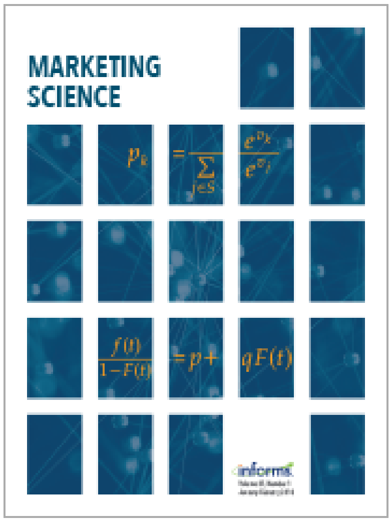

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Intra- and Interformat Competition Among Discounters and Supermarkets

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The price-aggressive discount format, popularized by chains such as Aldi and Lidl, is very successful in most Western economies. Its success is a major source of concern for traditional supermarkets. Discounters not only have a direct effect on supermarkets' market shares, but they also exert considerable pressure to improve operational efficiency and/or to decrease prices.

We use an empirical entry model to study the degree of intra- and interformat competition between discounters and supermarkets. Information on the competitive impact of new entrants is derived from the observed entry decisions of supermarkets and discounters in a large cross section of local markets, after controlling for a number of local market characteristics. In our modeling framework, we endogenize the number of retailers and allow for asymmetric intra- and interformat competitive effects in a flexible way.

We apply our modeling approach to the German grocery industry, where the discount format has stabilized after two decades of continued growth. We find evidence of intense competition within both the supermarket and discounter format, although competition between supermarkets is found to be more severe. Most importantly, discounters only start to affect the profitability of conventional supermarkets from the third entrant onwards. This may explain why many retailers rush to add a discount chain to their portfolio: early entrants may benefit from the growth of the discount-prone segment without cannibalizing the profits of their more conventional supermarket stores.

Key words: empirical entry model; hard discounters; interformat competition; grocery industry
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1. Introduction

Over the last decade, the grocery-retailing landscape has changed dramatically in most Western economies. The emergence of the hard-discount format, popularized by companies such as Aldi and Lidl, has altered the dynamics of the industry significantly. Hard discounters are distinct from every-day-low-price retailers such as Wal-Mart (studied in Singh et al. 2006 and Zhu et al. 2009) in the United States, and from large supermarkets such as Albert Heijn and Tesco in Europe. First, they offer much fewer categories of goods, and stock only a limited selection of items—typically fewer than 1,400 stock-keeping units (SKUs), compared to the 15,000+ items carried in most supermarkets or the 80,000+ items in a Wal-Mart supercenter. Second, they offer very few, or even no, manufacturer brands. Their assortment is dominated by private labels whose quality is often as good as that of leading national brands. Third, their stores are relatively small, with a trading area often not exceeding 11,000 square feet (PlanetRetail 2006a). The shopping environment is very functional (even minimalistic), and few services are offered to consumers. For example, discounters tend to have bare walls, and customers typically have to select their groceries from cardboard boxes stacked on pallets. Above all, prices are very low. They can be up to 60% lower than the price of leading name brands and as much as 40% lower than traditional retailers' private-label products.

Early on, conventional retailers dismissed hard discounters as an anomaly from Germany, where the format originated. However, its two most successful discount chains, Aldi and Lidl, which together operate over 13,000 stores and account for more than 50% of the discount sales in Europe, have brought their tactics (mimicked by many other chains) to other parts of Europe and far beyond. In countries such as Austria (18.9% discount share), Denmark (15.8%), and Belgium (10.9%), the discount share of the grocery market already exceeds 10%, and shares as high as 26.9% and 34.7% are obtained in Germany and Norway. At the moment, there are around 35,000 discount grocery stores in Europe, a number forecasted to increase nearly 30% to 45,000 in 2010 (PlanetRetail 2006a). Apart from Aldi and Lidl, well-known European discount chains include Plus and Penny in Germany, NORMA and Ed in France, Dia in Spain, Asda Essentials in the United Kingdom, and Dansk in Denmark. In the United States, comparable stores are price-aggressive grocery discounters, such as Save-A-Lot, who witness rapid growth as well. Several leading European players, among which are Aldi and Lidl, have recently announced plans to considerably expand their U.S. presence.

The success of discounters has become a major source of concern for traditional retailers. Discounters not only have a direct effect on traditional retailers' market share, but they also put pressure on other players to increase operational efficiency and/or decrease prices (van Heerde et al. 2008). Conventional retailers can fight back on two fronts. First, they can become involved in the discount format themselves. Carrefour, Casino, and Rewe, for example, have already established discount chains of their own (i.e., ED, Leader Price, and Penny), whereas Auchan and Tesco are experimenting along the same lines. In so doing, these retailers hope to capitalize on the growth of the discount-prone segment and to curb the growth of competitors such as Aldi and Lidl, who only operate through the discount format. Still, this practice may well cannibalize their core business, i.e., their conventional supermarkets. At the other side of the spectrum, retailers may emphasize the intrinsic strengths of the conventional supermarket format, such as the higher service level and the more extensive choice offered to maximally differentiate themselves from the no-frills, limited-choice discounters.

To assess the relative merits of both strategies, insights are needed on the nature and extent of competition between supermarkets and discounters. On the one hand, retail competition is unlikely to be restricted completely to intraformat rivalry, as different formats essentially compete for business from most, if not all, consumer segments. On the other hand, the actual level of interformat competition is attenuated by the formats' degree of diversification (Soberman 2005). Given the substantial differences in positioning, assortment composition, pricing, and store environment, the extent of interformat competition is expected to be smaller than the extent of intraformat competition. However, it is hard to predict a priori how large this difference will be. It is also not clear whether interformat competition is symmetric. In other words, are conventional supermarkets and hard discounters equally vulnerable when a store of the other format enters their trading zone, and how does this vulnerability compare to the competitive impact of a same-format entry? Moreover, does this competitive threat vary with the number of incumbents of either format?

To answer these questions, we adapt recent empirical entry models from the industrial organization literature. Although several studies have already looked at interformat competition (as shown in Table 1), few considered simultaneously intra- and interformat competition. Within the subset that does so, only two studies (Gijsbrechts et al. 2008, González-Benito et al. 2005) focused on the competition between supermarkets and discounters. In these studies, however, the presence of the different chains was predetermined (exogenous). As such, no insights could be obtained on how the extent of competition would vary as the number of players of either format varied. Such insights are one of the key outputs of our approach and are of vital importance (as recognized by the UK Competition Commission) in any competitive assessment.[1]

The general idea of our approach is to infer information on the competitive impact of new entrants from the observed entry decisions of supermarkets and discounters in a broad cross section of local markets, as opposed to a focus on a single market (e.g., city) in most prior research. Rather than looking at consumers' choices among existing stores, we focus on the observed entry decisions of the different retailers and link these decisions to their unobservable profit. Retailers are assumed to only enter into (and stay in) a local market if profitable. This profitability falls with the entry of additional players, even though the extent of this decline may differ across formats. As such, observed market structures result from the different firms' profit-maximizing decisions, taking into account the expected conduct and performance of both incumbent and potential competitors (Bresnahan and Reiss 1991b).

The model we develop is very flexible. First, we allow for differential (asymmetric) effects both within and between formats. Moreover, we estimate the effect of the number of intra- and interformat incumbents in a semiparametric way. As such, we

[1] See, e.g., http://www.competition-commission.org.uk/inquiries/ref2006/grocery/provisional_decision_remedies.htm.

Table 1 Overview of Marketing Literature on Interformat Competition

Study	Type of competition	Formats studied	Geographical scope	Treatment of chain presence
Bell et al. (1998)	Intra and inter	EDLP and HiLo supermarkets	One metropolitan area	Exogenous
Bell and Lattin (1998)	Inter	EDLP and HiLo supermarkets	One city	Exogenous
Bhatnagar and Ratchford (2004)	Inter	Supermarkets, convenience stores, food warehouses	One city and one town	Exogenous
Fox et al. (2004)	Intra and inter	Grocery stores, mass merchandisers, drug stores	One metropolitan market	Exogenous
Gijsbrechts et al. (2008)	Intra and inter	Hard discounters, large discounters, superstores, and supermarkets	Different local markets	Exogenous
González-Benito et al. (2005)	Intra and inter	Supermarket, hypermarket, and discount stores	One city	Exogenous
Lal and Rao (1997)	Inter	EDLP and HiLo supermarkets	One small region	Exogenous
Popowski-Leszczyc et al. (2000)	Intra and inter	EDLP and HiLo supermarkets	One city	Exogenous
Popowski-Leszczyc et al. (2004)	Intra and inter	EDLP and HiLo supermarkets	One suburban area	Exogenous
Rhee and Bell (2002)	Intra and inter	EDLP and HiLo supermarkets	One local market	Exogenous
Singh et al. (2006)	Inter	Supercentre and HiLo supermarket	One suburban town	Exogenous
Present study	Intra and inter	Supermarkets and discounters	Entire German market	Endogenous

allow for differential effects of different numbers of competitors and quantify whether the competitive impact increases (perhaps even disproportionally) as the number of incumbents increases—or alternatively, whether this effect is largest for the first entry of a certain format in a local market. We control for various local market characteristics when estimating the competitive impact of new entrants, and these effects are allowed to vary across formats.

We apply our modeling approach to the German grocery industry, which offers a good setting to study how the discount format affects the competitive structure within the sector. Although the discount phenomenon is still growing in most Western countries, the German discount market has recently stabilized after almost a half century of continued growth.

2. Conceptual Development

Store formats can be considered broad, competing categories that provide benefits to match the needs of different types of consumers and/or shopping situations (González-Benito et al. 2005). Although different formats provide different types of benefits, they increasingly compete with one another for the same consumers across overlapping product categories. This is referred to as *interformat* competition. In this paper, we focus on the competition between conventional supermarkets and discounters, as these two formats are among the most widespread formats in Europe. Retailers of the same format also compete for their respective share of the consumers' wallet, a phenomenon called *intraformat* competition. This is assumed to be more pronounced than the extent of interformat competition, because stores of the same format target a similar consumer segment with similar marketing policies (Fox et al. 2004).

2.1. Intraformat Competition

Similar to brand competition, the degree of competition between stores is linked to the similarity of benefits they offer. Because store formats consist of relatively homogeneous groups of stores in terms of positioning strategy (Fox et al. 2004), we expect intense intraformat competition for both supermarkets and discounters.

We expect a particularly intense intraformat competition among supermarkets, as they are known to fight a fierce market-share battle because of an increasing saturation in their market, culminating in frequent promotional and advertising (re)actions (Rao and Syam 2001). However, for discounters as well, we expect some extent of intraformat competition. Although they differentiate themselves less on dimensions such as assortment and service level, and even though they are known to use fewer advertising and promotional campaigns, they do compete on the price dimension. By estimating format-specific intraformat competitive effects, we will be able to infer whether, and to what extent, the intraformat competition is indeed more pronounced among supermarkets than among discounters.

2.2. Interformat Competition

Supermarkets and discounters emphasize different consumer benefits and can therefore be seen as targeting different consumer segments. In practice, however, no full differentiation is expected. Although supermarkets usually have a much broader and deeper assortment, product offerings in both formats show considerable overlap. As such, stores in both formats may still experience considerable interformat competition.

We have no firm priors as to which format has the highest clout (or is least vulnerable). On the one hand, discounters may influence the overall price sensitivity in the market because of their focus on very aggressive prices (van Heerde et al. 2008). On the other hand, supermarkets can use frequent and/or deep price promotions to attract customers from the lower-price-tier discounters (Rajiv et al. 2002). Also, other marketing instruments matter. Supermarkets often use the diversity in their assortment as the main selling proposition. Discounters, in turn, increasingly add national brands to their assortment to strengthen their competitive position relative to supermarkets (Deleersnyder et al. 2007). To compare the vulnerability and clout of both formats, we allow for asymmetric intercompetitive effects.

2.3. Control Variables

We control for several factors that may impact the attractiveness of a local market.

As *population* size can be considered a proxy of market size (see, e.g., Bresnahan and Reiss 1991b), the demand for groceries is expected to increase with the number of inhabitants in the local market. This will have a positive impact on the profitability of both supermarkets and discounters. *Income* reduces price sensitivity as well as the preference for private labels (Ailawadi et al. 2001). Given that discounters have a lower average price and more private labels than supermarkets, a higher income may shift demand from discounters to supermarkets. People of foreign ethnicity are usually more price sensitive (Hoch 1996). We therefore expect demand to shift from supermarkets to the lower-price discounters in markets with more *foreign households*. Larger families have been shown to be more price sensitive as well (Hoch et al. 1995). A larger average *household size* in the local market may therefore shift demand towards the grocery discounters. Older people (*age*) are, on average, more price sensitive (Hoch et al. 1995) and buy more store brands (Hoch 1996), which may shift their preference from the supermarket to the discount format. Hoch et al. (1995) have shown that unemployed customers are usually more price sensitive. Furthermore, unemployed people have an increased inclination for private labels (Hoch 1996). Therefore, we expect a demand shift from supermarkets to discounters in markets with a higher *unemployment* level.

As cities may attract business from smaller towns, we expect a negative impact on the profitability of both grocery formats when a *city* is nearby. We add the *surface* of the market to control for a potential spread of competitors, which may lead to a higher markup because of softened competition. On the other hand, when markets are larger, consumers incur more travel costs, which may decrease their spending on groceries. The net effect of these opposing forces is hard to predict beforehand. We add the *distance to the nearest town* to control for potentially overlapping markets (see Asplund and Sandin 1999 for a similar practice). When markets overlap, consumers may cross the border to do their shopping in a nearby town. Depending on the amount of demand attraction from and loss of demand to the nearby town, the effect on supermarket and discounter profitability may be positive or negative. As *population growth* can be considered a proxy for market-size expectations, we predict markets with a higher population growth to attract more supermarkets and discounters.

Given that *hypermarkets* will, to some extent, compete for the same business as supermarkets and discounters, we predict a negative impact of hypermarket presence on the profitability of both formats. Although not comparable in demand and cost factors to stores belonging to large chains, we predict a negative impact of *independent supermarkets* because of overlapping product offerings.

3. Model

Our empirical entry model can be situated in the "multiple-agent qualitative-response" models introduced in the industrial organization literature (see Berry and Reiss 2007 for a recent overview). This approach aims to make inferences about unobserved profits from the firms' observed entry decisions. It extends single-agent discrete-choice models (McFadden 1982) by allowing for the interdependence between the agents' decisions, based on game-theoretic equilibrium concepts.

The starting point in an empirical entry model is the assumption that the firms' entry decisions form a Nash equilibrium. The conceptual problem, however, is that there may be multiple Nash equilibria for the same underlying conditions, making it impossible to unambiguously infer the unobserved profits from the observed entry decisions (see Bresnahan and Reiss 1991a for a discussion of this multiplicity problem). For example, in an entry game with two potential entrants, A and B, one Nash equilibrium may be that firm A enters, whereas firm B does not; and another Nash equilibrium may be that B enters, whereas A does not.

Various solutions to the multiplicity problem have been proposed in the literature. First, Bresnahan and Reiss (1991b) look at the aggregate entry outcome in a game with homogeneous firms, i.e., the total number of firms for which there is a unique prediction. This approach has recently been applied in marketing to examine competition between video stores (Cleeren et al. 2006). Second, Berry (1992) allows for heterogeneous firms but explicitly introduces a sequential move structure so that a unique subgame perfect equilibrium results. In the above example, if firm A moves first, the unique equilibrium will be that firm A enters, whereas firm B does not. A recent application of this approach in a retail setting is by Zhu et al. (2009). A third approach to the multiplicity problem is offered by Seim (2006). She introduces incomplete information about the other firms' profitability. Under certain parameter conditions, this modification gives a unique Bayesian Nash equilibrium. Finally, Ciliberto and Tamer (2009) cope with the multiplicity problem by focusing on the upper- and lower-bound entry probabilities. Their econometric methodology restricts the estimated parameters to a set instead of concentrating on point estimates and thus obtains partial identification without imposing homogeneous firms or an equilibrium refinement.

Our entry model is in the spirit of Mazzeo (2002), which is a combination of the first two approaches discussed above. He allows for two types of firms and assumes that firms of the same type are identical. He considers a Stackelberg entry game where firms sequentially decide on entry and type of firm. His sequential move game generates unique equilibrium predictions on the number of firms of each type. Our modeling approach contributes to Mazzeo (2002) in two ways. First, we show how to characterize the multiplicity of Nash equilibria in a general way, which is useful for other applications in this line of research (see the appendix for a detailed discussion). Second, we consider a modified version of Mazzeo's entry game, where firms have first chosen their product type (format) before deciding whether to enter and then follow a predetermined sequence of moves.[2] Not only is this approach more realistic in our setting, it also leads to a simpler likelihood function with only rectangular areas of integration. This decreases computational difficulties in estimating the model (see also Berry and Reiss 2007 (§3.2.3) on the computational difficulties with nonrectangular areas of integration).

3.1. Econometric Framework

Stores are assumed to belong to either of two formats, $f = S, D$, where S and D represent, respectively, the supermarket and discount format. Profits for a chain of format f in a particular market are given by the latent variable Π_f, which consists of a deterministic part, $\pi_f(N_S, N_D)$, and a random part, ε_f:

$$\Pi_f(N_S, N_D) = \pi_f(N_S, N_D) - \varepsilon_f, \tag{1}$$

with N_S and N_D, respectively, the number of supermarket and discount chains in town.[3,4] Marketing policies and shopping behaviors are rather homogeneous within each format, but different across formats (Fox et al. 2004). Therefore, we allow for different profit functions for supermarkets and discounters while assuming identical payoffs within a format (see also Mazzeo 2002). The payoff for a chain that does not enter the market is set to zero.

The unobserved firm profitability can be linked to the observed number of firms by explicitly modeling the entry process. A first assumption is that chains of the same format are substitutes, which implies a negative impact of own-format entry on profitability. More formally, we can formulate this assumption as follows:

Assumption 1 (Intraformat Substitutability).

$$\pi_S(N_S+1, N_D) < \pi_S(N_S, N_D),$$
$$\pi_D(N_S, N_D+1) < \pi_D(N_S, N_D).$$

In addition, different formats compete, to some extent, for business from the same consumers. Therefore, interformat competitors are assumed to have a negative impact on profitability. However, as the degree of substitutability was found to be larger within than between formats (Fox et al. 2004, González-Benito et al. 2005), the decrease in store payoff is assumed to be largest when the entrant is of the same format. This amounts to the following assumptions:

Assumption 2A (Interformat Substitutability).

$$\pi_S(N_S, N_D+1) \le \pi_S(N_S, N_D),$$
$$\pi_D(N_S+1, N_D) \le \pi_D(N_S, N_D).$$

Assumption 2B (Stronger Intraformat than Interformat Substitutability).

$$\pi_S(N_S+1, N_D-1) < \pi_S(N_S, N_D),$$
$$\pi_D(N_S-1, N_D+1) < \pi_D(N_S, N_D).$$

[2] Note that Dranove et al. (2003) and Cohen and Mazzeo (2007) also abstract from format choice. However, because these papers still assume that the most profitable firm enters first, the nonrectangular areas of integration remain.

[3] Note that this model assumes that all consumers and stores are located at one central point in the market.

[4] Note that we consider profitability (and hence, entry) at the *chain* rather than at the individual *store* level. In subsequent validation exercises, we will test the robustness of our key insights to this practice.

Assumption 2A implies that a store's profitability is decreasing with the number of chains of the other format.[5] In turn, Assumption 2B states that the negative impact of entry is larger when the entrant is of the same format than when the entrant is of the other format; i.e., there is stronger intraformat than interformat substitutability.

Based on these assumptions, we now derive the equilibrium number of chains of each format and construct the implied likelihood function.[6] We start from the Nash equilibrium concept, according to which all potential chains enter (and stay in) the market if and only if this is profitable in the long run, given the entry decisions of the other chains. More specifically, the market configuration (n_S, n_D) is a Nash equilibrium if the random profit components ε_S and ε_D satisfy the following conditions:

$$\begin{aligned} \pi_S(n_S+1, n_D) &< \varepsilon_S \leq \pi_S(n_S, n_D), \\ \pi_D(n_S, n_D+1) &< \varepsilon_D \leq \pi_D(n_S, n_D). \end{aligned} \tag{2}$$

Under (2), n_S supermarket chains find it profitable to enter the market ($\Pi_S(n_S, n_D) \geq 0$), whereas one extra supermarket would be unprofitable ($\Pi_S(n_S+1, n_D) < 0$). Similarly, n_D discount chains have nonnegative payoffs, whereas one more discounter would make a loss. Therefore, the conditions in (2) indeed describe a Nash equilibrium.

However, there may be many Nash equilibria for some realizations of the error terms (Bresnahan and Reiss 1991a). This precludes straightforward econometric estimation, as there is no unique relationship between the unobserved profits and the observed entry decisions. Figure 1 visualizes the problem in a simple game with one potential entrant for each format. The vertical lines indicate when the supermarket chain can profitably enter, given that the discount chain also enters (line $\pi_S(1,1)$) or given that the discount chain does not enter (line $\pi_S(1,0)$). The horizontal lines are similar profitability lines for the discounter, given the supermarket's entry decision. For low realizations of both ε_S and ε_D, the unique Nash equilibrium is $(1,1)$; i.e., both firms enter. Conversely, for large realizations of ε_S and ε_D the unique Nash equilibrium is $(0,0)$. Asymmetric market configurations $(1,0)$ or $(0,1)$ may also be obtained as unique Nash equilibria for a range of realizations of ε_S and ε_D (the upper left and bottom right areas). However, for intermediate realizations of both ε_S and ε_D, the market configurations $(1,0)$ or $(0,1)$ are both Nash equilibria, as indicated by the shaded rectangle. Intuitively, for these realizations there is a coordination problem, and either the supermarket or the discounter enters the market.

In the general case with more than one potential entrant of each format, the multiplicity problem becomes considerably more complicated. When (n_S, n_D) is a Nash equilibrium, there may in principle be multiplicity with many other possible market configurations. However, under Assumptions 1 and 2, the multiplicity of equilibria can be characterized by three simple claims, as we show in the appendix.

Claim 1. *(n_S, n_D) may only show multiplicity with equilibria of the form (n_S+m, n_D-m), where m is a positive or negative integer. Thus, $(2,3)$ can show multiplicity with, say, $(3,2)$ or $(0,5)$ but not with, say, $(1,5)$. Hence, there is a unique prediction for the total number of entrants $n = n_S + n_D$.*

Claim 2. *(n_S, n_D) necessarily shows multiplicity with (n_S-1, n_D+1) and (n_S+1, n_D-1).*

Claim 3. *Whenever (n_S, n_D) shows multiplicity with (n_S+m, n_D-m), the multiplicity area is necessarily a subset of the multiplicity area with (n_S+1, n_D-1) for $m>0$ and a subset of the multiplicity area with (n_S-1, n_D+1) for $m<0$.*

Taken together, these three claims imply that the area of $(\varepsilon_S, \varepsilon_D)$ for which (n_S, n_D) shows multiplicity with any other Nash equilibrium is simply given by the areas of overlap with (n_S+1, n_D-1) and (n_S-1, n_D+1). The area of multiplicity with (n_S+1, n_D-1) is simply

$$\begin{aligned} \pi_S(n_S+1, n_D) &< \varepsilon_S \leq \pi_S(n_S+1, n_D-1), \\ \pi_D(n_S+1, n_D) &< \varepsilon_D \leq \pi_D(n_S, n_D). \end{aligned} \tag{3a}$$

Similarly, the area of multiplicity with (n_S-1, n_D+1) is

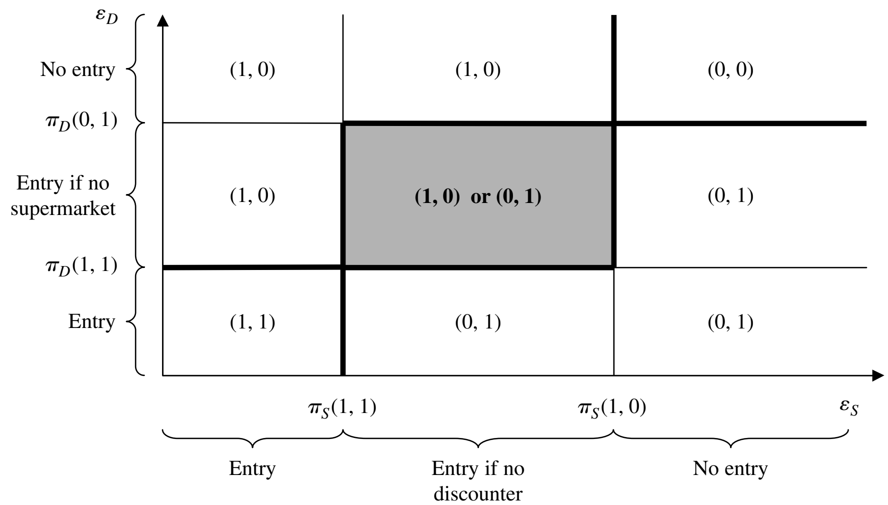
$$\begin{aligned} \pi_S(n_S, n_D+1) &< \varepsilon_S \leq \pi_S(n_S, n_D), \\ \pi_D(n_S, n_D+1) &< \varepsilon_D \leq \pi_D(n_S-1, n_D+1). \end{aligned} \tag{3b}$$

To obtain unique entry predictions, we put additional structure on the entry game by assuming that firms enter according to a certain sequence and refine the Nash equilibrium concept to that of subgame perfection. Consider the example of Figure 1 with one potential entrant of each format, and suppose that the supermarket can make the entry decision before the discounter. The market configuration $(1,0)$ would then be selected as the subgame perfect equilibrium (SPE) when there is multiplicity with $(0,1)$; i.e., the

[5] If the conditions hold with equality, the different formats are said to be independent.

[6] The implied likelihood function will be estimated without any parameter restrictions. In §5, we verify whether the estimated parameters are consistent with these assumptions (see Schaumans and Verboven 2008 for a similar practice). In so doing, these assumptions become testable and could also be referred to as hypotheses (we thank an anonymous reviewer for this observation).

Figure 1 Multiplicity Problem for a 2 × 2 Game



supermarket chain enters while the discounter stays out of the market.

More generally, for any market configuration (n_S, n_D) SPE will be equal to the Nash area (2) from which we either subtract the overlap area (3a) or (3b) or nothing. What we subtract depends on the underlying sequence of entry that one assumes. For example, in a setting with up to two supermarkets and up to five discount chains, the entry sequence could be described as SSDDDDD (all supermarkets first), DDDDDSS (all discounters first), SDSDDDD (alternating with a supermarket first), DSDSDDD (alternating with a discounter first), etc. There are, therefore, many possible sequences. However, when looking at a market configuration (n_S, n_D) only the first $n = n_S + n_D$ moves in the assumed sequence are relevant.[7] Furthermore, only the number of players of each type during these first n moves matters, and their exact order of entry is otherwise irrelevant.

Formally, let the number of players of format S during the first n moves be $\tilde{n}_S$ (so that the number of format D players during this sequence is $\tilde{n}_D = n - \tilde{n}_S$). We can then assign the following areas of $(\varepsilon_S, \varepsilon_D)$ as an SPE for the market configuration (n_S, n_D):

(i) Suppose we have exactly n_S format S movers during the sequence n; i.e., $\tilde{n}_S = n_S$. Then (n_S, n_D) obtains as an SPE whenever there is multiplicity, so the whole Nash equilibrium area (2) describes (n_S, n_D) and nothing has to be subtracted.

(ii) Suppose we have at least $n_S + 1$ format S movers during the sequence n; i.e., $\tilde{n}_S > n_S$. Then $(n_S + 1, n_D - 1)$ (or even $(n_S + 2, n_D - 2)$, etc.) obtains as an SPE whenever there is multiplicity, so we need to subtract the area (3a) from (2).

(iii) Suppose we have at most $n_S - 1$ format S movers during the sequence n; i.e., $\tilde{n}_S < n_S$. Then $(n_S - 1, n_D + 1)$ (or even $(n_S - 2, n_D + 2)$, etc.) obtains as an SPE whenever there is multiplicity, so we need to subtract the area (3b) from (2).[8]

We can now write the probability of observing market configuration (n_S, n_D) as an SPE:

$$
\begin{aligned}
P(N_S = n_S, N_D = n_D) &= \int_{\pi_S(n_S+1,\, n_D)}^{\pi_S(n_S,\, n_D)} \int_{\pi_D(n_S,\, n_D+1)}^{\pi_D(n_S,\, n_D)} \phi(u_S, u_D)\, du_S\, du_D \\
&\quad - I(\tilde{n}_S - n_S) \int_{\pi_S(n_S+1,\, n_D)}^{\pi_S(n_S+1,\, n_D-1)} \int_{\pi_D(n_S+1,\, n_D)}^{\pi_D(n_S,\, n_D)} \phi(u_S, u_D)\, du_S\, du_D \\
&\quad - I(n_S - \tilde{n}_S) \int_{\pi_S(n_S,\, n_D+1)}^{\pi_S(n_S,\, n_D)} \int_{\pi_D(n_S,\, n_D+1)}^{\pi_D(n_S-1,\, n_D+1)} \phi(u_S, u_D)\, du_S\, du_D,
\end{aligned} \tag{4}
$$

where $I(x)$ is an indicator function equal to one if $x > 0$, and equal to zero otherwise. $\phi(.)$ is the standardized bivariate normal density function with correlation parameter ρ, which accounts for common shocks in the unobserved components of the profit functions. The first term in (4) describes the Nash equilibrium area as given by (2); the second term subtracts the area of overlap with $(n_S + 1, n_D - 1)$ as given by (3a), when $\tilde{n}_S > n_S$; and the third term subtracts the area of overlap with $(n_S - 1, n_D + 1)$ as given by (3b), when $\tilde{n}_S < n_S$. Notice that the second and third terms

[7] This follows from Claim 1, according to which the total number of entrants can be uniquely determined as $n = n_S + n_D$.

[8] To illustrate, consider the sequence of entry where supermarkets enter first, i.e., SSDDDDD. For an observed market structure $(n_S, n_D) = (1, 1)$, we have $n = 2$ and the relevant sequence is thus restricted to the first two moves; i.e., SS. The number of movers of format S during these first two moves is $\tilde{n}_S = 2$. This implies that $\tilde{n}_S > n_S (2 > 1)$. As such, when $(1, 1)$ shows multiplicity with $(2, 0)$, $(2, 0)$ obtains as the SPE, and the area in Equation (3a) is subtracted from (2).

in (4) equal zero if supermarkets and discounters have no direct impact on each other's profit functions. In this case there is no multiplicity problem, and thus only the first term remains. The model then reduces to a bivariate ordered probit model with a correlation parameter ρ. If, in addition, this correlation parameter is restricted to zero, the model reduces to two separate ordered probit models, one for each format, as in the well-known model of Bresnahan and Reiss (1991b).

The probability of observing (n_S, n_D) as given by (4) requires a specification of the ordering of moves. Because the traditional supermarket format was developed long before the discounter format, we assume that supermarkets entered the market first. In this case, whenever there are multiple Nash equilibria, the market configuration with the higher number of supermarket chains will be selected as the unique SPE.[9] The probability of observing market configuration (n_S, n_D) then simplifies to

$$\begin{aligned} &P(N_S = n_S, N_D = n_D) \\ &= \int_{\pi_S(n_S+1,\, n_D)}^{\pi_S(n_S,\, n_D)} \int_{\pi_D(n_S,\, n_D+1)}^{\pi_D(n_S,\, n_D)} \phi(u_S, u_D)\, du_S\, du_D \\ &\quad - I(\tilde{n}_s - n_s) \int_{\pi_S(n_S+1,\, n_D)}^{\pi_S(n_S+1,\, n_D-1)} \int_{\pi_D(n_S+1,\, n_D)}^{\pi_D(n_S,\, n_D)} \phi(u_S, u_D)\, du_S\, du_D. \end{aligned} \tag{5}$$

Intuitively, when there is multiplicity we always subtract from the (n_S, n_D) area the overlap with Nash equilibria where *more* supermarket chains would enter, as described by the area of multiplicity with $(n_S + 1, n_D - 1)$ given by (3a). Because the ordering of moves where supermarkets enter first is most reasonable in our application, we take (5) as our point of departure for the likelihood function. In §6 we use the more general likelihood contribution (4) to assess the sensitivity of our results with respect to alternative ordering of moves.

3.2. Specification

The deterministic profitability part $\pi_f(N_S, N_D)$ in Equation (1) is specified as a function of the level of competition and market characteristics. As for the level of competition, we estimate (as described above) both intra- and interformat competitive effects. In addition, we control for the impact of other market characteristics that may influence the local market potential. We allow for asymmetric competitive effects by estimating per-type intra- and interformat competition. In addition, given that supermarkets and discounters may attract different consumer segments (Bell et al. 1998), we estimate format-specific parameters for the control variables. Therefore, $\pi_s(N_S, N_D)$ and $\pi_D(N_S, N_D)$ are specified as

$$\begin{aligned} \pi_S(N_S, N_D) &= \alpha_S \ln(\text{POP}) + \beta_S X - \lambda_S^{N_S} - \frac{\gamma_S^{N_D}}{N_S}, \\ \pi_D(N_S, N_D) &= \alpha_D \ln(\text{POP}) + \beta_D X - \lambda_D^{N_D} - \frac{\gamma_D^{N_S}}{N_D}, \end{aligned} \tag{6}$$

where POP is the market population, and X is a vector of market characteristics. The parameters $\lambda_f^{N_f}$ are fixed effects, measuring the impact of the number of intraformat chains on performance. A positive difference between $\lambda_f^{N_f}$ and $\lambda_f^{N_f-1}$ can be interpreted as evidence that the entry of a chain of format f has a negative impact on the performance of chains of the same format. Similarly, the parameters $\gamma_f^{N_{-f}}$ measure the effect of interformat players on store profitability. A significant increase in these parameter values for a larger number of other-type chains indicates a significant interformat competitive effect. We divide the $\gamma_f^{N_{-f}}$ parameters by N_f to reflect that the total competitive impact of an other-format competitor is actually carried by (spread out over) all same-format players.[10]

The parameters estimated from (6) can be used directly to test the impact of the covariates on the store performance of supermarket and discount chains. However, they can also be used to derive entry thresholds, i.e., the minimum market sizes required to support a given number of chains. These thresholds offer insights on how entry affects the extent of competition. Specifically, if an additional chain provides a strong constraint on firm profits, the entry threshold to carry the extra chain raises more than proportionally (Bresnahan and Reiss 1991b). The entry threshold $T_f^{N_f, N_{-f}}$ is defined by the population level at which the chains of format f would break even given that there are N_f chains of the same format and N_{-f} other-format chains. The threshold is thus equal to the market size at which the deterministic part of the profit for the given market outcome is equal to zero. Using (6), $T_f^{N_f, N_{-f}}$ can be computed as

$$T_f^{N_f, N_{-f}} = \exp\left(-\frac{\beta_f X - \lambda_f^{N_f} - \gamma_f^{N_{-f}}/N_f}{\alpha_f}\right). \tag{7}$$

Entry threshold *ratios* can be used to examine intra- and interformat competition. First, the intraformat threshold ratios ($\text{INTRA\_TR}_f^{N_f}$) measure to what

[9] In terms of the previous notation, this means we can rule out the third possibility, $\tilde{n}_S < n_S$.

[10] It is not necessary to divide the own-format $\lambda_f^{N_f}$ parameters by N_f; this would simply amount to a rescaling of the parameters, say, $\tilde{\lambda}_f^{N_f} = \lambda_f^{N_f}/N_f$, and would be mathematically equivalent. The "unit-free" threshold ratios in (8) and (9) would therefore remain the same.

extent the market size *per chain* needs to increase to support an extra chain of the same format when no chains of the other format are present (see Dranove et al. 2003 for a similar practice). It is defined as the ratio of the *per-store* threshold in a market with N_f intraformat and zero interformat chains over the *per-store* threshold with $N_f - 1$ intraformat and zero interformat chains:[11]

$$\text{INTRA\_TR}_f^{N_f} = \frac{T_f^{N_f,0}}{N_f} \bigg/ \frac{T_f^{N_f-1,0}}{N_f-1} = \exp\left(\frac{\lambda_f^{N_f} - \lambda_f^{N_f-1}}{\alpha_f}\right) \times \frac{N_f-1}{N_f}. \quad (8)$$

An intraformat ratio larger than one indicates a disproportional increase in the breakeven market size because of the extra player, which can be interpreted as an increase in the extent of intraformat competition (Bresnahan and Reiss 1991b).

Similarly, interformat entry threshold ratios ($\text{INTER\_TR}_f^{N_{-f}}$) measure the increase in the per-firm market size needed to support a monopolist of format f when an additional chain of the other format enters. It is defined as[12]

$$\text{INTER\_TR}_f^{N_{-f}} = \frac{T_f^{1,N_{-f}}}{1} \bigg/ \frac{T_f^{1,N_{-f}-1}}{1} = \exp\left(\frac{\gamma_f^{N_{-f}} - \gamma_f^{N_{-f}-1}}{\alpha_f}\right). \quad (9)$$

An interformat threshold ratio larger than one indicates that the increase in market size needed to carry the monopolist of format f because of the additional interformat entrant is significant, which can be interpreted as the presence of an interformat competitive effect.

4. Data and Industry

4.1. The German Grocery Industry

Germany is not only the largest consumer market in Western Europe, it is also among the countries with the highest concentration in grocery retailing. In 2006, the top five players, Edeka, Rewe, Metro, Lidl (the Schwarz Group), and Aldi, accounted for over 70% of the market, with the top 10 having a combined share of 86.9%. The German market is characterized by stagnating sales, fierce price competition, and a high price awareness among consumers. Because Germany is the home market of Aldi and Lidl, discounters have a strong presence. Discount sales account for almost 30% of all grocery sales, and 85% of the German population can reach a discount store within 15 minutes from their home (PlanetRetail 2006b). Recently, the German discount market has stabilized after more than two decades of sustained growth (PlanetRetail 2006a). Overall, the network of discount stores is stagnating with the net rate of discount store openings leveling off to less than 0.5% in 2006. The latter feature is especially relevant as the modeling approach (see §3) assumes a steady-state equilibrium.

4.2. Sample Composition and Dependent Variables

Our main database consists of the addresses of all supermarkets and discounters in Germany in 2006. Following Carree and Dejardin (2006), we analyze our data at the town level. In Germany, these towns correspond to the "Gemeindes." As is common in the empirical entry literature, we exclude too-small towns, which are unlikely to be self-contained. Therefore, we eliminate all local markets with a population smaller than 3,000 (see Zhu et al. 2009 for a similar practice). Similarly, we also exclude all towns with a population of more than 25,000 because those markets are likely to contain submarkets (see also Carree and Dejardin 2006).

Data on the number of supermarket and discounter chains were obtained from Trade Dimensions, a data provider specializing in store-by-store data for the retail industry. This database additionally includes information on the format of all stores. We consider discounters and supermarkets. The former are defined as food retail shops that offer a limited product range, a small depth of assortment, simple shop equipment, and a focus on aggressive prices. The latter include nondiscount stores with a sales area between 400 and 2,500 square metres (see González-Benito et al. 2005 for similar definitions).

As indicated before, the German grocery industry is highly concentrated, with a few large companies dominating both the supermarket and discounter format. Following Zhu et al. (2009), we focus on the number of large chains present in the market, because independent stores are hardly comparable in terms of demand and cost conditions. For the discount format, we consider Aldi, Tengelmann (Plus), Schwarz (Lidl), Rewe (Penny), Edeka (e.g., Netto), and NORMA. We hereby

[11] Similarly, intraformat ratios can be calculated in the case when interformat competitors are present. This leads to a more complicated form of the ratios, including a function of the $\gamma_f^{N_{-f}}$ parameters. Restraining the number of interformat competitors to zero removes the effect of the $\gamma_f^{N_{-f}}$ parameters in the equation, reducing the ratio to the pure competitive intraformat entry interpretation in Bresnahan and Reiss (1991b).

[12] Interformat ratios when more same-type competitors are present can also be defined. In this case, the number of intraformat competitors N_f will appear in the denominator. When $N_f = 1$, this effect disappears, restricting the ratio to the pure interformat competitive effect.

Table 2 Number of Towns per Market Structure

	Supermarkets			
Discounters	0	1	2	Total (%)
0	412	458	49	919 (26%)
1	281	504	112	897 (25%)
2	165	488	152	805 (22%)
3	97	314	150	561 (16%)
4	44	170	99	313 (9%)
5	9	55	34	98 (3%)
Total (%)	1,008 (28%)	1,989 (55%)	596 (17%)	3,593

capture the complete discount format. In terms of the supermarket format, we measure whether or not the Edeka, Rewe, and Tengelmann groups have a supermarket in the local market. Together, these three companies capture more than 90% of the total sales of the supermarket format. To control for the few independent stores left, we add them as an exogenous variable to the profit functions. Because there are too few local markets with more than two supermarket chains or more than five discount chains to make reliable estimates of their effects on the extent of intra- and interformat competition, we do not take these observations into account.[13] In total, we consider 3,593 local markets, with an average population size of 8,184. Note that our geographical scope is much broader than in most previous studies inferring interformat competition from consumer choice data (see Table 1 for an overview), as these were often restricted to a single city (e.g., González-Benito et al. 2005) or metropolitan area (e.g., Fox et al. 2004).

Table 2 presents summary statistics on the relative occurrence of the various market structures. A majority of the towns have one supermarket chain (55%), whereas other towns have either zero or two supermarket chains (1,008 and 596 cases). In contrast, the number of towns with zero, one, or two discount chains are more or less comparable, accounting for 26% (zero), 25% (one), and 22% (two) of the sample. A minority of towns have three, four, or five different discount chains (respectively, 16%, 9%, and 3%). The market structures with one chain of each format is observed most often (504 cases), followed by the one with two discounters and one supermarket (488 cases), and the one supermarket-zero discounter structure (458 cases).

4.3. Explanatory Variables

Data on the local markets' demographic characteristics were obtained from the German National Institute of Statistics (Statistisches Bundesamt Deutschland) and Gfk Geomarketing, and information on the other supermarkets and hypermarkets was obtained through Trade Dimensions. Summary statistics are given in Table 3.

Table 3 Descriptive Statistics

Variable	Description	Mean	Std. dev.
Population	Number of inhabitants in 1,000	8.184	5.150
Income	Net income per inhabitant in 1,000 euro	17.81	2.65
Foreign hh	Fraction of households with a foreign nationality	4%	3%
Household size	Average household size	2.28	0.17
Age	Fraction of population that is 65 years or older	18%	3%
Unemployment	Fraction of working population that is unemployed	7%	4%
City	Dummy variable indicating a city within 10 km	0.15	0.35
Surface	Surface in 100 km^2	0.48	0.39
Distance to nearest town	Distance to the nearest town centre in km	6.51	3.04
Population growth	Growth in population from 2001 to 2003 as a percentage of 2003 population	0.5%	4%
Hypermarkets	Dummy variable indicating presence of town with hypermarket within 25 km	0.92	0.28
Other supermarkets	Number of independent supermarkets in town	0.22	0.53

Following Cleeren et al. (2006), we measure the *population* through the number of inhabitants (in 1,000). *Income* is measured by the average net income (in 1,000 euro) per inhabitant, and the ethnic composition is operationalized as the percentage of households with a *foreign* nationality (*foreign hh*). Household composition is captured by the average *household size*. We operationalize *age* as the percentage of people 65 years or older, and *unemployment* as the percentage of the working population (18 to 64 years old) that is unemployed. In addition, we create a dummy variable to indicate the nearby presence of a *city* within a radius of 10 km[14] and include the *surface* (in 100 km^2) of the market. Following Asplund and Sandin (1999), we measure the *distance to nearest town* as the Euclidean distance from the town centre to the nearest town centre (in kilometres). Furthermore, we calculate the percentage change in population size over the last two years to measure *population growth* (see Bresnahan and Reiss 1991b for a similar practice). We operationalize the presence of *hypermarkets* with a

[13] Together, they make up only 1% of the sample. Still, we will assess in §6 the robustness of our main findings if these observations are included.

[14] A city is defined as a local market with more than 25,000 inhabitants.

dummy variable that indicates whether a hypermarket is situated in a town within 25 km of the considered town centre.[15] The 25 km cutoff value is based on the trading area of hypermarkets reported in Campo and Gijsbrechts (2004). Finally, the number of *other supermarkets* corresponds to the number of non-chain-affiliated supermarkets in town.

5. Empirical Results

Table 4 shows the parameter estimates from the model outlined in §3. The estimated $\lambda_f^{N_f}$ show an increasing pattern ($\lambda_f^{N_f} < \lambda_f^{N_f+1}$) for each format, which is consistent with Assumption 1 in that performance is decreasing with the number of own-type stores. Similarly, the estimated $\gamma_f^{N_{-f}}$ are increasing with N_{-f} ($\gamma_f^{N_{-f}} < \gamma_f^{N_{-f}+1}$) for both formats, which is in line with Assumption 2A, stating that performance is decreasing with the number of other-type stores.[16] Finally, the estimated $\lambda_f^{N_f}$ and $\gamma_f^{N_{-f}}$ are consistent with Assumption 2B, stating that the profit implication of an intraformat entry is larger than that of an extra interformat store.[17] Because our parameter estimates (which are freely estimated) do not violate any of the model assumptions, we infer that our model is internally consistent (see Schaumans and Verboven 2008 for a similar practice).

As discussed in §3, the model specification reduces to two traditional ordered probit entry models in the spirit of Bresnahan and Reiss (1991b) if there is no effect from interformat competitors ($\gamma_f^{N_{-f}} = 0$) and if the unobserved profit components of discounters and supermarkets are uncorrelated ($\rho = 0$). A likelihood-ratio test shows that this traditional specification is rejected in favor of the full model specification ($\chi^2(7) = 13.87, p < 0.05$). Various $\gamma_f^{N_{-f}}$ parameters are significant, implying a direct effect of interformat entry on profitability in those cases. Moreover, the correlation parameter ρ is significantly positive, implying that the unobserved factors influencing the market attractiveness for a supermarket are positively related to those affecting discounter performance.

5.1. Intraformat Competition

We first focus on the competition between stores of the same format. Because the magnitudes of the $\lambda_f^{N_f}$ are difficult to interpret as such, we use them to construct the intraformat entry threshold ratios, ($\text{INTRA\_}TR_f^{N_f}$) as given by (8). These ratios are a measure of intraformat competition, because they indicate to what extent the market size per firm needs to increase to support an extra firm of the same format when no other-format stores are present. When the ratio is greater than one, the breakeven market size increases disproportionally, implying an increase in the extent of intraformat competition because of the extra store.

The intraformat threshold ratio shown in Table 5 for supermarkets is 2.03, indicating that the per-firm breakeven market size is 2.03 times higher for a duopoly than for a monopoly. Because this ratio is significantly different from one ($p < 0.01$), the extent of intraformat competition is found to increase extensively when the second supermarket enters the market. This supports the general feeling that supermarkets are involved in a fierce competitive battle.

Discounters experience an increase in intraformat competition from the third entrant onwards. The results show that the per-firm market size needed to support a third, fourth, and fifth entrant increases by, respectively, 10%, 21%, and 39%. These ratios are

Table 4 Estimation Results

	Supermarkets		Discounters	
	Estimate	Std. err.	Estimate	Std. err.
Logpopulation	1.38[a]	(0.07)	1.98[a]	(0.06)
Income	−0.01	(0.01)	−0.05[a]	(0.01)
Foreign hh	−1.31[c]	(0.78)	4.03[a]	(0.71)
Household size	0.17	(0.18)	0.62[a]	(0.17)
Age	4.46[a]	(0.94)	5.64[a]	(0.87)
Unemployment	−2.63[a]	(0.80)	8.81[a]	(0.70)
City	−0.32[a]	(0.06)	−0.37[a]	(0.06)
Surface	−0.35[a]	(0.07)	−0.29[a]	(0.07)
Distance to nearest town	−0.02[b]	(0.01)	−0.06[a]	(0.01)
Population growth	0.01	(0.01)	0.02[a]	(0.01)
Hypermarkets	−0.61[a]	(0.08)	−0.46[a]	(0.07)
Other supermarkets	−0.41[a]	(0.04)	−0.11[a]	(0.04)
λ_f^1	1.78[a]	(0.67)	4.06[a]	(0.61)
λ_f^2	3.71[a]	(0.67)	5.17[a]	(0.61)
λ_f^3	—		6.17[a]	(0.61)
λ_f^4	—		7.11[a]	(0.61)
λ_f^5	—		8.21[a]	(0.62)
γ_f^1	0	(—)	0.10	(0.10)
γ_f^2	0.11[c]	(0.09)	0.33[c]	(0.20)
γ_f^3	0.33[a]	(0.13)	—	
γ_f^4	0.54[a]	(0.18)	—	
γ_f^5	0.72[a]	(0.26)	—	
ρ	0.18[a]	(0.06)		

Notes. The estimates are based on a sample of 3,593 local markets. γ_S^1 is restricted to zero as it was insignificantly smaller than zero. a, b, and c indicate a significant result at, respectively, 1%, 5%, and 10% significance levels. Reported significance tests are one-sided for the $\lambda_f^{N_f}$ and $\lambda_f^{N_{-f}}$ parameters and two-sided for the control variables and ρ.

[15] Following González-Benito et al. (2005), hypermarkets are defined as grocery stores with a sales area of at least 2,500 square metres.

[16] As γ_S^1 was insignificantly negative, we impose the equality in Assumption 2A and restrict this parameter to zero.

[17] Under specification (5), Assumption 2B amounts to $\lambda^{N_f+1} - \lambda^{N_f} > (\gamma^{N_{-f}} - \gamma^{N_{-f}-1})/(N_f+1) + (\gamma^{N_{-f}})/(N_f(N_f+1))$ for each market structure. It can be verified that this inequality indeed holds at the estimated $\lambda_f^{N_f}$ and $\gamma_f^{N_{-f}}$.

Table 5 **Estimated Intraformat Threshold Ratios**

	Supermarkets	Discounters		
$INTRA\_R_f^2$	2.03[a]	0.87[a]		
	(0.12)	(0.02)		
$INTRA\_R_f^3$		1.10[a]		
		(0.02)		
$INTRA\_R_f^4$		1.21[a]		
		(0.02)		
$INTRA\_R_f^5$		1.39[a]		
		(0.04)		
Test on ratios*				
	$INTRA\_R_D^2$	$INTRA\_R_D^3$	$INTRA\_R_D^4$	$INTRA\_R_D^5$
$INTRA\_R_S^2$	77.62[a]	54.07[a]	42.74[a]	23.12[a]

Notes. Intraformat ratios are calculated for the case of zero interformat competitors. Standard errors are calculated using the delta method and are presented in parentheses. a indicates a ratio significantly different from one at the 1% significance level.

*Reported numbers are the Wald test statistics for the null hypothesis that the two ratios are equal to each other. a indicates a significant difference at the 1% significance level.

significantly larger than one ($p < 0.01$). In contrast, the first estimated intraformat ratio for discounters is significantly smaller than one ($p < 0.01$), indicating that the per-firm breakeven market size for a duopolist is smaller than for a monopolist. This suggests that the very first entrant offers a stamp of legitimization, reducing the uncertainty for other potential entrants (Carroll and Hannan 2000, Gielens and Dekimpe 2007).

After having established the existence of intraformat competition for both formats, we assess their relative size. To that extent, we compare the intraformat threshold ratio for supermarkets with each of the estimated ratios of the discounter format. While the market size needs to more than double to carry a second supermarket, the maximum increase in breakeven market size because of an extra discounter is only 39%. As shown in the second panel of Table 5, Wald tests indicate that all estimated intraformat ratios for the discounter format are significantly smaller than the ratio for supermarkets ($p < 0.01$). In other words, the extent of intraformat competition is more pronounced within the supermarket format.[18]

5.2. Interformat Competition

As mentioned in §3, we can use the estimated γ and α parameters to calculate interformat threshold ratios ($INTER\_TR_f^{N_{-f}}$). These measure the increase in the market size needed to support a monopolist of format f when an extra firm of the other format enters.

Table 6 **Estimated Interformat Threshold Ratios**

	Supermarkets	Discounters
$INTER\_R_f^1$	1.00	1.05
	(—)	(0.05)
$INTER\_R_f^2$	1.09	1.12[b]
	(0.07)	(0.07)
$INTER\_R_f^3$	1.17[b]	
	(0.08)	
$INTER\_R_f^4$	1.17[b]	
	(0.10)	
$INTER\_R_f^5$	1.13	
	(0.15)	
Test on ratios*		
	$INTER\_R_D^1$	$INTER\_R_D^2$
$INTER\_R_S^2$	0.20	0.18
$INTER\_R_S^3$	2.05	0.25
$INTER\_R_S^4$	1.36	0.20
$INTER\_R_S^5$	0.26	0.01

Notes. Interformat ratios are calculated for the case of one intraformat player. Standard errors are calculated using the delta method and are presented in parentheses. b indicates a ratio significantly larger than one at 5% significance level.

*Reported numbers are the Wald test statistics for the null hypothesis that the two ratios are equal to each other.

A ratio that is significantly larger than one indicates an increase in the extent of interformat competition because of the entrant.

Supermarkets do not experience a significant competitive effect from the entry of the first two discounters (ratios in Table 6 are 1.00 and 1.09, and $p > 0.1$). This suggests that there is still sufficient differentiation between supermarkets and discounters as long as few of the latter are present in the local market. Zhu et al. (2006) also found that the profit implications for supermarkets are limited when Wal-Mart enters their local market. An underlying interpretation is that the discounter (or Wal-Mart) draws the price-sensitive consumers out of the market for the product categories it carries, allowing supermarkets to focus on the more profitable price-insensitive segment and increase prices on their unique product offerings. Moreover, as consumers can save expenditures on the product categories offered by the discounter, they have more disposable income for the other categories of the supermarket (Gielens et al. 2008). Discounters may also initially draw their business mainly from other grocery formats, such as hypermarkets and mom-and-pop stores.[19]

Significant and substantial interformat competition is observed from the third discounter onwards. The

[18] Note that discounters typically have smaller stores and fewer SKUs, which may also translate to a different efficient scale for both formats. We thank an anonymous reviewer for pointing this out.

[19] Note that hypermarket presence indeed has a negative impact on discounter profitability (see Table 4), whereas the number of mom-and-pop stores has decreased substantially over time in all European countries.

breakeven market size for a supermarket increases each time by 17% when the third and fourth discounters enter the market ($p < 0.05$ for both ratios). When the number of discounters in a market increases, the amount of product categories uniquely offered by supermarkets is likely to decrease, which reduces the opportunities of diversification (and associated higher prices) through assortment. Moreover, because more discounters are present, their combined impact on consumers' price sensitivity will be larger, increasing the pressure on supermarkets to decrease their prices (Hausman and Leibtag 2007).

A similar pattern of interformat competition is found for the discounters. The first supermarket does not increase the extent of rivalry significantly ($p > 0.1$). In contrast, the breakeven market size of a discounter increases by a significant 12% when the second supermarket enters ($p < 0.05$). Although the formats thus appear differentiated for the first entrant (confirming our earlier results for the supermarkets), an interformat competitive effect for discounters becomes apparent when more supermarkets are present in the market. No significant differences are found between the interformat ratios obtained for both formats, suggesting no asymmetric effects in terms of their vulnerability and clout.

5.3. Control Variables

We controlled for a number of covariates that may impact the attractiveness of a local market. In addition to their main function as controls, we can also interpret the parameter estimates to assess their impact on the profitability of supermarkets and discounters.

Income has a negative impact on discounter profits, which is consistent with an increased price sensitivity and private label inclination for low-income families (Ailawadi et al. 2001). The percentage of foreign households increases discounter profitability substantially, whereas it has a negative impact on supermarkets. Foreigners have been shown to be more price sensitive (Hoch 1996), which may shift their demand from the higher-priced supermarkets to discounters. The average household size has a positive impact on discounter profitability, consistent with a higher price sensitivity for larger families (Hoch 1996). The percentage of elderly has a positive effect on the profitability of both formats. Older people are more price sensitive and buy more private labels (Hoch 1996), which may explain their patronage of the low-price discount stores. However, older people also spend more in supermarkets. This may be due to a higher availability of time, which makes them more promotion sensitive (Drèze and Vanhuele 2004). This increases their likelihood to also visit promotion-intensive supermarkets. The percentage of unemployed has a positive effect on discounter performance and a negative impact on supermarket profits. This result is consistent with an increased price sensitivity and inclination toward private labels by unemployed people (Hoch et al. 1995, Hoch 1996), resulting in a demand shift from supermarkets to discounters. The presence of a nearby city has a significant negative impact on the profitability of both formats, reflecting the predicted attraction effect of cities (see Carree and Dejardin 2006 for a similar result). Similarly, market surface has a negative impact on the profitability of both formats, suggesting that the negative demand effect—caused by larger travel costs for consumers in larger markets—is larger than the positive markup effect caused by a decrease in competition because of a larger spread of stores in larger markets. The distance to the nearest town has a negative effect in both profit equations, indicating that nearby markets positively influence the profitability of both formats. This suggests that people from nearby markets cross the market border to purchase part of their groceries and thereby increase the demand within the local market (see Bresnahan and Reiss 1991b for a similar finding). Furthermore, population growth has a significant positive impact on discounter profitability, which indicates that past growth plays a role in determining the effective market size. Rapidly growing markets attract discounters even if the market as such is not large at this moment. No such effect is found for supermarkets. Finally, both the presence of a nearby hypermarket and the number of independent supermarkets have the expected negative influence on the profits of both formats.

5.4. Simulations

To provide further insight into the economic significance of the estimated parameters, we simulate the effect of an increase in the control variables on the total number of supermarkets and discounters (see Mazzeo 2002 for a similar practice). The results can be found in Table 7. Note that the reported numbers indicate the percentage change in the total number of supermarkets and discounters after a 1% increase in the value of the control variable in each market. The numbers can thus be interpreted as elasticities.

For example, we find that an increase of 1% in the unemployment level in every market leads to a decrease in the total number of supermarkets of 1.9%, and an increase in the number of discounters of 4.6%. Note that we can split this total effect into a direct effect—caused by the estimated effect of the covariate on supermarket and discounter profitability—and an indirect effect that is linked to a change in the number of interformat competitors.[20] As such, for the supermarkets, the direct effect (−1.3%) contributes about

[20] The direct effect of the change in the covariate can be estimated by simulating the effect in the case of no interformat competitive effects (i.e., all $\gamma = 0$).

Table 7 Simulated Effect of Changes in the Covariates on the Total Number of Supermarkets and Discounters

Variable	Number of supermarkets (%)	Number of discounters (%)
Population	+0.7	+1.0
Income	+0.03	−0.4
Foreign hh	−1	+2.1
Household size	+0.2	+0.7
Age	+2.3	+2.8
Unemployment	−1.9	+4.6
Surface	−0.1	−0.1
Distance to nearest town	−0.1	−0.2
Population growth	0	0
Other supermarkets	−0.05	−0.01

Note. Reported numbers are the percentage change in the total number of supermarkets and discounters after a 1% increase in the control variable.

two-thirds to the total negative effect, whereas the indirect effect contributes about 1/3 (−0.6%). In contrast, for discounters the total positive effect is almost exclusively caused by a direct positive effect of 4.3% (i.e., 95% of the total effect).

Another interesting result relates to the percentage of foreign households. An increase of 1% in the percentage of foreigners in every market leads to 1% fewer supermarkets and 2.1% more discounters. For supermarkets, this total effect is due to a direct effect of −0.7% (i.e., 70% of the total effect) and an indirect effect of −0.3% (i.e., 30% of the total effect). For discounters, the total positive effect is again mainly because of a large positive direct effect (2%, which is 95% of the total effect).

6. Robustness Checks

Four sets of robustness checks were conducted. As such, we assess the sensitivity of our findings with respect to our sample selection criteria, as well as with regard to the sequential entry assumption that we adopted. Furthermore, we acknowledge that some firms may operate chains of both formats, and we see whether this affects our results. Finally, we test for the sensitivity of our results with respect to the fact that certain chains may have multiple stores in a particular market.[21]

6.1. Sensitivity to Sample Selection Criteria

Our results are based on a sample of towns with a population between 3,000 and 25,000. First, we check the robustness with respect to the upper and lower bound of these population criteria and increase/decrease them by 10%. Furthermore, we use the population density as an additional selection criterion to prevent the occurrence of submarkets in the considered markets (see, e.g., Schaumans and Verboven 2008). Specifically, we also exclude towns with a population density of more than 632 inhabitants per square kilometer. This cutoff corresponds to the 5% most densely populated towns in Germany. Moreover, we check for the robustness of our results with regard to the exclusion of observations with three supermarkets or six discounters. These were not considered because there were too few observations to make a separate category of market structures for them. As such, we create a 2+ category for the supermarkets, which also incorporates the observations with three supermarket chains. Similarly, for discounters we construct a 5+ category including the markets with six discount chains (see Cleeren et al. 2006 for a similar practice).

The results in all validation samples turned out to be very robust for the findings reported above. Both formats experience an extensive intraformat rivalry, although for discounters this is only apparent from the third entrant. Furthermore, in all samples intraformat competition is asymmetric in that it is more pronounced for supermarkets than for discounters. Also, with regard to the extent of interformat competition, we find similar patterns as reported in Table 6. Specifically, interformat competition is only significant for supermarkets from the third discounter onwards, whereas only the second supermarket has a significant impact on a discounter's profitability.

6.2. Sensitivity to Order-of-Entry Assumption

To ensure uniqueness of equilibria for every condition of the error terms, we assumed sequential entry. Given that the supermarket format was developed long before the discounters, we presumed that supermarkets entered the market first. Because we observe up to two supermarkets and up to five discounters across all markets, this amounts to the sequence SSDDDDD, resulting in the likelihood contribution given by (5). To check the robustness of our results with regard to this assumption, we also considered two alternative sequences of moves using the more general likelihood function (4); i.e., all discounters entered the market first (DDDDDSS) and the sequence SDDDDDS. Both the parameter estimates and the estimated entry threshold ratios were very robust in both scenarios, and the same conclusions as summarized in the previous paragraph held. This indicates the insensitivity of our results with respect to the order-of-entry assumption, an observation also made by Einav (2009) and Mazzeo (2002).

6.3. Sensitivity to Firms Owning Multiple Formats

The same parent firm may be present in both formats. In that case, interformat competition could be

[21] Full details on all validation exercises are available from the first author upon request.

less intense, as firms may want to avoid excessive cannibalization. In 788 (22%) of the markets in our sample, one of the firms operated both discount stores and supermarkets. To assess the sensitivity of our results to these specific markets, the model was reestimated without these observations. Again the same conclusions were obtained. The only difference was that while a second supermarket had a (marginally) significant effect on discounter profits in the full sample, a (marginally) insignificant effect was found in the limited sample.

6.4. Sensitivity to Chains Owning Multiple Stores

We model the presence of supermarket and discounter *chains* in local markets. However, a particular chain may actually have more than one store in a given local market, which may again have an influence on the actual extent of intra- and/or interformat competition. We therefore ran 9 (10) additional validation analyses in which each time we deleted those markets that had, respectively, more than one (i) Aldi store (138 markets), (ii) Edeka discounter (146), (iii) NORMA store (14), (iv) Rewe discounter (28), (v) Lidl store (22), (vi) Tengelmann discounter (48), and (vii) Edeka (387), (viii) Tengelmann (13), or (ix) Rewe (146) supermarket. The threshold ratios were once more very robust and led to the same substantive conclusions. The only difference was that the first interformat threshold ratio for discounters (INTER_R_D^1) became marginally significant in the case where all markets with more than one Edeka supermarket were deleted. In that case, the breakeven market size of discounters becomes higher as soon as one supermarket is present (rather than from the second onwards). However, our key insight that the first discounter does not affect the breakeven market size required by supermarkets was very robust in all instances, as were all findings on the extent of intraformat competition. This was also the case in the extreme setting where we deleted all markets (747, or 21%) where at least one of the chains had more than one store, even though discounters then start to have an impact on supermarkets from the second (rather than the third) chain onward.

7. Conclusions and Directions for Future Research

We used an empirical entry model to study competition between grocery discounters and traditional supermarkets in Germany. We find evidence for intense competition *within* both the supermarket and discount format. The former finding supports the common notion that supermarkets are engaged in fierce competition. However, we also find strong evidence of intraformat competition between discounters. Price comparisons are easy, especially among stores with few promotional activities. Additional discounters therefore not only attract customers from the more expensive supermarkets, but they also compete with one another.

We also quantified the extent of *interformat competition*. Common wisdom suggests that the entry of a discount store should have an immediate negative impact on supermarkets' performance. This is indeed intuitive if one concentrates on market share and/or volume as a performance metric. Focusing on profitability, however, we find that the two first discounters have no significant effect on the performance of supermarkets in the area. This result is in line with Zhu et al. (2006), who point out that supermarkets can focus on the more profitable price-insensitive segment when a discounter is present. When more discounters enter the local market, however, things start to change. First, the discounters' combined impact on the general price sensitivity becomes larger, putting extra pressure on incumbent supermarkets to also decrease prices (Hausman and Leibtag 2007), which reduces their profit margins. Moreover, unless the assortments of competing discounters overlap completely, a smaller fraction of the supermarkets' broad assortment will not be carried by any of the discounters. Discounters increasingly try to differentiate themselves by carrying a limited number of leading national brands (Deleersnyder et al. 2007). As more discounters add national brands, the selling proposition of supermarkets as the place to be to buy leading national brands becomes eroded.

Many conventional supermarket chains are currently starting their own discount banner. For example, the traditional French supermarket chains Carrefour (with ED) and Intermarché (with Netto) have added discount banners to their portfolio (Carboni 2004). Similar developments are underway in the United Kingdom. Our results suggest that early discount entrants can avoid cannibalizing the profits of their supermarkets in the area. Managers seem to realize this sense of urgency. Discussing the type of lessons drawn from observing other retailers, including Aldi, the CEO of Tesco argues: "The trick in this business is to watch everyone…and to learn from them quicker than they learn from you" (*Grocer* 2007, p. 7).

Several insights on the extent of intra- and interformat competition between discounters and supermarkets were obtained, even though the data requirements to attain these results were quite limited. To do so, however, we had to make a number of model assumptions. Relaxing these assumptions offers various avenues for future research.

First, we limited our attention to the German grocery industry. A replication of our analysis in other countries would be useful. However, the model in this paper assumes a long-term equilibrium. Specifically, we assume that the observed number of stores per type coincides with the profit-maximizing number of players. Given the maturity of both formats in Germany (PlanetRetail 2006a), this appears to be a defendable assumption. However, in other countries, the nature of competition in the grocery industry is still evolving. Our model can be used to verify our findings in these other settings once the examined formats have reached the saturation stage. Alternatively, capturing the dynamics in evolving markets could provide additional interesting insights as well. Although the estimation of dynamic games is still computationally challenging, some recent research efforts in the area are very promising (see Chintagunta et al. 2006 for a similar observation).

Second, in this paper, we focus exclusively on supermarkets and discounters, as they can be considered the main local competitors. Although we considered the hypermarket presence as an exogenous control variable; future research could endogenize this entry decision. This would not only involve extending the model to allow for more than two types but also require accounting for the fact that hypermarkets compete in larger geographic markets. One could also envision modeling the entry decision of each chain in our sample separately to capture within-format heterogeneity. This would not only allow us to estimate chain-specific competitive effects, but the results would also provide insights on the role of multimarket contact. Although an extension of the number of types renders the econometric specification more difficult given the complex regions of integration for the unobservables, simulation techniques can be used to compute the required integrals (see, e.g., Zhu et al. 2009 for a recent application). Finally, we derived inferences on the overall level of competitiveness among discounters and supermarkets under different market structures. It would be useful to assess in future research whether this overall level can be attributed mostly to competition along the price dimension, the promotional strategy, the assortment composition, and/or the service dimension. Although it would be difficult to get accurate measures on each of these dimensions for all (or even a subset of) players in the market, the insights obtained in that way could complement our more aggregate insights.

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Appendix
This appendix characterizes the multiplicity of Nash equilibria. We first provide an example to show the possible complexities and then provide a general characterization of the multiplicity of Nash equilibria.

Consider an example where up to two supermarkets and up to two discounters can enter. Figure A.1 shows the possible equilibria in the $(\varepsilon_S, \varepsilon_D)$ space. The horizontal and vertical lines have a similar interpretation as in Figure 1. Figure A.1 shows that there are many areas with two equilibria: $(2, 0)$ and $(1, 1)$; $(2, 1)$ and $(1, 2)$; $(0, 2)$ and $(1, 1)$, and $(1, 0)$ and $(0, 1)$. Furthermore, there is an area with three possible equilibria: $(2, 0)$, $(1, 1)$, and $(0, 2)$. This suggests a very large number of possibilities. Nevertheless, not every combination of outcomes is possible. For example, there are no areas where $(2, 0)$ shows multiplicity with $(1, 0)$ or $(0, 1)$. Furthermore, whenever $(2, 0)$ shows multiplicity with $(0, 2)$, it also shows multiplicity with a third equilibrium, $(1, 1)$. These properties actually hold more generally and lead to a drastically simplified characterization of the multiplicity problem.

Consider this general characterization. Suppose that Assumption 2A holds with strict inequality. In this specification, supermarkets and discounters are dependent on each other, which gives rise to a multiplicity problem. In principle, a Nash equilibrium (n_S, n_D) may show multiplicity with any outcome of the form $(n_S + m_S, n_D + m_D)$. Below, we prove three important claims. First, (n_S, n_D) may only show multiplicity with equilibria of the form $(n_S + m, n_D - m)$, where m is a positive or negative integer (Claim 1). Thus, $(2, 3)$ can show multiplicity with, say, $(1, 4)$ or $(0, 5)$ but not with, say, $(1, 5)$. Second, (n_S, n_D) necessarily shows multiplicity with $(n_S - 1, n_D + 1)$ and $(n_S + 1, n_D - 1)$ (Claim 2). Third, whenever (n_S, n_D) shows multiplicity with $(n_S + m, n_D - m)$, the multiplicity area is necessarily a subset of the multiplicity area with $(n_S + 1, n_D - 1)$ for $m > 0$, and a subset of the multiplicity area with $(n_S - 1, n_D + 1)$ for $m < 0$ (Claim 3). Taken together, these claims imply that the area of $(\varepsilon_S, \varepsilon_D)$ for which (n_S, n_D) shows multiplicity with any other Nash equilibria is simply given by the areas of overlap with $(n_S + 1, n_D - 1)$ and $(n_S - 1, n_D + 1)$. This greatly facilitates the construction of the likelihood function.

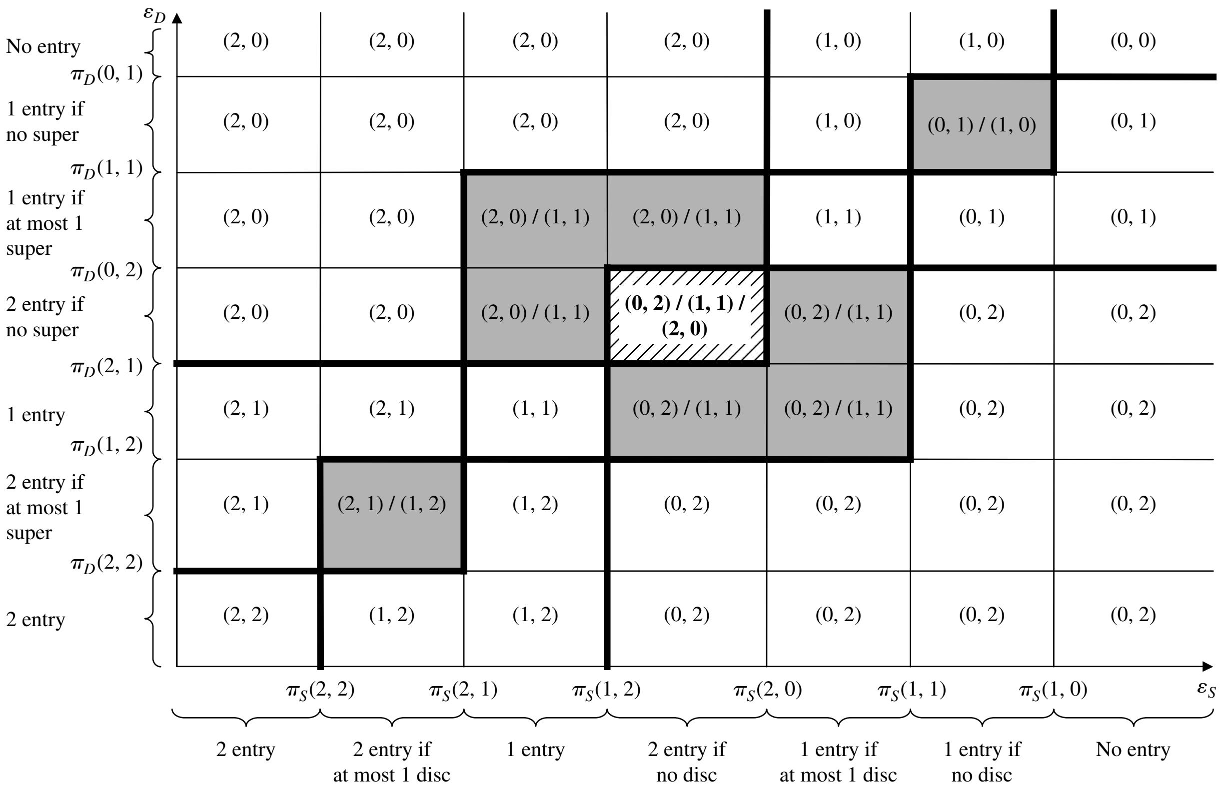
To show these claims, define A as the set of $(\varepsilon_S, \varepsilon_D)$ for which (n_S, n_D) is a Nash equilibrium, as given by conditions (2). In addition, define $B(m_S, m_D)$ as the set of $(\varepsilon_S, \varepsilon_D)$ for which both (n_S, n_D) and $(n_S + m_S, n_D + m_D)$ are Nash equilibria, where m_S and m_D may be any integer.

Claim A.1. *$B(m_S, m_D)$ is empty if $m_D \neq -m_S$.*

Proof. Suppose to the contrary that when (n_S, n_D) is a Nash equilibrium there are also equilibria of the form $(n_S + m_S, n_D + m_D)$ with $m_S \neq -m_D$. We consider all possible cases and show that we obtain a contradiction.

(i) $m_S > 0$ and $m_D > 0$. Then the inequalities (2), Assumption 2A, and Assumption 1, respectively, imply that $\varepsilon_S \leq \pi_S(n_S + m_S, n_D + m_D) \leq \pi_S(n_S + m_S, n_D) \leq \pi_S(n_S + 1, n_D)$. This contradicts with the inequalities (2), which imply that $\pi_S(n_S + 1, n_D) < \varepsilon_S$.

Figure A.1 Multiplicity Problem If Two Potential Entrants in Each Format



(ii) $m_S > 0$, $m_D \leq 0$, $m_S > -m_D$. Then the inequalities (2), Assumption 2B, and Assumption 1, respectively, imply that $\varepsilon_S \leq \pi_S(n_S + m_S, n_D + m_D) \leq \pi_S(n_S + m_S + m_D, n_D) \leq \pi_S(n_S + 1, n_D)$. This contradicts with the inequalities (2), which imply that $\pi_S(n_S + 1, n_D) < \varepsilon_S$.

(iii) $m_S \geq 0$, $m_D < 0$, $m_S < -m_D$. Then Assumption 1, Assumption 2B, and the inequalities (2), respectively, imply that $\pi_D(n_S, n_D) \leq \pi_D(n_S, n_D + m_S + m_D + 1) \leq \pi_D(n_S + m_S, n_D + m_D + 1) < \varepsilon_D$. This contradicts with the inequalities (2), which imply that $\pi_D(n_S, n_D) \geq \varepsilon_D$.

(iv) $m_S < 0$, $m_D < 0$. Then Assumption 1, Assumption 2A, and the inequalities (2), respectively, imply that $\pi_S(n_S, n_D) \leq \pi_S(n_S + m_S + 1, n_D) \leq \pi_S(n_S + m_S + 1, n_D + m_D) < \varepsilon_S$. This contradicts with the inequalities (2), which imply that $\pi_S(n_S, n_D) \geq \varepsilon_S$.

(v) $m_S \leq 0$, $m_D > 0$, $m_S > -m_D$. Then the inequalities (2), Assumption 2B, and Assumption 1, respectively, imply that $\varepsilon_D \leq \pi_D(n_S + m_S, n_D + m_D) \leq \pi_D(n_S, n_D + m_S + m_D) \leq \pi_D(n_S, n_D + 1)$.This contradicts with the inequalities (2), which imply that $\pi_D(n_S, n_D + 1) < \varepsilon_D$.

(vi) $m_S < 0$, $m_D \geq 0$, $m_S < -m_D$. Then Assumption 1, Assumption 2B, and the inequalities (2), respectively, imply that $\pi_S(n_S, n_D) \leq \pi_S(n_S + m_S + m_D + 1, n_D) \leq \pi_S(n_S + m_S + 1, n_D + m_D) < \varepsilon_S$. This contradicts with the inequalities (2), which imply that $\pi_S(n_S, n_D) \geq \varepsilon_S$. □

Claim A.2. *$B(1, -1)$ and $B(-1, 1)$ are not empty.* □

Proof. The set $B(1, -1)$ is given by the conditions (3), which is not empty by Assumption 2A. A similar reasoning holds for the set $B(-1, 1)$.

Claim A.3. *$B(m, -m) \subset B(1, -1)$ for $m > 0$ and $B(m, -m) \subset B(-1, 1)$ for $m < 0$.* □

Proof. The set $B(m, -m)$ is given by

$$\pi_S(n_S + 1, n_D) < \varepsilon_S \leq \pi_S(n_S + m, n_D - m),$$
$$\pi_D(n_S + m, n_D - m + 1) < \varepsilon_D \leq \pi_D(n_S, n_D).$$

By Assumption 2B, the right-hand side on the first row increases as m decreases, and the left-hand side on the second row decreases as m decreases. The set $B(m, -m)$ therefore increases as m decreases so that it is maximized at $m = 1$. Hence, $B(m, -m) \subset B(1, -1)$. A similar reasoning shows that $B(-m, m) \subset B(-1, 1)$. □

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