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Merger Formation
in the Oil Industry**

Leslie Neubecker and Manfred Stadler

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Leslie Neubecker and Manfred Stadler*

Abstract

This paper analyzes the recent mergers in the oil industry. Oil is assumed to be a homogeneous good which is produced by a small number of firms with different unit costs. Merger formation is endogenously explained as a result of cooperative decisions. We show that the mergers are amongst very asymmetric firms if initial size differences are moderate. If size differences are large, however, the more efficient firms participate in the mergers, while the least efficient firms are not attractive partners and, therefore, remain independent in the post-merger market.

Keywords: Asymmetric horizontal mergers; Coalition formation; Oil industry

JEL classification: C71, G34, L71

* University of Tübingen, Dept. of Economics, Mohlstraße 36, D-72074 Tübingen, Germany. e-mail: leslie.neubecker@uni-tuebingen.de and manfred.stadler@uni-tuebingen.de, homepage: http://www.uni-tuebingen.de/vw15/index_en.html.

1 Introduction

During the last decade, a number of important industries experienced consolidation by horizontal mergers. A prominent example is the rapid succession of mergers in the oil industry from 1998 to 2001. Crude oil is a rather homogeneous good which is produced by a small number of firms with different unit costs. We argue that the merger formation in this industry can be explained as a result of cooperative decisions taken in order to realize efficiency effects. Previous theoretical analyses of merger activities focused on the issue of concentration, whereas explanations of efficiency effects are still rare. By accounting for asymmetries in merger participants' unit costs, we are able to show that the hunt for gains in efficiency is the driving force behind merger activities. Hence, our study contributes to the literature on endogenous asymmetric merger formation.

In line with the seminal papers by *Salant et al.* (1983), *Deneckere, Davidson* (1985), *Farrell, Shapiro* (1990), and *Rodrigues* (2001), a large part of the literature assumes symmetric firms. However, the dependence of the post-merger market structure on the extent of prior asymmetry is an important result of some recent analyses (see, e.g. *Barros* 1998, *Böckem* 2001, *Faulí-Oller* 1997, 2002, *Tombak* 2002). *Tombak* (2002) analyzes sequential mergers of heterogeneous firms resulting from a Nash-bargaining process where, despite of differences in their efficiency, potential merger partners have equal bargaining power. *Faulí-Oller* (2002) focuses on the welfare effect of mergers, whereas our aim is to explain the post-merger market structure. *Faulí-Oller* (2000) considers a model of two efficient firms sequentially bidding for rivals using inferior technologies. Mergers between the less efficient firms, however, are excluded by assumption. In contrast, our paper does not restrict attention to mergers initiated by technologically advanced firms. *Barros* (1998) analyzes endogenous merger formation in a homogeneous market with three asymmetric firms. Our model builds on *Barros'* (1998) triopoly model. However, we depart from his approach in two important ways and hence obtain some novel results. Firstly, we consider a pre-merger market with four firms allowing for a more sophisticated analysis of the process of merger formation. Secondly, we employ the core as suggested by *Horn, Persson* (2001a) as a cooperative equilibrium concept in order to endogenously explain merger formation.

Most mergers are a result of strategic considerations of firms competing in oligopolistic markets. The prospective partners usually communicate freely about contract terms and can legally enforce the reached agreements. Although the conditions of the merger are negotiated and the contract on the merger is binding, traditional

models assume that a merged entity must be stable even if participants act non-cooperatively (e.g. *Kamien, Zang* 1990, *Böckem* 2001). This assumption seems restrictive except in the case of an acquisition of a rival firm. It neglects the fact that the owners of the merging firms are free to negotiate any division of combined profits. In our opinion, formation of mergers in the oil industry is better characterized by a model of cooperative merger decisions. Thus, applying solution concepts of cooperative game theory can offer new insights into the pattern of mergers and the resulting market structure. At the same time, firms contemplating a merger must consider the influence of their decisions on product-market competition. Until recently, however, models of coalition formation were not suitable to analyze such settings. Earlier studies investigated the formation and internal structure of coalitions using arbitrary assumptions on the behavior of outsiders. Only few models explicitly consider the external spillover effects of coalition formation on outsiders. Initially, these studies were restricted to symmetric participants (see, *Bloch* 1995, 1997). A large part of the literature on cooperative game theory analyzes coalition formation in contexts where participants' costs decrease in the size of their coalition (see, *Bloch* 2002 for an excellent survey of this line of models). If asymmetries are permitted, tractability is imposed by additional simplifying assumptions. A recent example is the model by *Belleflamme* (2000) which restricts the number of coalitions to two if players are asymmetric. *Espinosa, Inarra* (2000) apply the equilibrium concept of stable sets in order to predict the number of competitors in the post-merger market structure. They assume symmetric firms which share fixed costs of production in case of a merger. In their model, mergers depend on economies of scale. *Horn, Persson* (2001a,b), in contrast, follow *Barros* (1998) by assuming that the coalitions use the technology of the most efficient participant. They suggest an extension of the traditional concept of the core using the idea of a partition function as originally developed by *Thrall, Lucas* (1963). This approach proves to be suitable to model the formation of mergers in oligopolies.

Our paper applies the core concept in the formulation by *Horn, Persson* (2001a) to analyze the recent merger activities in the oil industry which is characterized by cost and size asymmetries between competitors. We conclude that differences in the size of firms determine the post-merger market structure. Due to initial size differences, the free rider effect as discussed by *Selten* (1973) and *Salant et al.* (1983) is outweighed by efficiency gains if these differences are not negligible. Hence, merger activities result in a market structure with the highest permitted degree of concentration. If cost differences are small, efficiency gains are decisive. Merger partners are very asymmetric so that only the best technologies are used after the merger formation. This also holds if several firms have access to the best

technology. If asymmetries are large, the least efficient firm produces only a small quantity. Hence, its inclusion in a merger deal does not result in a significant output reduction. With large asymmetries, the more efficient firms merge, whereas the least efficient one remains as a small independent competitor. The results from our theoretical model coincide with the empirical evidence in the oil industry where smaller and less efficient firms were acquired by large, well-run competitors.

The crude oil market experienced considerable concentration in recent years. Merger formation predominantly involved firms of major importance in exploration and production. Costs of crude oil production depend on the accessibility of oil reservoirs and hence differ considerably between the competitors. By merging, firms gained access to new production sites and technologies. We argue that the merger formation resulted from firms' quest to gain a larger market share by reducing production costs.

The rest of the paper is organized as follows. In Section 2, we describe the market conditions and the mega-mergers in the oil industry from 1998 to 2001. Section 3 presents a cooperative game-theoretic model which is applied to analyze this merger formation. Section 4 presents our conclusions concerning the equilibrium market structure resulting from these endogenously derived merger decisions. We compare our results with those of earlier work in Section 5. Finally, Section 6 concludes.

2 Recent Mergers in the World Oil Industry

Before we turn to the details of our theoretical model, we describe the most important features of the international oil market and the sequence of mergers that occurred from 1998 to 2001.

2.1 The Structure of the Oil Market

More than half of the crude oil volume is traded internationally. Crude oil exploitation is a global business, whereas technical factors of refining and distribution have led to a segmentation into regional markets (see, *Weston* 2002, p. 70). The upstream business of production and distribution is rather lucrative whereas the downstream activities of refining and retailing are subject to fierce competition offering only small profit margins. Our study focuses on competition in crude oil extraction. The oil industry consists of firms with a large variety of scope and organizational structure

ranging from huge vertically integrated companies engaged in exploitation, refining and marketing, to specialized oil service firms, local refineries and independent gas stations. The vertical structure of the companies, however, has no significant impact on competition in crude oil exploration and production and will therefore be neglected in our theoretical analysis.

Oil exploration and production is dominated by a top group of privately owned companies and a number of large firms owned by oil-producing countries, e.g. Saudi Aramco of Saudi Arabia or Petrobras of Brazil. 95.7% of the oil reserves in possession of the 20 largest companies are controlled by governments. Only the remaining 4.3% are in private hands. Hence, competition for easily accessible oil deposits is especially fierce among the private firms. Due to differences in the accessibility, oil lifting costs as well as exploration and development expenditures vary significantly depending on the region of origin. In contrast, quality differences of crude oil from different reservoirs do not matter much. The production costs thus strongly depend on a company's portfolio of oil fields (see, *Energy Information Administration* 2002a). Consolidation of oil deposits, improvement of business practices and access to superior technology were often achieved by mergers. As the state-run firms are not possible merger partners, we consider only the privately owned companies.

2.2 The Succession of Horizontal Mergers

In the first half of the 1980s, the oil industry experienced a first wave of unsuccessful conglomerate mergers. Simultaneously, there were several horizontal mergers as well as sales of oil companies to firms in other industries (see, *Weston* 1999). The focus of this paper is on the second period of intense merger activity. From 1998 to 2001, there was a rapid succession of mergers between some industry's majors which induced a strong concentration process in the top group of the petroleum industry as illustrated in Figure 1. Only private firms participated in the mergers given in Table 1.

It is a distinguishing feature that mergers occurred between the most and the less efficient firms. The five newly formed oil companies are among the six largest private firms in the industry. Table 1 shows that only two competitors merged at the same time even if the final firm consisted of three or four formerly independent producers. Examples for the latter are BP-Amoco merging with Arco and Phillips-Tosco and Conoco-Gulf merging to form Conoco-Phillips. All these mergers were of the horizontal type. As all initial firms are integrated industry majors, they can be

Figure 1: Oil Companies Involved in the Mergers, 1998-2001

Date	BP	Amoco	Exxon	Mobil	Total	PetroFina	Arco	Elf	Texaco	Chevron	Phillips P.	Tosco	Conoco	Gulf
8/98	BP-Amoco		Exxon	Mobil	Total	PetroFina	Arco	Elf	Texaco	Chevron	Phillips P.	Tosco	Conoco	Gulf
12/98	BP-Amoco		Exxon-Mobil		Total	PetroFina	Arco	Elf	Texaco	Chevron	Phillips P.	Tosco	Conoco	Gulf
12/98	BP-Amoco		Exxon-Mobil		TotalFina		Arco	Elf	Texaco	Chevron	Phillips P.	Tosco	Conoco	Gulf
4/99	BP-Amoco-Arco		Exxon-Mobil		TotalFina		Elf	Texaco	Chevron	Phillips P.	Tosco	Conoco	Gulf	
7/99	BP-Amoco-Arco		Exxon-Mobil		TotalFina-Elf			Texaco	Chevron	Phillips P.	Tosco	Conoco	Gulf	
10/00	BP-Amoco-Arco		Exxon-Mobil		TotalFina-Elf			Texaco-Chevron		Phillips P.	Tosco	Conoco	Gulf	
2/01	BP-Amoco-Arco		Exxon-Mobil		TotalFina-Elf			Texaco-Chevron		Phillips-Tosco		Conoco	Gulf	
5/01	BP-Amoco-Arco		Exxon-Mobil		TotalFina-Elf			Texaco-Chevron		Phillips-Tosco		Conoco-Gulf		
11/01	BP-Amoco-Arco		Exxon-Mobil		TotalFina-Elf			Texaco-Chevron		Phillips-Tosco - Conoco-Gulf = ConocoPhillips				

regarded as symmetric except in their production costs.¹

Table 1: Mergers in the Oil Industry, 1998-2001

Date	Participating Firms	New Name
8/1998	British Petrol (BP) Amoco	BP Amoco
12/1998	Exxon Mobil	Exxon Mobil
12/1998	Total PetroFina	TotalFina
4/1999	BP-Amoco Arco	BP Amoco
7/1999	TotalFina Elf Aquitaine	TotalFinaElf
10/2000	Chevron Texaco	ChevronTexaco
2/2001	Phillips Tosco	Phillips
5/2001	Conoco Gulf Canada	Conoco
11/2001	Phillips Conoco	ConocoPhillips

¹ As firms' market power is low in both the upstream as well as in the downstream markets, the recent merger wave did not raise great concern from antitrust authorities. To prevent dominance in certain regions or business areas, however, each of the merged companies was required to abandon some lines of business or to sell certain assets (see, *Weston* 2002). Simultaneously to these mergers of majors, consolidation occurred amongst the regional players in the USA and Europe (see, *Energy Information Administration* 2002b and the business press). These "mergers of minors", however, had no significant impact on the petroleum market.

This second horizontal merger wave in the petroleum industry was triggered by a price decline to around 10\$ per barrel of crude oil in 1998. Within this second wave, the first mergers were used by firms to restructure their exploitation and refining businesses in order to reduce costs and remain competitive even in times of low oil prices. Later mergers, however, were formed despite a price recovery. The dominant objective of these deals was to realize synergy effects and to increase the market shares and, hence, the value of the firms. Indeed, contrary to many mergers in other industries, the merger formation in the oil industry increased firms' efficiency and size. These mergers indeed raised firms' profits, with ExxonMobil by far surpassing expectations in this respect (see, e.g. *Weston* 2002).

One source of increased efficiency due to mergers was the acquisition of oil fields requiring similar exploitation technologies or leading to a consolidation of spheres of interest, e.g. Exxon's presence in Azerbaijan and Mobil's activities in Kazakhstan and Turkmenistan. Reduction of excess capacities, elimination of parallel divisions and adoption of the best management strategies for the different areas of business were stated as the most important objectives by the representatives of all majors involved in these mergers. BP and Amoco were a good match in this respect, BP being more efficient in production and Amoco being more successful on the downstream side of business from refining to marketing. Moreover, Amoco was strongest in the USA where BP was not very active before the merger. In contrast to mergers in many other industries, the oil mergers indeed achieved the expected efficiency gains. Another important feature of the mergers is the larger market share of the merged firm compared to that of each previously independent company. The size gain due to the merger offers several competitive advantages. Firstly, it raises the companies' financial power. Due to the fact that only a small share of the world's crude oil reserves are under control of private firms, competition for the discovery and exploitation of new fields is intense. The combined financial resources of two formerly independent competitors enable the merged firm to invest in projects with higher capital costs carrying higher risks. Hence, a merged entity has a larger choice of investment projects resulting in an increased profitability. A second important benefit of increased firm size is a higher lobbying power. Such political influence is a major factor for the success of an industry where production, access to pipelines and hence profits strongly depend on political stability in countries with large oil resources as well as on the benevolence of the local political leaders. Firms thus strive for size not only in order to raise market shares and sales, but also to increase investment possibilities and political influence.

3 A Model of Asymmetric Merger Formation

We analyze the merger decisions in the world oil industry by using a stylized theoretical model. The assumptions of our theoretical model are set in order to reflect the most important features of the world oil market. As will be shown, our results coincide with the main characteristics of the mergers described above. Since quality differences of crude oil seem to be of minor importance, we assume a homogeneous market consisting of only a few firms. These firms produce with asymmetric unit costs due to different accessibility to their oil deposits. Efficiency gains due to a merger are reflected by the assumption that merged entities use the most efficient technology available to the formerly independent companies.

3.1 The Pre-Merger Market

In order to keep the analysis tractable, we restrict our attention to the case of four firm owners in the pre-merger industry. We assume that initially every owner runs a single firm. The inverse demand function is given by $p = 1 - Q$, where Q is the market output. With respect to the size asymmetry, we consider two cases. In case 1, we assume that all firms in the pre-merger market differ in their unit costs. Asymmetric efficiency is characterized by a constant difference $\Delta > 0$ between the firms' unit costs.

$$c_1 + 3\Delta = c_2 + 2\Delta = c_3 + \Delta = c_4 < 1. \quad (1)$$

This particular specification is adopted from *Barros* (1998). The restriction on the cost levels guarantees that all four firms are active in the pre-merger market. In order to guarantee this, we place a restriction on the cost level of the least efficient firm. In case 2, we alternatively derive the post-merger market structure for a market characterized by two top firms producing with low costs c_l and two less efficient rivals with higher costs c_h . The extent of asymmetry in the market is smaller than in case 1 since there are only two levels of technology. Firms' cost differences are given by

$$c_l + \Delta = c_1 + \Delta = c_2 + \Delta = c_3 = c_4 = c_h < 1. \quad (2)$$

Our distinction between the situations with four and with only two different cost levels sheds additional light on the importance of the extent of asymmetries for the equilibrium market structure and is intended to prove the robustness of our results with respect to alternative assumptions on the firms' efficiency. The merger game

consists of two stages. In the first stage, owners are permitted to form coalitions until all bargaining possibilities are exhausted. In most cases, mergers are motivated by cost synergies. In order to reflect such efficiency gains, we adopt a standard assumption of the industrial organization literature. The unit production cost of a merged entity is the lower one of those of the merging firms. The merger decisions determine the post-merger market structure for the second stage in which the remaining firms in the industry play a Cournot game.

3.2 The Merger Stage

Let $N = (1, \dots, 4)$ be the set of owners and M^w be a possible ownership market structure where M^w is a partition of N . To account for the fact that antitrust authorities will not give clearance to mergers raising concentration over a prespecified threshold, we exclude mergers which would result in a monopoly and yield the highest overall profit. Therefore, 14 post-merger market structures, summarized in Table 2, are possible candidates for an equilibrium.

Table 2: Market Structures With Four Owners

$$\begin{array}{ll}
 M^0 = \{1, 2, 3, 4\} & M^K = \{12, 34\} \\
 M^A = \{12, 3, 4\} & M^L = \{13, 24\} \\
 M^B = \{13, 2, 4\} & M^P = \{14, 23\} \\
 M^C = \{14, 2, 3\} & M^Q = \{1, 234\} \\
 M^D = \{1, 23, 4\} & M^R = \{2, 134\} \\
 M^E = \{1, 24, 3\} & M^S = \{3, 124\} \\
 M^G = \{1, 2, 34\} & M^T = \{4, 123\}
 \end{array}$$

In order to derive the post-merger equilibrium market structures, it is necessary to introduce a relation that compares the outcomes of one market structure to another. Following *Horn, Persson (2001a)*, we make use of a binary dominance relation. According to this relation, a market structure M^i is dominated by a market structure M^j , if the owners who have the power to enforce either of the two market structures, prefer M^j over M^i . The group of decisive owners who are able to determine the ranking of the two market structures is defined in the following way. Let \mathcal{H}^w be a subset of the firms in M^w , and let $\mathcal{O}(\mathcal{H}^w)$ be the set of owners possessing the firms in \mathcal{H}^w . Then, a group of decisive owners, \mathcal{D}^{ij} , comprises all owners influencing the ranking of the two alternative market structures M^i and M^j . This decisive group is defined by

- (i) $\mathcal{D}^{ij} = \mathcal{O}(\mathcal{H}^i) = \mathcal{O}(\mathcal{H}^j) \neq \emptyset$
- (ii) $\mathcal{H}^i \cap \mathcal{H}^j = \emptyset$
- (iii) $\nexists \mathcal{D} \subset \mathcal{D}^{ij} \mid \mathcal{D} \text{ fulfills (i) and (ii).}$

On the basis of the group of decisive owners, the binary dominance relation can be defined. Market structure M^j is said to dominate market structure M^i via \mathcal{D}^{ij} , i.e. $M^i \prec M^j$, if and only if

$$\sum_{k \in \mathcal{H}^j} \tilde{\pi}_k^j > \sum_{k \in \mathcal{H}^i} \tilde{\pi}_k^i, \quad (3)$$

where $\tilde{\pi}_k^i$ and $\tilde{\pi}_k^j$ are the (combined) profits of the firms in the decisive group D^{ij} . In some cases, the ranking of market structures can be determined by two disjoint groups of decisive owners, e.g. $M^K = \{12, 34\} \succ M^O = \{1, 2, 3, 4\}$ via $\mathcal{D}^{OK} = \{\{1, 2\}, \{3, 4\}\}$. In principle, these groups might favor different market structures. In our model, all changes from the initial to a duopolistic market structure by pairwise mergers benefit both groups of decisive owners. Hence, the problem of conflicting interests does not arise here.

The dominance relation ranks any pair of market structures. It determines the set of equilibria contained in the core, i.e.

$$\mathcal{M} \setminus \{M^i \in \mathcal{M} \mid M^j \in \mathcal{M} \text{ such that } M^i \prec M^j\}.$$

If all firms differ in their production costs, the core is empty for a small range of size differences. In the case of two efficient and two inefficient firms, however, the core will not be empty.

3.3 The Production Stage

At the production stage, we consider a Cournot oligopoly with two, three or four firms producing with different unit costs, depending on the previous merger decisions. In equilibrium, profits are given by

$$\tilde{\pi}_k^w = \frac{(1 - nc_k + \sum_{k' \neq k} c_{k'})^2}{(n+1)^2}. \quad (4)$$

for any firm k in the post-merger market structure w .

In case 1, we consider a pre-merger market consisting of four asymmetric firms. Since several possible post-merger market structures are characterized by equal unit costs of firms, we refer to them by their cost structures. The corresponding merger patterns are presented in Table 3.

Table 3: Cost Structures Corresponding to the Market Structures in Case 1

Cost Structures	Market Structures
$\{c_1, c_2, c_3, c_4\}$	$M^O = \{1, 2, 3, 4\}$
$\{c_1, c_2, c_3\}$	$M^C = \{14, 2, 3\}$ $M^E = \{1, 24, 3\}$ $M^G = \{1, 2, 34\}$
$\{c_1, c_2, c_4\}$	$M^B = \{13, 2, 4\}$ $M^D = \{1, 23, 4\}$
$\{c_1, c_3, c_4\}$	$M^A = \{12, 3, 4\}$
$\{c_1, c_2\}$	$M^L = \{13, 24\}$ $M^P = \{14, 23\}$ $M^Q = \{1, 234\}$ $M^R = \{134, 2\}$
$\{c_1, c_3\}$	$M^K = \{12, 34\}$ $M^S = \{3, 124\}$
$\{c_1, c_4\}$	$M^T = \{4, 123\}$

Inserting (1) and the definition $d \equiv \Delta/(1 - c_1)$ into (4), we derive the profits $\tilde{\pi}_k^w$ in the different market structures. In order to simplify the expressions, we divide all profits by $(1 - c_1)^2/3600$ and summarize the adjusted values π_k^w in Table 4.

Table 4: Firms' Profits in the Market Structures in Case 1

Cost Structure	Profits of the Firms
$\{c_1, c_2, c_3, c_4\}$	$\pi_1^O = 144(1 + 6d)^2$, $\pi_2^O = 144(1 + d)^2$, $\pi_3^O = 144(1 - 4d)^2$, $\pi_4^O = 144(1 - 9d)^2$
$\{c_1, c_2, c_3\}$	$\pi_{14}^C = \pi_1^E = \pi_1^G = 225(1 + 3d)^2$, $\pi_2^C = \pi_{24}^E = \pi_2^G = 225(1 - d)^2$, $\pi_3^C = \pi_3^E = \pi_{34}^G = 225(1 - 5d)^2$
$\{c_1, c_2, c_4\}$	$\pi_{13}^B = \pi_1^D = 225(1 + 4d)^2$, $\pi_2^B = \pi_{23}^D = 225$, $\pi_4^B = \pi_4^D = 225(1 - 8d)^2$
$\{c_1, c_3, c_4\}$	$\pi_{12}^A = 225(1 + 5d)^2$, $\pi_3^A = 225(1 - 3d)^2$, $\pi_4^A = 225(1 - 7d)^2$
$\{c_1, c_2\}$	$\pi_{13}^L = \pi_{14}^P = \pi_1^Q = \pi_{134}^R = 400(1 + d)^2$, $\pi_{24}^L = \pi_{23}^P = \pi_{234}^Q = \pi_2^R = 400(1 - 2d)^2$
$\{c_1, c_3\}$	$\pi_{12}^K = \pi_{124}^S = 400(1 + 2d)^2$, $\pi_{34}^K = \pi_3^S = 400(1 - 4d)^2$
$\{c_1, c_4\}$	$\pi_{123}^T = 400(1 + 3d)^2$, $\pi_4^T = 400(1 - 6d)^2$

In case 2, we analyze a market where initially a top group of two more efficient competitors faces two less efficient rivals. If there are just these two levels of unit costs as given in (2), all market structures are equivalent to one of five cost structures as shown in Table 5.

Table 5: Cost Structures Corresponding to the Market Structures in Case 2

Cost Structures	Market Structures
$\{c_l, c_l, c_h, c_h\}$	$M^O = \{1, 2, 3, 4\}$
$\{c_l, c_l, c_h\}$	$M^B = \{13, 2, 4\}$ $M^C = \{14, 2, 3\}$ $M^D = \{1, 23, 4\}$ $M^G = \{1, 2, 34\}$ $M^E = \{1, 24, 3\}$
$\{c_l, c_h, c_h\}$	$M^A = \{12, 3, 4\}$
$\{c_l, c_l\}$	$M^L = \{13, 24\}$ $M^P = \{14, 23\}$ $M^R = \{134, 2\}$ $M^Q = \{1, 234\}$
$\{c_l, c_h\}$	$M^K = \{12, 34\}$ $M^S = \{124, 3\}$ $M^T = \{123, 4\}$

The firms' profits π_k^w (adjusted as in case 1) in the different market structures are summarized in Table 6.

Table 6: Firms' Profits in the Market Structures in Case 2

Cost Structure	Profits of the Firms
$\{c_l, c_l, c_h, c_h\}$	$\pi_1^O = \pi_2^O = 144(1 + 2d)^2$ $\pi_3^O = \pi_4^O = 144(1 - 3d)^2$
$\{c_l, c_l, c_h\}$	$\pi_{13}^B = \pi_2^B = \pi_{14}^C = \pi_2^C = \pi_1^D = \pi_{23}^D = \pi_1^E = \pi_{24}^E = \pi_1^G = \pi_2^G = 225(1 + d)^2$ $\pi_4^B = \pi_3^C = \pi_4^D = \pi_3^E = \pi_{34}^G = 400(1 - 4d)^2$
$\{c_l, c_h, c_h\}$	$\pi_{12}^A = 225(1 + 2d)^2$, $\pi_3^A = \pi_4^A = 225(1 - 2d)^2$
$\{c_l, c_l\}$	$\pi_{13}^L = \pi_{14}^P = \pi_1^Q = \pi_{134}^R = 400$, $\pi_{24}^L = \pi_{23}^P = \pi_{234}^Q = \pi_2^R = 400$
$\{c_l, c_h\}$	$\pi_{12}^K = \pi_{124}^S = \pi_{123}^T = 400(1 + d)^2$, $\pi_{34}^K = \pi_3^S = \pi_4^T = 400(1 - 2d)^2$

4 Endogenous Merger Formation

Using the core concept, we are now able to solve for the post-merger equilibrium market structures in both cases described above.

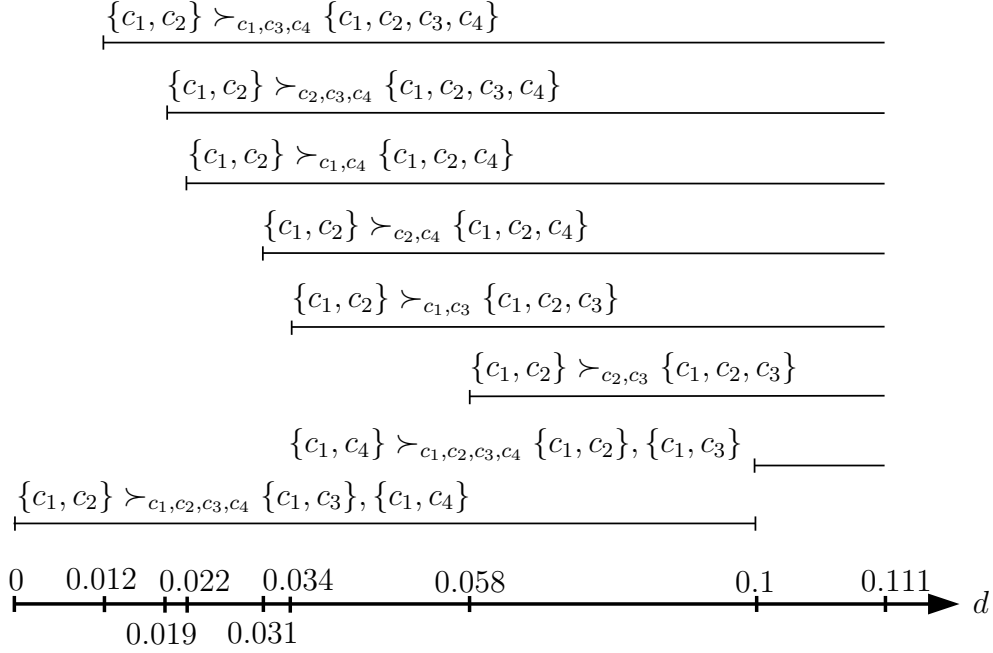
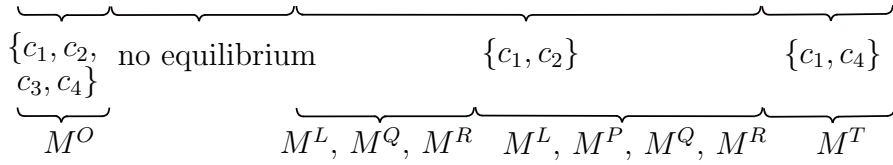
4.1 Case 1: Four Asymmetric Firms

According to (3), the post-merger market structure is determined by pairwise comparisons of profits of decisive owners in all possible market structures as given in Table 4. As the least efficient firm 4 ceases production if the extent of asymmetry is larger than $d = 1/9$ (≈ 0.111), we consider only cost differences corresponding to the interval $d \in (0, 1/9)$. Comparisons of profits of the decisive owners in alternative market structures yield the binary dominance relations. Straightforward calculations show that the pre-merger market structure dominates all triopolies for cost asymmetries larger than $d = 7/183$ (≈ 0.038). Moreover, the least efficient duopoly characterized by production costs $\{c_1, c_4\}$ is stable if the extent of asymmetry is large, corresponding to $d \geq 1/12$ (≈ 0.083). The comparisons most relevant for the determination of the equilibria are shown in the upper part of Figure 2. For reasons of consistency, decisive owners are also referred to by their technology, i.e. their unit costs.

Obviously, mergers do not occur as long as the extent of asymmetry is very small. The first dominance relation illustrated in Figure 2 shows that the pre-merger market structure M^O dominates even the duopoly of firms using the most efficient technologies if differences are small, $d < (44 - 15\sqrt{6})/586$ (≈ 0.012). For slightly larger asymmetries, $d \in [(44 - 15\sqrt{6})/586, 1/29 \approx 0.034)$, the core is empty. As duopolies, triopolies and the four-firm oligopolies cyclically dominate each other, there is no equilibrium market structure.

For larger technology gaps, duopolies are the only candidates for an equilibrium. The dominance relations comparing duopolies with different cost structures are represented by the seventh and the eighth lines in Figure 2. They indicate that the “intermediate” duopolies with cost levels of $\{c_1, c_3\}$ are dominated by the least efficient duopoly characterized by $\{c_1, c_4\}$ if costs differ to a large extent, $d \geq 1/10$, and by the duopolies with the lowest unit costs, $\{c_1, c_2\}$, for all other values. The duopoly consisting of firms using the best and the worst technology, respectively, is therefore an equilibrium only for large asymmetries, $d \geq 1/10$, almost forcing the least efficient firm to exit the market. Here, the core implies the market structure $M^T = \{4, 123\}$. However, for an intermediate range of asymmetry, consistent with

Figure 2: Merger Formation of Asymmetric Firms

Merger Preferences of Decisive Groups:**Dominant Post-Merger Market Structures:**

values $d \in [1/29 \approx 0.034, 1/10)$, only duopolies characterized by the cost structure $\{c_1, c_2\}$ are candidates for equilibria. The “efficient” duopoly $M^Q = \{1, 234\}$ is an equilibrium for intermediate asymmetries as determined by the fourth dominance relation in Figure 2. The fifth relation, $\{c_1, c_2\} \succ_{c_1, c_3} \{c_1, c_2, c_3\}$, compares the triopolies $M^C = \{14, 2, 3\}$ and $M^G = \{1, 2, 34\}$ to the duopoly $M^R = \{2, 134\}$. The decisive owners 1, 3 and 4 enforce duopoly M^R if the technology gap exceeds $d = 1/29$. This relation also shows that the decisive owners 1 and 3 prefer the duopoly $M^L = \{13, 24\}$ to $M^E = \{1, 24, 3\}$ for such values of size asymmetry. Thus, the duopolies M^L , M^Q and M^R are equilibria for the whole range of asymmetries covered by $d \in [1/29, 1/10)$. The merger changing the market structure from $M^C = \{14, 2, 3\}$ to $M^P = \{14, 23\}$, however, is evaluated by the dominance relation $\{c_1, c_2\} \succ_{c_2, c_3} \{c_1, c_2, c_3\}$. Owners 2 and 3 are decisive in this ranking. If the extent of asymmetry is given by $d \in [1/29, 1/17 \approx 0.058)$ this duopoly is dominated by the triopoly M^C which is itself dominated by the duopoly M^R . This

sixth dominance relation shows that the duopoly $M^P = \{14, 23\}$ is an equilibrium only in the smaller interval $d \in [1/17, 1/10)$. The equilibrium market structures arising from the dominance relations are shown in the lower part of Figure 2. Table 7 summarizes these results.

Table 7: Equilibrium Market Structures

Size of Asymmetry	Dominant Post-Merger Market Structures
$d \in [0, (44 - 15\sqrt{6})/586)$	$M^O = \{1, 2, 3, 4\}$
$d \in [(44 - 15\sqrt{6})/586, 1/29)$	no equilibrium
$d \in [1/29, 1/17)$	$M^L = \{13, 24\}$, $M^Q = \{1, 234\}$, $M^R = \{2, 134\}$
$d \in [1/17, 1/10)$	$M^L = \{13, 24\}$, $M^Q = \{1, 234\}$, $M^R = \{2, 134\}$ $M^P = \{14, 23\}$
$d \geq [1/10, 1/9)$	$M^T = \{4, 123\}$

Mergers allow the participating firms to increase their efficiency and size. If asymmetries are large, firms with inferior technologies produce a small quantity. Therefore, output contraction due to the merger would be negligible. As a consequence, a merger involving the least efficient firms is not attractive. For this reason, $M^T = \{4, 123\}$ is the equilibrium market structure in the interval of largest efficiency and size differences. In the intermediate range of technological differences, $d \in [1/29, 1/10)$, the core implies the efficient duopolies as equilibria. At a first sight, the instability of the market structure $M^P = \{14, 23\}$ for the lower values of asymmetry, $d \in [1/29, 1/17)$, may seem surprising. However, this conclusion confirms our more general result of asymmetric merger formation for smaller differences in efficiency. The merger to $M^R = \{2, 134\}$ makes it possible to improve technology by two Δ , the merger to $M^P = \{14, 23\}$ only by Δ . The merger of firms 14 and 3 is therefore more asymmetric and offers a higher efficiency gain.² The single step to the next efficient technology by a merger to M^P , in contrast, is only profitable if the extent of asymmetry is larger, corresponding to the upper part of intermediate technological differences, $d \in [1/17, 1/10)$.³ If differences are

² The merger of the independent producers 2 and 3 resulting in the market structure $M^P = \{14, 23\}$ involves firms with costs c_2 and c_3 . The merger of the firm in possession of owners 1 and 4 with the single-owner firm 3 involves producers with costs c_1 and c_3 .

³ Unfortunately, we have no access to the data of the firms' production costs. Thus, we are not able to compare this prediction with the cost and ownership structures of firms in the post-merger oil market.

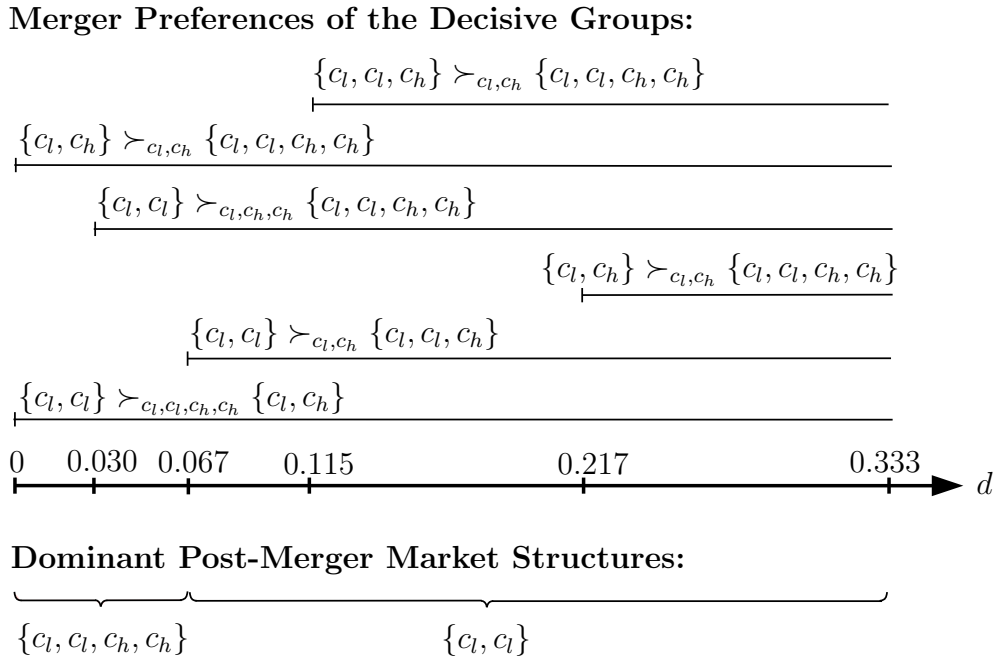
very small, $d < (44 - 15\sqrt{6})/586$, the output increase of the outsiders to a merger dominates any potential efficiency gain. No merger occurs and the initial market structure is the only equilibrium.

In the next subsection, we analyze the merger formation assuming size differences of firms as discussed in case 2. As will be shown, the conclusions derived for case 1 continue to hold in a qualitative sense.

4.2 Case 2: Pairwise Symmetric Firms

We derive the equilibria resulting from merger activities by pairwise comparisons of the profits of decisive owners gained in all possible market structures summarized in Table 6. As the profits of merged firms and firms with a single owner are determined by their technology, we refer to the different market structures and groups of decisive owners by their cost levels. All dominance relations are shown in the upper part, the equilibrium market structures in the lower part of Figure 3. An inefficient firm exits the market if asymmetries are large. In order to exclude such situations, we restrict attention to cost differences corresponding to $d \in [0, 1/3)$.

Figure 3: Merger Formation of Pairwise Symmetric Firms



The pre-merger market structure dominates triopolies with a cost structure given by $\{c_l, c_h, c_h\}$. Figure 3 shows that triopolies characterized by $\{c_l, c_l, c_h\}$ are stable merger patterns for larger cost differences, $d \in [7/61 \approx 0.115, 1/3)$. These market

structures, however, are dominated by efficient duopolies, $\{c_i, c_i\}$, over the relevant range of asymmetry. However, these duopolistic structures are themselves dominated by the initial market structures if the technology gap is lower than $d = 1/15$ (≈ 0.067). Hence, merger activities lead to a duopoly of efficient firms if cost levels differ to a large extent. If technological differences are small, mergers are unprofitable. The resulting equilibrium market structures are presented in Table 8.

Table 8: Equilibrium Market Structures

Size of Asymmetry	Dominant Post-Merger Market Structures
$d \in [0, 1/15)$	$M^O = \{1, 2, 3, 4\}$
$d \in [1/15, 1/3)$	$M^L = \{13, 24\}$, $M^P = \{14, 23\}$, $M^R = \{1, 234\}$, $M^Q = \{2, 134\}$

As in the previous case, the driving force of merger formation is the reduction of production costs. If efficiency differences of the initial competitors are small, mergers are unattractive. In this case, the pre-merger market structure remains unchanged. For an intermediate extent of asymmetry, corresponding to values of $d \in [1/15, 1/3)$, the core implies duopolies using the superior technology. For large cost differences, a market structure without mergers yields the highest profits. An inefficient firm, however, exits the market if asymmetries are large, reflected by $d \geq 1/3$. As a result, only the technologically advanced firms remain in the market for these sizes of cost differences. Hence, as long as the technology gap is significant, $d \in [1/15, 1/3)$, a duopoly of efficient firms is the equilibrium market structure.

From the two cases considered, we obtain similar conclusions with respect to the merger formation in the oil market. All competitors involved in the mergers produced considerable quantities in the pre-merger market. Firms' size and cost differences thus correspond to an intermediate range of asymmetry, $d \in [1/29 \approx 0.034, 1/10)$ or $d \in [1/15, 1/3)$ in cases 1 and 2, respectively.

As predicted by the model, the firms in the oil industry have chosen asymmetric merger partners since such deals offered the largest efficiency gains and the largest increase of profits. Both versions of our model suggest that mergers in the oil industry were driven by firms' hunt for such efficiency gains. Furthermore, according to the theoretical analysis, firms' profits increase due to merger formation. This is indeed an important feature of the mergers observed in the oil industry.

5 A Comparison with Alternative Solution Concepts

Our assumptions were set to reflect the most important characteristics of the crude oil market. A comparison with other theoretical work, however, is of independent interest. From a technical point of view, our results confirm *Barros'* (1998) conclusion that for lower size asymmetries, mergers occur between the more asymmetric firms. *Barros* derives the endogenous merger decisions using the criterion of internal and external cartel stability as proposed by *Selten* (1973) and *D'Aspremont et al.* (1983). In order to apply it to an asymmetric market, he restricts the number of initial competitors to three. Moreover, he assumes that firms participate in a merger as long as the outsider is not able to offer a more profitable alternative, that is a larger share of profits from an alternative merger. The resulting market structure, however, is not unique. In order to achieve uniqueness of the solution, *Barros* imposes an additional criterion selecting the merger with the largest internal gain as the equilibrium merger pattern. Moreover, the criteria of internal and external stability are applicable only to the triopoly case where mergers involving two firms are trivially externally stable if merger to monopoly is forbidden by antitrust laws. This analysis, however, cannot be extended to markets with more than three firms. Hence, the choice of this stability criterion considerably limits the applicability of the *Barros* model.

The extension of the core concept as suggested by *Horn, Persson* (2001a) permits an application to our example of an asymmetric oligopoly. In contrast to *Horn, Persson* (2001a,b), we are able to predict the technologies in use after the mergers depending on the initial asymmetry. Moreover, the predictions of our model with respect to the ownership structures of the firms in the post-merger market are quite detailed, especially in the case of asymmetric firms. In addition, our analysis has shown that very inefficient firms are not involved in mergers if technology differences are large. This result continues to hold in the more general model by *Horn, Persson* (2001a) which assumes that merger participants obtain higher profits in the case of *all* mergers resulting in the most concentrated market structure allowed by cartel laws. This assumption implies very high incentives for mergers, e.g. due to large efficiency gains. Although in our model a merged entity produces with the most efficient technology of the participating firms, the efficiency gains from mergers are high enough to meet this assumption only if the extent of cost differences is considerable. However, our model allows us to derive the equilibrium market structures for the whole range of cost differences. Although *Horn, Persson's* (2001a) critical

assumption is not fulfilled, our analysis yields the qualitatively identical results on concentration and cost levels in the post-merger market structure.

As was argued in the introduction, merger deals are not confined to offering the market value of a prospective partner as the potential outsider (the assumption used by *Kamien, Zang* 1990) or the share of profit leaving the initiator himself indifferent between participation in a merger or becoming an outsider (see, *Barros* 1998). *Espinosa, Inarra's* (2000) and *Thoron's* (1998) assumption that merger partners share profits equally applies only to a limited number of cases with “mergers of equals”. However, even in these cases, the shares of the participating firms are not necessarily converted one-to-one into shares of the merged entity. In the oil industry for example, Conoco and Phillips announced a “merger of equals” (see, *Weston* 2002, 70). By choosing the corresponding takeover price, any division of profits between prospective participants can be achieved in principle. The core concept requires no restriction on the division of future profits. Hence, it is applicable to a broader set of merger cases, those in the oil industry included.

6 Summary and Conclusion

This paper has analyzed mergers in the world oil industry by using a stylized oligopoly model. In the oil market, competitors produce with different unit costs. Firms therefore differ in their size. As mergers in this industry resulted from prolonged bargaining over the details of the contract, we modeled merger formation as a result of cooperative decisions. Under alternative assumptions on the size asymmetries of pre-merger firms, we derived the following conclusions on mergers in markets with asymmetric firms:

- Mergers lead to the maximal concentration allowed by antitrust laws.
- Mergers are driven by a hunt for size: Firms strive to increase their market share by the cost reduction attainable through a merger.
- For a large range of moderate cost differences, merged firms consist of rather asymmetric partners. If the extent of asymmetry is extreme, producers with inferior technology remain independent competitors in the post-merger market.

The results of our model are in accordance with the empirical evidence on the mega-mergers in the oil industry. In this industry, concentration due to merger formation

was considerable. As predicted by the model, efficient firms merged with less efficient competitors. Moreover, the efficiency gains were realized by merger formation raising participants' combined market shares and profits. Our model of cooperative merger decisions in a market with asymmetric competitors reproduces these facts. Its applicability, however, is not limited to the oil industry. Our conclusions carry over to all oligopolistic markets where firms differ in size and efficiency gains realized by a merger are sufficiently strong.

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