A DISCRETE-RESPONSE APPROACH TO FIRM ACQUISITIONS

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Abstract. This paper proposes a model of firm acquisitions where firms are assumed to make preference rankings of potential partners. Using a mechanism of bid proposals among firms, we define a condition for firm acquisitions in terms of profit index comparisons. A profit index is defined as the profit to firm A from acquiring firm B, compared to the option of operating alone. Under specific assumptions regarding firm preferences, we derive expressions for the probability of a particular acquisition, and also a log-likelihood function for estimation of preference parameters using firm-specific data. The acquisition model is estimated on a panel data set consisting of European firms from the pulp and paper industry.

Key words: firm acquisitions, matching markets, discrete response
JEL classification:

1. Introduction

Firm mergers and acquisitions have received an extensive coverage both in the theoretical literature and in applied work. The potential decrease in consumer welfare due to increased market concentration has been an important policy concern for a long time. Therefore, it is of great interest to be able to measure the effects of mergers on, e.g., consumer prices. Another issue of interest is the analysis of firms' merger incentives, which the present paper deals with.

The aim of this study is to provide an empirical framework for analyzing firm-acquisition incentives. It is assumed that a researcher has data on a sample of firms, consisting of recorded acquisitions and of firm-specific attributes, such as size, previous profit, industry classification, country of origin, etc. We are interested in investigating the firms' motives for whether to take part in a merger or not, whether to acquire or be acquired, and in addition, with whom to merge. Since acquisition decisions of this type are taken at firm level, the aim is to provide a model based on firm-specific decision rules. On the theoretical side, this implies a rather complex decision framework.

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Acquisitions are discrete events, and are in principle well suited for an analysis by discrete-response models. But they imply difficult challenges, which makes standard discrete-response models unsuitable to apply without restrictive assumptions. The reason is the complex dependence among firms' choices. Firms taking part in a merger formation cannot really make a choice of merging with another firm. At most, the steering board may want to participate in a merger, and take appropriate actions. That may or may not lead to an actual merger, depending of course on what the potential partner's steering board and shareholders want, but also on actions taken by other firms.

Consider for instance using the conditional logit model. It examines the choice situation of an agent (in our setting, a firm) choosing among a number of alternatives (other firms to acquire). The probability of the agent making a specific choice (e.g., acquiring a specific firm) is a function of both firms' attributes. This may seem an attractive and simple way of modelling firm mergers, but the process of firm mergers cannot be assumed to be so simple. There is an implicit interdependence of the firms' merger decisions: For instance, a firm can be precluded from acquiring a potential target because a third firm acquires the target instead; or because the potential target acquires still another firm, and so forth. So in practice, a firm cannot take an acquisition decision itself. Instead, the decision depends on the incentives of the potential target and in addition, on other potential targets and/or acquirers. The model proposed in the present study incorporates such a decision framework. Every firm is allowed to merge with any other, and the challenge is to sort out the specific mergers that will take place.

Despite the inherent complexity of mergers, standard discrete-choice models are frequently used to analyze them. This is often done by imposing rather restrictive assumptions regarding merger formation. When applying discrete-choice models to firm mergers, many empirical papers do not spend much time in stating their assumptions regarding the choice situation that firms face. The study by Palepu (1982), which is probably the most influential methodological study in this field, is an exception.[1] Palepu derives a functional relationship between the probability that a firm gets acquired and its firm-specific characteristics. The main idea is that a potential target will agree to be acquired only if the net benefit to its shareholders is maximized over the potential acquirers. The net benefit itself is a function of both the acquirer's and the target's characteristics. A crucial assumption is that there are many potential acquirers for each target. Using a specific functional representation for the net benefit to the target's shareholders, and using arguments from asymptotic theory, the acquirers' characteristics do not need to be used. Instead, under specific assumptions, treating the joint net benefit of the acquirer and the target as random implies that the value it takes under net-benefit maximization

[1]Palepu (1982) is a PhD-dissertation and not easily obtainable. A shortened version of the acquisition model can be found in Palepu (1986).

on behalf of the target is extreme-value distributed. Therefore, a standard logit model can be used to model the acquisition likelihood of the potential target as a function of its own characteristics only. Many empirical studies use the acquisition model proposed in Palepu. Some examples are Ambrose and Megginson (1992), Song and Walkling (1993), Powell (1997), Dickerson, Gibson, and Tsakalotos (2002) (who use the probit instead of the logit), and Espahbodi and Espahbodi (2003).

The assumption of many potential acquirers for each target is very convenient, because it leads to the logit model in an elegant way. Unfortunately, it is hardly realistic. It is difficult to imagine real-life situations where each target has at least, say, 20 potential acquirers. (In fact, even 20 potential acquirers is too low to build any asymptotic results on.) Most often, firms attract bids from one or at most a couple of acquirers.

In addition, the model places an implicit restriction on the number of acquisitions in the population. To see this, consider a population of 200 firms consisting of potential targets as well as potential acquirers. As Palepu's model is specified, the target picks the acquirer that brings the highest net benefit to the target, compared to all other potential acquirers. There is an implicit assumption that no potential acquirer can bid for more than one firm. This is because if the latter were allowed, there would be a positive probability for two targets picking the same acquirer, and Palepu does not consider this case. Given that potential acquirers cannot overlap over different targets, and if the number of potential acquirers is to be at least 20 for each target, then at most 10 acquisitions can take place in a population of 200 firms. Generally, for a population of n firms, there can be at most $n/20$ acquisitions, if 20 is regarded to be a large enough number to build asymptotic results upon.

Many discrete-choice empirical analyses of firm acquisitions use Palepu's model, although not all of them explicitly state so. Some alternative attempts have been made to model merger incentives. One example is Bertrand, Mucchielli, and Zitouna (2004), where firms' location choice is examined given that a firm acquires another firm from a different country. The setup is the following: A firm located in one country wishes to acquire a firm from another country. Acquiring a firm (any firm) in a country implies a certain gain for the acquirer, and countries differ with respect to their location attractiveness. The acquirer's gain depends on country- and sector-level characteristics of both the acquirer and target, and the acquirer chooses to merge with any firm in the country that maximizes this gain. In the empirical application the authors employ the conditional logit to model the probability that a firm in a certain country chooses to acquire a firm in another country.

There are several problems with this approach. The choice model is defined conditional on acquisitions abroad – all firms have taken part in one. This means that only a part of the firms' choice situation is examined. Using the nested logit model would have been a better option. For instance, at stage one in their decision making, firms choose whether to acquire or not, and in stage two, in which country to acquire. But even stated in this way, the model does not seem very attractive: It implies that a firm either makes the choice of location before deciding which specific firm to merge with, or, even more unrealistically, simply picks a firm from the selected country at random. In reality, it is more likely that acquirers pick their targets based on both location- and firm-specific attributes, and both characteristics are considered simultaneously. When motivating their approach, Bertrand, Mucchielli, and Zitouna (2004, p. 3) ask the question:

> 'Put differently, we ask why a French firm has more incentives to take over or to merge with a German firm rather than a British one, or conversely?'

Unfortunately, this question cannot be answered by using their proposed model, unless firms only care about location when merging. If an acquiring firm makes a tradeoff between firm-specific characteristics of the target and country choice, then using only country-specific data is not enough. For instance, consider a French firm that, ceteris paribus, prefers to merge with British firms rather than with German ones. If location is the only decision variable that matters to French firms, then the firm will clearly choose to merge with a British firm. But what if firm-specific attributes also matter? If the French firm dislikes the firm-specific attributes of each available British firm, and at the same time finds a specific German firm very attractive, then it may choose to merge with the German firm. But this choice reveals nothing about the location preferences of French firms.

The model proposed in the next section is a behavioural model of firm acquisitions that addresses all the problems with existing studies described above. The inspiration for the model can be found in the literature on matching markets, which is treated in detail in the book by Roth and Sotomayor (1990). The book covers mostly two-sided matching, which in our setting would mean that firms can be divided into acquirers and targets in advance, a division which in this paper is assumed to be endogenous. For instance, firm A might be considering to acquire firm B, but if firm C approaches firm A with a really nice bid proposal (i.e., an offer to buy the outstanding shares from the owners of A at price much above the market share price), then the owners of A might choose to sell their shares to C, thus ending up being a target. Two-sided matching is therefore more suitable for analyzing situations where the group of agents can be naturally divided into two subgroups.

Dagsvik (2000) develops a general framework suited for empirical analysis of two-sided matching markets. Under specific distributional assumptions regarding the agents' preferences, he derives a functional relationship between the number of realized matches of a certain type (i.e., corresponding to a certain combination of attributes of agents from each type) and the number of agents with specific attributes from each type. Using this relationship, parameters from the preferences of the agents can be estimated. In Dagsvik, Flaatten, and Brunborg (1998), the framework is applied to the well known two-sex marriage model. In the empirical application, men and women are grouped with respect to age. Unfortunately, Dagsvik's framework cannot be applied to firm mergers, because it is only applicable to two-sided matching markets.

The roommate problem is a matching game where all agents a priori are of the same kind (i.e., they are not exogenously divided into two or more groups). That makes it suitable for applying to firm mergers, and Angelov (2005) uses it to define a probabilistic model of firm mergers, based on individual firm behaviour. One drawback of the roommate game is that it results in very complex expressions for merger probabilities, and thus Angelov only presents results for a merger game among three firms. This restricts the empirical usefulness of the roommate approach to oligopoly situations, whereas the model from the present study is applicable to any number of firms.

The next section contains the formal model and ends with a derivation of a maximum-likelihood estimator of the model parameter vector. The application of the model to a data set from the European paper and pulp industry is presented in 3. The analysis is concluded in section 4 and the appendices contain an omitted derivation, tables, and figures.

2. A probabilistic model of acquisitions

In similarity with a large part of the matching literature we assume a group of agents that rank each other with respect to attractiveness of some kind. In the present study the agents are firms and they are assumed to rank each other with respect to merger attractiveness. Assume a set of firms $\{f_1, f_2, \ldots, f_n\}$. Each firm is assumed to rank the rest of the firms (including itself) and thus f_i's preference ordering can be expressed by arranging the n firms in descending order. An example of f_i's preferences is given by

$$W_i = \{f_2, f_1, f_i, f_6, \ldots, f_n\},$$

implying that firm f_i's first choice is, if possible, to merge with firm f_2. If that is impossible, its second choice is to merge with firm f_1, and if that also is unattainable, the firm prefers to continue operating on its own. All firms that are higher in the preference ordering than the stand-alone option are called acceptable. The firms and their preference orderings form an economic model of acquisitions, where the outcome is a matching denoted by μ. The matching implies that each firm is either self-matched (i.e., continues to operate on its own), acquires one or more other firms, or is acquired.

Assume that the position of f_j in f_i's preference ordering depends solely on the index Π_{ij}, where $i, j = 1, 2, \ldots, n$. The index represents the profit to f_i's owners from a merger with f_j and can be defined as the sum of all future discounted profits that the owners of f_i receive, if f_i acquires f_j.

We assume that if $\Pi_{ij} > \Pi_{ik}$, then f_j is ranked higher than f_k in W_i; thus, there is a one-to-one correspondence from Π_{ij} to $W_i \; \forall \; j$. Consequently, if $\Pi_{ij} > \Pi_{ii}$, then f_j is acceptable to f_i. Expressed in words, this means that if f_i profits from merging with f_j, relative to operating alone, then f_i would like the merger to take place. The notion of profit from a merger relative to operating alone is so central for this analysis, that it calls for a formal notation. Thus, the relative profit indices are defined as

$$D_{ij} \equiv \Pi_{ij} - \Pi_{ii} \; \forall \; i, j.$$

To illustrate, consider an example of three firms with the following profit indices:

$$\Pi_{12} > \Pi_{11} > \Pi_{13}$$
$$\Pi_{23} > \Pi_{21} > \Pi_{22}$$
$$\Pi_{32} > \Pi_{31} > \Pi_{33}.$$

Transforming these into relative profit indices preserves the preference ordering of each firm (i.e., the order within each row):

$$D_{12} > 0 > D_{13}$$
$$D_{23} > D_{21} > 0$$
$$D_{32} > D_{31} > 0.$$

Note that if Π_{11}, Π_{22}, and Π_{33} are not equal, relative profit comparisons between firms (i.e., D-comparisons between rows) will not give the same results as profit comparisons (i.e., Π-comparisons between rows). Since $D_{ii} \equiv 0 \; \forall \; i$, all relevant information is contained in the sign and magnitude of $D_{ij} \; \forall \; i \neq j$. Only the relative profit indices will be used in the sequel.

This paper is concerned with firm acquisitions. An acquisition is a special type of merger, where f_i somehow induces the shareholders of f_j to sell all their shares to f_i. The first stage of the analysis consists of defining an acquisition rule, based on individual firm behaviour.

Consider f_i's acquisition incentives from the perspective of the shareholders. All acceptable firms are also desirable targets, since they imply a higher profit than the stand-alone alternative. But in a reasonable economic model, f_i's wish to acquire cannot be enough for a takeover – the rest of the firms must also be in favour or be persuaded to accept. This leads to a formal condition for a particular acquisition, which is proposed below:

Condition 1. For f_i to acquire f_j, the relative profit indices must be in accordance with all of the following four inequalities:

(i) $D_{ij} > 0$;
(ii) $D_{ij} > D_{mj} \; \forall \; m \neq i, j$;
(iii) $D_{ij} > D_{si} \; \forall \; s \neq i, j$; and
(iv) $D_{ij} > D_{jh} \; \forall \; h \neq j$.

This condition will be discussed in some length below, and as will become clear, it represents a rather simplified model of an acquisition mechanism. Nevertheless, it comprises several sensible characteristics of an acquisition game, and is empirically tractable due to its relative simplicity. Before continuing, note that the condition can only be applied to cases where preferences are strict. This is not a problem in the present paper, because the econometric specification (to be defined after the discussion of Condition 1) ensures strict preferences.

Recall that D_{ij} is defined as the profit to f_i's owners from acquiring f_j, relative to operating alone. As already mentioned, the first prerequisite for an acquisition is that the acquirer profits from it, which is ensured by (i).

In addition to f_i's willing to acquire, the key economic explanation for Condition 1 can be stated in terms of bid proposals among firms. While (i) provides f_i's incentive to take over f_j, (ii) represents f_i's prospects of winning a bidding for f_j. In real life, it is often the case that there is a transfer of resources from f_i to f_j that takes the form of an offer from f_i to buy the shares of f_j at a price higher than the market price. Consequently, we assume that D_{ij} is divided between f_i and f_j, the idea being that f_i transfers a part of its profit coming from the acquisition, to f_j, in order to induce f_j to be acquired. In fact, there is a need of being even more specific, so in order for the economic interpretation of Condition 1 to be completely clear, we need to specify how the division is made. This is formalized below:

Assumption 1 (Profit division)**.** Firm f_i's bid to the owners of f_j is equal to $D_{ij}/2$, i.e., if the acquisition wins power, f_i will transfer $D_{ij}/2$ to f_j.

The main idea is that if the owners of f_i gain a certain amount when merging a firm, compared to being self-matched, they will be willing to pay half of that amount in order to acquire it. And if no other firm gets a higher profit of merging f_j, none can make a higher bid. Consequently, f_i will win the bidding and acquire f_j, and in addition transfer the amount of the bid to f_j's owners. The latter also explains why f_j's owners agree to the acquisition: They get a positive amount from f_i, and since $D_{jj} \equiv 0$, they prefer being acquired to staying self-matched.

The inequalities (i) and (ii) in Condition 1 supply both the motives and the means for an acquisition, but two additional issues need to be considered for the acquisition to win power. Firstly, it is clearly inappropriate to allow an acquisition of f_i by another firm, at the same time as f_i takes over f_j. Consequently, (iii) is a way of ensuring this: To preclude the possibility of, say, f_s taking over f_i, $D_{ij}/2$ has to be higher than $D_{si}/2$. The economic intuition is that if f_i's owners get a higher profit from acquiring f_j less their bid, than they can receive through a bid from f_s, they will choose to acquire f_j. Note that this need not be the case if Assumption 1 were not imposed. Then f_s might offer f_i more than $D_{si}/2$, say, $0.8D_{si}$. And we might have $0.8D_{si} > D_{ij}/2$, even if $D_{ij} > D_{si}$, in which case f_i would accept f_s's offer.

Finally, if f_i acquires f_j, it does not make sense allowing f_j to acquire another firm f_h. The inequality in (iv) prevents this from happening using similar arguments as in (iii): If $D_{ij} > D_{jh}$ the owners of f_j will gain more from receiving the amount that f_i is offering them through its bid, than from acquiring f_h. Thus, they will choose to accept the offer.

Before continuing, note that by construction, Condition 1 has the following important implications: Firstly, it allows a firm to make more than one acquisition, as long as its relative profit from acquiring firms is positive (and the rest of Condition 1 is fullfilled). Secondly, no firm can be acquired twice, which is ensured by Condition 1 (ii). Finally, as long as there is at least one positive relative profit index, there will be at least one acquisition. The only situation leading to all firms being self-matched is when no firm profits from merging another one. To see this, assume that D_{ij} is the only positive relative profit. Firm f_i will offer $D_{ij}/2$ to the shareholders of f_j and since $D_{jj} \equiv 0$, the offer will be accepted. No other firm profits from acquiring f_j, since all other relative profits are negative or zero by assumption, and thus f_i will not have any competitors and will win the bidding. Naturally, if more that one relative profit index is positive, then Condition 1 will determine the acquisitions that take place. But if all relative profits are negative, no firm will ever want to acquire another one, and there will be no acquisitions.

The setting thus far has been deterministic in the sense than the relative profit indices were assumed to be known. But interest in this paper lies in modelling the probability of firm acquisitions, given firm-related characteristics. This will be done by specifying a log-likelihood function and maximizing it, thus obtaining a maximum-likelihood estimator. To this end, we leave the deterministic case by assuming that the relative profit index consists of a deterministic part and of the stochastic ε_{ij}. Both are assumed to be known to the firm, while the econometrician can only observe the deterministic part, except for an unknown parameter vector. Formally, we adopt the following assumption, valid for all $i \neq j$ (remember that $D_{ij} \equiv 0$ when $i = j$):

Assumption 2. $D_{ij} = g(\boldsymbol{\beta}|\boldsymbol{x}_i, \boldsymbol{x}_j) + \varepsilon_{ij}$, where $g(\cdot)$ is a known function of f_i's and f_j's observed attributes ($\boldsymbol{x}_i$ and $\boldsymbol{x}_j$, respectively) up to an unknown parameter vector $\boldsymbol{\beta}$, and each ε_{ij} in is i.i.d. extreme value with location parameter equal to zero and scale parameter equal to one, implying the p.d.f. $f_{\varepsilon_{ij}}(\varepsilon_{ij}) = e^{-\varepsilon_{ij}} e^{-e^{-\varepsilon_{ij}}}$.

This assumption ensures strict preferences, since the indices have continuous cumulative distribution functions.

Since ε_{ij} are independently distributed, so are D_{ij}. This is crucial for the further development of the model. Firstly, it allows a convenient rewriting of Condition 1, and secondly, together with the specific distributional assumption, it permits an analytical derivation of acquisition probabilities. Beginning with the rewriting of the acquisition condition, notice that independently distributed D_{ij} imply that the right-hand sides of each of the four inequalities also are independent. The additional fact that all four left-hand sides are equal to D_{ij} allows us to rewrite Condition 1 in a much more convenient way. Formally, it boils down to the following:

Condition 2. Firm f_i will acquire f_j if and only if $D_{ij} > \max\big\{0; D_{mj} \ \forall\, m \neq i,j; D_{si} \ \forall\, s \neq i,j; D_{jh} \ \forall\, h \neq j\big\}$.

This simple expression deserves some attention. It states that f_i will acquire f_j if the relative profit that f_i's owners get from a takeover is positive and greater than each of the profits in a specific set, henceforth called the alternative set. But this means that the acquisition game presented here results in takeover conditions somewhat similar to conditions for consumer choice in multinomial discrete choice models. Consider for instance the conditional logit model presented in McFadden (1974), where decision maker i is faced with a choice between J alternatives. Each alternative is associated with a utility index and the one giving the highest utility is chosen by the decision maker. Thus, in the logit model, the alternative set is represented by the utilities of all alternatives except the chosen one.

The following example shows that the alternative set of the acquisition model differs in one important aspect – it is endogenous with respect to the specific acquisition considered. Assume that there are four firms. The resulting matching solely depends on the order of the relative profit indices, which are arranged in descending order below (remember that $D_{ij} \equiv 0$ for $i = j$):

$$\{D_{12}, D_{32}, D_{42}, D_{14}, D_{24}, D_{13}, D_{21}, D_{43}, 0, D_{34}, D_{31}, D_{41}, D_{23}\}\,.$$

It is easy to see that Condition 2 is fulfilled with respect to f_1 acquiring f_2, i.e., $D_{12} > \max\{0, D_{32}, D_{42}, D_{31}, D_{41}, D_{21}, D_{23}, D_{24}\}$. This could be viewed as a logit model, where the set on the right-hand side of the inequality plays the role of a choice set. But the alternative set changes with the acquisition of interest. To see this, note that the other possible acquisitions are $\{13, 14, 21, 23, 24, 31, 32, 34, 41, 42, 43\}$, where ij means that f_i acquires f_j. The condition for 34 is $D_{34} > \max\big\{0, D_{14}, D_{24}, D_{13}, D_{23}, D_{41}, D_{42}, D_{43}\big\}$ which is not fulfilled in this specific case. The alternative set is clearly different from the one above and the only common elements are $D_{23}, D_{24}, D_{41}, D_{42}$.

Under Condition 2, and for an arbitrary number of firms, the probability of f_i acquiring f_j is given by

$$\mathsf{P}_{ij} = \mathsf{P}\big(D_{ij} > \max\{0; D_{mj}\ \forall\ m \neq i,j; D_{si}\ \forall\ s \neq i,j; D_{jh}\ \forall\ h \neq j\}\big). \quad (1)$$

As mentioned earlier, the assumption of ε_{ij} being i.i.d. extreme-value makes it possible to derive an analytical expression for the above probability. For conciseness, define $V_{ij} \equiv g(\boldsymbol{\beta}|\boldsymbol{x})$, where $\boldsymbol{x} = (\boldsymbol{x}_i\ \boldsymbol{x}_j)$. The parameter vector of interest is $\boldsymbol{\beta}$, and it is assumed that the dependence of the profit index on data is known up to $\boldsymbol{\beta}$. Note that linearity of the profit indices is not assumed at this stage. Certainly, a specific form needs to be chosen when the model is taken to data, which is done in the next section.

Using the definition $\mathcal{V} \equiv \{V_{ij}; V_{mj}\ \forall\ m \neq i,j; V_{si}\ \forall\ s \neq i,j; V_{jh}\ \forall\ h \neq j\}$ and applying Assumption 2 to (1) gives

$$\mathsf{P}_{ij} = \frac{e^{V_{ij}}\left(1 - e^{-\sum_{V_{kl}\in\mathcal{V}} e^{V_{kl}}}\right)}{\sum_{V_{kl}\in\mathcal{V}} e^{V_{kl}}}. \quad (2)$$

A formal derivation of this expression is provided in the appendix. To give an intuition for it, it is useful to relate it to the logit choice probability. If the inequality $D_{ij} > 0$ were not present in Condition 1, i.e., if D_{ij} were allowed to be negative, then (2) would have taken the form of a logit choice probability, namely $e^{V_{ij}}/\sum_{V_{kl}\in\mathcal{V}} e^{V_{kl}}$. Intuitively, since there is a positive probability that D_{ij} is negative and still larger than the relative profits in the alternative set, forcing it to be positive should reduce P_{ij}. In fact that is what happens, because the expression in (2) is equal to the logit choice probability multiplied by $1 - e^{-\sum_{V_{kl}\in\mathcal{V}} e^{V_{kl}}}$. It is easy to check that the last expression lies between zero and one, and so the derived probability for an acquisition is at most as high as a corresponding logit choice probability.

When deriving the log-likelihood function, it is assumed that a researcher can observe a specific matching among n firms with at least one acquisition. For instance, if $n = 6$, we could have $\mu_1 = \{12, 33, 44, 55, 66\}$, or $\mu_2 = \{12, 34, 55, 66\}$. The probability of observing μ_1 can be calculated directly using (2) – it is simply equal to P_{12}. The matching μ_2 implies that f_1 acquires f_2 *and* f_3 acquires f_4, and so $P_{12,34} = P_{12}P_{34}$. It is easy to see that the probability of any possible matching with at least one acquisition can be expressed using (2). As already mentioned, there is a possibility of a matching with zero acquisitions, namely if and only if all relative profit indices are negative. In this paper we do not derive the probability for that event, but deriving it is straightforward and can be done in a similar way as (2).

The empirical setup is the following: Each year with at least one acquisition there is data on n_t firms. The probability of each year's matching is calculated, and the likelihood function is the product of the matching probabilities over the years. Taking logs gives the log-likelihood function:

$$\ell(\boldsymbol{\beta}|\boldsymbol{X}) = \sum_{t=1}^{T} \ln \mathsf{P}_{O_t}(\boldsymbol{\beta}|\boldsymbol{x}_t), \tag{3}$$

where $\mathsf{P}_{O_t}(\boldsymbol{\beta}|\boldsymbol{x}_t)$ is the probability of observing the matching outcome during year t (O_t), with n_t firms whose attributes are gathered in $\boldsymbol{x}_t$, and $\boldsymbol{X} = (\boldsymbol{x}_1 \ \boldsymbol{x}_2 \ \cdots \ \boldsymbol{x}_T)$. The population parameter vector $\boldsymbol{\beta}$ is assumed to be fixed, but in principle it could be allowed to be time-varying. Interpretation of the parameter depends on the functional form of $g(\boldsymbol{x}_i, \boldsymbol{x}_j)$, and will be discussed later on.

Maximizing (3) gives the maximum-likelihood estimator $\widehat{\boldsymbol{\beta}}$, which under certain regularity conditions is consistent and asymptotically efficient.[2] The Fisher information matrix will be used as an estimate of the variance-covariance matrix of $\boldsymbol{\beta}$. In a somewhat similar setting Angelov (2005) shows that the MLE has reasonable finite-sample properties. More specifically, for finite samples, the Fisher information matrix does a fair job at estimating the true variance, and the MLE exhibits low bias. Nevertheless, the variance is underestimated in finite samples, which must be borne in mind when discussing the estimation results.

The next section contains an application of the model to a real data set, but before any estimation results are shown, we will spend some time discussing how parameters are to be interpreted. Although the model is similar to standard discrete-choice models, parameter interpretation is different.

Consider again the relative profit indices

$$D_{ij} = g(\boldsymbol{x}_i, \boldsymbol{x}_j) + \varepsilon_{ij}.$$

Unlike what is the case in standard discrete choice models, for f_i, both differences in profit and the overall profit level (relative to that of other firms), matter. The reason for that can be found in the condition for an acquisition, where D_{ij} is compared to $D_{mj}\ \forall\ m$ when deciding whether f_i will win the bidding for f_j, and in addition to $D_{jk}\ \forall\ k$ when deciding whether f_i will take over f_j or f_j will take over another firm.

Moreover, although the parameter vector $\boldsymbol{\beta}$ given data affects the probability of a certain acquisition, it does so in an indirect way. The reason is that a firm cannot choose to acquire another; at most, it can give a high rank to one. In turn, the high ranking increases the probability of a merger via the acquisition mechanism.

In general, the level of $\boldsymbol{\beta}$ cannot be given any precise meaning. But depending on the form of $g(\boldsymbol{x}_i, \boldsymbol{x}_j)$, the role of the sign is rather clear. This general function consists of f_i- and f_j-specific components. To see how parameters can be interpreted, consider the following hypothetical example: Assuming that data on firm size (s), earnings (e), and

[2]See Casella and Berger (2002, Section 10.6.2).

geographical location (l) are decisive of the firms' ranking of merge partners, we could have $g(\boldsymbol{x}_i, \boldsymbol{x}_j) = (s_i,\ e_i - e_j,\ l_j)$. If the relative profit index is linear in the independent variables, we end up with the specification

$$D_{ij} = \beta_1 s_i + \beta_2 (e_i - e_j) + \beta_3 l_j + \varepsilon_{ij}.$$

Assume for simplicity that all parameters are positive – how are they to be interpreted? The effect of s_i does not matter for f_i's ranking of other firms, but it does matter for the likelihood of f_i winning the bidding over the other firms that might be willing to acquire f_j. Thus, $\beta_1 > 0$ means that large firms, on average, are more likely to win a bidding, and thus, more likely to acquire other firms.

What about earnings differences? A positive increase in earnings differences does on average two things: it gives f_j a higher rank, and it increases the probability of f_i winning the bidding for f_j. Thus, a large $e_i - e_j$ on average has a positive effect on P_{ij}.

Finally, consider geographical location. Hypothetically, l_j might consist of a scale between one and five, where one represents a far location with bad infrastructure, and five represents an excellent location. For a positive β_3, the more well located a firm is, the more attractive it is to take over, and thus it has higher rank in an average firms preference ordering. This in turn implies that the probability that an average firm (and thus f_i) acquires f_j increases.

3. Empirical example

This section provides an example of an application of the model to a data set. The main focus of the present study is its methodological part, and consequently this empirical application is to be regarded as an illustration of the model's possibilities, rather than an investigation of merger incentives for firms in the specific data set. The main limitation of the data set is that it includes too few firm-specific characteristics.

The unbalanced panel database consists of data for 141 European and non-European firms – the latter being quite few – for the period 1984–2000. A particular firm is selected in the sample if a) the firm owns a pulp and paper plant in a western-European country[3], and b) the firm is included in any of the annual top lists of two industry-statistics yearbooks[4]. For each firm and year there is data on nationality, sales, earnings, pulp production, and production of paper and board. Data on nationality and sales cover the whole period, while data on earnings and production quantities are generally not available prior to the beginning of the 1990s.

During the period covered by the database, a total of 45 acquisitions are recorded, as displayed in Table 1, where the domicile of the firm is within parentheses. From the

[3]The pre-2004 EU-15, minus Luxembourg and Greece, plus Norway and Switzerland
[4]Fact & Figures, Pulp & Paper international, and Paper Data Base, European paper

beginning of the 1990s and onwards, except for 1993 and 2002, there were at least two mergers per year. In 1990 as many as 8 mergers took place. As can be seen in Figure 1, it is quite hard to see any time trend in the number of mergers per year.

Using the information on acquisitions, the firms can be divided into acquirers, targets, merged (which consists of acquirers and targets), and a control group. Figure 2 shows box-plots of the variables sales and earnings/sales for each group. If sales can be seen as a proxy for size, two conclusions can be drawn from a visual inspection of the first plot: the average acquirer is larger than the average target, and both are larger than the average firm that has not taken part in a merger. If earnings/sales can be seen as a proxy for profit, it seems that acquirers on average have a lower profit than targets, and firms that have not taken part in a merger are the most profitable. Naturally, this visual control is not systematic in any way, and since no statistical tests are applied to data it cannot be used to draw any conclusions.

Let us now turn to the real data application. We will only consider the case of hostile takeovers, and as mentioned earlier, yearly data on four firm characteristics are available: nationality, sales, earnings, and production. Both sales and production could be used as proxies for size, but sales is a better choice for at least two reasons. Firstly, data on sales is available for each year, while production only from the beginning of the 1990s and onwards. Secondly, sales are comparable over all firms, since they are expressed in the same units, while production is not. It is divided into two broad categories in the data set, namely production of pulp, and of paper and board. But if a firm produces physically more of lower-quality paper for daily newspapers than another firm produces of more expensive paper for monthly magazines, an economist would hardly call the first firm larger, without taking pricing into consideration. Sales can be seen as a weighted average of a firm's production, the weights being the prices of different kinds of products. Therefore, sales are a more universal proxy for size in economic terms, and will be used instead of production.

The nationality of the firm is the country where its head office is based, and thus that variable cannot be used as it is. Suppose that it were possible to rank the countries with respect to how good a location for either acquirers or targets each country is. This location variable could then be used as an independent variable in the specification, in similarity with the hypothetical example from the previous section. But such information is not available in the data set, and therefore we choose to form a dummy variable which is one if acquirer and target are in the same country, and zero otherwise. As mentioned earlier, data on nationality is available for the whole period.[5]

[5]A measure of geographical distance between the countries would be a more precise variable to use, showing not only whether firms are in the same country, but also how far they are from each other.

The level of earnings is not comparable between firms, since it depends on each firm's size. To make it comparable, it can be divided by sales, thus serving as a rough profit approximation.

The results from estimating the model under some different specifications are shown in table 2, where s_i are sales for f_i, N_{ij} is one if the domicile of the firms is the same and zero otherwise, and e_i are earnings for f_i. If a merger has taken place at t, we assume that the acquisition decisions were taken at $t-1$, and therefore the independent variables from $t-1$ are used. This seems a reasonable assumption, and besides, we are forced to make it, since no data is available for the target at the year of the merger.

Although the focus of this paper is not on testing a specific hypothesis, it might be helpful to do so when discussing the estimation results. Thus, assume that we want to test whether large firms, on average, rank smaller firms higher in their preference ordering. The first specification includes sales difference as the only independent variable, and the positive sign and significance of $\widehat{\alpha}$ seems to confirm the hypothesis. The second and third specifications can be seen as a way of introducing control variables in order to see how robust the result is. In fact, in each specification $\widehat{\alpha}$ is positive and significant. The same applies to $\widehat{\gamma}$, indicating that firms on average rank firms based in their own country higher than firms from abroad. The first and second specifications are estimated on the whole sample period, while the third only from 1990 and onward, because data on earnings is not available prior to 1990.

In fact, if one believes that earnings differences matter for the ranking, it would be more sensible to consider at least a couple of years before a merger. The problem is that we would lose even more data for each lagged value of e_i.

4. Concluding remarks

This paper proposes a model of firm acquisitions based on individual firm behaviour. It consists of a framework in which every firm is allowed to merge with any other, and provides a decision rule that sorts our the specific mergers that will take place. We also provide an empirical example using a data set from the European pulp and paper industry.

Although we believe that the model is more realistic than existing ones, it can be made even more so. There are several things that can be improved:

An implicit feature of the model is that D_{ij} does not depend on the actions of firms other than f_i and f_j. For situations with many firms, this can be fairly realistic, but perhaps not so in near-oligopoly situations. Consider for instance the relative profit to f_1 from merging f_2, denoted as D_{12}, when there are four firms on the market. It is implicit in the model that D_{12} is the same regardless of what f_3 and f_4 do. But if the latter two also merge, we end up with a duopoly, and the concentration in the market increases considerable. Increased market power might then be assumed to increase future expected profits for all firms. It might be interesting to investigate whether Condition 1 is still reasonable, and if not, how to alter it. But there is a trade-off between complexity of the acquisition rules and the tractability of the log-likelihood function. In Angelov (2005), the rules of the well-known roommate game are used, resulting in a much more complex likelihood function which is difficult to define for more than three firms.

When it comes to the econometric specification, the set of independent variables might for instance be extended with lagged values. It is likely that when one firm considers acquiring another, it looks at firm attributes during a period of time, rather than only at the latest data. On the other hand, including lagged variables in a panel-data setting introduces a time dependence between D_{ij} at time t and, say, $t-1$, and thus, a time dependence in firm's decision process, which needs to be analyzed.

Finally, a note on the economic interpretation of Condition 1 is worth mentioning. As discussed in length in Section 2, the acquisition condition can be rationalized using the notion of bid proposals among firms. We stated the following reason for f_j to accept being acquired, compared to being self-matched: The target f_j receives the bid proposal $D_{ij}/2$ from f_i, and given that f_j cannot acquire another firm, and since $D_{jj} \equiv 0$, f_j prefers being acquired to staying self-matched. But consider the case when D_{ji} is negative and $|D_{ji}| > D_{ij}/2$. Then if f_j is acquired, its net profit is $D_{ij}/2 + D_{ji} < 0$, and accepting the bid does not comply with profit maximization on behalf of f_j. There are two possible ways of dealing with this problem. One is to rationalize it by saying that this is a notion of a hostile takeover: Since f_i can induce the shareholders of f_j to sell their shares to f_i at a price higher than the market price, and since f_j cannot acquire another firm, the acquisition will take place. Perhaps a better solution is to include an inequality of the type $D_{ij}/2 + D_{ji} > 0$ for $D_{ij} < 0$, or a simpler and technically tractable version of it, in Condition 1. This is left for future research.

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Appendix A. Omitted probability derivation

It is claimed in the text that

$$\begin{aligned} \mathsf{P}_{ij} &= \mathsf{P}\big(D_{ij} > \max\{0; D_{mj}\ \forall\ m \neq i,j; D_{si}\ \forall\ s \neq i,j; D_{jh}\ \forall\ h \neq j\}\big) \\ &= \frac{e^{V_{ij}}\left(1 - e^{-\sum_{V_{kl}\in\mathcal{V}} e^{V_{kl}}}\right)}{\sum_{V_{kl}\in\mathcal{V}} e^{V_{kl}}}, \end{aligned}$$

where D_{ij} is according to Assumption 2, $V_{ij} = g(\boldsymbol{\beta}|\boldsymbol{x})$, $\boldsymbol{x} = (\boldsymbol{x}_i\ \boldsymbol{x}_j)$, and $\mathcal{V} = \{V_{ij}; V_{mj}\ \forall\ m \neq i,j; V_{si}\ \forall\ s$ Without the positivity constraint on D_{ij} this would have been a standard logit choice probability with a special choice set, namely the expression within curly brackets which is called the alternative set in this paper. Consequently, the derivation will be much in line with the logit choice probability derivation in, e.g., McFadden (1974).

The explanation behind the multiple integral that will be used to derive the probability is simple: The alternative set consists of zero and a number of random variables. We need to calculate the probability of each of those random variables being less than D_{ij}, while keeping D_{ij} positive. Note that $D_{ij} > D_{kl}$ can be rewritten as

$$\begin{aligned} & V_{ij} + \varepsilon_{ij} > V_{kl} + \varepsilon_{kl} \\ \Leftrightarrow\ & V_{ij} - V_{kl} + \varepsilon_{ij} > \varepsilon_{kl}. \end{aligned}$$

Each ε_{kl} is i.i.d. extreme value with location parameter equal to zero and scale parameter equal to one. We begin by integrating out each ε_{kl} over the range $(-\infty, V_{ij} - V_{kl} + \varepsilon_{ij})$. Then ε_{ij} is integrated over $(-V_{ij}, \infty)$, since $D_{ij} > 0$ can be written as $\varepsilon_{ij} > -V_{ij}$.

For conciseness, perform the indexation

$$\{V_{mj}\ \forall\ m \neq i,j; V_{si}\ \forall\ s \neq i,j; V_{jh}\ \forall\ h \neq j\} = \{V_1, V_2, \ldots, V_q\},$$

where $q = 3n-5$ and n is the number of firms.[6] The order is irrelevant, but it is important that every element is uniquely indexed. Below we will also use the notation ε_r to denote the random variable corresponding to V_r; for instance, if V_{kl} is indexed as V_r, then ε_{kl} is

[6] The number of elements is $3n-5 = 3(n-2)+1$ because two of the three subsets consists of $(n-2)$ elements and the last one contains $(n-1)$ elements. To see this, consider e.g., $\{V_{mj}\ \forall\ m \neq i,j\}$. If $i = 1$ and $j = 2$ this is equal to the set $\{V_{32}, V_{42}, \ldots, V_{n2}\}$, which has $(n-2)$ elements.

indexed as ε_r. Now we are ready to define the sought-for probability

$$\mathsf{P}_{ij} = \int_{-V_{ij}}^{\infty} e^{-\varepsilon_{ij}} e^{-e^{-\varepsilon_{ij}}} \left(\int_{\Omega} \cdots \int \prod_{r=1}^{q} e^{-\varepsilon_r} e^{-e^{-\varepsilon_r}} \; d\varepsilon_1 \, d\varepsilon_2 \cdots d\varepsilon_q \right) d\varepsilon_{ij},$$

where $\Omega \equiv \big\{ (\varepsilon_1, \varepsilon_2, \ldots, \varepsilon_q) \in \mathbb{R}^q : \varepsilon_1 \leq (V_{ij} - V_1 + \varepsilon_{ij}), \varepsilon_2 \leq (V_{ij} - V_2 + \varepsilon_{ij}), \ldots, \varepsilon_q \leq (V_{ij} - V_q + \varepsilon_{ij}) \big\}$. We begin by integrating out ε_1 which gives

$$\mathsf{P}_{ij} = \int_{-V_{ij}}^{\infty} \underbrace{e^{-\varepsilon_{ij}} e^{-e^{-\varepsilon_{ij}}} e^{-e^{-(V_{ij} - V_1 + \varepsilon_{ij})}}}_{\equiv A} \left(\int_{\Omega \backslash \varepsilon_1} \cdots \int \prod_{r=2}^{q} e^{-\varepsilon_r} e^{e^{-\varepsilon_r}} \; d\varepsilon_2 \cdots d\varepsilon_q \right) d\varepsilon_{ij}.$$

Next, note that we can write

$$\begin{aligned} A &= e^{-\varepsilon_{ij}} e^{-\left(e^{-\varepsilon_{ij}} + e^{-(V_{ij} - V_1 + \varepsilon_{ij})} \right)} \\ &= e^{-\varepsilon_{ij}} e^{-e^{-\varepsilon_{ij}} \left(1 + e^{V_1 - V_{ij}} \right)}. \end{aligned}$$

Using this while integrating out $\{\varepsilon_2, \ldots, \varepsilon_q\}$ allows us to finalize the derivation:

$$\begin{aligned} \mathsf{P}_{ij} &= \int_{-V_{ij}}^{\infty} e^{-\varepsilon_{ij}} e^{-e^{-\varepsilon_{ij}} \left(1 + \sum_{r=1}^{q} e^{V_r - V_{ij}} \right)} \; d\varepsilon_{ij} \\ &= \frac{1}{1 + \sum_{r=1}^{q} e^{V_r - V_{ij}}} \left(\lim_{b \to \infty} e^{-e^{-b} \left(1 + \sum_{r=1}^{q} e^{V_r - V_{ij}} \right)} - e^{-e^{V_{ij}} \left(1 + \sum_{r=1}^{q} e^{V_r - V_{ij}} \right)} \right) \\ &= \frac{1 - e^{-e^{V_{ij}} \left(1 + \sum_{r=1}^{q} e^{V_r - V_{ij}} \right)}}{1 + \sum_{r=1}^{q} e^{V_r - V_{ij}}} = \frac{1 - e^{-\left(e^{V_{ij}} + \sum_{r=1}^{q} e^{V_r} \right)}}{e^{-V_{ij}} \left(e^{V_{ij}} + \sum_{r=1}^{q} e^{V_r} \right)} \\ &= \frac{e^{V_{ij}} \left(1 - e^{-\left(e^{V_{ij}} + \sum_{r=1}^{q} e^{V_r} \right)} \right)}{e^{V_{ij}} + \sum_{r=1}^{q} e^{V_r}} = \frac{e^{V_{ij}} \left(1 - e^{-\sum_{V_{kl} \in \mathcal{V}} e^{V_{kl}}} \right)}{\sum_{V_{kl} \in \mathcal{V}} e^{V_{kl}}}. \end{aligned}$$

Appendix B. Tables

Table 1: Recorded acquisitions

Year	Acquirer	Target
1986	Kymmene (Finland)	Kaukas (Finland)
1988	SCA (Sweden)	Italcarta (Italy)
	SCA (Sweden)	Laakirchen (Austria)
	Rauma-Repola (Finland)	Stracel (France)
	MoDo (Sweden)	Holmen (Sweden)
	MoDo (Sweden)	Iggesund (Sweden)
	Kymmene (Finland)	Wilh Schauman (Germany)
	La Rochette Sempa (France)	La Cellulose du Rhon d'Aquitaine (France)
1989	Norske Skogsindustrier (Norway)	Follum (Norway)
1990	Saffa (Italy)	Sarrio Comp P de Leiza (Spain)
	Stora (Sweden)	Feldmuhle (Germany)
	Stora (Sweden)	Förenede Papirfabriken (Norway)
	JA/Mont (Ireland)	Nokia (Finland)
	SCA (Sweden)	Reed-Intl (the United Kingdom)
	Wiggins Teape (the United Kingdom)	Arjomari (France)
	Kymmene (Finland)	Chapelle Darblay (France)
	Stora (Sweden)	Papyrus (Sweden)
1991	UPM (Finland)	Rauma-Repola (Finland)
	Rauma-Repola (Finland)	Kajaani (Finland)
1992	KNP (the Netherlands)	Buhrmann-Tetterode (the Netherlands)
	Enso-Gutzeit (Finland)	Tampella (Finland)
1993	KNP (the Netherlands)	Leykam-Murtztaler (Austria)
1994	Metsä-Serla (Finland)	UK Paper (Bowater) (the United Kingdom)
	Enso-Gutzeit (Finland)	Berghuizer (the Netherlands)
	Jefferson Smurfit (Ireland)	La Cellulose du Pin (France)
	AssiDomän (Sweden)	NCB (Sweden)
1995	Kimberly-Clark (USA)	Scott (USA)
	Metsä-Serla (Finland)	Metsä-Botnia (Finland)
	SCA (Sweden)	PWA (Germany)
	Trebruk (Sweden)	Munkedals (Sweden)
1996	UPM-Kymmene (Finland)	Kymmene (Finland)
	Enso Oy (Finland)	Veitsiluoto (Finland)
	Metsä-Serla (Finland)	Biber (Switzerland)
	Myllykoski (Finland)	Biber (Switzerland)
	Ahlstrom (Finland)	Sibille Stenay (France)
1997	Reno di Medici (Italy)	Saffa (Italy)
	Enso Oy (Finland)	Holtzmann Papier (Germany)
1998	Stora-Enso (Finland)	Stora (Sweden)
	Jefferson Smurfit (Ireland)	Nettingsdorfer (Austria)
1999	Cham Holding (Switzerland)	Hunsfos (Norway)
	Sappi (South Africa)	Leykam-Murtztaler (Austria)
2000	Georgia Pacific Corporation (USA)	Fort James Corp. (USA)
	Metsä-Serla (Finland)	MoDo Paper (Sweden)
2001	UPM-Kymmene (Finland)	Haindl'sche Papierpabriken (Germany)
	Portucel (Portugal)	Soporcel (Portugal)
	M-Real (Finland)	Zanders Feinpapiere (Germany)

specification	parameter estimates			
	$\widehat{\alpha}$	$\widehat{\gamma}$	$\widehat{\theta}$	LR index
$D_{ij} = \alpha \ln(\frac{s_i}{s_j}) + \varepsilon_{ij}$	0.6966 [4.9957]			0.1028
$D_{ij} = \alpha \ln(\frac{s_i}{s_j}) + \gamma N_{ij} + \varepsilon_{ij}$	0.7783 [5.0782]	2.2541 [5.3455]		0.1837
$D_{ij} = \alpha \ln(\frac{s_i}{s_j}) + \gamma N_{ij} + \theta(e_i/s_i - e_j/s_j) + \varepsilon_{ij}$	0.6867 [1.9746]	1.7975 [1.5763]	0.9936 [0.4598]	0.1523

Table 2: Parameter estimates with t-values within parentheses, resulting from three different specifications. The LR index is defined as $1 - \frac{\ell(\widehat{\boldsymbol{\beta}}|\boldsymbol{X})}{\ell(\mathbf{0}|\boldsymbol{X})}$.

Appendix C. Figures

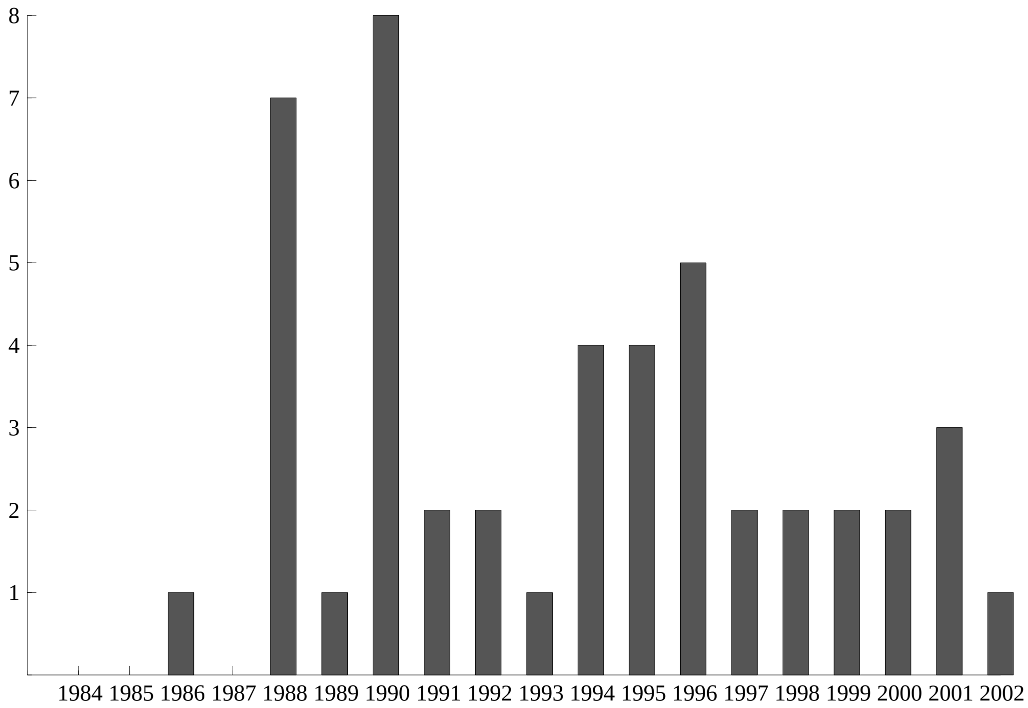

Figure 1: Number of mergers per year.

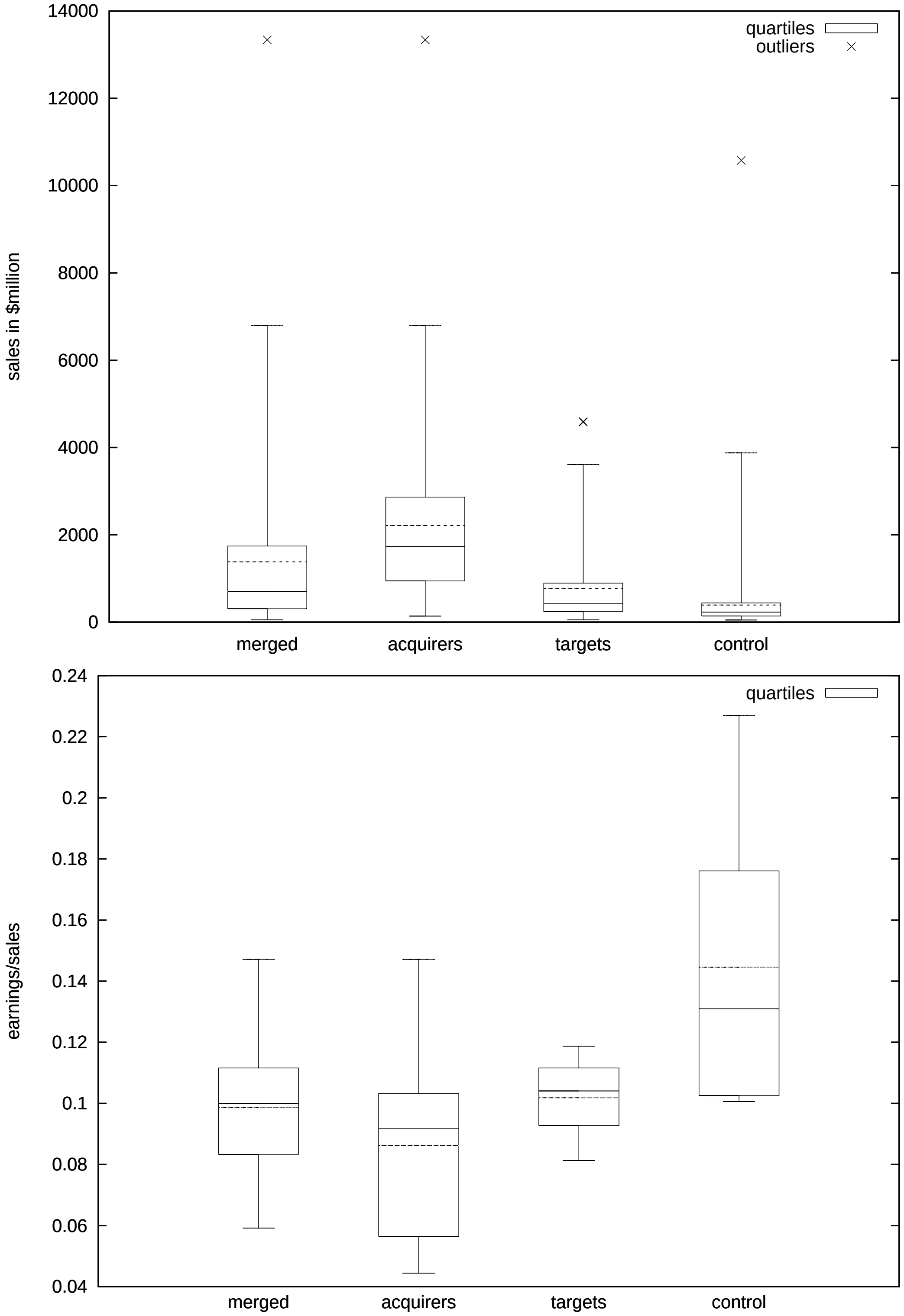

Figure 2: Box-plot of sales and earnings; dotted line represents the mean.