production over two periods while the outsiders deplete their entire stocks within one period.

Proof: Similar to the proof of Lemma 1.

Due to similar reasoning as in the symmetric case, Lemma 2 leads to results similar to Propositions 1-2, whereby more mergers are profitable than in the SSR case, and these mergers harm consumers. What is the role of \( \beta \) here? The larger is \( \beta \) the more the firms value...
future profits. Therefore, the greater the reduction in Period 1 output and consequently the
greater the merger-induced increase in industry profit. From (25), it follows that the greater
is $\beta$, the greater the ranges of stocks, $\{S_1, S_2, S_3\}$, for which Case 2 is realized, and therefore
the merger is profitable.

**Proposition 3:** For any $m \in \{2, 3\}$, a merger of $m$ firms is profitable iff $2S_i + S_j + S_k < 
(1 - \beta) (A - c) < 2S_i + 2S_j + S_k$.

Proof: Similar to the proof of Proposition 1.

**Example 2:** To illustrate that in Case 2, industry profits increase due to a merger, recall
Example 1. Further assume that $S_1 = \frac{5}{4} S$, $S_2 = S$, and $S_3 = \frac{1}{2} S$.

Figure 4: Industry profit as a funcion of $S$.

For sufficiently small values of $S$, we have that (24) holds, such that Case 1 occurs. Thus,
in Figure 1, for small values of $S$, there is no difference between industry profits with and
without the merger. For sufficiently large values of $S$, we have that (25) holds, such that
Case 2 occurs. For this range of $S$, the merger increases industry profit since the merged
entity gains market power, as in the case with symmetric firms.

**Proposition 4:** For $2S_i + S_j + S_k < (1 - \beta) (A - c) < 2S_i + 2S_j + S_k$, cumulative consumer
surplus over time is lower due to the merger than it would be in the absence of the merger.

Proof: Similar to the proof of Proposition 2.
4.1 Endogenous mergers

In this subsection, we ask which merger would be realized in equilibrium if firms were allowed to endogenously choose among different possible mergers, rather than imposing an exogenously given merger of $m$ firms.

In order to endogenize the merger process, we apply the model presented in Horn and Persson (2001). Given any two ownership structures, the subset of owners who receive different payoffs in the two structures under consideration are referred to as the decisive owners. In our three firm case, all firms are decisive owners. The decisive owners are able to bargain with each other by making side payments. When comparing two possible ownership structures, the structure that yields the higher combined profits of the decisive group of owners dominates the other. In our case, the merger that yields the highest industry profit dominates the other. Selection of the ownership structure is seen as a solution to the merger formation game based on pairwise dominance rankings of all feasible ownership structures. Merger to monopoly is not allowed.

Within our context, for $n = 3$, the merger with the greatest industry profits occurs in equilibrium. Thus, our question becomes which merger yields the highest industry profit, that between firms 1 and 2, or 1 and 3 or 2 and 3? In Example 2, the merger of firms 1 and 2 yield the greatest industry profit and therefore occurs in equilibrium, as is clear from Figure 4. This result can be generalized as follows. The larger the post-merger stock of the merged entity, the greater the reduction in period 1 industry output, and therefore, the greater the increase in market power in period 1. Thus, the larger the post-merger stock of the merged entity, the greater the industry profits over both periods.

Without loss of generality, consider the case where $S_1 > S_2 > S_3$. We will always have firms 1 and 2 (the firms with the largest stocks) merging in equilibrium. The merger of firms 1 and 2 is always more profitable than the merger of firms 1 and 3. The least profitable merger will involve the two firms with the smallest joint stocks (firms 2 and 3 in Example 2).
4.2 Monopolization of the industry

In the previous subsection merger to monopoly was not allowed. In this subsection, we ask a different question. Is monopolization of the industry more likely when firms face resource constraints than in a standard Cournot oligopoly without such constraints? This question becomes relevant in light of the serial acquisitions undertaken by several large firms in this industry, starting with Standard Oil in the early 1900’s. For example, Exxon acquired Mobil in 1999 for $74.2 billion, and Exxon Mobil acquired XTO Energy in 2009 for $41 billion. BP acquired Amoco in 1998 for $63 billion, then BP-Amoco acquired Arco in 2000 for $27 billion, then BP-Amoco acquired Burmah Castrol in 2000 for £3 billion, and BP-Amoco acquired Veba Oil in 2001. French Total acquired Belgium’s Petrofina in 1999 for $12 billion and became Total Fina. After a two-month battle in 1999, Total Fina acquired Elf Aquitaine for $54.2 billion.\(^6\)

In order to endogenize the merger process, we adapt the model presented in Kamien and Zang (1990). We assume that the acquirer makes take it or leave it offers of acquisition prices to the other firms (the targets). Each target’s reservation price is equal to the profit it would earn if it unilaterally decided not to sell out to the acquirer. In the three firms case, the acquirer will only monopolize the industry if the equilibrium monopoly profit less the acquisition price of Target 1 less the acquisition price of Target 2 less the acquirer’s profit if no acquisitions are made is strictly positive. Kamien and Zang (1990), using a standard Cournot model with linear demand, constant marginal cost and no stock constraints, showed that for \( n \geq 3 \), monopolization is not profitable. Does this result carry over to exhaustible resource sectors?

If monopolization occurs, let the monopoly profit of the merged entity in period \( t \) be denoted by \( \pi_{Mon,t} \), such that the total profit over both periods is given by \( \pi_{Mon,1} + \beta \pi_{Mon,2} \).

\(^6\)These figures are available in Kumar (2012).
where
\[
\begin{align*}
\pi_{\text{Mon},1} &= (A - c - q_{\text{Mon},1}) q_{\text{Mon},1} \\
\pi_{\text{Mon},2} &= (A - c - S_i - S_j - S_k + q_{\text{Mon},1}) (S_i + S_j + S_k - q_{\text{Mon},1})
\end{align*}
\] (26)

(27)

If monopolization does occur within our context, there are two possible cases that may be realized in the post-monopolization equilibrium.

Case 1: The monopoly depletes its entire stock within one period iff

\[
\frac{\partial (\pi_{\text{Mon},1} + \beta \pi_{\text{Mon},2})}{\partial q_{\text{Mon},1}} |_{q_{\text{Mon},1}=S_i+S_j+S_k} > 0
\] (28)

From (26) and (27), it follows that:

\[
\frac{\partial (\pi_{\text{Mon},1} + \beta \pi_{\text{Mon},2})}{\partial q_{\text{Mon},1}} = (A - c - q_{\text{Mon},1}) - q_{\text{Mon},1} + \beta ((A - c - S_i - S_j - S_k + q_{\text{Mon},1}) (-1) + (S_i + S_j + S_k - q_{\text{Mon},1}))
\]

with

\[
\frac{\partial (\pi_{\text{Mon},1} + \beta \pi_{\text{Mon},2})}{\partial q_{\text{Mon},1}} |_{q_{\text{Mon},1}=S_i+S_j+S_k} = (A - c - 2 (S_i + S_j + S_k)) + \beta ((A - c) (-1))
\] (29)

(30)

From (29), we have that (28) is only satisfied if

\[
(1 - \beta) (A - c) > 2 (S_i + S_j + S_k)
\] (31)

From (31), it follows that the monopoly depletes its entire stock within one period if either the profit margin is sufficiently high or the discount factor sufficiently low.

Case 2: The monopoly splits production over two periods. Recall that all firms deplete their stocks within one period in the absence of any merger iff (16) holds. This, together with
(31) implies that Case 2 occurs if

\[ 2S_i + S_j + S_k < (1 - \beta) (A - c) < 2S_i + 2S_j + 2S_k \]  

(32)

In contrast to Kamien and Zhang (1990, 1991, 1993), and Gaudet and Salant (1991), we find that within our context, monopolization may be profitable. This is because, in this context, there exists more than one period, and by acquiring the rival firms in the first period and postponing extraction to the later period, the acquirer gains monopoly profit in the future period. The higher is the discount factor, the lower the gains from monopolization.

**Example 3:** Using the same parameter value as Example 1, and different combinations of the stocks of firms, the gains from monopolization are illustrated in Figure 5.

![Figure 5: Gains from Monopolization](image)

Example 3 yields an interesting result. It is not always the firm with the largest stock that has the greatest incentive to acquire its rivals.

**Result 1:** The more asymmetric the stocks (if the smallest firm is sufficiently smaller than the rest) the more likely that the greatest incentive to monopolize is with the smallest firm.

The smallest firm gains the most if the other two firms merge, since the merged entity is able to reduce output more the larger its combined stock. Thus, the greater the asymmetry, the more expensive it becomes to acquire the smallest firm. For this reason, in Figure 5, when \( S_1 = (1.25) S \), \( S_2 = S \), and \( S_3 = (0.5) S \), the largest firm has the least incentive to
monopolize the industry by acquiring its smaller rivals, and the smallest firm’s gains from monopolization are the greatest. This is in contrast to the case where the stocks are more symmetric, that is, when $S_1 = (1.1)S$, $S_2 = S$, and $S_3 = (0.9)S$.

5 Conclusion

We show that there exists an intermediate range of firm-specific stocks such that more mergers are profitable than under standard Cournot without stock constraints. These mergers reduce consumer surplus and total surplus, and therefore, antitrust authorities should be cautious of mergers in exhaustible resource industries. A caveat to this result is that mergers sometimes yield synergies which reduce marginal cost and therefore price, which we have abstracted away from in our model.

Moreover, we show that for a subset of the firms merging, the merger involving the largest firms is the most profitable, and therefore, most likely to occur in equilibrium. This explains why this industry has seen so many mega-mergers in the past. Also, the largest firm may or may not have the largest incentive to monopolize through acquisitions, depending on the degree of asymmetry. The more asymmetric the stocks (if the smallest firm is sufficiently smaller than the rest) the more likely that the greatest incentive to monopolize is with the smallest firm.
References


