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

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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 a so-called "efficiency defence". 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 anti-competitive (market power) effects of mergers. We present evidence for the semiconductor industry that RJVs indeed represent viable alternatives to mergers. We empirically account for the endogenous formation of mergers and RJVs.

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1 Introduction

Many economists argue that competition authorities should take efficiency gains into account when examining merger cases. For example, Williamson (1968) highlighted the trade off between market power and efficiency effects. The US Department of Justice and Federal Trade Commission *Horizontal Merger Guidelines'* revisions (1992 and 1997) clarify the approval of mergers based on the "efficiency defence". 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), the merger may be cleared.[1] Under these circumstances, price may decrease and consumer welfare may increase, see also Farrell and Shapiro (1990). 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 Guidelines explicitly mention joint ventures that may achieve comparable efficiencies possibly without the anti-competitive 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 assess their substitutability. This study provides insights to what extent mergers generate (net) efficiency effects, and whether these could possibly be achieved by viable alternatives, such as research joint ventures (RJVs).

Mergers and RJVs can achieve a number of remedies to the shortcomings of the innovation process.[2] Most notably, participating firms can internalize the positive externalities of R&D through coordinating their R&D investments. Other motives are e.g. avoiding wasteful duplication through information sharing, exploiting scale and scope effects in

[1]Similar regulations are currently discussed by the European Commission (see Draft Commission Notice on the appraisal of horizontal mergers under the Council Regulation on the control of concentrations between undertakings, 11 December, 2002).

[2]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).

R&D, sharing risks associated with uncertain technologies as well as sharing large sunk set-up costs.[3] This may increase R&D investment and hence improve efficiency, which causes market shares to increase and prices to decrease (efficiency effect). 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.[4] 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 US Department of Justice enacted the *National Cooperative Research Act of 1984* in order to enforce RJVs. This act protects registered RJVs under the antitrust laws, such that they cannot be considered per se illegal, 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.[5]

The crucial difference between mergers and RJVs consists in 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

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

[4]Widely cited theoretical contributions are Brander and Spence (1983), Spence (1984), Katz (1986), d'Aspremont and Jacquemin (1988) and Kamien, Muller and Zang (1992). See DeBondt (1996) 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), Röller, Siebert and Tombak (2000) or Kaiser (2002) among others, and for the effects on R&D spending or patenting activity, see Irwin and Klenow (1996) and Branstetter and Sakakibara (2002) among others.

[5]In the European Union, treatment of RJVs is also generally favorable. Under certain restrictions, there is a block exemption for R&D cooperation if the combined market shares of the cooperating firms are 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 EU Treaty. There are also a number of government sponsored R&D projects worldwide, e.g. Sematech (Semiconductor Manufacturing Technology) in the USA, VLSI (Very Large Scale Integrated Circuits) in Japan or the Fifth Framework Programme in the EU.

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

internalize the competitive externality in the product market and insiders reduce their production inducing market price to increase (market power effect).

Prominent contributions on the effects on mergers are primarily based on numerical methods, see e.g. Berry and Pakes (1993), Gowrisankaran (1999), Dockner and Gaunersdorfer (2001) and Werden and Froeb (1994). However, empirical evidence on the effects of mergers or RJVs on cost efficiencies or market power is rather scant.[7] Up to date, there are only four studies that estimate the effects of mergers by using market shares.[8] Goldberg (1973) finds no significant change in market shares of 44 companies acquired in the 50ies and 60ies 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 ambituous study of mergers and market share, uses FTC 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 endogeneity problems in merger formation. We are not aware of any study analyzing the effects of RJVs on market shares.

Our theoretical framework in analyzing the net effects of mergers and RJVs follows

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1995).

[7]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). For an overview of *contemporary empirical merger analysis*, see Baker (1997).

[8]The evaluation of market shares has several significant advantages. Among others, they allow to implicitly derive the efficiency and market power effects without using cost data. Cost data, e.g. 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 post-merger equilibrium market shares is that we avoid solving for equilibrium quantities in closed-form solutions, which is a difficult task, even for very simple oligopoly models.

Farrell and Shapiro (1990). Most commonly used models of oligopoly 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. For example, in a Cournot model with homogenous products, Farrell and Shapiro (1990) implicitly derive the cost efficiencies, which are necessary for price to decline, from the change of merging firms' market shares. In the Appendix we show that results hold up when allowing for differentiated products.[9]

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 US-patent applications increases by approximately 16% every year, from 2,196 in 1989 to 6,036 in 1996 (see Hall, Jaffe and Trajtenberg, 2001). The worldwide total revenues of the semiconductor industry reached 168.9 Billion USD in 1999, compared to 52.7 Billion USD in 1989.

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, e.g. the size and innovativeness of the firm etc., as well as endogenous factors, i.e. 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. We apply

[9]Other merger studies investigating differentiated product markets in combination with price competition are e.g. Deneckere and Davidson (1985) and Werden and Froeb (1994).

these estimation procedures to the 4-digit (3344 NAICS) semiconductor industry, as well as to the 6-digit (334418 NAICS) memory and the 6-digit (334413 NAICS) microcomponents industry.

We find for all three industry-levels that mergers raise the market share of participating firms as do RJVs, providing evidence that efficiency effects dominate market power effects for both forms of cooperation. However, we also find that the efficiency gains caused by mergers may have been achieved by RJVs as well. Therefore, RJVs often represent viable alternatives to mergers from the consumer welfare point of view.

The paper is structured as follows. Section 2 describes our dataset on mergers and RJVs in the semiconductor industry. In Section 3, we apply the empirical analysis, and we conclude in Section 4. The Appendix presents an extension of the theoretical model by Farrell and Shapiro (1990), which allows for product differentiation and provides the basis for our empirical part.

2 The Industry Description and Data

Firms' annual market shares in the semiconductor industry are provided by Gartner Group. This company collects production data for each firm operating in the semiconductor industry on an annual basis. Thus, we 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 Mio. USD 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 as their prices have significant impact on many other downstream industries, such as the computer, automobiles, and communications industry. Semiconductors are mainly used as inputs for the computer industry (45% of its sales), consumer electronics (23%), and communications equipment (13%). The semiconductor market consists of memory chips, micro components, and other components such as logic devices. The industry is characterized by worldwide selling companies mainly from the United States, Japan, Europe, and other countries in the Asian-Pacific region, with a 39.6%, 40.1%, 8.5%, and 11.8% market share, respectively (Dataquest, 1999). The international production rates vary drastically depending on the type of semiconductor component (see Table 1a).[10]

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 Mio. US-$ on average from 1989 to 1999. The Herfindahl index is around 400, with the HHI being much larger in the microcomponents (more than 2000 in the last two years) than in the memory segment.[11]

The memory and the microcomponents markets make up for 50% of the sales in the semiconductor industry, with each generating between 25 and 30 billion US-$, 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

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

[11] According to the US Merger Guidelines mergers are generally not challenged when the HHI is smaller than 1000, when the HHI is between 1000 and 1800 and the merger

will increase the HHI by less than 100 points, or when the HHI is larger than 1800 and the merger will increase the HHI by less than 50 points. All other mergers might be challenged.

number of firms increased from 51 in 1989 to 88 in 1999).

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 90's. Prominent examples are SEMATECH, MITI and ESPRIT, consortia established by the U.S., Japan and Europe in order to promote the technological pace and the development of semiconductor chips, see also Song (2003). Table 2 presents statistics on the number of completed deals. There are 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.[12] A similar number of RJVs have been formed in the memory and the microcomponents industry (57 and 63, respectively), while the number of mergers 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 industry. 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%.[13] Both groups of firms are able to expand their market shares until $t + 3$. Tables 3b-c reveal that RJV firms experience increases in market shares in both sub-segments, while merging firms' market shares increase only in the microcomponents segment post merger.

[12]This is consistent with the notion that the potential beneficial effects of RJVs increase with the number of participating firms, since technological spillovers increase (see Baumol, 2001).

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

3 The Empirics

In line with Farrell and Shapiro (1990) one way to quantify the market power versus efficiency effects of mergers and RJVs, is to compare pre-merger with post-merger market shares, see also our extension in the Appendix. More precisely, if the sum of the market shares of merger or RJV insiders increase following a merger or the formation of an RJV, the efficiency gains created by the merger/RJV overcompensate the (potential) market power effects, and price will necessarily decline. This holds for any degree of product differentiation in the market. Therefore, in what follows we establish the desirability of mergers or RJVs by analyzing their effects on market shares.

3.1 A Dummy Variable Approach

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

$$sc_{i,t} = a_c + b \cdot sc_{i,t-x-1} + \sum_{y=0}^{x} m_y \cdot Merger_{i,t-y} + \sum_{y=0}^{x} r_y \cdot RJV_{i,t-y} + \epsilon_{i,t} \tag{1}$$

for $i = 1 \ldots 263$ and $t = 1989 \ldots 1999$. If there is no merger, $sc_{i,t}$ is simply the market share of firm i in period t. If there is a merger, $sc_{i,t}$ is the sum of the market shares of the acquiring and acquired company, i.e. the combined market share, before the merger, and the market share of the acquiring firm after merger. The parameters a_c are country/country group dummies for the *USA*, *Europe*, *Japan* and *South Korea*. In order 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 $Merger_{i,t-y} = 1$, if firm i took over another firm in period $t - y$, and zero elsewise, or by analogy, $RJV_{i,t-y} = 1$, if firm i participated in a research joint venture in period $t-y$, and zero elsewise.[14] The inclusion of the lagged dependent variable $sc_{i,t-x-1}$ effectuates that the coefficients on the dummy variables measure changes in market shares. Equation (1)

[14]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.

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 indicate that the efficiency effect dominates the market power effect.

Unit root tests 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).[15] Thus, these values are above the 1% critical values as e.g. 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, towards zero. Therefore, we instrument $sc_{i,t-x-1}$ by the stock of patents in the semiconductor industry by firm i as of year $t-1-x$ 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 zero.

Table 4 reports the regression results for equation (1). As shown, mergers significantly increase the market share of the combined entity relative to pre-merger levels in the semiconductor industry. The cumulative effect of mergers on market shares is +1.0 percentage points ($t = 7.22$) three years after the merger ($x = 3$). The results also indicate that RJVs significantly increase the market shares of participating firms. RJVs significantly affect

[15] 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 $\Delta \mu_{it}$. The Anderson and Hsiao (1982) estimator is consistent when $N \longrightarrow \infty$ or $T \longrightarrow \infty$ or both.

market share in the second and third years after formation (see columns for $x = 3$). The cumulative effects of RJVs on market share of the participating firms 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 three years after the formation. 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 anti-competitive effects. 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. However, RJVs raise market shares of participants by 0.5 percentage points more, collectively. Moreover, from Table 4 and x = 3, mergers have a negative (albeit insignificant) effect in year three after the merger, while RJVs still positively and significantly influence market shares of insiders. This suggests that the beneficial effects of RJVs are longer-lasting than those of mergers.

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 90ies (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). US and European semiconductor firms were about equally successful in retaining their market share. This is consistent with popular opinion.

Equation (1) is robust to the following modifications. (1) 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. (2) 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. (3) 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.

3.2 Endogenous Switching

The main criticism of mergers 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, not being 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 are 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 pre-merger (pre-RJV) market shares (see Mueller (1985), the endogenous switching model is in line with Lee, 1978):

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

$$sc_{m,i,t} = a_{m,0} + a_{m,1} \cdot sc_{m,i,t-x-1} + \varepsilon_{m,i,t} \quad (2)$$

$$sc_{nm,i,t} = a_{nm,0} + a_{nm,1} \cdot sc_{nm,i,t-x-1} + \varepsilon_{nm,i,t} \quad (3)$$

Equation (2) is a selection equation that determines whether or not the firm takes over another firm in year t (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 non-merging observations. Variables for the RJV estimations are determined by analogy.

If $I^*_{i,t} > 0$, the firm forms a merger (RJV), and the market share is determined by equation (2), otherwise its market share is determined by equation (3). 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 $sc_{m,i,t}$ if $I^*_{i,t} > 0$, or $sc_{nm,i,t}$ otherwise, but never both. Secondly, we have a simultaneity problem, and OLS estimation of equations (2) and (3) gives inconsistent estimates, because $\mathrm{E}(\varepsilon_{m,i,t}|I^*_{i,t} > 0) \neq 0$ and $\mathrm{E}(\varepsilon_{nm,i,t}|I^*_{i,t} \leq 0) \neq 0$. Thus, we substitute equations (2) and (3) into equation (2), and estimate the "reduced form" probit by ML. From this estimation, we retrieve the inverse Mills ratio and estimate equations (2) and (3) consistently with 2SLS.[16] 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 $a_{nm,1}$, i.e. the percentage of market share retained of merging versus non-merging 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 (1-3), time (4) and country specific (5). All of them are proxies in one form or the other of the costs and benefits of undertaking a merger or being member in an RJV.

(1) 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 and 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 brougth "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.

(2) 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

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

and other cooperative activity. For example, larger firms are much more likely to be the aquirers in merger deals, and larger firms potentially benefit more from innovation, e.g. 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.

(3) 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%. Multi-market firms are expected to both have a higher propensity to take over another firm, e.g. because there are more synergies to be achieved, and form more RJVs, e.g. because spillovers can be better appropriated, than more focused firms.

(4) 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 e.g. Shleifer and Vishny, 2001, or Gugler et al., 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 (e.g. 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.

(5) 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 or public policy may differ. Thus, we include the country(-group) dummies *USA*, *Europe*, *Japan* and *South Korea*.

The selection of the determinants variables 1-5 are very much in line with previous studies. Table 5 presents the switching estimation results for $x = 3$, i.e. 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 multi-market nature positively affect 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. It appears that regulation and/or public policy differs more for mergers than for RJVs across countries/county 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 market share by 19% three years after a merger as compared to non-merging firms loosing nearly 14% during that period, on average. RJV participating firms are able to expand their market share by nearly 10% three years after the formation of an RJV as compared to non-RJV firms loosing more than 12% during that period, on average. These numbers are very much in line with the estimates from section 3.1 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.

3.3 Level of Aggregation

So far we have analyzed mergers and RJVs at the 4-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, e.g. the 6-digit level.[17] Thus, in this section we test for robustness of our findings at the 6-digit level of aggregation, i.e. the memory and microcomponents markets.

For these two cleanly delineated markets, we re-estimate 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 e.g. in the microcomponents market. By analogy, market shares, patents etc. are re-defined.

Table 6 presents the estimates for system (2) to (4) for the microcomponents, 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 multi-market variables again carry a positive sign, indicating that scale and scope effects are 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 lower number of observations.

Mergers and RJVs are particularly beneficial in the microcomponents segment. Here, merging firms can raise their market share by 25%, RJV participating firms by 15.3%. Results for the memory market differ from those for the microcomponents market in so far that mergers do not raise market shares for merging firms, while RJVs continue to have positive net efficiencies.

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 micro-

[17] 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 multi-market conduct or vertical relationships. Thus a too narrow scope may underestimate these effects.

components and memory markets. Our results for mergers apply most significantly for the microcomponents market.[18]

4 Conclusion

Our study contributes to merger and RJV control policy. A merger may be approved based on a so-called *"efficiency defence"*: If firms can convince merger control authorities that the efficiencies generated by the merger more than outweigh the anti-competitive 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 comparable or lower anti-competitive effects, such as RJVs.

This study finds that mergers increase the market shares of participating firms. This points to an efficiency enhancing role of mergers. However, we also find that RJVs are indeed viable alternatives to mergers. Cumulatively, RJVs raise insiders' market shares by more than a merger and achieve higher efficiency gains and consumer welfare. This result is robust to endogenous merger or RJV formation. We conclude 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 result - RJVs are often viable alternatives to mergers - for other industries, as to establish more insight for antitrust control authorities and the evaluation of consumer

[18]This shows that a rigid application of a market share or Herfrindahl criterion to determine the likely anti-competitive effects of mergers is not warranted. This is recognized in the US and EU Merger Guidelines.

welfare.

5 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

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

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 being profitable, hence $a > c$, and assume that no entry or exit occurs.

We consider two different types of coalitions. (1) Research Joint Ventures, where firms cooperate in R&D but not in the product market, and (2) 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 cooperations occur only when they are 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.

5.1 The Outsiders

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

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

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

5.2 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):[19]

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

Solving for the equilibrium quantities and rearranging yields the following relation

$$\frac{2b + g\,(M-2)}{2b - g} q^{*m} - q^{*nm} = \frac{c^{nm} - c^m}{2b - g}. \tag{4}$$

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 ($g = b$), $Mq^{*m} = q^{*nm}$, and we can confirm the results established by Salant, Switzer and Reynolds (1983), that the insiders reduce their production by so much that Cournot symmetry is again established in the post-merger 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 (4) 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

[19] Note, that an aquiror may have an incentive to increase its product portfeuille by taking over another firm. The assumption of jointly maximizing profits would meet this incentive.

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 (4) 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 to the pre-merger price. Moreover, the more the products are differentiated, the lower 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.

5.3 The Insiders in an RJV

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

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

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

$$q^{*R} - q^{*nR} = \frac{c^{nR} - c^R}{2b - g}. \tag{5}$$

The higher the efficiency gains $\left(c^R < c^{nR}\right)$ generated by the RJV, the more the insiders will increase their output compared to outsiders $\left(q^{*R} > q^{*nR}\right)$. 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 post merger (RJV) market shares. If the insiders' post-merger (RJV) shares increase compared to pre-merger (RJV) shares, the efficiency gains overcompensate the (potential) market power effects, and price will necessarily decline.[20] This holds for any degree of product differentiation.

[20]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 Röller and Stahl (2002) for the welfare effects of mergers and joint ventures.

6 References

Anderson, T.W. and C. Hsiao, 1982, "Estimation of Dynamic Models with Error Components", Journal of the American Statistical Association 76, 598–606.

Baker, J.B., 1997, "Contemporary Empirical Merger Analysis", speech published in George Mason University Law Review, vol. 5, pp. 347-61.

Baldwin, J. and P.A. Gorecki, 1990, "Mergers Placed in the Context of Firm Turnover", in Bureau of the Census, 1990 Annual Research Conference, Proceedings, Washington D.C.: U.S. Department of Commerce, 53–73.

Baumol, W.J., 2001, "When is inter-firm coordination beneficial? The case of innovation", International Journal of Industrial Organization 19, 727–737.

Berry, S. and A. Pakes, 1993, "Some Applications and Limitations of Recent Advances in Empirical Industrial Organization: Merger Analysis", American Economic Review, Vol. 83, No. 2, 247–252.

Blonigen, B.A. and C.T. Taylor, 2000, "R&D Intensity and Acquisition in High-Technology Industries: Evidence from the US Electronic and Electrical Equipment Industries, Journal of Industrial Economics, Vol. XLVIII, No. 1, 47–70.

Brander, J.A. and B. Spencer, 1983, "Strategic Commitment with R&D: the Symmetric Case", Bell Journal of Economics 14, 225–235.

Branstetter, L. G. and M. Sakakibara, 2002, "When Do Research Consortia Work Well and Why? Evidence from Japanese Panel Data", American Economic Review, Vol. 92, No. 1, 143–159.

Cassiman, B. and R. Veugelers, 1999, "R&D Cooperation and Spillovers: Some Empirical Evidence", CEPR discussion paper 2330.

Cohen, W.M. and D.A. Levinthal, 1989, "Innovation and Learning: The Two Faces of R&D", The Economic Journal 99, 569–596.

D'Aspremont, C. and A. Jacquemin, 1988, "Cooperative and Non-Cooperative R&D in Duopoly with Spillovers", The American Economic Review 78, 1133–1137.

Dataquest, 1999, *Semiconductor Data partly provided by Dataquest.*

DeBondt, R., 1997, "Spillovers and Innovative Activities", International Journal of Industrial Organization 15, 1–28.

Deneckere, R. and C. Davidson, 1985, "Incentives to Form Coalitions with Bertrand Competition," Rand Journal of Economics, 16, 473–486.

Dockner, E.J. and A. Gaunersdorfer, 2001, "On the Profitability of Horizontal ' Mergers in Industries with Dynamic Competition," Japan and the World Economy, 13, 195–216.

Farrell, J. and C. Shapiro, 1990, "Horizontal Merger: An Equilibrium Analysis", American Economic Review, Vol. 80, No. 1, 107–126.

Flamm, K., 1996, "Mismanaged Trade?", Brookings Institution Press, Washington, D.C.

Fuller, W.A., 1976, "Introduction to Statistical Time Series", J. Wiley & Sons, Inc., New York.

Goldberg, L., 1973, "The Effect of Conglomerate Mergers on Competition", Journal of Law and Economics, 16, 137–158.

Gowrisankaran, G., 1999, "A Dynamic Model of Endogenous Horizontal Mergers" RAND Journal of Economics, Spring, Vol. 30(1), 56-83.

Gruber, H., 1992, "The Learning Curve in the Production of Semiconductors Memory Chips", Applied Economics, 24, pp. 885-894.

Gruber, H., 1996, "Trade Policy and Learning by Doing: The Case of Semiconductors", Research Policy, 25, pp. 723-739.

Gugler, K., Mueller, D. C. and Yurtoglu, B.B., 2003, ”The Determinants of Merger Waves”, University of Vienna, presented at the EARIE 2003 meeting in Helsinki.

Gugler, K., D.C. Mueller, B.B. Yurtoglu and C. Zulehner, 2003, “The Effects of Mergers: An International Comparison”, International Journal of Industrial Organization, Vol. 21 (5), 625-653.

Hall, B.H., A.B. Jaffe and M. Trajtenberg, 2001, “The NBER Patent Citation Data File: Lessons, Insights and Methodological Tools” NBER Working Paper No. 8498.

Irwin, D. and P. Klenow, 1994, “Learning by Doing Spillovers in the Semiconductor Industry”, Journal of Political Economy, 102, pp. 1200-1227.

Irwin, D.A. and P.J. Klenow, 1996, “High-tech R&D Subsidies: Estimating the Effects of Sematech”, Journal of International Economics 40, 323–344.

Jacquemin, A., 1988, “Cooperative Agreements in R&D and European Antitrust Policy”, European Economic Review 32, 551–569.

Jorgenson, D.W., 2001, “Information Technology and the U.S. Economy”, American Economic Review, Vol. 91, no. 1, pp. 1-32.

Jorde, T.M. and D.J. Teece, 1990, “Innovation and Cooperation: Implications for Antitrust”, Journal of Economic Perspectives 4, 75–96.

Kaiser, U., 2002, “An empirical test of models explaining research expenditures and research cooperation : evidence for the German Service sector”, International Journal of Industrial Organization 20, 747–774.

Kamien, M.I., E. Muller and I. Zang, 1992, “Research Joint Ventures and R&D Cartels”, American Economic Review 82, 1293–1306.

Katz, M., 1986, “An Analysis of Cooperative Research and Development”, Rand Journal of Economics 17, 527–543.

Katz, M. and J. Ordover, 1990, “R&D Cooperation and Competition”, Brookings Papers on Economic Activity, Microeconomics, 137–191.

Lee, L.F., 1978, “Unionism and Wage Rates: A Simultaneous Equations Model with Qualitative and Limited Dependent Variables”, International Economic Review, 19, No. 2, 415–433.

Martin, S., 1995, “R&D Joint Ventures and Tacit Product Market Collusion”, European Journal of Political Economy 11, 733–741.

Mueller D.C., ed., “The Determinants and Effects of Mergers: An International Comparison”, Cambridge, Mass.: Oelgeschlager, Gunn & Hain, 1980.

Mueller, D.C., 1985, “Mergers and Market Share”, Review of Economics and Statistics, 67(2), 259–267.

Pesendorfer, M., 2003, ”Horizontal Mergers in the Paper Industry”, Rand Journal of Economics, 34(3), pp. 495-515.

Ravenscraft, D.J. and F.M. Scherer, 1987, “Mergers, Sell-Offs and Economic Efficiency”, The Brookings Institution, Washington, D.C.

Röller, L.H., R. Siebert and M.M. Tombak, 2000, “Strategic Choice of Partners: Research Joint Ventures and Market Power”, Wissenschaftszentrum Berlin.

Röller, L.H. and K. Stahl, 2002, “Merger vs. Research Joint Venture under R&D Efficiencies”, Wissenschaftszentrum Berlin and University of Mannheim.

Salant, S.W., S. Switzer and R.J. Reynolds, 1983, “Losses from Horizontal Merger: The Effects of an Exogenous Change in Industry Structure on Cournot-Nash Equilibrium”, Quarterly Journal of Economics, Vol. XCVIII, No. 2, 185–199.

Shapiro, C. and R.D. Willig, 1990, “On the Antitrust Treatment of Production Joint Ventures”, Journal of Economic Perspectives 4 (3), 113–130.

Shleifer, A. and R. Vishny, 2001, Stock Market Driven Acquisitions, NBER WP No. 8439.

Song, M., 2003, "A Dynamic Model of Cooperative Research in the Semiconductor Industry", Ph.D. Thesis, Harvard University.

Spence, M., 1984, "Cost Reduction, Competition and Industry Performance", Econometrica 52 (1), 101–121.

Werden, G.J., and L.M. Froeb, 1994, "The Effects of Mergers in Differentiated Products Industries: Logit Demand and Merger Policy", Journal of Law, Economics, and Organization, 10 (2), 407–426.

Werden, G.J., and L.M. Froeb, 1998, "The Entry-Inducing Effects of Horizontal Mergers: An Exploratory Analysis", Journal of Industrial Economics, 46 (4), 525–543.

Williamson, O.E., 1968, "Economies as an Antitrust Defense: The Welfare Tradeoffs", American Economic Review, 58, 18–36.

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 (Mio $-US)	Herfindahl Index	No. of active firms
1989	52,751	404	132
1990	54,578	383	140
1991	59,341	391	132
1992	64,774	386	157
1993	85,328	395	153
1994	109,402	402	154
1995	152,875	365	172
1996	143,402	430	158
1997	150,911	401	172
1998	138,747	475	188
1999	169,311	454	167
Average	107,402	408	157

Table 1c: Revenues and market shares in the memory industry

Years	Revenues (Mio $-US)	Herfindahl Index	No. of active firms
1989	14,502	637	49
1990	12,107	611	52
1991	12,668	602	52
1992	15,425	568	59
1993	23,274	563	57
1994	33,394	594	55
1995	55,842	616	55
1996	38,480	615	52
1997	31,324	611	55
1998	24,438	641	54
1999	34,591	804	48
Average	26,913	624	54

Table 1d: Revenues and market shares in the microcomponents industry

Years	Revenues (Mio $-US)	Herfindahl Index	No. of active firms
1989	7,789	983	51
1990	9,575	1145	54
1991	11,763	1241	59
1992	14,315	1356	72
1993	19,970	1620	77
1994	26,393	1532	79
1995	35,293	1434	83
1996	42,331	1746	84
1997	51,360	1803	87
1998	49,316	2141	92
1999	57,018	2176	88
Average	29,557	1562	75

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 $t-1$ until $t+3$

	$t-1$	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 $t-1$ until $t+3$

	$t-1$	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 $t-1$ until $t+3$

	$t-1$	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	-	-	-	-

Table 4: Results for equation (1)

Dependent variable: $sc_{i,t}$								
Equation	1		2		3		4	
	$x = 0$		$x = 1$		$x = 2$		$x = 3$	
	Coef	t-value	Coef	t-value	Coef	t-value	Coef	t-value
USA	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
$sc_{i,t-x-1}$	0.93022	19.76	0.91129	12.47	0.90007	8.16	0.88813	7.47
$Merger_{i,t}$	0.00028	0.56	0.00384	5.31	0.00522	7.06	0.00505	5.17
$Merger_{i,t-1}$			0.00169	2.34	0.00326	5.15	0.00439	6.46
$Merger_{i,t-2}$					−0.00014	−0.13	0.00191	2.72
$Merger_{i,t-3}$							−0.00098	−0.66
$RJV_{i,t}$	0.00009	0.27	−0.00020	−0.38	−0.00085	−1.04	0.00069	0.64
$RJV_{i,t-1}$			0.00076	1.45	0.00117	1.53	0.00087	0.86
$RJV_{i,t-2}$					0.00114	1.46	0.00240	2.39
$RJV_{i,t-3}$							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.

Table 5: An endogenous switching model: Estimates of system (2) to (3) for the semiconductor industry, for $x = 3$

	Mergers		RJVs	
	Coef	Coef/St.E	Coef	Coef/St.E
Selection equation:				
$(\widehat{sc_{m,i,t} - sc_{nm,i,t}})$	46.869	8.74	22.619	6.27
$Patents_{i,t}$	−0.746	−2.58	0.170	6.77
$Size_{i,t}$	0.136	2.49	0.133	2.35
$Multi_{i,t}$	0.941	4.02	0.725	2.81
Corrected market share equation:				
$sc_{m,i,t-3}$	1.191	13.06	1.096	4.80
$sc_{nm,i,t-3}$	0.862	105.18	0.876	109.66
Variance parameters:				
Sigma (0)	0.612		0.585	
Rho(0, v)	0.874		0.104	
Sigma (1)	0.159		0.154	
Rho(1, v)	−0.365		−0.107	
Log likelihood function:	2358.7		1966.0	
No. Obs.	807		807	

Note: $(\widehat{sc_{m,i,t} - sc_{nm,i,t}})$ is the estimated difference in (combined) market shares between the two regimes; $\text{Patents}_{i,t}$ are the total number of patents accumulated of each firm until year t; $\text{Size}_{i,t}$ is the natural logarithm of total assets in Mio USD; $\text{Multi}_{i,t}$ is a dummy variable equal to one, if the firm operates in more than one segment of the semiconductor industry, zero else; Included in the selection equation but not reported are a full set of year dummies and country dummies for the USA, Europe, Japan and South Korea. X^2 statistics (p-values): Merger equation: Year dummies: 14.08 (0.029); Country dummies: 21.28 (0.000); RJV equation: Year dummies: 32.92 (0.000); Country dummies: 2.02 (0.568).

Table 6: Estimates of system (2) to (3) for the microcomponents market, for $x = 3$

	Mergers		RJVs	
	Coef	Coef/St.E	Coef	Coef/St.E
Selection equation:				
$(\widehat{sc_{m,i,t} - sc_{nm,i,t}})$	19.370	3.64	12.334	2.27
$Patents_{i,t}$	−0.046	−0.58	0.220	2.77
$Size_{i,t}$	0.103	2.19	0.093	1.35
$Multi_{i,t}$	0.741	2.32	0.425	1.81
Corrected market share equation:				
$sc_{m,i,t-3}$	1.253	9.16	1.153	3.76
$sc_{nm,i,t-3}$	0.822	44.22	0.876	32.63
Variance parameters:				
Sigma (0)	0.244		0.354	
Rho(0, v)	0.842		0.481	
Sigma (1)	0.511		0.423	
Rho(1, v)	−0.366		−0.076	
Log likelihood function:	1128.7		926.0	
No. Obs.	312		312	

Note: 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 USA, Europe, Japan and South Korea. X^2 statistics (p-values): Merger equation: Year dummies: 3.23 (0.779); Country dummies: 64.76 (0.000); RJV equation: Year dummies: 4.59 (0.205); Country dummies: 0.47 (0.494).

Table 7: Estimates of system (2) to (3) for the memory market, for $x = 3$

	Mergers		RJVs	
	Coef	Coef/St.E	Coef	Coef/St.E
Selection equation:				
$(\widehat{sc_{m,i,t} - sc_{nm,i,t}})$	8.223	0.64	22.334	1.27
$Patents_{i,t}$	−0.146	−2.58	0.120	0.77
$Size_{i,t}$	0.173	2.23	0.193	1.98
$Multi_{i,t}$	0.980	1.12	0.625	1.41
Corrected market share equation:				
$sc_{m,i,t-3}$	1.021	5.23	1.113	2.32
$sc_{nm,i,t-3}$	0.987	32.12	0.854	21.19
Variance parameters:				
Sigma (0)	0.283		0.387	
Rho(0, v)	0.375		0.902	
Sigma (1)	0.096		0.473	
Rho(1, v)	−0.274		−0.036	
Log likelihood function:	993.7		832.0	
No. Obs.	212		212	

Note: 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 USA, Europe, Japan and South Korea. X^2 statistics (p-values): Merger equation: Year dummies: 0.65 (0.420); Country dummies: 1.51 (0.823); RJV equation: Year dummies: 6.89 (0.076); Country dummies: 5.38 (0.020).