Small is Successful!?

A Study of Exit Behavior in a Declining Markets Experiment

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ABSTRACT. This paper provides experimental evidence on exit behavior of asymmetrically sized firms in a duopoly with declining demand. We conduct three treatments: (a) The basic model with indivisible real capital. The structure of this treatment represents the main findings of Ghemawat and Nalebuff (1985); (b) an extension of the basic model by introducing a bankruptcy constraint; (c) here we allow for divisible real capital (Ghemawat and Nalebuff (1990)). In all three treatments we find behavior that is, by and large, in line with subgame perfect Nash Equilibrium. However, there is a problem of multiplicity of equilibria in (b) and we find an anchor effect as well as learning effects in (c).
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1. Introduction

Do large firms always crowd out small firms when market demand declines? Or, as the title of our article suggests, do small firms have specific advantages over larger firms if markets contract? At first glance, one might argue that large-scaled firms should be capable to drive out smaller competitors if demand is declining, but a closer look reveals that there are some forces at work which favor small firms. E.g., they may behave more flexibly if market conditions change and therefore sustain their production even if demand declines. Our paper presents experimental evidence about exit behavior of asymmetrically sized firms in a laboratory environment.

The interest in the analysis of firms' behavior in declining industries was sparked by Harrington (1980). Since then this topic has been subject to a larger number of theoretical and empirical studies. Using a game-theoretic approach, e.g. Ghemawat and Nalebuff (1985, 1990), Londregan (1990), Ruiz-Aliseda (2003), Reynolds (1988) or Whinston (1988) analyze firms' exit and capacity reduction decisions if market demand declines. Even if the underlying assumptions and results of these models differ, they draw similar conclusions in that a firm's size has a significant impact on its projected behavior. If firms differ only in size, i.e. production capacities, and steady capacity adjustments are impossible, Ghemawat and Nalebuff (1985) show that the smaller firm in a duopoly always forces her rival out of the market in subgame perfect equilibria. This counter-intuitive result is driven by the fact that a small monopoly firm can stay in the market for a longer time than a large monopolist if demand continuously declines.

Similar results are valid for the oligopoly case, where firms exit in decreasing order of their capacities even if small cost differences occur. Accounting for re-entry possibilities, Londregan (1990) shows that the former results still hold. Allowing for gradual capacity reductions in the exit game, Ghemawat and Nalebuff (1990) draw the conclusion that the large firm always reduces its capacities first until it has reached the size of the initially smaller firm. Regarding the decline of a whole industry, the largest firm always contracts first to the size of the second-largest firm. Afterwards, both firms shrink jointly to the size of the third-largest firm and so on. As a result, firms' sizes will flatten over time. Ambiguous hypothesis on firms exit behavior are obtained if divestment is possible only in fixed decrements.

In the case of equal sized plants, Reynolds (1988) obtains similar results to Ghemawat and Nalebuff (1990). However, if firms have plants of different size, Whinston (1988) finds multiple equilibria. Hence, it need not always to be the largest firm which exits or cuts capacity first. If firms do not face differences in size, theoretical literature confirms that it is the difference in relative costs which determines exit and divestment patterns. So high-cost plants will always be closed before low-cost plants as stated by Reynolds (1988). Ghemawat and Nalebuff (1985) show similar results in concluding, that always the high-cost firm exits first. In a recent paper, Ruiz-Aliseda (2003) reports similar results by modelling (re-)entry and exit decisions in a duopoly over the entire product life-cycle. Since the high opportunity cost firm always has stronger incentives to exit first, the low cost firm can credibly threaten to trigger a promising war of attrition. Hence, the high opportunity cost firm - like the larger firm in Ghemawat and Nalebuff - always leaves the market at an earlier date. Furthermore, Ruiz-Aliseda shows that in a declining industry, no other firm will enter the market, no matter how many firms are still active.

The model by Filson and Songsamphant (2001) represents an expansion of Ghemawat and Nalebuff (1985), which accounts for possibilities of mergers in declining markets and the firms' profitability. Here, the overall profits and social welfare may be higher if the small firm exits first, i.e. the larger firm buys the smaller one and shuts her down so that the market is consolidated. Filson and Songsamphant show conditions, under which the likelihood of mergers increases. By using empirical data for declining U.S. manufacturing industries during 1975-1995, they find empirical evidence for their theoretical results. Dierickx et al. (1991) argue, that the order of exit of asymmetrically sized firms also depends on the causes of demand decline, i.e. a shrinkage in the consumer base or a decrease in consumers' willingness to pay.

Exit patterns in declining industries have also been subject to a larger set of empirical works. Amongst others, Baden-Fuller (1989) concludes in his analysis of closings in the UK steel castings industry, that strongly diversified and financially strong firms are more likely to shut down than other firms. Schary (1991) shows for the U.S. cotton textile industry, that the exit pattern is not related to profitability and that there is no uniform exit pattern. Anderson and Tushman (2001) argue that it is the firms' capabilities to cope with uncertainty which determines the probability of "surviving"in the market. Dunne et al. (1988) points out the heterogeneity of entry and exit patterns across U.S. manufacturing industries. Troske (1996) shows that firms' entry and exit in the manufacturing sector is a longer lasting process than in the finance, insurance and real estate sector.

In contrast to theoretical and "classic" empirical research, experimental research on firms' exit behavior seems to be less developed. Oprea et al. (2006) analyze a laboratory market with an excess number of suppliers but a stable demand. Cost asymmetries induce a timing of exits that is fairly close to Fudenberg and Tirole (1986). Actually, we are not aware of any experimental work with respect to exit behavior in declining markets. Hence, our paper aims at filling this gap by evaluating the insights of game-theoretic exit models using laboratory experiments. In doing so, our objective is to analyze whether the theoretical results which are based on strict behavioral assumptions of economic subjects can serve as a workable predictor of actual human behavior in a laboratory environment. Our experiments are based on the models and hypothesis derived by Ghemawat and Nalebuff (1985, 1990).

The paper is organized as follows. The experimental set up, procedures, and hypotheses are described in section 2. Section 3 states the main results. A discussion of the results and a conclusion is given in section 4.

2. The Experiment

We carried out three treatments that are closely related to Ghemawat and Nalebuff (1985) and (1990)[1]. Our basic treatment is related to the main model in Ghemawat and Nalebuff (1985). In that paper the demand function of a duopoly is given by $p(q)$. It is assumed that

$$\frac{dp}{dt} < 0, \quad \frac{dp}{dq} < 0, \quad lim_{t \to \infty} p_t = 0, \quad \frac{d(pq)}{dq} > 0.$$

Accordingly, prices are decreasing in time and quantities and marginal revenues are strictly positive. Given that total costs consist of fixed capacity costs, the last property of demand causes that it is always optimal for both suppliers to fully utilize their capacities as long as they stay in the market. Capacities, however, are exogenously given and asymmetric. One firm owns a large capacity, the other firm has a smaller one. Capacity costs can be avoided only by exiting the market. In each period firms have to make two simultaneous decisions: (1) They have to decide whether to exit or to stay. (2) Firms choose the quantities being supplied on the market. After that period profits are earned and a new period with an even lower demand begins.

In equilibrium both firms stay in the market as long as both make profits by supplying a quantity being equal to their exogenous capacities. When demand has declined to the level that revenues cannot cover capacity costs anymore, one of the firms exits. There are two equilibria differentiated only by the firm leaving first. However, only the equilibrium with the large firm leaving first is subgame perfect.

In our second treatment referring also to Ghemawat and Nalebuff (1985) we add a credit constraint (CC). As a consequence, it is possible to have multiple subgame perfect equilibria or to have a unique subgame perfect equilibrium (SPE) with the small firm leaving first.

Finally, our third treatment allows for flexible capacity adjustments (CA), i.e. capacity reductions (Ghemawat and Nalebuff 1990). In this case equilibrium behavior is characterized by both players playing the Cournot Equilibrium in each period. Starting with different capacities, this means that the large firm reduces its capacities first until both firms have the same size. After that they decline symmetrically.

[1] An english version of the original instructions is available online at http://www.wiwi.tu-clausthal.de/abteilungen/volkswirtschaftslehre/forschung/arbeitspapiere/.

2.1. The Numerical Models and Predictions

In all treatments we defined demand by

$$p_t = \frac{0.9^t}{(q_A + q_B)^{3/4}} \cdot 100$$

which satisfies all properties listed above. In the first two treatments capacities of firms A and B are given by $C_A = 10$ and $C_B = 17$. Capacity costs are given by $TC_i = 6C_i$ so that $TC_A = 60$ and $TC_B = 102$.

In SPE both firms stay in the market up to period 3. In period 4 firm B exits and in period 11 firm A leaves the market.

In Treatment CC we add credit constraints. Here we have firms in mind that distribute all profits each period. An accumulation of losses, however, decreases firms' credit worthiness. We assume that there is an upper bound for accumulated losses. If the small firm can hold on for a longer time, there is no change in equilibrium behavior. However, if the small firm's credit constraint binds first, this may have an impact on equilibrium. Therefore, we assume that accumulated losses of firm A must not exceed 14 and those of firm B have remain below or equal to 75. In this case, it turns out, that there are multiple SPE. There are two SPE with firm B leaving in period 4 and firm A leaving in period 11. Another two SPE are characterized by exits of firm A in period 4 and firm B in period 7. A fifth SPE in mixed strategies is characterized by randomizing in periods 4 and 5. If only one firm stays in the market it will remain there until period 11 (firm A) or period 7 (firm B). If both firms are still in the market in period 6, the large firm B will exit immediately.

Table 1: Symmetric SPE behavior with two suppliers in Treatment CA

t	p(0)	p(1)	p(2)	p(3)	p(4)	p(5)	p(6)	p(7)	p(8)	p(9)	p(10)
1											1
2										1	
3								0.85	0.15		
4							0.63	0.37			
5							1				
6						1					
7					1						
8	0.03				0.97						
9	0.05			0.96							

10	0.13			0.87
11	0.17		0.83	
12	0.36		0.65	
13	0.5	0.47	0.03	
14	0.8	0.2		
15	1			

In Treatment CA firms are allowed to decrease their capacities gradually. In the experiment participants could choose only integer capacities, however. This is easier for participants but leads to the more complicated symmetric equilibrium being described in Table 1.

In Table 1 $p(q)$ is the probability that each player chooses quantity q. All empty cells correspond to a probability of zero. In t = 1 p(10) = 1 means that in SPE both players choose quantity 10 with probability one.

Table 1 shows that first exits may happen in period 8 (with probability 0.03) and that both players should leave the market in period 15. This is even true for firms being monopolists in period 15. If one firm has left the market the other one being a monopolist will then play different quantities that are not presented here.

According to our objective of testing existing theories the hypotheses given below are basically identical to the characteristics of the corresponding equilibria:

Hypothesis 1 (all treatments): *Production (supply) is used to full capacity.*

Hypothesis 2: *In the basic treatment firm-A-players exit in period 11 and firm-B-players exit in period 4.*

Hypothesis 3: *In Treatment CC firm-A-players exit in periods 4, 5, or 11 and firm-B-players exit in periods 4, 5, or 7.*

Hypothesis 4: *In Treatment CA both firms offer the same quantities in all periods.*

Hypothesis 5: *In Treatment CA there will be a symmetric decline in supplied quantities that are given by the corresponding equilibrium quantities.*

Hypothesis 6: *In Treatment CA first exits will appear in period 8.*

Hypothesis 7: *At the latest, both players exit in period 15.*

2.2. Experimental Design and Procedures

The experiment was conducted in June 2004 at Clausthal University of Technology, Germany. We carried out four computerized sessions using z-tree (Fischbacher 1999). The composition of sessions is shown in Table 2. The basic treatment and Treatment CC were carried out in sessions 1 and 2 in reverse order and players kept their roles within a session. In Sessions 3 and 4 we concentrated on Treatment CA because it is much more time-consuming. Sessions lasted on average about 2.5 hours and average earnings amounted to € 19.90 including a show up fee of € 10.

Table 2: Composition of sessions

Session	1st Treatment	2nd Treatment	Participants
1	Basic	CC	20
2	CC	Basic	20
3	CA		20
4	CA		20

3. Results

Because total costs consist of only capacity costs, i.e. there are no further production costs, and because of our assumptions about the demand function, we expected players to accomplish full capacity utilization in all treatments. This is confirmed by the data.

Result 1: *In the overwhelming majority of cases capacities are fully utilized.*

Table 3 shows the data on capacity utilization. In Treatments Basic and CC more than 97 % of cases are in accordance with our hypothesis. In Treatment CA we find a little bit more than 6 % of deviations from the hypothesis. However, it seems to be clear that participants did understand the profitability of full capacity utilization.

Table 3: Capacity utilizations

Treatment	Cases	Full utilization	Percentage of full utilization
1	2649	2585	97.58 %
2	2113	2051	97.07 %
3	4167	3909	93.81 %
All	8929	8545	95.7 %

3.1. Exit Behavior in the Basic Treatment

Subgame Perfect Nash Equilibrium provides a prediction of a clear cut exit behavior in our basic treatment with firm A exiting in period 11 and firm B exiting in period 4. In view of the somewhat counter-intuitive character of the equilibrium, it was not at all clear what kind of exit behavior would appear. However, the results are rather unambiguous.

Result 2: *Exit behavior in Treatment Basic basically confirms the subgame perfect equilibrium, i.e. firms A exit in period 11 and firms B exit in period 4.*

In 93.5 % of the cases players A exit in period 11. Obviously, players A have been well aware of their advantageous position. Players B, however, chose the equilibrium exit period in only three out of four cases. Another 15 % of exits are found in periods 5 and 6. We view this behavior as a trial to switch the exit order. As it is not worth for firms B to hold out for a long time − in period 7 they would leave the market anyway − they have to give in rather quickly. Finally, note that there are no session effects.

Table 4: Exit Behavior in Treatment Basic

Period	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	−
Exit A				1	2	1	1	3		1	**187**	3			1	
Percent				0.5	1	0.5	0.5	1.5		0.5	**93.5**	1.5			0.5	
Exit B	3	1		**156**	19	13	4	1		1						2
Percent	1.5	0.5		**78**	9.5	6.5	2	0.5		0.5						1

3.2. Exit Behavior in the Credit Constraint Treatment

In Treatment CC (with credit constraints) we have multiple SPE. As we do not see a simple and obvious way for participants to coordinate their behavior, any behavior that is in accordance with one of the equilibria is to be expected.

Result 3: *Exit behavior is basically in accordance with the SPE. In the overwhelming majority of cases players of type A exit in periods 4, 5, or 11. Also as expected, players B exit in periods 4, 5, and 7.*

Table 5 shows that 96 % of all firm-A-exits happen in periods 4, 5, and 11. In the same vein, 86.5 % of the exits of firms B occur in periods 4 and 7. Note, however, that there is also a number of firms B exiting prematurely in periods 1 – 3. We do not have an explanation for this yet.

Table 5: Exit Behavior in Treatment CC

Period	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	−
Exit A		2		**45**	**73**	2					**74**	4				
Percent		1		**22.5**	**36.5**	1					**37**	2				
Exit B	8	2	2	**78**	7	4	**95**	1	2	1						
Percent	4	1	1	**39**	3.5	2	**47.5**	0.5	1	0.5						

Result 5: There is a significant difference of exit behavior between sessions.

Table 6 shows the exit decisions arranged by sessions. In session 1 firm A is far less successful in achieving the preferred equilibrium than in session 2. As a consequence, firm B manages to realize his preferred equilibrium more often in session 1 than in session 2. An explanation we can offer for this is based on the sequence of treatments. In session 1 Treatment Basic is played first. Consequently, player A starts with the superior position. When the second treatment begins, players of type B may want to catch up to their counterparts and thus try to squeeze them out of the market. For example, if some of the players are inequality averse (Bolton and Ockenfels 2000, Fehr and Schmidt 1999) they will prefer the equilibrium with firm B staying in the market in the second treatment of session 1: players of type A will be inclined to exit earlier and players of type B will insist on their market position more strictly. This is different in session 2. Here Treatment CC is played first so that there is no bias in favor of one of the equilibria.

Table 6: Sessions and exits

	Period	4	5	6	7	11
Exit A (%)	Session 1	**36**	45	–	–	**15**
	Session2	**9**	28	2	–	**59**
Exit B (%)	Session 1	**30**	2	2	**65**	–
	Session 2	**48**	5	2	**30**	–

Summarizing, our experiment rather strongly confirms theory in Treatments Basic and CC.

3.3. Supply and Exit Behavior in the Capacity Adjustment Treatment

Most hypotheses we introduced in section 1 are related to Treatment CA. Here firms are allowed to decrease their capacities gradually. According to theory initial capacities are irrelevant to firms behavior because they can freely be adapted to the corresponding Cournot quantities. As we have a symmetric game in capacities, we have a symmetric equilibrium. Yet the data show that behavior deviates from this prediction in several periods.

Result 5: *In Treatment CA there are significant differences in production within the first four periods.*

Table 7 shows mean production quantities for each period. In the first four periods there is a significant deviation of B's production from its equilibrium quantity. Furthermore, firm B's production is significantly higher than firm A's supply which is rather close to the equilibrium prediction.

Table 7: Mean production in Treatment CA

Period	Production A	Production B	Equilibrium (2 firms supplying)
1	9	13.695	10
2	8.655	12.58	9
3	7.965	10.835	7 or 8
4	7.08	8.79	6 or 7
5	6.105	7.035	6
6	5.53	5.365	5

7	4.385	4.16	4
8	3.405	3.145	0 or 4
9	2.315	2.495	0 or 3
10	1.765	2.02	0 or 3
11	1.26	1.615	0 or 2
12	0.87	1.195	0 or 2
13	0.755	0.915	0,1, or 2
14	0.61	0.71	0 or 1
15	0.155	0.43	0

We regard firm B's excessive supply as an anchor effect of initial capacities. This anchor effect, however, is reduced over time (periods):

Result 6: *Beginning with period 5, the decline of production is, by and large, symmetric and close to theoretical predictions.*

Except for period 14, production of firms A is not significantly different from production of firm B in all periods after period 4. Above that, in those periods quantities are fairly close to their equilibrium values.

In spite of active firms producing close to equilibrium quantities, we find significant deviations in exit decisions.

Result 7: *There is a non-negligible amount of early and late exits.*

According to theory, first exits should occur in period 8 and latest exits should happen in period 15. Table 8 shows, however, 24 % of players exit in periods 1 – 7. and about 10 % of firms do not leave the market at all. Note that firms of type B are more inclined to exit early.

Table 8: Exit in Treatment CA

Periods	Frequency (Percent)		
	Firm A	Firm B	Both Firms
Early exit (periods 1-7)	38 (19 %)	59 (29.5 %)	97 (24.25 %)
Regular exit (periods 8-15)	139 69.5 %)	123 (61.5 %)	162 (65.5 %)

No exit at all	23 (11.5 %)	18 (9 %)	41 (10.25 %)
Cases	200	200	400

89 % of the players exiting early realized losses in the preceding period. In approximately 75 % of early exits respective competitors supplied more than Cournot quantities. To be precise, early exits are preceded by a competitor's average excess supply of 3.5 units. We conclude from this that most early exits can be explained by out-of-equilibrium behaviour of competitors.

In order to get a better understanding of production choices in Treatment CA, we also carry out a regression analysis. Basically, we test four models.

Model 1 called BR-Model tests whether players anticipated their competitors supply and choose the corresponding best responses to such a behaviour. Model 2 assumes that players take their competitor's supply of the preceding period as a predictor of their choice in the current period and choose the corresponding best reply. We call this model BR-Lagged. Finally, in the NE-Model we test whether Cournot quantities[2] might serve as a predictor of behavior in our experiment. In all models an ideal estimation would result in a constant close to zero and a parameter of the predictor close to one. The estimation results are shown in Table 9.

Table 9: Estimation of production quantities

	BR-Model	BR-Lagged	NE-Model	NE & Learning-Model
BR-Quantity	0.845803			
BR-Quantity lagged		0.8291115		
NE-Quantity			1.071031	0.9752746
Own lagged deviation				0.7433707
Other lagged deviation				–0.1262595

[2] Here we take Cournot monopoly quantities if only one firm is left in the market and we take duopoly quantities in the other case.

Dummy Periods 1-4				0.8484995
Constant	3.294164	3.655013	1.008583	0.1719379
Observations	4526	4126	4526	4126
Adj. R^2	0.375	0.2728	0.5004	0.7622

The first two models, BR- and BR-Lagged, show fairly similar parameters. The constant is significantly above zero indicating a somewhat excessive supply. In contrast to this, the estimated slope of the function is well below one. Although constant and slope of the NE-Model are closer to zero and one, respectively, the differences are still significant. However, if we amend the NE-Model and allow for learning the results improve substantially. Let "Own lagged deviation" be a players own difference between actual and equilibrium behaviour in the preceding period. Likewise "Other lagged deviation" is defined as the corresponding value of the competitor. We have already discussed the anchor effect of initial capacities in the first periods. To cover this effect, we add a corresponding dummy variable "Dummy Period 1-4".

Column 4 of Table 9 shows the estimation results. Estimated parameters are much closer to zero (constant) and one (slope of NE-Quantity) now. In particular the slope is not significantly different from one, anymore. Summarizing, players behaviour in Treatment CA is best understood as a mixture of equilibrium and learning behaviour.

4. Conclusions

The study of firms' exit behavior in markets with declining demand has been subject to a larger amount of theoretical and empirical research. Yet, to our knowledge, experimental methods have not been applied in this area of research. Our paper contributes to fill this gap by testing specific theoretical exit models in an experimental environment.

The experimental tests of the game-theoretic exit models by Ghemawat and Nalebuff (1985, 1990) show that subgame perfect Nash Equilibria, even if they are regarded to be counter-intuitive, offer a great attraction to real subjects in our laboratory environment. Even in the case of multiple equilibria players' behavior is mainly in line with theory. By and large, especially in the first two treatments, experimental data confirm our hypotheses. With respect to Treatment CA allowing for gradual capacity reductions theoretical predictions are only partially confirmed: production does follow the predicted values. However, learning and anchor effects also seem to influence behavior.

Our experiment is a pure theory test of Ghemawat and Nalebuff (1985, 1990). In order to test models' relevance for real markets, further experiments have to be carried out. Especially treatments with less information on the side of participants seem to be important. Firstly, demand functions in real markets, in particular future demand functions, are usually not known to firms. Experiments should take this into account. Secondly, just as in real markets demand in the laboratory should be added by a stochastic component. Thirdly, it seems worth adding treatments with private information about one's own cost parameters. Finally, there are other aspects of the exit decision that are not covered by Ghemawat and Nalebuff (1985, 1990). For a robust theory of exit behavior these have to be tested as well.

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