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Kathleen Cleeren, Marnik G. Dekimpe,
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**Kathleen Cleeren, Maastricht University
Marnik G. Dekimpe, Catholic University of Leuven and Tilburg University
Katrijn Gielens, University of North Carolina
Frank Verboven, Katholieke Universiteit Leuven and CEPR**

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Centre for Economic Policy Research
90–98 Goswell Rd, London EC1V 7RR, UK
Tel: (44 20) 7878 2900, Fax: (44 20) 7878 2999
Email: cepr@cepr.org, Website: www.cepr.org

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ABSTRACT

Intra- and Inter-Format Competition Among Discounters and Supermarkets*

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, 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 inter-format 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 retailers' entry decisions, and allow for asymmetric intra- and inter-format 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.

JEL Classification: L10 and M30

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Kathleen Cleeren
Assistant Professor
Maastricht University
PO Box 616
6200 MD Maastricht
THE NETHERLANDS
Email: k.cleeren@mw.unimaas.nl

Marnik G. Dekimpe
Research Professor of Marketing
Tilburg University
PO Box 90153
5000 LE Tilburg
THE NETHERLANDS
Email: m.g.dekimpe@uvt.nl

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Katrijn Gielens
Associate Professor of Marketing
University of North Carolina
Chapel Hill, Campus Box 3490
McColl Building
Chapel Hill, NC 27599-3490
USA
Email: katrijn_gielens@unc.edu

Frank Verboven
Faculty of Economics Applied
Economics
Katholieke Universiteit Leuven
Naamsestraat 69
B-3000 Leuven
BELGIUM
Email:
frank.verboven@econ.kuleuven.be

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1. INTRODUCTION

Over the last decade, the grocery-retailing landscape has changed dramatically in most Western economies. Especially the emergence of the hard-discount format, popularized by companies such as Aldi and Lidl, has altered the dynamics of the industry. Hard discounters are very distinct from every-day-low-price retailers such as Wal-Mart (studied in Singh et al. 2006 and Zhu et al. 2008) in the US, and from large supermarkets such as Albert Heijn and Tesco in Europe. First, they offer much less categories of goods, and stock only a limited selection of items; typically fewer than 1,400 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.¹ 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), 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

¹ Discounters carrying somewhat more national brands are sometimes referred to as soft discounters. However, this distinction is quite blurred, and even the ultimate hard discounter Aldi has recently added some national brands to its assortment. As such, no such distinction is made in the remainder of the paper.

around 35,000 discount grocery stores in Europe, a number forecasted to increase with nearly 30% to 45,000 in 2010 (Planet Retail 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 UK, and Dansk in Denmark. In the US, comparable stores are the price-aggressive grocery discounters such as Dollar General and Family Dollar Stores, who witness rapid growth as well. In 2006, over 20,000 such stores were already operated in the US by several key players, an increase with 52% compared to 2001 (PlanetRetail 2006b). Several leading European players, among which Aldi and Lidl, have recently announced plans to considerably expand their US 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, 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), while Auchan and Tesco are experimenting along the same lines. In so doing, they 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 intra-format rivalry, as different formats essentially compete for business from most, if not all, consumer segments. On the other hand, the actual level of inter-format 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 inter-format competition is expected to be smaller than the extent of intra-format competition. However, it is hard to predict a priori how large this difference will be. It is also not clear whether or not inter-format competition is symmetric. Put differently, 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. Unlike most previous work on inter-format competition, we do not take the stores' locations as given, but endogenize entry decisions. Treating store locations as exogenous may bias one's inferences as market structure not only influences conduct and performance. Conduct can, in turn, affect market structure.

Even though several studies have already looked at inter-format competition (as shown in Table 1), few considered simultaneously intra- and inter-format competition. Within the subset that does so, only two studies (Gijsbrechts et al. 2008 and González-Benito et al. 2005) focused on the competition between supermarkets and discounters. In these studies, however, store locations were given (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 (as recognized by the UK Competition Commission) of vital importance in any competitive assessment.²

² See e.g. http://www.competition-commission.org.uk/inquiries/ref2006/grocery/provisional_decision_remedies.htm

[Insert Table 1 about here]

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 (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 1991a).

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 inter-format incumbents in a semi-parametric way. As such, we allow for differential effects of different numbers of competitors, and quantify whether the competitive impact increases (perhaps even disproportionately) 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 also 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. While the discount phenomenon is still growing in most Western countries, the German discount market has recently stabilized after almost half a 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). Even though 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 *inter-format* competition. In this paper, we focus on the competition between conventional supermarkets and discounters, as these two formats are amongst the most widespread formats in Europe. Retailers of the same format also compete for their respective share of the consumers' wallet, a phenomenon called *intra-format* competition.

Intra-format competition

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

It is not a priori obvious, however, whether intra-format competition is more pronounced among supermarkets or discounters. On the one hand, supermarkets fight a fierce market-share battle because of an increasing saturation in their market, resulting in frequent promotional and advertising (re)actions (Rao and Syam 2001). On the other hand, discounters focus primarily on price, and differentiate themselves less on other dimensions such as assortment and service level. Since price is more easily comparable across different stores, this could lead to more intense competition among discounters. By estimating format-specific intra-format competitive effects, we will infer in which format the rivalry is most intense.

Inter-format 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. Even though 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 inter-format 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 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 inter-competitive effects.

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 1991a), 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 with a 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 (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. While 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 1991b for a discussion on 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, while 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 (1991a) 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 Zhu et al. (2008). 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 (2004) 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. Not only is this approach more appealing in our setting, it also leads to a likelihood function with only rectangular areas of integration. This decreases computational difficulties in estimating the model (see also Berry and Reiss 2007 (section 3.2.3) on the computational difficulties with non-rectangular areas of integration).

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 store 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 :

$$\Pi_f(N_S, N_D) = \pi_f(N_S, N_D) - \varepsilon_f \quad , \quad (1)$$

with N_S and N_D , respectively, the number of supermarkets and discounters in town.³

Marketing policies and shopping behaviors are rather homogenous 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 firm 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 stores 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: intra-format substitutability

$$\begin{aligned} \pi_S(N_S + 1, N_D) &< \pi_S(N_S, N_D); \\ \pi_D(N_S, N_D + 1) &< \pi_D(N_S, N_D). \end{aligned}$$

In addition, different formats compete, to some extent, for business from the same consumers. Therefore, inter-format 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: inter-format substitutability

$$\begin{aligned} \pi_S(N_S, N_D + 1) &\leq \pi_S(N_S, N_D) \\ \pi_D(N_S + 1, N_D) &\leq \pi_D(N_S, N_D). \end{aligned}$$

³ Note that this model assumes that all consumers and stores are located at one central point in the market. 10

Assumption 2b: stronger intra-format than inter-format substitutability

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

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

Assumption 2a implies that a store's profitability is decreasing with the number of firms of the other format.⁴ 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 intra-format than inter-format substitutability.

Based on these assumptions, we now derive the equilibrium number of firms for each format, and construct the implied likelihood function.⁵ We start from the Nash equilibrium concept, according to which all potential firms enter (and stay in) the market if and only if this is profitable, given the entry decisions of the other firms. 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 supermarkets find it profitable to enter the market ($\Pi_S(n_S, n_D) \geq 0$), while one extra supermarket would be unprofitable ($\Pi_S(n_S + 1, n_D) < 0$). Similarly, n_D discounters have nonnegative payoffs, while 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, 1991b). This precludes straightforward econometric estimation, as there is no unique relationship between the unobserved profits and the observed entry

⁴ If the conditions hold with equality, the different formats are said to be independent.

⁵ The implied likelihood function will be estimated without any parameter restrictions. In Section 5, we verify whether the estimated parameters are consistent with these assumptions (see Schaumans and Verboven 2008 for a similar practice).

decisions. Figure 1 visualizes the problem in a simple game with one potential entrant for each format. The vertical lines indicate when the supermarket can profitably enter, given that the discounter also enters (line $\pi_S(1,1)$), or given that the discounter 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.

[Insert Figure 1 about here]

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, 2a and 2b we show that the multiplicity of equilibria can be characterized in a simple way. In particular, the areas for the random terms ε_S and ε_D for which the Nash equilibrium (n_S, n_D) shows multiplicity with any other Nash equilibrium are limited to the areas of overlap with the Nash equilibria $(n_S + 1, n_D - 1)$ and $(n_S - 1, n_D + 1)$. In the Appendix, we provide proof for this claim. The area of multiplicity with $(n_S + 1, n_D - 1)$ is simply:

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

and similarly for the area of multiplicity with $(n_S - 1, n_D + 1)$.

To obtain unique entry predictions, we put additional structure on the entry game by assuming that firms enter sequentially, and refine the Nash equilibrium concept to that of subgame perfection. As the traditional supermarket format was developed long before the discounter format, we assume that supermarkets entered the market first.⁶ In the example of Figure 1 with one potential entrant of each format, the market configuration $(1,0)$ would then be selected when there is multiplicity with $(0,1)$, i.e. the supermarket enters while the discounter stays out of the market. In the general case of many potential entrants of each format, the market configuration with the highest number of supermarkets will be selected as the unique subgame perfect equilibrium if there are multiple Nash equilibria.

Using our earlier simple characterization of the multiplicity of Nash equilibria, this implies that (n_S, n_D) is the unique subgame perfect equilibrium if the random terms ε_S and ε_D satisfy the Nash equilibrium conditions (2), unless this coincides with Nash equilibria where *more* supermarkets would enter, as described by the area of multiplicity with $(n_S + 1, n_D - 1)$ given by (3). Therefore, the probability of observing market configuration (n_S, n_D) as the unique subgame perfect equilibrium outcome is:

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

⁶ In Section 6, we will test the sensitivity of our results with respect to this assumption.

with $\phi(\cdot)$ 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), while the second term subtracts the area of overlap with $(n_s + 1, n_d - 1)$ as given by (3). Notice that the second term in (4) is equal to zero if supermarkets and discounters have no direct impact on each other's profit functions. In this case, only the first term remains, and the model reduces to a bivariate ordered probit model with a correlation parameter ρ . If also 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 (1991a).

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 inter-format 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 inter-format 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:

$$\pi_s(N_S, N_D) = \alpha_s \ln(\text{POP}) + \beta_s \mathbf{X} - \lambda_s^{N_s} - \frac{\gamma_s^{N_D}}{N_s}, \quad (5)$$

$$\pi_D(N_S, N_D) = \alpha_D \ln(\text{POP}) + \beta_D \mathbf{X} - \lambda_D^{N_D} - \frac{\gamma_D^{N_S}}{N_D}.$$

where POP is the market population, and \mathbf{X} is a vector of market characteristics. The parameters $\lambda_f^{N_f}$ are fixed effects, measuring the impact of the number of intra-format stores

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 store of format f has a negative impact on the performance of stores of the same format. Similarly, the parameters $\gamma_f^{N_{-f}}$ measure the effect of inter-format players on store profitability. A significant increase in these parameter values for a larger number of other-type stores indicates a significant inter-format 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.⁷

The parameters estimated from (5) can be used directly to test the impact of the covariates on the store performance of supermarkets and discounters. However, they can also be used to derive entry thresholds, i.e. the minimum market sizes required to support a given number of firms. These thresholds offer insights on how entry affects the extent of competition. Specifically, if an additional firm provides a strong constraint on firm profits, the entry threshold to carry the extra store raises more than proportionally (Bresnahan and Reiss 1991a). The entry threshold $T_f^{N_f, N_{-f}}$ is defined by the population level at which the stores of format f would break even given that there are N_f stores of the same format and N_{-f} other-format stores. The threshold is thus equal to the market size at which the deterministic part of profit for the given market outcome is equal to zero. Using (5), $T_f^{N_f, N_{-f}}$ can be computed as:

$$T_f^{N_f, N_{-f}} = \exp\left(-\frac{\beta_f \mathbf{X} - \lambda_f^{N_f} - \gamma_f^{N_{-f}} / N_f}{\alpha_f}\right), \quad (6)$$

Entry threshold *ratios* can be used to examine intra- and inter-format competition. First, the intra-format threshold ratios ($INTRA_TR_f^{N_f}$) measure to what extent the market size *per*

⁷ 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 $\lambda_f^{N_f} = \lambda_f^{0, N_f} / N_f$, and would be mathematically equivalent. The “unit-free” threshold-ratios in (7) and (8) would therefore remain the same.

store needs to increase to support an extra store of the same format when no stores 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 intra-format and zero inter-format stores over the *per-store* threshold with $N_f - 1$ intra-format and zero inter-format stores:⁸

$$INTRA_TR_f^{N_f} = \frac{T_f^{N_f,0}}{N_f} \bigg/ \frac{T_f^{N_f-1,0}}{N_f-1} = \exp\left(\frac{\lambda_f^{N_f} - \lambda_f^{N_f-1}}{\alpha_f}\right) \times \frac{N_f-1}{N_f} . \quad (7)$$

An intra-format 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 intra-format competition (Bresnahan and Reiss 1991a).

Similarly, inter-format entry threshold ratios ($INTER_TR_f^{N-f}$) measure the increase in the per-firm market size needed to support a monopolist of format f when an additional store of the other format enters. It is defined as:⁹

$$INTER_TR_f^{N-f} = \frac{T_f^{1,N-f}}{1} \bigg/ \frac{T_f^{1,N-f-1}}{1} = \exp\left(\frac{\gamma_f^{N-f} - \gamma_f^{N-f-1}}{\alpha_f}\right) . \quad (8)$$

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

⁸ Similarly, intra-format ratios can be calculated in the case when inter-format competitors are present. This leads to a more complicated form of the ratios, including a function of the γ_f^{N-f} parameters. Restraining the number of inter-format competitors to zero removes the effect of the γ_f^{N-f} parameters in the equation, reducing the ratio to the pure competitive intra-format entry interpretation in Bresnahan and Reiss (1991a).

⁹ Inter-format ratios when more same-type competitors are present can also be defined. In this case, the number of intra-format competitors N_f will appear in the denominator. When $N_f = 1$, this effect disappears, restricting the ratio to the pure inter-format competitive effect.

4. DATA AND INDUSTRY

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. As 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 2006c). 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 2006.¹⁰ The latter feature is especially relevant as the modeling approach (see Section 3) assumes a steady-state equilibrium.

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. 2008 for a similar practice). Similarly, we also exclude all towns with a population of more than 25,000 as those markets are likely to contain submarkets (see also Carree and Dejardin 2006).

¹⁰ See www.planetretail.net

Data on the number of supermarkets and discounters was obtained from Tradedimensions, a data provider specialized in store-by-store data for different industries. 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 non-discount 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 Toivanen and Waterson (2005) and Zhu et al. (2008), we focus on the number of large companies present in the market, as 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 (Netto), and Norma. We hereby 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 98% of the total sales of the supermarket format.¹¹ To control for the few independent stores left, we add them as an exogenous variable to the profit functions. As there are too few observations 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 inter-format competition, we do not take these observations into account.¹² 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 previous studies inferring inter-format 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).

¹¹ See www.planetretail.net.

¹² Together, they make up only 1% of the sample. Still, we will assess in Section 6 the robustness of our main findings if these observations are included.

Table 2 presents summary statistics on the relative occurrence of the various market structures. A majority of the towns has one supermarket chain (55%), while 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).

[Insert Tables 2 & 3 about here]

Explanatory variables

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

Following Cleeren et al. (2006), we measure *population size* through the number of inhabitants (in 1,000). *Income* is measured by the average net income (in 1,000 euro) per inhabitant, while the ethnic composition is operationalized as the percentage of households with a *foreign* nationality. Household composition is captured by the average *household size*. We operationalize *age* as the percentage of people older than 64 years, 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,¹³ and include the *surface* (in 100 km²) of the market. Following Asplund and Sandin (1999), we measure the *distance to the nearest town* as the Euclidean distance from the town centre to the nearest town centre (in km). Furthermore, we calculate the percentage change in

¹³ A city is defined as a local market with more than 25,000 inhabitants.

population size over the last two years to measure *population growth* (see Manuszak 2002 for a similar practice). We operationalize *hypermarket* presence with a dummy variable that indicates whether a hypermarket is situated in a town within 25 km of the considered town centre.¹⁴ 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 Section 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 that performance is decreasing with the number of own-type stores. Similarly, also the estimated γ_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 that performance is decreasing with the number of other-type stores.¹⁵ Finally, the estimated $\lambda_f^{N_f}$ and γ_f^{N-f} are consistent with Assumption 2b, stating that the profit implication of an intra-format entry is larger than that of an extra inter-format store.¹⁶ As 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).

[Insert Table 4 about here]

As discussed in Section 3, the model specification reduces to two traditional ordered probit entry models in the spirit of Bresnahan and Reiss (1991a) if there is no effect from inter-

¹⁴ Following González-Benito et al. (2005), hypermarkets are defined as grocery stores with a sales area of at least 2,500 square metres.

¹⁵ As y_S^1 was insignificantly negative, we impose the equality in assumption 2a and restrict this parameter to zero.

¹⁶ 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 γ_f^{N-f} .

format 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 γ_f^{N-f} parameters are significant, implying a direct effect of inter-format 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.

Intra-format competition

We first focus on the competition between stores of the same format. Since the magnitudes of the λ_f^{Nf} are difficult to interpret as such, we use them to construct the intra-format entry threshold ratios, ($INTRA_TR_f^{Nf}$) as given by (7). These ratios are a measure of intra-format competition, since 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 disproportionately, implying an increase in the extent of intra-format competition because of the extra store.

[Insert Table 5 about here]

The intra-format 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. As this ratio is significantly different from one ($p < 0.01$), the extent of intra-format 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 intra-format 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 with, respectively, 10%, 21%, and 39%. These ratios are significantly larger than one ($p < 0.01$). In contrast, the first estimated intra-format 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 for other potential entrants (Gielens and Dekimpe 2007).

After having established the existence of intra-format competition for both formats, we assess their relative size. To that extent, we compare the intra-format 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 intra-format ratios for the discounter format are significantly smaller than the ratio for supermarkets ($p < 0.01$). Put differently, the extent of intra-format competition is more pronounced within the supermarket format.

Inter-format competition

As mentioned in Section 3, we can use the estimated γ and α parameters to calculate inter-format 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. A ratio that is significantly larger than one indicates an increase in the extent of inter-format competition because of the entrant.

[Insert Table 6 about here]

Supermarkets do not experience a significant competitive effect from the entry of the first two discounters (ratios in Table 6 are 1 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 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, as hypermarkets and mom-and-pop stores.¹⁷

Significant and substantial inter-format competition is observed from the third discounter onwards. The breakeven market size for a supermarket increases each time with 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, as 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 inter-format 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 inter-format competitive effect for discounters becomes apparent when more supermarkets are present in the market. No significant differences are found between the inter-format ratios obtained for both formats, suggesting no asymmetric effects in terms of their vulnerability and clout.

¹⁷ Note that hypermarket presence indeed has a negative impact on discounter profitability (see Table 4), while the number of mom-and-pop stores has decreased substantially over time in all European countries.

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, while 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 for 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 do part of their groceries, and thereby increase the demand within the local market (see Bresnahan and Reiss 1991a 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 (see Manuszak 2002 for a similar result). 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.

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 one-percent 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 one percent in the unemployment level in every market leads to a decrease in the total number of supermarkets with 1.9 percent, and an increase in the number of discounters with 4.6 percent. Note that we can split up 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 inter-format competitors.¹⁸ As such, for the supermarkets, the direct effect (-1.3 percent) contributes about 2/3 to the total negative effect, while the indirect effect contributes about 1/3 (-0.6 percent) . In contrast, for discounters the total positive effect is almost exclusively caused by a direct positive effect of 4.3 percent (i.e. 95 percent of the total effect).

[Insert Table 7 about here]

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

6. ROBUSTNESS CHECKS

Three 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. Finally, we acknowledge that some firms may operate chains of both formats, and see whether this affects our results.¹⁹

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 with 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

¹⁸ The direct effect of the change in the covariate can be estimated by simulating the effect in case of no inter-format competitive effects (i.e. all $\gamma = 0$).

¹⁹ Full details on all validation exercises are available from the first author upon request.

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. In a sixth validation sample, 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 to the findings reported above. Both formats experience an extensive intra-format rivalry, although for discounters this is only apparent from the third entrant. Furthermore, in all samples intra-format competition is asymmetric in that it is more pronounced for supermarkets than for discounters. Also with regard to the extent of inter-format competition, we find similar patterns as reported above. Specifically, inter-format competition is only significant for supermarkets from the third discounter onwards, while only the second supermarket has a significant impact on a discounter's profitability.

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. To check the robustness of our results with regard to this assumption, we rewrote the likelihood function and re-estimated the model under the opposite assumption that discounters entered the market first. The estimated entry threshold ratios were very robust, and the same conclusions as summarized in the previous paragraph held.

Sensitivity to firms owning multiple formats

The same parent firm may be present in both formats. In that case, inter-format competition could be 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 re-estimated 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.

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 intra-format 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, they also compete with one another.

We also quantified the extent of *inter-format 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 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, their 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 UK. 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" (The Grocer 2007).

Several insights on the extent of intra- and inter-format competition between discounters and supermarkets were obtained, even though the data requirements to attain these results were quite limited. In order 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 defensible 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. While we considered 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 on larger geographic markets. One could also envision modeling each chain's entry decision separately. This would not only allow to estimate chain-specific competitive effects, the results would also provide insights on the role of multimarket contact (see e.g. Shankar 1999). 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. 2008 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. While 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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Table 1: Overview of marketing literature on inter-format competition

Study	Type of competition	Formats studied	Geographical scope	Treatment of store locations
Bell et al.1998	Intra & 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 & Inter	Grocery stores, mass merchandisers, drug stores	One metropolitan market	Exogenous
Gijsbrechts et al. 2008	Intra & Inter	Hard discounters, large discounters, superstores and supermarkets	Different local markets	Exogenous
González-Benito et al. 2005	Intra & 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 & Inter	EDLP and HiLo supermarkets	One city	Exogenous
Popowski-Leszczyc et al. 2004	Intra & Inter	EDLP and HiLo supermarkets	One suburban area	Exogenous
Rhee and Bell 2002	Intra & 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 & Inter	Supermarkets and Discounters	Entire German market	Endogenous

Table 2: Number of towns per market structure

DISCOUNTERS	SUPERMARKETS			TOTAL (%)
	0	1	2	
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	1,989	596	3,593
(%)	(28%)	(55%)	(17%)	

Table 3: Descriptive statistics

Variable	Description	Mean	Standard Deviation
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	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

Table 4: Estimation results^(*)

	<i>Supermarkets</i>		<i>Discounters</i>	
	Estimate	St. error	Estimate	St. Error
Logpopulation	1.38 ^a	(0.07)	1.98 ^a	(0.06)
Income	-0.01	(0.01)	-0.05 ^a	(0.01)
Foreign	-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)		

(*) The estimates are based on a sample of 3,593 local markets. γ_f^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 level. Reported significance tests are one-sided for the $\lambda_f^{N_f}$ and γ_f^{N-f} parameters, and two-sided for the control variables and ρ .

Table 5: Estimated intra-format threshold ratios^(*)

	Supermarkets	Discounters
$INTRA_R_f^2$	2.03 ^a (0.12)	0.87 ^a (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

^(*) Intra-format ratios are calculated for the case of zero inter-format competitors. Standard errors are calculated with 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.

Table 6: Estimated inter-format threshold ratios^(*)

	Supermarkets	Discounters
$INTER_R_f^1$	1.00 (-)	1.05 (0.05)
$INTER_R_f^2$	1.09 (0.07)	1.12 ^b (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

(*) Inter-format ratios are calculated for the case of one intra-format player. Standard errors are calculated with the delta method and are presented in parentheses. ^b and ^c indicate a ratio significantly larger than one at, respectively, 5% and 10% significance level.

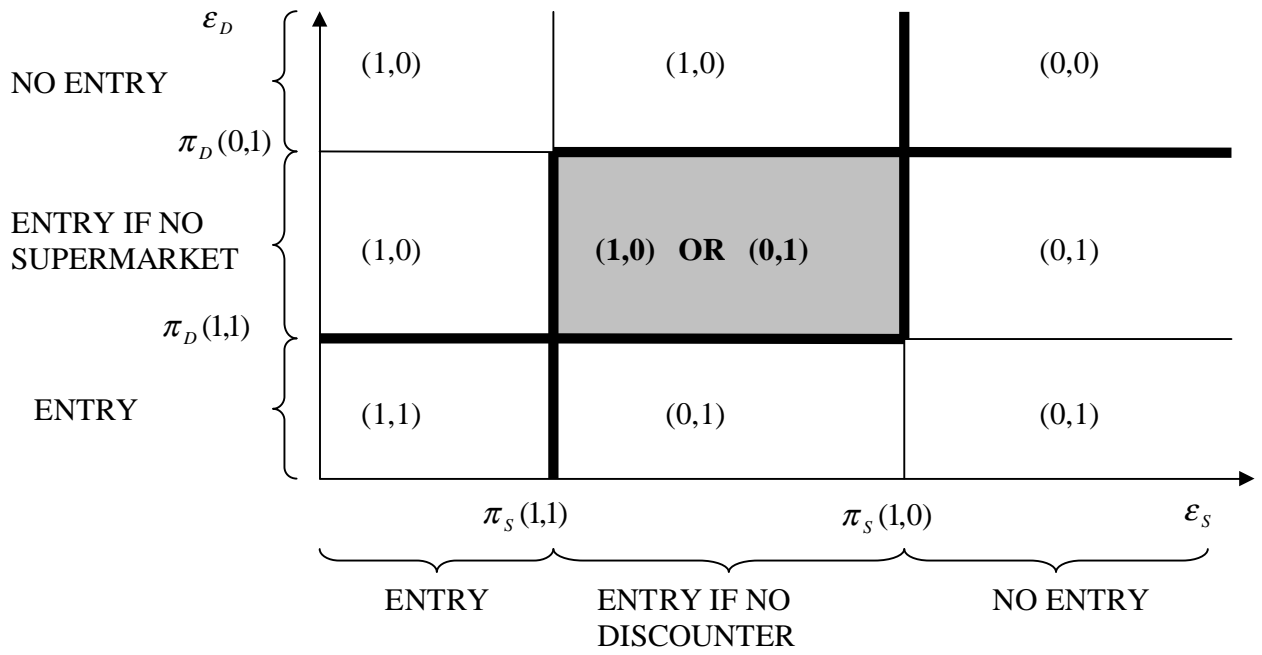
(**) Reported numbers are the Wald test statistics for the null hypothesis that the two ratios are equal to each other.

Table 7: Simulated effect of changes in the covariates on the total number of supermarkets and discounters^(*)

	Number of supermarkets	Number of discounters
Population	+0.7%	+1.0%
Income	+0.03%	-0.4%
Foreign	-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%

^(*) Reported numbers are the percentage change in the total number of supermarkets and discounters after a one percent increase in the control variable.

Figure 1: Multiplicity problem for a 2 by 2 game



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 $(n_S + m, n_D - m)$ or $(n_S - m, n_D + m)$, where m is a positive integer (Claim 1). So $(2,3)$ 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 $m > 1$, and a subset of the multiplicity area with $(n_s - 1, n_D + 1)$ for $m < 1$ (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 a Nash equilibrium, where m_s and m_D may be any integer.

Claim 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 2(a) 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 $\pi_s(n_s + 1, n_D) < \varepsilon_s$.

(ii) $m_S > 0, m_D \leq 0, m_S > -m_D$. Then the inequalities (2), Assumption 2(b) 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 2(b) 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 2(a) 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 2(b) 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 2(b) 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 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 2(a). A similar reasoning holds for the set $B(-1, 1)$.

Claim 3. $B(m, -m) \subset B(1, -1)$ and $B(-m, m) \subset B(-1, 1)$.

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 2(b), 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 $B(-m, m) \subset B(-1, 1)$.

Figure A. 1: Multiplicity problem when two potential entrants in each format

NO ENTRY $\pi_D(0,1)$		(2,0)	(2,0)	(2,0)	(1,0)	(1,0)	(0,0)	
	1 ENTRY IF NO SUPER $\pi_D(1,1)$	(2,0)	(2,0)	(2,0)	(2,0)	(1,0)	(0,1) / (1,0)	(0,1)
1 ENTRY IF AT MOST 1 SUPER $\pi_D(0,2)$	(2,0)	(2,0)	(2,0) / (1,1)	(2,0) / (1,1)	(1,1)	(0,1)	(0,1)	
2 ENTRY IF NO SUPER $\pi_D(2,1)$	(2,0)	(2,0)	(2,0) / (1,1)	(0,2) / (1,1) / (2,0)	(0,2) / (1,1)	(0,2)	(0,2)	
1 ENTRY $\pi_D(1,2)$	(2,1)	(2,1)	(1,1)	(0,2) / (1,1)	(0,2) / (1,1)	(0,2)	(0,2)	
2 ENTRY IF AT MOST 1 SUPER $\pi_D(2,2)$	(2,1)	(2,1) / (1,2)	(1,2)	(0,2)	(0,2)	(0,2)	(0,2)	
2 ENTRY	(2,2)	(1,2)	(1,2)	(0,2)	(0,2)	(0,2)	(0,2)	
		$\pi_S(2,2)$	$\pi_S(2,1)$	$\pi_S(1,2)$	$\pi_S(2,0)$	$\pi_S(1,1)$	$\pi_S(1,0)$	ϵ_S
	2 ENTRY	2 ENTRY IF AT MOST 1 DISC	1 ENTRY	2 ENTRY IF NO DISC	1 ENTRY IF AT MOST 1 DISC	1 ENTRY IF NO DISC	NO ENTRY	