MARKET POWER VERSUS EFFICIENCY EFFECTS OF MERGERS AND RESEARCH JOINT VENTURES: EVIDENCE FROM THE SEMICONDUCTOR INDUSTRY

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Abstract—Merger control authorities may approve a merger based on an "efficiency defense." An important aspect in clearing mergers is that the efficiencies need to be *merger-specific.* Joint ventures, and in particular research joint ventures (RJVs), may achieve comparable efficiencies possibly without the anticompetitive (market power) effects of mergers. We empirically account for the endogenous formation of mergers and RJVs and provide evidence that at the semiconductor level, mergers and RJVs achieve dominant (net) efficiency effects. Our counterfactuals provide evidence that the efficiency gains caused by mergers would have been achieved by RJVs as well. Therefore, RJVs often represent viable alternatives to mergers from the consumer welfare point of view. At the more disaggregate level we find that the efficiency effects are larger in the microcomponents than in the memory market. This finding emphasizes the importance of market determinants (such as product differentiation and entry) having an impact on efficiency and market power effects.

I. Introduction

There is an extensive debate about whether a merger control system should take efficiency gains from horizontal mergers into account and balance these against the anticompetitive effects of mergers. In the United States, Europe, and Canada, antitrust authorities consider efficiencies under their merger guidelines. Many economists argue that competition authorities should take efficiency gains into account when examining merger cases. For example, Williamson (1968) highlighted the tradeoff between market power and efficiency effects. The U.S. Department of Justice and Federal Trade Commission Horizontal Merger Guidelines' revisions (1992 and 1997) clarify the approval of mergers based on the "efficiency defense." If firms can convince merger control authorities that the efficiencies generated by the merger more than outweigh the market power effects (and the former are passed on to consumers), then price may decrease and the merger may be cleared.[1] Under these circumstances, consumer welfare increases.

A further aspect in clearing mergers is that the efficiencies need to be merger-specific. That is, the efficiencies are "unlikely to be accomplished in the absence of either the proposed merger or another means having comparable anticompetitive effects." The U.S. guidelines explicitly mention joint ventures that may achieve comparable efficiencies possibly without the anticompetitive effects of mergers. However, very little is known about the extent to which the different types of cooperations achieve efficiency and/or market power, and there are no studies comparing the different modes of cooperation and assessing their substitutability.

Mergers can achieve the following efficiency effects: (i) firms can rationalize production from reallocating production across firms, also often referred to as short-run economies of scale; (ii) members can save on factor prices by gaining higher bargaining power; (iii) scope economies can be exerted because participants can eliminate duplicative efforts and firms can internalize the positive externalities of R&D through coordinating their R&D investments; (iv) firms can reorganize their managerial structure and avoid X-inefficiency; (v) long-run economies of scale can be gained through increasing inputs and by sharing risks associated with uncertain technologies and large sunk setup costs; and (vi) technological progress may shift the production frontier through diffusion of know-how, increasing R&D incentives, and adopting new technologies.[2]

Research joint ventures (RJVs) mostly achieve the last four efficiency effects.[3] Many articles and case studies of RJVs confirm the fact that the vast majority of research joint ventures focus (exclusively) on the development of new product technologies resulting in cost reductions. Examples are Link (1996) and Roeller, Siebert, and Tombak (2007), who investigated RJVs registered under the National Cooperative Research Act. Moreover, case studies by Chang and Podolny (2002), Silverman (2002), and Yoffie (2005) describe the investment in process innovation. The studies illustrate the nature and objective of R&D activities in the semiconductor industry, which is to improve the production process with regard to dust, vibration levels, size of the wafers, and so on. They emphasize that R&D activities result in cost reductions and efficiency increases. The objectives of RJVs reemphasize the fact that many of the product technologies result in cost reductions.[4]

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[1] Similar regulations were implemented by the European Commission's guidelines on the appraisal of horizontal mergers, February 5, 2004.

[2] See further Katz and Ordover (1990) and Jacquemin (1988).

[3] Note that the first (last) three effects are frequently considered as short-run (long-run) effects.

[4] A representative example of a research joint venture is given as follows: A research joint venture named after one of the participants, International Business Machines (IBM), was filed in January 1993. It had as its objective to undertake cooperative research, experimentation, and development activities in the field of fabrication processes suitable for future generations of semiconductors, including a prototype 256 megabit dynamic random access memory (256 MB DRAM). The RJV's activities included formulating and developing processes for fabricating 0.25

Not surprisingly then, the theoretical as well as the empirical literature on RJVs conclude that RJVs can be seen as an instrument to achieve efficiency gains and are beneficial to consumer welfare.[5] The crucial difference between mergers and RJVs is the behavior of firms in the product market. Whereas in RJVs firms make their production decisions independently, by definition firms act cooperatively in mergers.[6] A merger enables insiders to internalize the competitive externality in the product market and lower their production rate, inducing market price to rise (market power effect). Moreover, RJVs—in contrast to full mergers—do not reduce the number of firms in the industry. Thus, the danger for market power increases appears to be much less for RJVs than for mergers. Competition authorities are well aware of this fact and view RJVs with benevolence. For example, the U.S. Department of Justice enacted the National Cooperative Research Act of 1984 to enforce RJVs. This act protects registered RJVs under the antitrust laws, such that they cannot be considered illegal per se and must be judged by the antitrust rule of reason. Moreover, the act reduces the damage penalty in case of a violation of the antitrust laws.[7]

This study investigates and compares the impact of mergers and RJVs on market shares. We provide insights to what extent mergers and RJVs generate (net) efficiency effects.[8] In order to accurately evaluate the impact of mergers on prices, it is important to capture efficiency and market power effects and to balance those against each other. The degree of efficiencies required for price to decrease or welfare to increase depends on market characteristics such as merging firms' market shares, price elasticity of demand, degree of product differentiation, concentration, entry and exit, marginal costs, product improvements, and firms' conduct in the market. We implicitly derive the (net) market power and efficiency effects by comparing the pre- and postmerger equilibrium market shares. The advantage with implicitly evaluating the impact of mergers on prices is that we do not need to specify what type of efficiency effects have an impact. Moreover, we avoid using costs and elasticities that are frequently not available, not reliable, or difficult to measure, especially given the time constraint that court cases mostly face.

Prominent contributions on the effects of mergers are primarily based on numerical methods; see for example Berry and Pakes (1993), Gowrisankaran (1999), Dockner and Gaunersdorfer (2001), and Werden and Froeb (1994). However, empirical evidence on the effects of horizontal mergers or RJVs on cost efficiencies or market power is rather scant. Some case studies provided evidence that market power has been an important motivation in a number of industries. Examples are the tobacco industry (Burns, 1986), the railroad industry (Prager, 1992), the airline industry (Kim & Singal, 1993; and Peteraf & Reed, 1994), as well as the steel industry (Mullin, Mullin, & Mullin, 1995).[9] To date, there are only four studies that estimate the effects of mergers by using market shares.[10] Goldberg (1973) finds no significant change in market shares of 44 companies acquired in the 1950s and 1960s in the (median three and a half) years following the merger. Baldwin and Gorecki (1990) find significant declines in market shares for plants acquired in horizontal mergers. Mueller (1985), the most ambitious study of mergers and market share, uses Federal Trade Commission market share data for the 1,000 largest companies in 1950 and 1972. His results indicate that while control-group firms (selected on the basis of industry and size) retained 55% of their 1950 market share in 1972, firms undertaking horizontal mergers retained only 14% of their 1950 market share. Pesendorfer (2003) found that 74.1% of merging firms lost on market shares. One difficult, but important, aspect in analyzing mergers is to account for

micron semiconductor features, formulating and developing the design of a 256 MB DRAM, and fabricating prototypes for the experimental demonstration of such process technology and 256 MB DRAM design. The members of this RJV were International Business Machines, Siemens AG, and Toshiba Corp.

[5] Widely cited theoretical contributions are Brander and Spencer (1983), Spencer (1984), Katz (1986), D'Aspremont and Jacquemin (1988), and Kamien, Muller, and Zang (1992). See DeBondt (1997) for a survey on the literature on spillovers and innovative activity. Empirical studies predominantly analyzed the determinants of RJV formation, as well as their impact on R&D investment, and profitability. For the determinants of RJVs, see Cassiman and Veugelers (1999), Roeller et al. (forthcoming), Kaiser (2002), and Hernan, Marin, and Siotis (2003), among others, and for the effects, see Irwin and Klenow (1996), Branstetter and Sakakibara (2002), and Benfratello and Sembenelli (2002), among others.

[6] Note, however, that RJVs may increase the possibility of collusion in the product market (see Martin, 1995).

[7] In the European Union, the treatment of RJVs is generally favorable. Under certain restrictions, there is a block exemption for R&D cooperation if the combined market share of the cooperating firms is no greater than 25%. Even if a proposed R&D cooperation does not fall under the block exemption, it may nonetheless be permitted under Article 81(3) of the E.U. Treaty. There are also a number of government-sponsored or -supported R&D projects worldwide, such as Sematech (Semiconductor Manufacturing Technology) in the United States, VLSI (Very Large-Scale Integrated Circuits) in Japan, or the Framework Programmes in the European Union.

[8] A priori, one would expect that most efficiency effects can be attributed to RJVs. Indeed, antitrust treatment is more strict in the case of production joint ventures than in the case of RJVs; see the discussion in Jorde and Teece (1990) and Shapiro and Willig (1990).

[9] For more empirical studies analyzing the effects of mergers on profitability or sales growth, see, among others, Mueller (1980), Ravenscraft and Scherer (1987), and Gugler et al. (2003). Pesendorfer (2003) investigates the U.S. paper and paperboard industry and finds that the efficiency of the majority of acquiring firms increases following an acquisition. Ivaldi and Verboven (2002) study a merger between Volvo and Scania in the truck industry. For an overview of contemporary empirical merger analysis, see Baker (1997). For recent theoretical contributions, see Toxvaerd (2004, 2005).

[10] The evaluation of market shares has several significant advantages. Among others, it allows implicitly deriving the efficiency and market power effects without using cost data. Cost data, such as fixed or sunk costs, are difficult to disentangle or to explicitly refer to a certain industry, like the semiconductor industry. For example, many semiconductor firms like IBM, Siemens, and Toshiba are prevalent in many industries. Therefore, it is rather difficult to refer part of their fixed costs to the semiconductor industry. Another advantage from inferring the efficiencies from the reallocation of pre- and postmerger equilibrium market shares is that one avoids solving for equilibrium quantities in closed-form solutions, which is a difficult task, even for very simple oligopoly models.

endogeneity problems in merger formation. Studies that treat mergers endogenously are Kamien and Zang (1990), Berry and Pakes (1993), Gowrisankaran (1999), and Gowrisankaran and Holmes (2004). We are not aware of any study analyzing the effects of RJVs on market shares.

We analyze and discuss that most commonly used models of oligopoly—for different types of firm behavior and market characteristics—predict that if the market power effect outweighs any efficiency gains due to a merger, the market share of the merged firm drops relative to the sum of the market shares of acquiring and target firm before the merger, and market price increases. In contrast, if a merger generates sufficient cost synergies to outweigh the market power effect, the merging firms' market share will increase, inducing price to decline and consumer welfare to increase. We use this robust prediction from economic theory as a guide for our empirical analysis.

We empirically analyze the efficiency versus market power effects of mergers and RJVs in one of the most important high-technology industries, the semiconductor industry, during the period 1989 to 1999. This industry is characterized by a high degree of process and product innovation as well as high capital intensity. For example, the semiconductor companies rank highest in spending R&D as a percentage of sales (13%), outranking the drug, computer, and other industries. The number of U.S. patent applications has increased by approximately 16% every year, from 2,196 in 1989 to 6,036 in 1996 (see Hall, Jaffe, & Trajtenberg, 2001). The worldwide total revenues of the semiconductor industry reached $168.9 billion in 1999, compared with $52.7 billion in 1989.

In our empirical analysis we apply dynamic panel data techniques taking endogenous merger formation into account. The empirical analysis proceeds in three steps. First, we follow previous studies and estimate a standard OLS merger/RJV effects regression by the introduction of dummy variables. Second, to account for the endogeneity of the merger/RJV formation, we estimate an endogenous switching model. In its first step, this model isolates the exogenous determinants of mergers/RJVs, such as the size and innovativeness of the firm, as well as endogenous factors, that is, the predicted market shares under the different regimes. Its second step, the effects regression, provides consistent estimates of the net effects of the mergers/RJVs on market shares, while accounting for endogenous selection. Finally, we apply these estimation procedures not only to the four-digit (3344 NAICS) semiconductor industry, but also to the six-digit (334418 NAICS) memory and the six-digit (334413 NAICS) microcomponents industries.

We find that mergers at the semiconductor level raise the market share of participating firms as do RJVs, providing evidence that efficiency effects dominate market power effects for both types of cooperation. RJVs may often represent viable alternatives to mergers from the consumer welfare point of view. It is interesting to note, however, that mergers achieve efficiencies sooner (for example, achieving short-run economies of scale through the elimination of duplicative efforts, rationalization of production, reduction of managerial slack, and gaining more purchasing power), whereas RJVs generate efficiencies in the longer term (for example, achieving long-run economies of scale and improving technological progress). At the more disaggregate level we can still confirm the finding from above. We find that the efficiency effects are larger in the microcomponents market than in the memory market. This finding emphasizes the importance of market characteristics: the microcomponents industry is characterized by more differentiated products and more net entry, resulting in lower market power effects and therefore higher net efficiency gains. On the other hand, firms in the memory market presumably impose higher negative externalities on each other, resulting in larger market power effects that require larger efficiencies for prices to decline.

The paper is structured as follows. Section II describes our data set on mergers and RJVs in the semiconductor industry. In section III, after discussing the most common models in industrial organization with respect to their predictions on market shares postmerger, we apply the empirical analysis. We conclude in section IV. In the appendix, we show that the results of Farrell and Shapiro (1990) hold up when allowing for differentiated products.

II. Industry Description and Data

Firms' annual market shares in the semiconductor industry are provided by Gartner Group. This company collects production data on an annual basis for each firm operating in the semiconductor industry. Thus, we cover the whole population of firms and do not need to rely on accounting information to infer market shares. The data source for research joint ventures and mergers is the Thompson Financial Securities Database. This database includes alliances with a deal value of more than $1 million, ensuring that the overwhelming majority of mergers and research joint ventures is covered.

The semiconductor industry is one of the most important high-technology industries. According to Jorgenson (2001), the semiconductor markets are especially important because their prices have significant impact on many other downstream industries, such as the computer, automobile, and communications industries. Semiconductors are mainly used as inputs for the computer industry (45% of its sales), consumer electronics (23%), and communications equipment (13%).

The semiconductor industry is characterized by worldwide selling companies mainly from the United States, Japan, Europe, and other countries in the Asia-Pacific region, with a 39.6%, 40.1%, 8.5%, and 11.8% market share, respectively (see Dataquest, 1999, and table 1A). For this and other reasons (such as worldwide production sites, price

TABLE 1A.—INTERNATIONAL PRODUCTION RATES IN THE SEMICONDUCTOR INDUSTRY

	U.S.	Japan	Europe	Other
Semiconductor	39.6%	40.1%	8.5%	11.8%
Memory	24.6%	43.5%	3.7%	28.2%
Microcomponents	70.1%	23.5%	4.1%	2.2%

TABLE 1B.—REVENUES AND MARKET SHARES IN THE SEMICONDUCTOR INDUSTRY

Years	Revenues ($ millions)	Herfindahl Index	No. of Active Firms	No. of Patents
1989	52,751	404	132	4,372
1990	54,578	383	140	4,914
1991	59,341	391	132	5,697
1992	64,774	386	157	5,769
1993	85,328	395	153	6,129
1994	109,402	402	154	8,032
1995	152,875	365	172	9,831
1996	143,402	430	158	11,068
1997	150,911	401	172	14,158
1998	138,747	475	188	13,668
1999	169,311	454	167	—
Average	107,402	408	157	8,363.8

transparency, intermediate good), we assume that the relevant market is the world.

The semiconductor market consists of memory chips, microcomponents, and other components such as logic, discrete, and optical devices. The memory market consists of dynamic random access memory chips; static random access memory chips; nonvolatile memory chips; erasable, programmable read-only memory chips, electrically erasable, programmable read-only memory chips; flash memory chips; mask read-only memory chips; and other memory chips. The microcomponents market consists of microprocessors, microcontroller units, microperipherals, and digital signal processors.

There are a variety of sources supporting the argument that the memory market is characterized by less differentiated products as well as a more intense price competition. One example is a recent article in the *Financial Times* (2005) about the decision by Phillips and Siemens (Infineon) to sell or spin off their memory segment. Moreover, Intel decided to exit the memory (DRAM) segment because price competition toward Japanese firms became too intense, see the case study by Cogan and Burgelman (1990). Other studies (such as Dick, 1994) investigate the dumping case that was mostly concentrated on the memory chip market. The dumping case highlights the tougher price competition in the memory market. The case studies by Chang and Podolny (2002) and Yoffie (2005) describe the intense price competition in the memory industry quite nicely. Moreover, memory chips are also frequently considered as a commodity good, see, for example, Cabral and Leiblein (2001) who state: "While new process technology can be used in the production of different types of semiconductors (i.e., memories, microprocessors, analogue integrated circuits, etc.) these submarkets have different market structures. For instance, while memory devices are frequently considered as commodities, there is significant product differentiation within the microprocessor industry." Referring to other sources, such as *The Economist* (June 13, 1998) and the Microprocessor Report (February 2000), Cabral and Leiblein (2001) conclude that "the memory industry is perceived to be quite competitive, the microprocessor industry is perceived to be oligopolistic." The international production rates vary drastically depending on the type of semiconductor component (see table 1A).[11] Tables 1B–D display statistics on industry revenues and number of firms in the semiconductor industry as a whole, as well as the memory and the microcomponents segments, of all firms producing for at least one year in the semiconductor industry worldwide from 1989 to 1999. In the 1990s, competition in the semiconductor industry increased dramatically, brought on by the larger number of firms, which rose from 132 in 1989 to 188 in 1998 (see table 1B). The semiconductor industry generated annually $107,402 million on average from 1989 to 1999. The Herfindahl-Hirschman index is around 400, with the HHI being much larger in the microcomponents (more than 2,000 in 1998 and 1999) than in the memory segment.[12]

The memory and the microcomponents markets make up for 50% of the sales in the semiconductor industry, with each generating between $25 billion and $30 billion, on average. The microcomponents segment grew much faster than the memory segment over the period of investigation: while the share of the memory segment in total semiconductors fell from 27.5% in 1989 to 20.4% in 1999, the share of the microcomponents segment increased from 14.8% to 33.7% during the same time period.

On average, 54 firms operated in the memory and 75 firms in the microcomponents segment in a given year during the 1989–1999 period. Again time trends are interesting: while the number of firms stayed nearly constant in the memory segment, the microcomponents segment is characterized by positive net entry over the 1989–1999 period (the number of firms increased from 51 in 1989 to 88 in 1999). Patent intensity is higher in the memory than in the microcomponents market (see tables 1C and 1D). Incremental process innovations occur more frequently in the memory segment, creating a higher density of the patent thicket. This fact is in line with the patent thicket literature;

[11] For more industry descriptions, see Irwin and Klenow (1994, 1996), Flamm (1996), and Gruber (1992, 1996).

[12] According to the U.S. merger guidelines, mergers are generally not challenged when the HHI is smaller than 1,000, when the HHI is between 1,000 and 1,800 and the merger will increase the HHI by less than 100 points, or when the HHI is larger than 1,800 and the merger will increase the HHI by less than 50 points. All other mergers might be challenged.

TABLE 1C.—REVENUES AND MARKET SHARES IN THE MEMORY INDUSTRY

Years	Revenues ($ millions)	Herfindahl Index	No. of Active Firms	No. of Patents
1989	14,502	637	49	1,850
1990	12,107	611	52	1,992
1991	12,668	602	52	2,336
1992	15,425	568	59	2,281
1993	23,274	563	57	2,567
1994	33,394	594	55	3,347
1995	55,842	616	55	3,791
1996	38,480	615	52	4,409
1997	31,324	611	55	5,635
1998	24,438	641	54	4,777
1999	34,591	804	48	—
Average	26,913	624	54	3,298.5

TABLE 1D.—REVENUES AND MARKET SHARES IN THE MICROCOMPONENTS INDUSTRY

Years	Revenues ($ millions)	Herfindahl Index	No. of Active Firms	No. of Patents
1989	7,789	983	51	358
1990	9,575	1,145	54	439
1991	11,763	1,241	59	441
1992	14,315	1,356	72	520
1993	19,970	1,620	77	532
1994	26,393	1,532	79	675
1995	35,293	1,434	83	951
1996	42,331	1,746	84	1,052
1997	51,360	1,803	87	1,252
1998	49,316	2,141	92	1,270
1999	57,018	2,176	88	—
Average	29,557	1,562	75	749

TABLE 2.—RESEARCH JOINT VENTURES AND MERGERS: NUMBER OF DEALS

	Semiconductor		Memory		Microcomponents	
Years	RJVs	Mergers	RJVs	Mergers	RJVs	Mergers
1989	13	4	2	2	7	0
1990	20	5	6	2	8	3
1991	35	4	5	0	5	2
1992	29	10	7	3	15	3
1993	36	4	8	2	11	2
1994	39	7	11	5	10	5
1995	24	12	10	4	0	6
1996	17	7	3	0	2	2
1997	18	11	3	1	1	7
1998	13	19	2	5	4	10
1999	0	28	0	10	0	13
1989–1999	244	111	57	34	63	53

TABLE 3A.—MEAN SEMICONDUCTOR MARKET SHARES OF DIFFERENT GROUPS OF FIRMS FROM $t-1$ TO $t+3$

	$t-1$	t	$t+1$	$t+2$	$t+3$
RJV firms	3.15	3.09	3.25	3.46	3.58
Mergers:					
Acquiring firms	2.46	2.82	3.34	3.75	3.71
Target firms	0.30	-	-	-	-

TABLE 3B.—MEAN MEMORY MARKET SHARES OF DIFFERENT GROUPS OF FIRMS FROM $t-1$ TO $t+3$

	$t-1$	t	$t+1$	$t+2$	$t+3$
RJV firms	4.10	4.16	4.22	4.37	4.48
Mergers:					
Acquiring firms	1.51	2.22	2.28	2.33	2.29
Target firms	0.90	-	-	-	-

TABLE 3C.—MEAN MICROCOMPONENTS MARKET SHARES OF DIFFERENT GROUPS OF FIRMS FROM $t-1$ TO $t+3$

	$t-1$	t	$t+1$	$t+2$	$t+3$
RJV firms	5.37	5.51	5.57	5.62	5.98
Mergers:					
Acquiring firms	5.30	6.03	6.22	6.43	6.67
Target firms	0.70	-	-	-	-

see, for example, Hall and Ziedonis (2001) and Shapiro (2001).[13]

A higher competitive pressure increased the technological pace, resulting in shorter life cycles over time; see Jorgenson (2001). As the semiconductor industry is heavily capital intensive, strategic alliances like mergers and RJVs became increasingly important during the 1990s. Prominent examples are Sematech, VLSI, and JESSI (Joint European Submicron Silicon), consortia established by the United States, Japan, and Europe to promote the technological pace and the development of semiconductor chips; see also Song (2005). Table 2 presents statistics on the number of completed deals. There were 111 horizontal mergers and 244 RJVs (actually RJV years) during the 1989–1999 period. A research joint venture is defined to operate in the semiconductor industry if the main objective of the research refers to the NAICS 3344. On average, 2.92 firms participate in an RJV.[14] A similar number of RJVs have been formed in the memory and the microcomponents industries (57 and 63, respectively), while the number of mergers that have taken place in the microcomponents industry is much higher (with 53) than in the memory industry (with 34).

Tables 3A–C present summary statistics on market shares of firms participating in mergers and RJVs for the semiconductor, memory, and microcomponents industries. As shown in table 3A, acquiring firms in a merger have a mean market share in the semiconductor industry of 2.5% in the year before the merger, while their targets are considerably smaller (mean 0.3%). The average (median) market share of RJV firms is 3.15%.[15] Both groups of firms are able to expand their market shares until $t+3$. Tables 3B–C reveal

[13] The observation that the number of patents in the memory market is far above the number of patents in the microcomponents market is consistent with the existing literature. For example, Cabral and Leiblein (2001) mention: "memory device manufacturers are 2.9 times more likely to adopt the new process technology than nonmemory manufacturers. This finding is consistent with arguments suggesting that product market characteristics affect the new technology investment as well as anecdotal evidence suggesting that it is both easier and less costly to introduce new semiconductor process technologies in memory devices due to their relatively simple product designs" (e.g. Flamm, 1993; Gruber, 1994).

[14] Baumol (2001) states that the potential beneficial effects of RJVs increase with the number of participating firms, since technological spillovers increase.

[15] This is consistent with the notion by Irwin and Klenow (1996) that larger firms gain more from RJVs and from R&D knowledge spillovers.

that RJV firms experience increases in market shares in both subsegments, while merging firms' market shares increase only in the microcomponents segment postmerger.

III. Theory and Empirics

A. *Theoretical Considerations*

As horizontal mergers reduce the number of competing firms in the industry, the common view is that mergers tend to increase price. For evaluating the impact of mergers on welfare, we need to obtain a thorough understanding of how market power and efficiency effects impact market shares and prices. One feature common to most models of industrial organization analyzing mergers is that increased market shares postmerger is a sign of increased efficiency of merging firms, or alternatively that the efficiency effects of the merger outweighed any market power effects. Hence, we implicitly derive the efficiency effects necessary to decrease prices by comparing the pre- and postequilibrium output or market shares. In what follows we will examine the robustness of price and market share effects of horizontal mergers with respect to various modes of competition, such as quantity or price-setting firms as well as homogenous and differentiated goods.

In a noncooperative Cournot model with homogeneous goods, Stigler (1950) identified the effect at work that mergers are more profitable for firms outside the merger, the business-stealing effect. Insiders contract output to reduce the negative externality, whereas outsiders expand output but by less. Consequently, industry output falls and price increases. Salant, Switzer, and Reynolds (1983) assume constant average costs, symmetric firms, and linear demand. They found that mergers need to encompass more than 80% of the market in order to gain from market power effects. Farrell and Shapiro (1990) use general demand and cost functions and show that if a merger generates no synergies, then it causes price to rise. For any given output by outsiders, insiders will contract their aggregate output when they merge because they will then internalize the inframarginal losses that they impart to each other. Thus, the output of insiders contracts and the output of outsiders expands (outputs are strategic substitutes). The output contraction of insiders outweighs the expansion of outsiders, thus, a merger that generates no synergies causes the price to rise. Since insider output contracts and outsider output expands, insider market shares decline. For a merger to lower price, considerable economies of scale or learning effects are required. The merged entity must enjoy substantially lower marginal costs than did its constituent firms for efficiency effects to overcompensate market power effects and induce prices to fall. Since reaction functions imply smaller responses in magnitude for rivals than for insider initial changes, it follows that whenever market shares of insiders increase, efficiency effects outweigh market power effects, and prices decline. Thus, a sufficient condition for price to decline postmerger is that insider market shares increase due to sufficient efficiency effects of the merger. The efficiency effects required to lower price and increase market shares postmerger are higher if the merger changes the behavioral mode in the industry from Cournot to something more collusive. They also show that a lower industry elasticity of demand requires greater efficiency effects in order for prices to fall.

The semiconductor industry is, however, better described by differentiated products. Hence, in the appendix we extend the homogenous Cournot framework by explicitly accounting for product differentiation. We show that the main results by Farrell and Shapiro (1990) on market shares and prices hold in a noncooperative Cournot model with differentiated goods as well. The main results are as follows: As products become differentiated, insiders impose fewer negative externalities on each other premerger and consequently reduce their output by less postmerger. Thus, insiders gain less on market power, inducing a lower increase in industry price. Therefore, lower efficiency gains are needed for prices to decline in more differentiated product markets.

Another model explicitly accounting for product differentiation is Salop's (1979) circular city model. In the following we show that the same qualitative predictions will hold regarding the price and market share effects of mergers as discussed above.[16] Suppose there are three firms at the outset located equidistantly at 12 (firm 1), 4 (firm 2), and 8 (firm 3) hours around the Salop circle, with indifferent consumers located at 2 (between firms 1 and 2), 6 (firms 2 and 3), and 10 (firms 3 and 1) hours. If firms 1 and 2 merge and the efficiency effect outweighs the market power effect, they reduce their prices and the indifferent consumers next to firm 3 (at 6 and 10 hours) move closer to firm 3. Since the consumers between firms 1 and 2 still buy from them, the market share of the combined firm 1 and 2 increases. Conversely, if the market power effect is larger than the efficiency effect, merging firms increase their prices and the indifferent consumers next to firm 3 move closer to firms 1 and 2. Even if all consumers between firms 1 and 2 still buy from them, the market share of the combined firm 1 and 2 decreases. The same logic applies to RJVs. The same logic also applies to mergers if merging parties withdraw one product from the market or even more so if merging firms/RJV firms invent new products. Suppose firms 1 and 2 merge and withdraw firm 2's products. *If* we nevertheless observe an increase in the combined market share of the surviving entity, it *must* be the enormously enhanced efficiency and reduced prices that let indifferent consumers move closer to firm 3. It could, however, be that although the market share of the combined firm decreases, the efficiency effect for product 1 is larger than the market power effect for it but too small to overcompensate the market

[16] See also Levy and Reitzes (1992) for a model of localized competition to study the price effects of mergers.

share losses due to the withdrawal of product 2 (which is of course another market power effect). Nevertheless, we would correctly infer that the market power effects were greater than the efficiency effect. If merging/RJV firms introduce new products thereby increasing their market shares, consumers are most likely to be better off and our predictions are correct.

The only case where other reasons may account for market share movements occurs when market conduct changes due to the merger, for example, if ex ante firms in Cournot competition merge and become Stackelberg leaders postmerger. Then the combined market share of insider firms may increase due to other than efficiency reasons, namely due to the strategic advantage the market leader now has over followers. Nevertheless, even in this case consumers may win, since Stackelberg prices (quantities) are lower (higher) than Cournot variables ceteris paribus.

Although we believe that quantity-setting models better describe the semiconductor industry than price-setting models (for example, capacity decisions are among the most important managerial choices), we briefly discuss price-setting models and show that the price and market share effects follow the same routine as in quantity-setting models.

Deneckere and Davidson (1985) study Bertrand competition with differentiated products. A qualitative difference to Cournot is that in Bertrand, reaction functions are upward sloping. Thus, the reaction of outsiders reinforces the initial price increase that results from the merger. They show that prices increase after a merger, at least in their linear demand model with symmetric competition and abstracting from synergy effects. With synergy effects, an increase in market shares implies that efficiency effects have been even larger in Bertrand than in Cournot to overcompensate the enlarged market power effect in Bertrand competition.

Werden and Froeb (1994) use the logit model for an industry with symmetric product differentiation. They show that the logit demand model results in higher prices after a merger that generates no cost savings. The magnitudes of the price increases are dependent on the market shares of the different products. The prices of the merging firms' products (weighted by their sales) increase by more than any of the competing firms' prices. Moreover, significant savings in marginal costs, below the lowest marginal cost of either partner involved in the merger, are required for prices to drop after the merger. It follows that the same qualitative predictions concerning market shares can be made for the logit model as for the simple Cournot model.

Dynamic merger studies are very rare. Ravenscraft and Scherer (1987) and Fauli-Oller (2000) realized that mergers occurred in waves. Tombak (2002) focuses on the sequence of horizontal mergers between asymmetric firms in order of the size of the targets. He finds that the most efficient firm will merge and purchase firms in descending order of efficiency. Pesendorfer (2005) studies merger incentives in a dynamic model (repeated game) when mergers and entry are treated endogenously. He shows that the result by Levin (1990) and Farrell and Shapiro (1990)—mergers in nonconcentrated industries raise welfare—may not hold anymore. Firms are willing to carry the temporary burden of an acquisition provided the merger leads to additional mergers in the future. Nevertheless, the interrelations between market share developments postmerger, prices, and total welfare are unaltered.

To summarize, the effects of mergers on market shares give very similar information as a study of prices (see also Roeller, Stennek & Verboven, 2001, p. 47). A robust prediction is that if all firms have identical and constant unit costs and mergers achieve no efficiency gains, most theories of oligopoly imply that the market share of the merged firm will drop and the price will increase. If the merger generates sufficient variable cost synergies, the merging firms may increase their market share. Hence, mergers that increase insider market shares reduce the price level, and mergers that decrease market shares increase the price level. Another robust statement for Cournot and Bertrand competition is that less differentiated markets require higher efficiency gains in order to reduce price. Thus, one way to quantify the market power versus efficiency effects of mergers and RJVs is to compare premerger with postmerger market shares. If the sum of the market shares of insiders in a merger or RJV increases, the efficiency gains created by the merger or RJV overcompensate the (potential) market power effects, and price will necessarily decline. This holds true for any degree of product differentiation in the market (see also the appendix). Therefore, in what follows we analyze the impact of mergers or RJVs on market shares.

B. A Dummy Variable Approach

In a first step, we estimate the following dummy variable model:

$$sc_{i,t_i} = a_c + b \cdot sc_{i,t_i-x-1} + \sum_{y=0}^{x} m_y \cdot Merger_{i,t_i} - y + \sum_{y=0}^{x} r_y \cdot RJV_{i,t_i-y} + \varepsilon_i,t_i \qquad (1)$$

for $i = 1 \ldots 263$ and $t_i = 1989 \ldots 1999$ (at most). We use an unbalanced panel of the population of semiconductor firms, that is, if firms start production in the semiconductor industry they enter the panel, if firms exit the industry they also exit our panel and become missing observations. If there is no merger, sc_{i,t_i} is simply the market share of firm i in period t_i. If there is a merger, sc_{i,t_i} is the sum of the market shares of the acquiring and acquired company, that is, the combined market share, before the merger, and the market share of the acquiring firm (the surviving entity) after

TABLE 4.—RESULTS FOR EQUATION (1)

Dependent variable: sc_{i,t_i}	1		2		3		4	
	x = 0		x = 1		x = 2		x = 3	
Equation	Coef.	*t*-value	Coef.	*t*-value	Coef.	*t*-value	Coef.	*t*-value
United States	0.00013	0.92	0.00027	1.06	0.00046	1.27	0.00068	1.27
Europe	0.00007	0.29	0.00007	0.06	−0.00003	−0.03	−0.00003	−0.03
Japan	−0.00138	−6.24	−0.00302	−7.75	−0.00592	−7.34	−0.00595	−7.34
South Korea	0.00125	3.31	0.00216	3.30	0.00357	3.65	0.00547	4.18
sc_{i,t_i-x-1}	0.93022	19.76	0.91129	12.47	0.90007	8.16	0.88813	7.47
$Merger_{i,t_i}$	0.00028	0.56	0.00384	5.31	0.00522	7.06	0.00505	5.17
$Merger_{i,t_i-1}$			0.00169	2.34	0.00326	5.15	0.00439	6.46
$Merger_{i,t_i-2}$					−0.00014	−0.13	0.00191	2.72
$Merger_{i,t_i-3}$							−0.00098	−0.66
RJV_{i,t_i}	0.00009	0.27	−0.00020	−0.38	−0.00085	−1.04	0.00069	0.64
RJV_{i,t_i-1}			0.00076	1.45	0.00117	1.53	0.00087	0.86
RJV_{i,t_i-2}					0.00114	1.46	0.00240	2.39
RJV_{i,t_i-3}							0.00124	2.23
Constant	−0.00010	−0.45	−0.00037	−1.00	0.00003	0.06	0.00059	0.87
R^2-adjusted	0.850		0.862		0.884		0.891	
No. obs.	1,433		1,185		985		807	
Tests:								
Sum merger coefs.	0.00028	0.56	0.00553	5.58	0.00834	7.25	0.01037	7.31
Sum RJV coefs.	0.00009	0.27	0.00056	0.74	0.00146	1.47	0.00520	3.33

Note: Estimation method is 2SLS with market share instrumented by patents accumulated in the semiconductor industry.

merger. The parameters a_c are country/country group dummies for the United States, Europe, Japan, and South Korea. To test for market power and efficiency effects of mergers and RJVs, we investigate the change of insiders' and outsiders' market shares by using a dummy variable approach: we define $Merger_{i,t_i-y} = 1$, if firm i took over another firm in period $t_i - y$, and 0 otherwise, or by analogy, $RJV_{i,t_i-y} = 1$, if firm i participated in a research joint venture in period $t_i - y$, and 0 otherwise.[17] The inclusion of the lagged dependent variable sc_{i,t_i-x-1} ensures that the coefficients on the dummy variables measure changes in market shares. Equation (1) is estimated separately for the different lag parameters $x = 0, 1, 2, 3$. Thus, we determine the impact of mergers and RJVs up to three years after the deals. For example, the total effect of a merger on market share undertaken in period t three years later is $\sum_{y=0}^{3} m_y$. A positive sum of coefficients on the dummy variables indicates that the efficiency effect dominates the market power effect.

Since equation (1) is an autoregression, market shares should be stationary to avoid spurious regressions. Unit root tests indeed indicate that the stochastic market share data-generating process is stationary. Dickey-Fuller as well as augmented Dickey-Fuller tests reject the null hypothesis that market share contains a unit root. The *t*-values for the coefficient of the lagged dependent variable in regressions of the first difference of market share on market share lagged by one period range from −5.45 (pooled OLS), −6.12 (OLS fixed effects), to −6.26 (IV method of Anderson and Hsiao, 1982).[18] Thus, these values are above the 1% critical values as, for example, tabulated by Fuller (1976). Since market shares are $I(0)$, least squares provides $\sqrt{T}$ consistent estimates for the parameters of interest, however these estimators will be biased for small T. In particular, the coefficient on the lagged dependent variable will be biased downwards, toward 0. Therefore, we instrument sc_{i,t_i-x-1} by the stock of patents in the semiconductor industry by firm i as of year $t_i - 1 - x$ and estimate by 2SLS. The firm's patents stock is supposed to capture efficiency differences between firms and appears to be a suitable instrument, since the simple correlation coefficient with market share is 0.61 ($p = 0.001$) and the correlation coefficient with the residuals of equation (1) is near 0.

Table 4 reports the regression results for equation (1). As shown, mergers significantly increase the market share of the combined entity relative to premerger levels in the semiconductor industry. The cumulative effect of mergers on the market share of insiders is +1.0 percentage points ($t = 7.31$) three years after the merger ($x = 3$). The results also indicate that RJVs significantly increase the market shares of participating firms. RJVs significantly affect market shares in the second and third years after formation (see columns for $x = 3$). The cumulative effects of RJVs on the market shares of each participating firm is 0.52 percentage points with a *t*-value of 3.33. As 2.92 firms form an RJV on average, the cumulative increase in market share is 1.5 percentage points on average three years after the forma-

[17] It should be noted that there are only two firm-years where there is both a merger and an RJV. Thus, multicollinearity among the merger and RJV dummies is no problem.

[18] The method of Anderson and Hsiao (1982) involves first-differencing to account for unobserved firm-level heterogeneity and then instrumenting $\Delta y_{i,t-1}$ by $\Delta y_{i,t-2}$ and/or $y_{i,t-2}$, which are valid instruments since they are correlated with $\Delta y_{i,t-1}$ but uncorrelated with $\Delta \mu_{i,t}$. The Anderson and Hsiao estimator is consistent when $N \to \infty$ or $T \to \infty$ or both.

tion.[19] The country dummy variables (jointly significant beyond the 1% level) indicate that Japanese semiconductor firms significantly lost market shares relative to all other countries depicted during the 1990s (they lost on average 0.14% per annum), while South Korean semiconductor firms significantly improved their relative market position (on average they gained 0.13% per annum). U.S. and European semiconductor firms were about equally successful in retaining their market share. This is consistent with anecdotal evidence.

It is worth putting our results into perspective. We estimated that mergers in the semiconductor industry increased the market share of insider firms by 1.0 percentage points. Since each merger involved exactly two firms, the average per-participant effect is around 0.5 percentage points. Each RJV increased the cumulative market share of participating firms by around 1.5 percentage points (2.92×0.52), the difference between the 1.0 and 1.5 percentage points being statistically significant ($t = 2.83$). In this sense we conclude that RJVs generate a larger market share effect than mergers. However, the per-participant effect of the merger or RJV is approximately the same (0.5 percentage points). For participating firms, therefore, mergers and RJVs deliver the same cost efficiencies that are passed on to consumers. While we cannot assure that RJVs do not lead to collusion in the product market, we can state that the efficiency effects of RJVs more than outweigh any potential anticompetitive effects. The same is true for mergers. Our results imply that mergers *and* RJVs raise the market shares of participating firms. This points to an efficiency-increasing role of mergers and RJVs in the semiconductor industry.

Thus from the view of competition policy, stressing consumer surplus, RJVs may be preferred to full mergers, since one RJV increases market shares by 1.5 percentage points compared with one merger increasing market shares by 1 percentage point, and not reducing the number of firms in the market. However, from a total welfare view, no rankings are possible and they may be equivalent, since the profitability of the two types of cooperation could differ. Moreover, the determinants of mergers and RJVs may differ (see below), giving rise to situations where only one or the other form of cooperation is feasible.

Equation (1) is robust to the following modifications: (i) Our dummy variable methodology treats each RJV-year symmetrically, however some firms form more than one joint venture in a given year. If we include the number of RJVs formed in a given year as a count variable, the results are virtually identical to the ones obtained by introducing dummies. (ii) Results are also nearly identical if we estimate equation (1) by OLS instead of 2SLS or in first-difference form instead of including a lagged dependent variable. (iii) Finally, the results are qualitatively identical if we include firm fixed effects and estimate the dynamic panel by the IV method of Anderson and Hsiao (1982). RJVs and mergers continue to significantly increase the market shares of firms in the semiconductor industry.

[19] The median number of participants in RJVs is two. In 30.7% of RJVs there are three or more participants; 15% (9.7%) of RJVs involve more than four (five) firms.

C. *Endogenous Switching*

The main criticism of merger or RJV studies is that the endogeneity of the merger/RJV formation is not accounted for. If the errors in the selection equation and the market share equations are correlated, we get a simultaneity bias in our parameters of interest. For example, it may happen that mergers or RJVs are formed among more productive firms, which will—even without merger/RJV—gain on market share in the future. A comparison with outsider firms may indicate increasing market shares due to the merger/RJV, which is in fact due to the higher productivity and not related to the merger. In other words, the within-firm variation in merger or joint venture activity may be (partially) endogenously determined, and merger or RJV years may be a self-selected sample of observations. We account for endogeneity by estimating the following endogenous switching model, which asks to what extent the firms were able to retain their premerger (pre-RJV) market shares (see Mueller, 1985; the endogenous switching model is in line with Lee, 1978):

$$I^*_{i,t_i} = b_0 + b_1(\widehat{sc_{m,i,t_i} - sc_{nm,i,t_i}}) + b_2 \cdot X_{i,t_i} - v_{i,t_i}, \tag{2}$$

$$sc_{m,i,t_i} = a_{m,0} + a_{m,1} \cdot sc_{m,i,t_i-x-1} + \varepsilon_{m,i,t_i}, \tag{3}$$

$$sc_{nm,i,t_i} = a_{nm,0} + a_{nm,1} \cdot sc_{nm,i,t_i-x-1} + \varepsilon_{nm,i,t_i}. \tag{4}$$

Equation (2) is a selection equation that determines whether the firm takes over another firm in year t_i (forms an RJV). Note that firm *i*'s decision to merge/form an RJV depends on the comparison of the expected market shares when it cooperates (merges) versus when it does not cooperate (merge). Variable X is a set of exogenous variables determining merger/RJV formation. Variables are defined as before, with the subscript m referring to merging observations and subscript nm referring to nonmerging observations. Variables for the RJV estimations are determined by analogy.

If $I^*_{i,t_i} > 0$, the firm forms a merger (RJV), and the market share is determined by equation (3); otherwise its market share is determined by equation (4). There are two problems with estimating the set of equations. First, we have a missing data problem. We only observe the market share given the chosen regime, that is, we observe sc_{m,i,t_i} if $I^*_{i,t_i} > 0$, or sc_{nm,i,t_i} otherwise, but never both. Secondly, we have a simultaneity problem, and OLS estimation of equations (3) and (4) gives inconsistent estimates, because $E(\varepsilon_{m,i,t_i}|I^*_{i,t_i} > 0) \neq 0$ and $E(\varepsilon_{nm,i,t_i}|I^*_{i,t_i} \leq 0) \neq 0$. Thus, we substitute equations (3) and (4) into equation (2), and estimate the reduced-form probit by ML. From this estimation, we retrieve the inverse Mills ratio and estimate equations (3) and

(4) consistently with 2SLS.[20] Using these estimates to calculate the predicted difference in market shares for the two regimes, plugging those into the "structural" probit equation (2), and estimating the whole system by ML, one gets consistent estimates of the *a*'s and *b*'s. The parameters of main interest are $a_{m,1}$ and $a_{nm,1}$, that is, the percentage of market share retained of merging versus nonmerging firms (RJV forming versus non-RJV forming firms) after *x* years, taking into account the endogenous nature of merger/RJV formation.

The set of exogenous drivers of merger/RJV formation include the following variables, which we group into firm (i–iii), time (iv), and country specific (v). All of them are proxies in one form or the other of the costs and benefits of undertaking a merger or being a member in an RJV.

(i) The number of accumulated patents of firm *i* until period *t* (*Patents*): The efficiency with which firms innovate is likely to be a significant determinant of merger or RJV formation. For example, absorptive capacity plays an important role in the R&D process (see Cohen & Levinthal, 1989). In an RJV (the "make" decision), firms may better capture spillovers from the other participating firms, the more patents they possess, if these proxy for absorptive capacity. Thus complementary aspects of the innovation process may prevail in RJVs (positive sign prediction). In a merger (the "buy" decision), on the other hand, R&D capacity may actually be brought "in house" to rectify own shortcomings (negative sign prediction). See Blonigen and Taylor (2000) for recent evidence on a negative relation between R&D and acquisition activity in high-tech industries.

(ii) The size of the firm (*Size*): Nearly all studies on mergers or RJVs as well as our summary statistics indicate that the size of the firm is a major determinant of its M&A and other cooperative activity. For example, larger firms are much more likely to be the acquirers in merger deals, and larger firms potentially benefit more from innovation, for example because they can apply a given marginal cost reduction to a larger number of units. We therefore include an absolute size measure, total assets of firm *i* in period *t,* into the determinants specification, and expect a positive sign for both the merger and the RJV equation.

(iii) The "scope" of the firm (*Multi*): The propensity to merge/form an RJV may depend on the "scope" of the firm, that is, whether a firm operates in more than one segment of the semiconductor industry (*Multi* = 1) or whether it is focused in one segment (*Multi* = 0). We distinguish between the "memory," "microcomponents," and "other" segments of the semiconductor industry. The mean *Multi* is 33.0%, that is, one-third of the firms operate in more than one segment; the rest is focused on one segment. Multimarket firms may be expected both to have a higher propensity to take over other firms, for example because there are more synergies (such as economies of scope) to be achieved, and to form more RJVs, for example, because spillovers can be better appropriated, than more focused firms.

(iv) Year effects: Several time-specific factors in the semiconductor industry may influence the propensity to merge/form an RJV. For example, one stylized fact in the merger literature is that mergers come in waves (see, for example, Shleifer & Vishny, 2001; or Gugler, Mueller, & Yurtoglu, 2003). The concentration in the industry may influence takeover activity and may change over time. Likewise, the number of firms and the turbulence in the industry (entry and exit) affect mergers and RJVs. Since we would have only (at most) eleven independent observations on these variables, and since there are endogeneity problems with some of them (such as concentration), we chose to include a full set of yearly time dummies instead. These account for any time-specific factors driving merger and RJV activity and are exogenous.

(v) The costs and benefits of merging or forming an RJV may also depend on the country/country group the firms stem from. For example, the legal environment, public policy, or corporate governance system systematically influencing takeover or cooperative intensities may differ. Thus, we include the country(-group) dummies United States, Europe, Japan, and South Korea.

The selection of the determinants variables i–v are very much in line with previous studies. Table 5 presents the switching estimation results for $x = 3$, that is, until three years after formation. The merger and RJV selection estimations from the "structural" probit equation show that merger/RJV formation indeed is significantly determined by the expected gains in market shares. Thus, firms expecting that a merger/RJV will increase their market shares are significantly more likely to actually take over another firm/form an RJV.

Turning to the exogenous determinants *X,* we find the following results: while own patents significantly negatively influence the decision to merge, they significantly positively influence the decision to form an RJV. This is consistent with RJVs being the "make" decision, where complementary aspects of the innovation process prevail, and mergers, the "buy" decision, are used to acquire external knowledge to substitute for own deficiencies. As expected, the size of the firm as well as its multimarket nature positively affect

[20] We again use the accumulated number of patents in the semiconductor industry of firm *i* in year $t_i - x - 1$ as an instrument for market shares in $t_i - x - 1$.

TABLE 5.—AN ENDOGENOUS SWITCHING MODEL: ESTIMATES OF SYSTEM (2) TO (4) FOR THE SEMICONDUCTOR INDUSTRY, FOR $x = 3$

	Mergers		RJVs	
	Coef.	Coef./s.e.	Coef.	Coef./s.e.
Selection equation:				
$(\widehat{sc_{m,i,t_i}-sc_{nm,i,t_i}})$	46.869	8.74	22.619	6.27
$Patents_{i,t_i}$	−0.746	−2.58	0.170	6.77
$Size_{i,t_i}$	0.136	2.49	0.133	2.35
$Multi_{i,t_i}$	0.941	4.02	0.725	2.81
Constant	−2.405	−4.16	−1.370	−1.62
Corrected market share equation:				
sc_{m,i,t_i-3}	1.191*	13.06	1.096*	4.80
sc_{nm,i,t_i-3}	0.862*	105.18	0.876*	109.66
t-test of difference		3.14		2.88
Variance parameters:				
Sigma (0)	0.612		0.585	
Rho (0, υ)	0.874		0.104	
Sigma (1)	0.159		0.154	
Rho (1, υ)	−0.365		−0.107	
Log likelihood function:	2,358.7		1,966.0	
No. obs.	807		807	

Note: *means significantly different to 1 at the 5% level. $(\widehat{sc_{m,i,t_i}-sc_{nm,i,t_i}})$ is the estimated difference in (combined) market shares between the two regimes; $Patents_{i,t_i}$ are the total number of patents accumulated of each firm until year t_i; $Size_{i,t_i}$ is the natural logarithm of total assets in $ millions; $Multi_{i,t_i}$ is a dummy variable equal to 1 if the firm operates in more than one segment of the semiconductor industry, 0 else. Included in the selection equation but not reported are a full set of year dummies and country dummies for the U.S., Europe, and Japan with the constant term measuring South Korea. *Chi*-squared statistics (p-values): merger equation: year dummies: 14.08 (0.029); country dummies: 21.28 (0.000); relative to South Korea (* significant): U.S. (−), Europe (−), Japan (−*); RJV equation: year dummies: 32.92 (0.000); country dummies: 2.02 (0.568); relative to South Korea: U.S. (+), Europe (−), Japan (−).

TABLE 6.—ESTIMATES OF SYSTEM (2) TO (4) FOR THE MICROCOMPONENTS MARKET, FOR $x = 3$

	Mergers		RJVs	
	Coef.	Coef./s.e.	Coef.	Coef./s.e.
Selection equation:				
$(\widehat{sc_{m,i,t_i}-sc_{nm,i,t_i}})$	19.370	3.64	12.334	2.27
$Patents_{i,t_i}$	−0.046	−0.58	0.220	2.77
$Size_{i,t_i}$	0.103	2.19	0.093	1.35
$Multi_{i,t_i}$	0.741	2.32	0.425	1.81
Constant	−3.75	3.66	−2.235	−1.98
Corrected market share equation:				
sc_{m,i,t_i-3}	1.253*	9.16	1.153*	3.76
sc_{nm,i,t_i-3}	0.822*	44.22	0.876*	32.63
t-test of difference		3.02		2.67
Variance parameters:				
Sigma (0)	0.244		0.354	
Rho (0, υ)	0.842		0.481	
Sigma (1)	0.511		0.423	
Rho (1, υ)	−0.366		−0.076	
Log likelihood function:	1,128.7		926.0	
No. obs.	312		312	

Note: *means significantly different to 1 at the 5% level. Variables are defined in analogy to table 5. Included in the selection equation but not reported are a full set of year dummies and country dummies for the U.S., Europe, Japan, and South Korea. *Chi*-squared statistics (p-values): merger equation: year dummies: 3.23 (0.779); country dummies: 64.76 (0.000); relative to South Korea (* significant): U.S. (+), Europe (−), Japan (−); RJV equation: year dummies: 4.59 (0.205); country dummies: 0.47 (0.494); relative to South Korea: U.S., (+), Europe (−), Japan (−).

the probability to merge and to form an RJV. The year dummies are significant determinants of both the decision to merge as well as to be member in an RJV, while the country dummies are only significant in the determinants of merger equation. This is consistent with time varying industry factors affecting the optimality to cooperate and regulation and/or public policy and/or corporate governance system differing more for mergers than for RJVs across countries/country groups.

Having accounted for the endogenous formation, we are able to consistently estimate the quantitative effects of the mergers or RJVs. As we see from the effects regressions, merging firms are able to expand their combined market share by 19% three years after a merger, as compared with nonmerging firms losing nearly 14% on average during that period. Each RJV-participating firm is able to expand its market share by nearly 10% three years after the formation of an RJV, as compared with non-RJV firms losing more than 12% on average during that period. These numbers are very much in line with the percentage estimates from section IIIB using a dummy variable technique and ignoring endogenous switching. In sum, while mergers and RJVs are to some extent endogenously determined, our main results are not altered by explicitly considering and correcting for this endogeneity.

D. *Level of Aggregation*

So far we have analyzed mergers and RJVs at the four-digit NAICS level of aggregation, the semiconductor industry. One may argue that the kinds of efficiency effects that firms achieve via cooperation should manifest themselves much more clearly at much lower levels of aggregation, such as at the six-digit level.[21] Thus, in this section we test for robustness of our findings at the six-digit level of aggregation, that is, the memory and microcomponents markets.

For these two cleanly delineated markets, we reestimate system (2) to (4). This procedure implies that the degree of horizontality of our mergers and RJVs is now even tighter, since now a horizontal merger or RJV is between firms for example in the microcomponents market. By analogy, market shares, patents, and so on are redefined.

Table 6 presents the estimates for system (2) to (4) for the microcomponents market and table 7 for the memory segment. The results for the determinants equations are similar to the semiconductor industry as a whole. For example, the size and multimarket variables again carry a positive sign, indicating that scale and scope effects continue to be important factors determining the formation of a merger/RJV at the lower level of aggregation. However, these effects are at lower significance levels than in the total semiconductor industry, which is not surprising given the smaller number of observations.

Mergers and RJVs are particularly beneficial in the microcomponents segment. Here, merging firms can raise their combined market share by 25%, each RJV participating firm

[21] However, some efficiency or market power effects are realized at rather higher levels of aggregation. For example, reductions of fixed costs or economies of scope may be realized at the firm level. Similarly, market power can stem from multimarket conduct or vertical relationships. Thus a too narrow scope may underestimate these effects.

TABLE 7.—ESTIMATES OF SYSTEM (2) TO (4) FOR THE MEMORY MARKET, FOR $x = 3$

	Mergers		RJVs	
	Coef.	Coef./s.e.	Coef.	Coef./s.e.
Selection equation:				
$(\widehat{sc_{m,i,t_i} - sc_{nm,i,t_i}})$	8.223	0.64	22.334	1.27
$Patents_{i,t_i}$	−0.146	−2.58	0.120	0.77
$Size_{i,t_i}$	0.173	2.23	0.193	1.98
$Multi_{i,t_i}$	0.980	1.12	0.625	1.41
Constant	−7.225	5.78	−0.489	−2.21
Corrected market share equation:				
sc_{m,i,t_i-3}	1.021	5.23	1.113*	2.32
sc_{nm,i,t_i-3}	0.987	32.12	0.854*	21.19
t-test of difference		0.73		2.51
Variance parameters:				
Sigma (0)	0.283		0.387	
Rho (0, υ)	0.375		0.902	
Sigma (1)	0.096		0.473	
Rho (1, υ)	−0.274		−0.036	
Log likelihood function:	993.7		832.0	
No. obs.	212		212	

Note: *Means significantly different to 1 at the 5% level. Variables are defined in analogy to table 5. Included in the selection equation but not reported are a full set of year dummies and country dummies for the U.S., Europe, Japan, and South Korea. Chi-squared statistics (p-values): merger equation: year dummies: 0.65 (0.420); country dummies: 1.51 (0.823); relative to South Korea (* significant): U.S. (+), Europe (−), Japan (−*); RJV equation: year dummies: 6.89 (0.076); country dummies: 5.38 (0.020); relative to South Korea: U.S. (+*), Europe (+*), Japan (−*).

can raise its market share by 15.3%. This is consistent with the results obtained using the dummy variable method: there we found 1 respectively 0.52 per-participant percentage point increase from a basis of around 3% market share. Results for the memory market differ from those for the microcomponents market insofar that mergers do not significantly raise market shares for merging firms, while RJVs continue to have positive and significant net efficiencies. This is what one expects a priori as the market power effect or the internalization of negative externalities very much depends on market characteristics as mentioned in the previous sections. The memory market is much more stable with regard to the number of firms than the microcomponents industry (see tables 1C and 1D). More differentiation in the microcomponents market imposes lower market power gains following from mergers, and fewer efficiency gains are necessary to overcompensate any market power effects (see section IIIA). Moreover, more net entry in the microcomponents market results in a higher response by outsiders, resulting in a higher industry output and lower prices. Therefore, we find more net efficiency-enhancing mergers/RJVs in the microcomponents industry relative to mergers/RJVs in the memory market.[22]

In summary, these results show that our findings of positive net efficiencies of mergers and RJVs for the semiconductor industry are robust and continue to hold for the microcomponents and memory markets. Our results for mergers apply most significantly for the microcomponents market.[23]

IV. Conclusion

Our study contributes to merger and RJV control policy. A merger may be approved based on a so-called efficiency defense: if firms can convince merger control authorities that the efficiencies generated by the merger more than outweigh the anticompetitive effects, the merger may be cleared. An important aspect in clearing mergers is that the efficiencies are merger-specific; that is, that the efficiencies cannot be achieved by any other means with lower anticompetitive effects, such as RJVs.

This study finds that both types of cooperation mergers and RJVs increase the market shares of participating firms. This points to an efficiency-enhancing role of mergers and RJVs. This result is robust to endogenous merger or RJV formation. This may imply that efficiency gains are frequently not merger-specific, given the possibility of a research joint venture.

At least two important caveats must be mentioned, however. First, we did not analyze other forms of joint ventures such as pure production joint ventures. It may well be that these forms of cooperation increase collusion in the product market without offsetting efficiency advantages. Second, our analysis is restricted to the semiconductor industry, one of the most R&D-intensive and innovative industries. Moreover, results for the microcomponents segment are much clearer than for the memory segment, which was in relative decline during the period of investigation. Future research is needed to confirm our main results for other industries, as to establish more insight for antitrust control authorities and the evaluation of consumer welfare.

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[22] The reader may wonder why concentration is much larger in the microcomponents than in the memory market (see tables 1C and 1D) and that increased concentration should rather lead to a higher probability of market power–enhancing mergers. We think that the larger concentration in the microcomponents market is attributable to the efficiency and innovativeness of Intel Corp and not to market power. Intel Corp increased its market share in the microcomponents segment from 24.8% in 1989 to 45.1% in 1999 *despite* net entry during that time period.

[23] This shows that a rigid application of a market share or Herfindahl criterion to determine the likely anticompetitive effects of mergers is not warranted. This is recognized in the U.S. and E.U. merger guidelines.

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APPENDIX

In this section, we show that the results by Farrell and Shapiro (1990) are robust to product differentiation. We consider N firms, each producing a single good. The goods are differentiated and the inverse demand function for firm i is

$$P_i = a - bq_i - g\sum_{\substack{j=1\\ j\neq i}}^{N} q_j,\ i = 1, \ldots, N,$$

where P_i denotes the price of firm $i,$ and q_i the quantity it produces. The substitutability parameter is g with $0 \leq g \leq b$. When $g = 0$ goods are totally differentiated and become closer substitutes the larger $g;$ when $g = b$ products are perfect substitutes. We allow production to be profitable, hence $a > c,$ and assume that no entry or exit occurs.

We consider two different types of coalitions: (i) research joint ventures, where firms cooperate in R&D but not in the product market and (ii) mergers, where firms combine their assets and cooperate in the R&D and the product market. In every type there are two groups of firms, the $M \leq N$ insiders, which participate in the coalition, and the $N - M$ outsiders. Through efficiency gains the insiders (I) may achieve lower ex post marginal costs than the outsiders (O), $c^I < c^O$.

Following Farrell and Shapiro (1990), we assume that cooperation occurs only when it is profitable. Thus, we do not endogenize the coalition process and do not investigate the effect on insiders' profits. In the product market, firms simultaneously choose their quantities. We first analyze the maximization problem for the outsiders, which is identical under merger and RJV, before we turn to the objectives for insiders in a merger and RJV, respectively.

1. *The Outsiders*

The $N - M$ outsiders (noncooperatively) maximize own profits:

$$\max_{q_i^O} \pi_i^O = \max_{q_i^O}\left\{\left[a - g\left(\sum_{j=1}^{M} q_j^1 + \sum_{\substack{j=M+1\\ j\neq 1}}^{N} q_j^O\right) - bq_i^O\right] q_i^O - c^O q_i^O\right\}, i = M+1, \ldots, N,$$

where q_i^O and q_j^I, $j = 1, \ldots, M$ are the outputs of an outsider and insider firm, respectively.

2. *The Insiders in a Merger*

Assuming symmetry among the M insiders in a merger (m), they maximize joint profits, given by (nm are the outsiders of the merger):

$$\max_{q^m} M\pi^m = \max_{q^m}\left\{M\left\{\left[a - g\left[\sum_{j=M+1}^{N} q_j^{nm} + (M-1)q^m\right] - bq^m\right]q^m - c^m q^m\right\}\right\}.$$

Solving for the equilibrium quantities and rearranging yields the following relation:

$$\frac{2b + g(M-2)}{2b - g} q^{*m} - q^{*nm} = \frac{c^{nm} - c^m}{2b - g}. \tag{A1}$$

Let us suppose that the merger generates no efficiency gains ($c^m = c^{nm}$), such that only the market power effect is present. When products are perfect substitutes ($g = b$), $M\, q^{*m} = q^{*nm}$, and we can confirm the results established by Salant et al. (1983), that the insiders reduce their production by so much that Cournot symmetry is again established in the postmerger equilibrium. Outsiders react by increasing their output, but by less than insiders reduced their output, and industry output declines and market price increases.

As products become more differentiated (g declines), insiders impose fewer negative externalities on each other and reduce their output less (see equation [5] with $\frac{\partial\left(\frac{2b+g(M-2)}{2b-g}\right)}{\partial g} > 0$). It follows that insiders gain less on market power, inducing a lower increase in industry price. When products are totally differentiated ($g = 0$), insider and outsider firms do not change output ($q^{*m} = q^{*nm}$). This is intuitive, since firms already behaved like monopolists before the merger and did not impose any externalities in the product market on each other. Hence, there is no further gain of market power and the industry price remains the same.

In case the merger creates efficiency gains ($c^m < c^{nm}$), and considering perfect substitutes ($g = b$), equation (5) results in $Mq^{*m} = \frac{c^{nm}-c^m}{b} + q^{*nm}$. If the efficiency gains due to the merger are sufficiently high, they may outweigh the market power effect, such that insiders increase output and prices decline. When products become more differentiated (g declines), the same argument as above holds and insiders decrease their output by less.

We can impose the following result: when the efficiency effect induced by the merger is sufficiently large, such that it dominates the market power effect, a single insider firm will produce a higher quantity than an outsider, and industry price declines compared with the premerger price. Moreover, the more the products are differentiated, the lower the efficiency gains are needed to overcompensate the market power effect. We have thus shown that the predictions by Farrell and Shapiro (1990) on market shares and prices are robust to any degree of product differentiation.

3. The Insiders in an RJV

The M insiders forming an RJV (R) maximize their profits noncooperatively,

$$\max_{q_i^R} \pi_i^R = \max_{q_i^R} \left\{ \left[a - g \left(\sum_{\substack{j=1 \\ j \neq 1}}^{M} q_j^R + \sum_{j=M+1}^{N} q_j^{nR} \right) - b q_i^R \right] q_i^R - c^R q_i^R \right\},$$

where nR denote non-RJV firms (outsiders). Solving for the corresponding equilibrium quantities and rearranging gives the following relation:

$$q^{*R} - q^{*nR} = \frac{c^{nR} - c^R}{2b - g}. \tag{A2}$$

The higher the efficiency gains ($c^R < c^{nR}$) generated by the RJV, the more the insiders will increase their output compared with outsiders ($q^{*R} > q^{*nR}$). Insiders will increase their output less, the more the products are differentiated. The outsiders respond by decreasing their output, but by less, resulting in a decline in industry price. Note that this argument holds under the assumption that firms do not collude in the product market. If RJV firms do collude in the product market, an RJV behaves like a merger and the same logic as above applies.

Summarizing, we can infer the extent to which mergers or RJVs generate efficiency effects by analyzing the change of pre- to postmerger (RJV) market shares. If the insiders' postmerger (RJV) shares increase compared with premerger (RJV) shares, the efficiency gains overcompensate the (potential) market power effects, and price will necessarily decline. This holds for any degree of product differentiation.

The likely consequences of allowing for entry and exit are the following: Market shares of insiders would increase by more if the efficiency effect dominates the market power effect, since some outsiders would exit. Market shares of insiders would decrease by more if the market power effect dominates the efficiency effect, since other firms may enter. Thus, the assumption of no entry and exit in our study makes the analysis even more conservative. See Werden and Froeb (1998) for an analysis of the entry-inducing effects of mergers. See also Roeller and Stahl (2002) for the welfare effects of mergers and joint ventures.