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PREEMPTION IN CAPACITY AND PRICE DETERMINATION – A STUDY OF ENDOGENOUS TIMING OF DECISIONS FOR HOMOGENEOUS MARKETS

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Abstract

Endogenous timing can help to derive the time structure of decision making instead of assuming it as exogenously given. In our study we consider a homogeneous market where, like in the model of Kreps and Scheinkman (1983), sellers determine “sales capacities” before prices. Sellers must serve customers, but at higher costs when demand exceeds “capacitiy”. Our model allows for preemption in “capacity” as well as in price determination. Since preemption means to decide before the random choice of cost parameters reflecting the stochastic nature of (excess) “capacity” costs, preemptive commitments are no obviously better timing dispositions.

JEL Classification: D4, D8, D2, L1

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1. Introduction

Ever since Cournot (1838) quantity competition on homogeneous markets has played an important role in micro-economics. But selling a certain amount and leaving it to the market at which price this amount is sold is only possible on markets with especially designed trade institutions like commodity or stock exchanges. Such institutions allow sellers to abstain from own pricing policies. If such institutions exist, one should, however, incorporate them when modelling homogeneous markets with quantity competition.

When costly institutions like (commodity or stock) exchanges do not exist, quantity competition is hardly an acceptable idea: What is a seller supposed to answer to the first customer asking for the price? To overcome the obvious absurdity Kreps and Scheinkman (1983) have offered a natural reinterpretation of quantity competition on homogeneous markets and of the results by Cournot (1838). Quantity competition is seen as the first stage of a **two stage-market decision process**: First sellers state their sales capacities which then become commonly known. Then, knowing the available capacities, sellers choose their individual sales prices.

According to the solution play sellers choose capacities matching the quantities of quantity competition (Cournot, 1838) and rely, on the second stage, on the price for which the sum of these capacities is demanded. Kreps and Scheinkman (1983) analyse only duopoly markets and assume a **special rationing scheme**: In subgames with larger capacities than the (Cournot-) solution quantities the seller with the lower price may not be able to serve all his customers. The residual demand for the seller with the higher price then depends crucially on whom the cheaper seller serves, respectively on whom he does not serve. Kreps and Scheinkman (1983) rely on the rationing scheme **maximizing consumer surplus**, i.e. the cheaper seller serves customers with the higher willingness to pay (see the partly critical discussion by Davidson and Deneckere, 1986).

In our view, the basic idea of Kreps and Scheinkman (1983) is very intuitive and should not be questioned by debatable assumptions of rationing and consequences like equilibria in mixed pricing strategies (in case of "too large" capacities prices have to be chosen randomly). One possibility is to rely on less rigorous cost functions. According to Kreps and Scheinkman a capacity is an upper bound for sales. This can be rephrased by saying that at the capacity level the costs of production are prohibitively large. What we will consider here is a similar jump in the cost of production at the capacity level, but only a moderate one. Given that capacities pose no longer absolute upper bounds for sales one can avoid rationing and equilibria in mixed pricing strategies by assuming that sellers must serve their customers.

Two other rather special assumptions of the model, analyzed by Kreps and Scheinkman (1983), are the deterministic framework and the simultaneity of capacity, respectively price choices. In our analysis both, simultaneous as well as asynchronous timing of capacity and price decisions are possible. Whereas delaying one's decisions allows for choosing when more information (about cost parameters and about others' choices) is available, early decisions can mean to preempt, i.e. to possibly enjoy the so-called first mover advantages. Are simultaneous decisions the likely result when there is cost uncertainty and when one can commit to one's action before or after the respective cost uncertainty is resolved? If so, is the probable market outcome still the one of quantity competition as analyzed by Cournot (1838)? Partly our study can be seen as an attempt to analyze the robustness of the Kreps and Scheinkman-result when cost uncertainty and asynchronous timing are possible where we rely on a weaker notion of "capacities" as in Güth (1995). Partly it is an exercise in endogenous timing on markets with a richer stage structure due to the original two stage-structure of the Kreps and Scheinkman-model.

Studies of endogenous timing or indirect evolution try to derive – instead of imposing exogenously – the timing of market decisions (see van Damme and Hurkens, 1999, for a brief review). In our model sellers can determine their "capacities" before or after the random choice of the constant unit (capacity) costs, i.e. the first stage of the Kreps and Scheinkman-model now consists of three successive substages (preemption, chance move, adjustment). By determining his sales capacity earlier a seller can try to preempt his competitor, similar to the sequential duopoly solution (von Stackelberg, 1934). Although this will be less important, we also allow for three substages on the second stage of the Kreps and Scheinkman-model (preemption in price setting, random choice of constant unit (excess capacity) cost, cost dependent choice).

(Endogenous)Timing of market activities before or after uncertainty is resolved has been studied by Spencer and Brander (1992) and Sadanand and Sadanand (1996). The results are mixed in the sense that all firms may prefer to wait (for the sake of flexibility) or to preempt or that asymmetric timing positions are stable. Here we are not primarily interested in deriving similar results for more complex market models although we derive general preemption and general waiting for specific examples. As mentioned before, our main focus is on analyzing whether the reinterpretation of the classical Cournot results (Cournot, 1838), supplied by Kreps and Scheinkman (1983), survives when its highly restrictive institutional assumptions do not hold: In the first place we avoid rationing schemes and mixed strategies by forcing sellers to serve customers beyond their planned sales amounts. Second we allow sellers to choose freely whether to choose planned sales amounts, the so-called capacities, and prices early or late. Only if the Cournot results carry over to such a more general setting they are, in our opinion, substantially justified by Kreps and Scheinkman.

Unfortunately, the price for the richness of institutional details in our framework is a loss of analytical tractability. It will be shown that results depend crucially on the stochastic nature of costs. It is in this respect where we can just provide examples instead of offering general results. Nevertheless, our numerical examples allow already some interesting insights: The Cournot results are neither a mere artifact of the restrictive assumptions, imposed by Kreps and Scheinkman (1983), nor the general solution under all possible circumstances. We identify classes of cost distributions implying Cournot, respectively non-Cournot results. We cannot yet answer whether our results cover the full range of possible outcomes or characterize under which conditions which result can be expected. In our view, the problem is, however, too important to delay its discussion until analytical results are obtained.

In section 2 we introduce our market model which we solve in section 3 for all possible constellations of timing dispositions. Based on these results we define in section 4 an evolutionary game or truncation by which, in section 5, we can derive the evolutionarily stable or optimal timing dispositions. After concluding the Appendix illustrates the multiplicity of price equilibria and how to select one of these.

2. The model

On the homogeneous duopoly market the two (risk neutral) sellers $i = 1, 2$ first have to determine their planned sales amounts k_i and then their actual sales prices. To allow for an easy terminology we refer to the planned sales amounts k_i as **capacities** although actual sales amounts x_i can be higher (as well as lower). Due to our distinction between capacities k_i and actual sales amounts x_i a cost function $C_i(\cdot)$ must assign a cost level $C_i(k_i, x_i)$ to every constellation (k_i, x_i) of capacity k_i and sales amount x_i. For the sake of simplicity we rely on piecewise **linear cost functions** of the form

$$C_i(k_i, x_i) = Ck_i + (C + D)\max\{0, x_i - k_i\} \text{ for } i = 1, 2 \qquad \text{(II.1)}$$

where $k_i \in \left[0, \frac{1}{2}\right]$ and $x_i \in \left[0, \frac{1}{2}\right]$ for $i = 1, 2$ and where the positive parameters C and D are assumed to be stochastic variables whose realizations, denoted by c and d, are the same for both sellers.

The idea of such cost functions is that a seller plans for a specific sales volume k_i. The costs for "capacity" k_i are sunk, i.e. must be paid even in case of lower sales than k_i. In case of a positive excess demand $x_i - k_i$ delivery is not excluded, but implies (by $d > 0$) higher unit cost. The assumption that demand must be served avoids complicated and debatable assumptions concerning demand rationing in case of excess demand and subgames with equilibria in mixed pricing strategies (see Kreps and Scheinkman, 1983, and the discussion of their model by Davidson and Deneckere, 1986).

Rigid capacity constraints in the sense of $D = +\infty$ are rather unlikely. Nevertheless we readily admit that the higher cost of excess demand $x_i - k_i$ will often question that excess demand is served. Here we concentrate on the possibly less likely situation where one always serves excess demand.

Since the market is homogeneous, a demand function $X(p)$ must assign a total (non-negative) demand level X to any non-negative price p not exceeding the prohibitive price. To allow for a simple and parameter free description we assume a linear demand function whose prohibitive price and satiation level are standardized to 1 (by an appropriate choice of the monetary unit as well as of the unit amount). Thus the **linear demand function** can be written as

$$X(p) = 1 - p \text{ for all } 0 \leq p \leq 1. \tag{II.2}$$

Market clearing implies, of course,

$$X(p) = x_1 + x_2. \tag{II.3}$$

Furthermore, due to the **homogeneity of the market** one has

$$p = \min\{p_1, p_2\} \tag{II.4}$$

where for $i = 1, 2$ the sales price is denoted by p_i. The profit π_i of seller $i = 1, 2$ is determined by k_i, p_i and p as follows:

$$\Pi_i(k_i, p_i, p) = \begin{cases} -C_i(k_i, 0) \text{ for } p_i > p = p_j \\ \\ px_i - C_i(k_i, x_i) \text{ for } p_1 = p_2 = p \\ \\ p(1-p) - C_i(k_i, 1-p) \text{ for } p_i = p < p_j \; (j \neq i) \end{cases} \tag{II.5}$$

where

$$x_i = max\left\{0; k_i + \frac{1-p-k_1-k_2}{2}\right\} \quad \text{(II.6)}$$

Except for the special case $p_1 = p = p_2$ our assumptions are standard ones. For $p_1 = p = p_2$ demand is distributed such that each seller encounters a demand level as close to his capacity as possible. If, for instance, $X(p) = k_1 + k_2$ both sellers $i = 1, 2$ will sell $x_i = k_i$ even when $k_i \neq k_j$ for $i \neq j$. Thus in case of equal prices total excess demand $1 - p - k_1 - k_2$ is distributed equally. This assumption can be justified as equal burden sharing among all efficient redistributions of demands. For other selections, e.g. when individual burdens are proportional to capacities, a similar analysis is possible.

The **decision process** describes the timing of decisions and what is learnt about them, i.e. when sellers make which choices under which information conditions. A seller first chooses his capacity what can be done before (stage K) or after (stage k) the realization c of the random variable C. Similarly, he can thereafter determine his price before (stage M) or after (stage m) the realization of the random variable D. As usual in stage games all former decisions are commonly known. The process is graphically illustrated and explained by Figure 1.

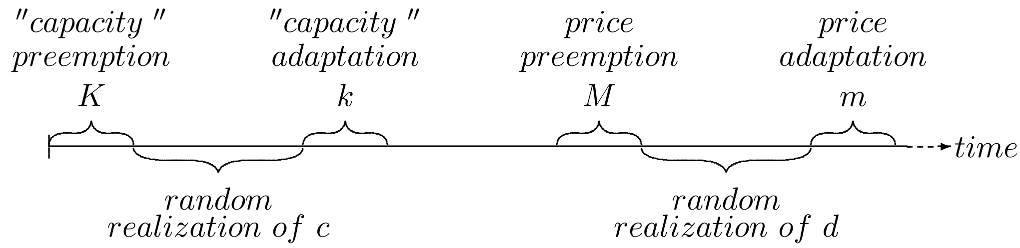

Figure 1: The market decision process (seller $i = 1, 2$ can determine his capacity k_i either in period K or, after the realization c of the random variable C, in period k; thereafter the sales prices p_i are chosen either in period M or, after the choice d of the random variable D, in period m; when deciding all former decisions are known)

Endogenous timing assumes that one determines strategically when to decide. An alternative is to view timing dispositions as basic (inherited or culturally acquired) traits which are subject to (genetical or cultural) evolutionary selection. In indirect evolution rational decisions are derived for all possible constellations of such individual traits. With the help of these results one then defines an evolutionary model to determine the evolutionarily stable constellations of individual traits. Thus an indirect evolutionary analysis allows to combine rational choice making (here of the capacities and the prices on the various stages of market interaction) with predetermined timing dispositions (here being early or late in choosing capacities or prices). The latter dispositions represent actual forward looking choices before period K when interpreting our model as an exercise in endogenous timing. In other words, viewing our study as an approach in endogenous timing means to interpret the model as a grand game in which every individual has to make four decisions, time and size of capacities as well as of prices have to be fixed. In the context of indirect evolution one instead considers the game in which sellers only choose the size of capacity and of prices whereas timing dispositions are part of their personal characteristics. Having solved this game one then determines which constellations of timing dispositions are evolutionarily stable.

The two stochastic variables C and D are assumed to have distributions concentrated on $\left[\frac{1}{2};1\right]$

$$C \in \left[\frac{1}{2}, 1\right] \text{ and } D \in \left[\frac{1}{2}, 1\right]. \tag{II.7}$$

We refer to their means as $\bar{c}$ and $\bar{d}$. Of course, one generally needs conditions guaranteeing $0 \leq p \leq 1$ and non-negative individual sales levels as well as capacities. We will confine ourselves to check these conditions for the solution outcomes only. Sellers are assumed to be risk neutral.

3. Optimal behavior for given timing dispositions

What has to be derived here are the optimal prices p_i^* as well as the optimal capacities k_i^* for the three constellations

$$(m_1, m_2) = \begin{cases} (m, m) \\ (M, M) \\ (M, m) \text{ or } (m, M) \end{cases}$$

of timing dispositions in pricing as well as for the three analogous constellations

$$(n_1, n_2) = \begin{cases} (k, k) \\ (K, K) \\ (K, k) \text{ or } (k, K) \end{cases}$$

of timing dispositions for choosing capacities. Since capacities are known when choosing prices, backward induction in the sense of **subgame perfect equilibria** (Selten, 1965, 1975) requires to solve first the (m_1, m_2)-constellations before investigating capacity choices.

a) The case $(m_1, m_2) = (m, m)$

What one encounters here is a deterministic (both, c and d are commonly known in period m) duopoly market with piecewise linear cost functions. If $p_1 \neq p_2$, one seller would encounter 0-demand. Thus there can be no equilibrium in pure pricing strategies with $p_1 \neq p_2$.

We now consider constellations $p_1 = p_2 = p$. For any capacity vector (k_1, k_2) let $p(k_1, k_2)$ denote the price for which

$$X(p(k_1, k_2)) = k_1 + k_2 \qquad \text{(III.a.1)}$$

holds, i.e. $p(k_1, k_2) = 1 - k_1 - k_2$. It is interesting that our model allows for more than just one pricing equilibrium (p_1, p_2) with $p_1 = p_2 = p$. A seller i, who underbids the common price p, has to serve the whole market demand at the lower price p. Thus the positive cost of serving positive excess demand in the sense of

$$X(p_i) = 1 - p_i > k_i$$

can prevent any attempt to underbid a common price $p = p_1 = p_2$. Here we will neglect the multiplicity of pricing equilibria and simply impose the solution $p_1^* = p_2^* = p(k_1, k_2)$ for which we now prove the equilibrium property. The chances of (p_1^*, p_2^*) to result from equilibrium selection are discussed later (Appendix). Although the results implied by familiar concepts (payoff and risk dominance) are not generally encouraging, it is interesting that in an experimental study of a related heterogenous duopoly market (Anderhub, Güth, Kamecke, Normann, 2000) the behavior $p_1^* = p_2^* = p(k_1, k_2)$ was close to being universally observed.

When checking the equilibrium property for $p_1^* = p_2^* = p(k_1, k_2)$ one obtains that $p_i > p_i^*$ can never be optimal. For

$$p_1^* = p_2^* = p(k_1, k_2) \tag{III.a.2}$$

to be in equilibrium one therefore only has to guarantee that a marginal price decrease from (III.a.2) is worse than $p_i^* = p(k_1, k_2)$. Comparing

$$p_i^* k_i - C_i(k_i, k_i) \tag{III.a.3}$$

and

$$p_i(1 - p_i) - C_i(k_i, 1 - p_i), \tag{III.a.4}$$

where p_i is only marginally smaller than $1 - k_i - k_j$, shows that no marginal price cut pays if

$$(c + d) k_j \geq (1 - k_i - k_j) k_j \tag{III.a.5}$$

or, for $k_j > 0$,

$$c + d \geq p(k_1, k_2) = 1 - k_1 - k_2. \tag{III.a.5'}$$

Due to $c, d \geq \frac{1}{2}$ and $k_i \geq 0$ for $i = 1, 2$ this condition is always fulfilled.

b) The case $(m_1, m_2) = (M, M)$

All what is changed here compared to the case $(m_1, m_2) = (m, m)$ is that sellers $i = 1, 2$ do not know the actual realization of d. Proceeding in the same way thus yields the condition

$$c + \overline{d} \geq 1 - k_1 - k_2 \tag{III.b.1}$$

which is less stringent than (III.a.5') and thus always fulfilled.

c) The case $(m_1, m_2) = (M, m)$

Assume that seller 1 does not know d, but seller 2 does. Clearly, in case of (III.a.5') and thus also of (III.b.1) neither seller has an incentive to slightly undercut the price $p(k_1, k_2)$. When deriving the results for the various timing constellations of "capacity" choices the results of the later decision stage are anticipated.

d) The case $(n_1, n_2) = (k, k)$

In case of $(n_1, n_2) = (k, k)$ capacities are chosen knowing the realization c. Assuming that always the prices $p(k_1, k_2)$ result (see the section a), b) and c) above) seller i's profit depends on k_i as follows:

$$\Pi_i(k_i, k_j) = (1 - k_i - k_j) k_i - ck_i \tag{III.d.1}$$

for $i = 1, 2$ and $j \neq i$. The equilibrium choices are

$$k_i^* = \frac{1 - c}{3} \text{ for } i = 1, 2, \tag{III.d.2}$$

i.e. the well-known duopoly solution (Cournot, 1838). Since $c \leq 1$ the optimal "capacities" are non-negative. The profit expectations resulting from (III.d.2) are

$$E\left\{\left(\frac{1 - c}{3}\right)^2\right\} \text{ for } i = 1, 2 \tag{III.d.3}$$

where $E\{\cdot\}$ denotes the expectation operator.

e) The case $(n_1, n_2) = (K, K)$

Here c in (III.d.2) must simply be substituted by its average $\bar{c}$ so that

$$k_i^* = \frac{1 - \bar{c}}{3} \text{ for } i = 1, 2 \tag{III.e.1}$$

guaranteeing a well-defined solution for all realizations of $C \in \left[\frac{1}{2}, 1\right]$ and all distributions of C on $\left[\frac{1}{2}, 1\right]$. The profit expectations resulting from (III.e.1) are

$$\left(\frac{1-\overline{c}}{3}\right)^2 \text{ for } i = 1, 2 \tag{III.e.2}$$

which are obviously non-negative since $\overline{c} \in \left[\frac{1}{2}, 1\right]$.

f) The case $(n_1, n_2) = (K, k)$

Assume that seller 1 does not yet know c whereas seller 2 does. From

$$\Pi_2(k_1, k_2) = (1 - k_1 - k_2) k_2 - ck_2 \tag{III.f.1}$$

one obtains seller 2's reaction function

$$k_2^*(k_1) = \begin{cases} \frac{1-c-k_1}{2} & \text{for } 0 \leq k_1 \leq 1-c \\ 0 & \text{for } k_1 > 1-c. \end{cases} \tag{III.f.2}$$

In order to determine seller 1's optimal capacity level k_1^* we first have to calculate his expected profit as a function of k_1. This function $E\{\pi_1(k_1)\}$ depends crucially on the distribution of C. In the following we will carry out the analysis for various different distributions. First we examine the case in which the distribution of C has a continuous Lebesgue-density and solve the special case of a uniform distribution explicitly. Then, as an example for measures with finite support, we study one-point measures and give one numerical example for a two-point measure.

f1) Continuous distributions

In this case seller 1's expected profit is

$$E\{\Pi_1(k_1)\} = \begin{cases} \int\limits_{\frac{1}{2}}^{1-k_1} \left(1 - k_1 - \frac{1-c-k_1}{2}\right) k_1 \varphi(c)\, dc + \\ \int\limits_{1-k_1}^{1} (1-k_1) k_1 \varphi(c)\, dc - k_1 \int\limits_{\frac{1}{2}}^{1} c\varphi(c)\, dc. \end{cases} \tag{III.f.3}$$

where $\varphi(\cdot)$ denotes the density of C on $\left[\frac{1}{2},1\right]$ and $\Psi(\cdot)$ its distribution with $\Psi'(c)=\varphi(c)$ and $\Psi\left(\frac{1}{2}\right)=0$, $\Psi(1)=1$. Equation (III.f.3) can be rewritten as

$$E\left\{\Pi_1(k_1)\right\}=\begin{cases}\int\limits_{\frac{1}{2}}^{1-k_1}\frac{1-k_1}{2}k_1\varphi(c)\,dc+\frac{k_1}{2}\int\limits_{\frac{1}{2}}^{1-k_1}c\varphi(c)\,dc\\ \\ +(1-k_1)\,k_1\int\limits_{1-k_1}^{1}\varphi(c)\,dc-\overline{c}k_1\end{cases} \tag{III.f.3'}$$

or

$$E\left\{\Pi_1(k_1)\right\}=\begin{cases}-\frac{1-k_1}{2}k_1\Psi(1-k_1)+\frac{k_1}{2}\int\limits_{\frac{1}{2}}^{1-k_1}c\varphi(c)\,dc\\ \\ +(1-k_1)\,k_1-\overline{c}k_1\end{cases}. \tag{III.f.3''}$$

From the first order condition of a local maximum of (III.f.3) one obtains

$$1-2k_1-\left(\frac{1}{2}-k_1\right)\Psi(1-k_1)+\frac{1}{2}\int\limits_{\frac{1}{2}}^{1-k_1}c\varphi(c)\,dc=\overline{c} \tag{III.f.4}$$

as an implicit formula for the interior maximum k_1^*. Moreover

$$\frac{d^2}{dk_1^2}E\left\{\pi_1(k_1)\right\}=-2+\Psi(1-k_1)-\frac{k_1}{2}\varphi(1-k_1)<0\text{ for all }k_1\in\left[0,\frac{1}{2}\right].$$

Thus $E\left\{\pi_1(k_1)\right\}$ is strictly concave, i.e. the first order conditions are necessary and sufficient for a global maximum, and the left-hand side of equation (III.f.4) is strictly decreasing. By inserting $k_1=0$ and $k_1=\frac{1}{2}$ into (III.f.4) one can now easily show that, for every continuous distribution of C, the equation has a unique solution in $\left[0;\frac{1}{2}\right]$. For the special case of the uniform density $\varphi(\cdot)$ on $\left[\frac{1}{2},1\right]$, i.e. $\Psi(c)=2\left(c-\frac{1}{2}\right)$ for $\frac{1}{2}\leq c\leq 1$, this implies, for instance,

$$k_1^2+\frac{2}{3}k_1=\frac{7}{12}-\frac{2}{3}\overline{c}=\frac{7}{12}-\frac{2}{3}\cdot\frac{3}{4}=\frac{1}{12} \tag{III.f.5}$$

or

$$k_1^*=-\frac{1}{3}+\frac{\sqrt{25-24\overline{c}}}{6}=\frac{\sqrt{7}-2}{6}=.1076252. \tag{III.f.5'}$$

Let Π_1^* denote the profit expectation of seller 1 resulting from k_1^* and the subsequent choice $k_2^*(k_1^*)$ by seller 2. Let, furthermore, Π_2^* be the corresponding profit expectation of seller 2 who is second in determining the sales capacity. For the special case of the uniform density $\varphi(\cdot)$ on $\left[\frac{1}{2}, 1\right]$ we obtain

$$E\{\Pi_1^*\} = k_1^* \left[(1 - k_1^*)\left(1 + \frac{k_1^*}{2}\right) - \frac{7}{8}\right] \approx 0.007 \tag{III.f.6}$$

and

$$E\{\Pi_2^*\} = (1 - k_1^*)\left[\frac{1}{8} - \frac{1}{6}(1 - k_1^*)\left(\frac{1}{2} + k_1^*\right)\right] - \frac{1}{48} \approx 0.01, \tag{III.f.7}$$

i.e. if preemption takes place, on average, the seller, who first determines his capacity, is worse off.

f2) One-point measures

We now look at the situation where the distribution of C is a one-point measure, i.e. where the cost parameter c is no longer random. Obviously this case is equivalent to the classical (von Stackelberg, 1934) leadership model.

Maximizing seller 1's expected profit function

$$E\{\pi_1(k_1)\} = \begin{cases} (1 - k_1 - k_2^*(k_1)) \cdot k_1 - \bar{c} \cdot k_1 & \text{if } 0 \leq k_1 \leq 1 - \bar{c} \\ (1 - k_1) \cdot k_1 - \bar{c} \cdot k_1 & \text{if } k_1 > 1 - \bar{c} \end{cases}$$

leads to

$$k_1^* = \frac{1 - \bar{c}}{2} \tag{III.f.8}$$

$$k_2^* = \frac{1 - \bar{c}}{4} \tag{III.f.9}$$

$$E\{\pi_1^*\} = \frac{(1 - \bar{c})^2}{8} \tag{III.f.10}$$

and

$$E\{\pi_2^*\} = \frac{(1 - \bar{c})^2}{16}. \tag{III.f.11}$$

Clearly, in contrast to the case of a uniform distribution, the position of the leader is more profitable than the one of the follower.

f3) Two-point measures

As a final example we analyze the case where C can have exactly two values c_1 and c_2 with $c_1 < c_2$. Since solving the maximization problems for arbitrary two-point measures involves a complex case distinction, we restrict ourselves to one numerical example. Let the distribution of C be the measure assigning probability 1/2 to the numbers $c_1 = 0.69$ and $c_2 = 0.81$, respectively.

The expected profit of seller 1 is

$$E\{\pi_1(k_1)\} = \begin{cases} \frac{k_1}{2} \cdot \{1 - k_1 - \overline{c}\} & \text{if } c_2 \leq 1 - k_1 \\ k_1 \cdot \left\{\frac{3}{4}(1 - k_1) + \frac{1}{4}c_1 - \overline{c}\right\} & \text{if } c_2 > 1 - k_1 \text{ and } c_1 \leq 1 - k_1 \\ k_1 \cdot \{1 - k_1 - \overline{c}\} & \text{if } c_1 > 1 - k_1 \end{cases} \tag{III.f.12}$$

By maximizing this function we obtain

$$k_1^* = \frac{1}{8} \tag{III.f.13}$$

$$k_2^* = \begin{cases} 0.0925 & \text{if } c = c_1 \\ 0.0325 & \text{if } c = c_2 \end{cases} \tag{III.f.14}$$

$$E\{\pi_1^*\} = \frac{1}{128} \approx 0.0078 \tag{III.f.15}$$

$$E\{\pi_2^*\} \approx 0.0048 \tag{III.f.16}$$

Here again, as in the case of one-point measures, the seller who preempts is more successful than his opponent.

4. The truncated or evolutionary game

In general, the market decision process in Figure 1 allows for four constellations of individual timing dispositions, namely (K, M), (K, m), (k, M), and (k, m). For our purposes it suffices that a stable timing dispositions is a unique best reply to itself, i.e. a symmetric equilibrium (the concept of evolutionarily stable strategies imposes an additional condition when the best reply is not unique). Here the task of deriving the stable timing dispositions is, however, reduced to the problem whether both will be of type K or k or whether the bimorphisms with one being of type K and the other of type k are stable. This is implied by our assumption that equilibrium prices on the second stage (of the Kreps-Scheinkman-model) induce full capacity utilization, i.e. $p_i^* = p(k_1, k_2)$ for $i = 1, 2$. If this holds for all constellations (k_1, k_2) of capacities, it obviously does not matter whether one sets one's price before or after the parameter d is randomly determined.

According to indirect evolution timing dispositions regarding capacities are not consciously chosen, but rather evolve. The stable timing constellation is thus viewed as the final result of an evolutionary process. Endogenous timing assumes instead that timing dispositions are consciously and independently determined before stage K in Figure 1 and then publicly announced. The entries of Table 2 are the expected payoffs of seller 1 resulting from the optimal capacity vectors (k_1^*, k_2^*) and the resulting equilibrium prices $p_1^* = p_2^* = p(k_1^*, k_2^*)$ for the four possible constellations (k, k), (k, K), (K, k), and (K, K) of timing dispositions.

seller 1 \ seller 2	k	K
k	$\frac{E\left\{(1-c)^2\right\}}{9}$	$E\{\Pi_2^*\}$
K	$E\{\Pi_1^*\}$	$\frac{(1-\bar{c})^2}{9}$

Table 2: The symmetric evolutionary game or truncation as defined by Π_1^*

For the case at hand the distinction between indirect evolution and endogenous timing matters more for the interpretation rather than for the nature of the results.

To give an example assume that (k^*, K^*) and thus (due to symmetry) also (K^*, k^*) is stable. For indirect evolution this would mean that both bimorphisms are stable and that it depends on the initial state of the evolutionary process and possibly on random results which of the two will actually prevail, i.e. the final results would be path dependent.

In view of endogenous timing such a result would be more troublesome since one cannot recommend which timing disposition a seller should choose without equilibrium selection (e.g. Harsanyi and Selten, 1988). There also exists a mixed strategy equilibrium which is, however, non-strict and therefore a less suitable solution candidate.

A general analysis of Table 2 for all distributions $\varphi(\cdot)$ allows no informative results. We therefore concentrate on specific distributions $\varphi(\cdot)$ for which we have determined the expected profits $E\{\Pi_1^*\}$ and $E\{\Pi_2^*\}$. For the special case of the uniform distribution with $\varphi(c) = 2$ for all $\frac{1}{2} \leq c \leq 1$ Table 2 becomes

seller 2 / seller 1	k	K
k	$\frac{1}{108} = .009$	$.01$
K	$.007$	$\frac{1}{144} = .007$

Table 2': The special case of the uniform density $\varphi(c) = 2$ for $\frac{1}{2} \leq c \leq 1$

If C is constant, i.e. the distribution of C is a one-point measure with $C \equiv \bar{c}$, Table 2 is of the form

seller 2 / seller 1	k	K
k	$\frac{(1-\bar{c})^2}{9}$	$\frac{(1-\bar{c})^2}{16}$
K	$\frac{(1-\bar{c})^2}{8}$	$\frac{(1-\bar{c})^2}{9}$

Table 2": The case of a one-point distribution $C \equiv \bar{c}$

For the numerical case of the two-point measure introduced in section 3.f3) Table 2 is of the form

seller 1 \ seller 2	k	K
k	0.0073	0.0048
K	0.0078	0.0069

Table 2"': The two-point measure where $C = 0.69$ and $C = 0.81$, each with probability $\frac{1}{2}$

We now turn to the question whether k or K will finally evolve, respectively be chosen strategically.

5. The evolutionarily stable or optimal timing constellation

For the special case of the uniform density the unambiguous result is the constellation (k, k). This is true since the expected profit for k is always larger than the one for K (see Table 2'). Thus k strictly dominates K and is both, the unique evolutionarily stable strategy of Table 2' as well as the only optimal timing disposition.

If the distribution of C is concentrated on $\overline{c}$ we again obtain a unique evolutionarily stable strategy as long as $\overline{c} \neq 1$. Table 2" shows that K strictly dominates k. This result is very intuitive: The realization of c is of no interest at all, thus (K, K) and (k, k) lead to equal profits. But choosing K instead of k offers each seller the chance to substitute a (Cournot) duopoly by a (von Stackelberg) leadership model with him in the leading position and avoids the risk of ending as a follower.

Table 2"' proves that in our example of a two-point measure, as in the case of one-point measures, K strictly dominates k. Whereas in the deterministic case $C \equiv \overline{c}$ the capacities in the unique strict equilibrium (K, K) equaled those for the timing disposition (k, k), we have now found an example where ex post equilibrium capacities deviate from the deterministic (Cournot, 1838) duopoly solution $k_i = \frac{1-c}{3}$. What is justified by (K, K) is the analogous solution of a stochastic duopoly market on which sales amounts are determined before the cost levels are randomly selected. This result does not hold for all two-point measures. For other values of c_1 and c_2 and other probabilities for them the constellation (k, k) can also be a unique strict equilibrium. Unfortunately we could neither find nor exclude bimorphic equilibria.

More generally, stability or optimality of (k, k) in the sense of (k, k) being a strict equilibrium of Table 2 requires

$$E\left\{(1-c)^2\right\}/9 > E\left\{\Pi_1^*\right\}. \tag{V.1}$$

For (K, K) the condition is

$$\frac{(1-\overline{c})^2}{9} > E\left\{\Pi_2^*\right\} \tag{V.2}$$

whereas for the bimorphism (k, K) or (K, k) the conditions are

$$E\left\{\Pi_1^*\right\} > E\left\{(1-c)^2\right\}/9 \text{ and } E\left\{\Pi_2^*\right\} > \frac{(1-\overline{c})^2}{9}. \tag{V.3}$$

6. Conclusions

Quantity competition requires special institutions like commodity or stock exchanges which, when they exist, should be appropriately captured by the market model. The alternative is to rely on the natural and intuitive idea of Kreps and Scheinkman (1983) who justify quantity competition by a two stage-decision process of simultaneous decisions (first capacities, then sales prices).

Now simultaneous decision making on two stages is just one of several possibilities. In our model it is possible to preempt on both stages. Even when sellers decide simultaneously, they can do this early (before the random choice of cost) or later (after this chance move). Unfortunately, no general conclusion seems possible. Especially, up to now we have no general result justifying or rejecting the implicit assumption of Kreps and Scheinkman (1983) that sellers decide simultaneously. More specifically, we could not prove the impossibility of stable bimorphisms (k, K) nor find an example for which such bimorphisms are stable. Thus the troublesome ambiguity remains although now at a deeper level. Different cost densities might imply different market decision processes. Simultaneous or independent market decisions can, furthermore, avoid cost uncertainty (when both sellers wait) or not (when both sellers preempt).

Our model differs from the one of Kreps and Scheinkman (1983) mainly by our different interpretation of "capacities" which appears more natural (usually production and sales can be more or less easily varied even beyond their planned levels). An analysis like ours for the original Kreps and Scheinkman-model is very difficult or even practically impossible. Whereas our model can be easily extended to oligopoly markets (see Güth, 1995), the results of Kreps and Scheinkman (1983) still await such a generalization.

Such advantage has, of course, its price in the form of three crucial and debatable assumptions, namely: (i) In case of equal prices demand is distributed according to capacities (see equation (II.6)). (ii) Sellers must serve demand even beyond their planned sales level. (iii) On the price setting stage the solution $p_1^* = p_2^* = p(k_1, k_2)$ is just an ad hoc-selection (see Appendix below). One can justify (i) as a result of renegotiating the demand distribution by the two sellers. Assumption (ii) could be valid when not serving a customer would result in losing him forever. The ad hoc-selection (iii) relies mainly on the intuition that sellers coordinate on prices which fulfill their initial expectations as represented by their total planned sales level $k_1 + k_2$. The experimental results of Anderhub at al. (2000) seem to confirm the focal role of such prices. Thus the three crucial assumptions are not outrageous, but their main justification is, of course, that they greatly simplify the analysis.

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Appendix

Equilibrium selection for price competition on homogeneous markets

Due to the obligation to serve all customers price competition on homogeneous markets may have other equilibria than just $p_1^* = p_2^* = p(k_1, k_2)$ on which our previous analysis has been based. Here we want to investigate this possibility in more detail. By applying the theory of equilibrium selection (Harsanyi and Selten, 1988) we also explore whether one can justify our solution candidate $p_1^* = p_2^* = p(k_1, k_2)$. As we have seen before, in equilibrium both sellers set the same price p. We first compare the equilibrium $p_1 = p_2 = p(k_1, k_2)$ to equilibria $p_1 = p_2 = p$ with $p < p(k_1, k_2)$, then we analogously analyse the case $p > p(k_1, k_2)$.

Case A.1: $p < p(k_1, k_2)$

Let (p_1, p_2) be an arbitrary strategy constellation $p_1 = p_2 = p$ with $p < p(k_1, k_2)$. Analogously to the proof of the equilibrium property of $p_1^* = p_2^* = p(k_1, k_2)$ in section 3 one can show that this constellation is an equilibrium if and only if, at price p, production beyond the capacity k_i causes losses. More formally, $p_1 = p_2 = p$ with $p < p(k_1, k_2)$ is a strict equilibrium if and only if

$$p(1-p) - (c+d_i)(1-p-k_i) < pk_i + (p-c-d_i)\frac{1-p-k_1-k_2}{2} \text{ for } i = 1, 2$$

or

(A.1.A) $p < c + d_i$ for $i = 1, 2$

where d_i is the value of D individual i expects when setting his price, i.e. $\overline{d}$ if seller i has timing disposition M and d if this timing disposition is m.

Since we only want to compare $p(k_1, k_2)$ to other equilibria, we focus on those prices p which fulfill the equilibrium condition (A.1.A). In the cases where timing dispositions are asymmetric, i.e. $(m_1, m_2) = (m, M)$ or (M, m), it is obvious which of the two equilibrium prices p and $p(k_1, k_2)$ should be selected, namely the one which is payoff dominant. Anticipating that the second mover sets the same price the first mover clearly prefers the price which yields higher profits for both sellers.

It remains to analyse the symmetric cases (M, M) and (m, m), i.e. the situations where $d_1 = d_2 = \overline{d}$, respectively $d_1 = d_2 = d$ with d denoting the realization of the random variable D. The payoff implications of all price constellations p_i with $p_i = p(k_1, k_2)$ or $p_i = p$ for $i = 1, 2$ can be represented as a 2 x 2-bimatrix game (Table 3) where one can neglect the cost of "capacity" k_i since these cost are sunk on the price setting stage. Of course, one cannot neglect cost which result from selling more than one's capacity.

p_1 \ p_2	$p(k_1, k_2)$	p
$p(k_1, k_2)$	$(1 - k_1 - k_2) k_1$ $(1 - k_1 - k_2) k_2$	0 $(1 - p)(p - c - d_2) + (c + d_2) k_2$
p	$(1 - p)(p - c - d_1) + (c + d_1) k_1$ 0	$pk_1 + (p - c - d_1) \frac{1-p-k_1-k_2}{2}$ $pk_2 - (p - c - d_2) \frac{1-p-k_1-k_2}{2}$

Table 3: The 2 x 2-bimatrix game for $p < p(k_1, k_2)$

The equilibrium (p, p) would be **payoff dominated** by (p_1^*, p_2^*) when

$$(1 - k_1 - k_2) k_i > pk_i + (p - c - d_i) \frac{1 - p - k_1 - k_2}{2} \tag{A.1}$$

or

$$(1 - p - k_1 - k_2)(2k_i + c + d_i - p) > 0 \tag{A.1'}$$

holds for $i = 1, 2$. It is interesting that here the condition for payoff dominance depends on the sum $c + d_i$ whereas the corresponding condition (A.7) for the case $p > p(k_1, k_2)$ is completely independent of the cost parameters. Since $1 - p > k_1 + k_2$ this is equivalent to

$$2k_i + c + d_i > p. \tag{A.2}$$

Due to $k_i \geq 0$ and the equilibrium condition (A.1.A) this is always fulfilled. This shows that strict equilibria (p_1, p_2) with $p_1 = p_2 < p(k_1, k_2)$ are always payoff dominated by (p_1^*, p_2^*).

Payoff dominance completely neglects the risks implied by coordinating on a specific strict equilibrium. Such risks are, however, carefully considered by **risk dominance** (Harsanyi and Selten, 1988) which, for the case at hand, is axiomatically characterized by three requirements, namely best reply and isomorphic invariance and monotonicity. Actually the axioms can be constructively used when deriving which of the two strict equilibria risk dominates the other.

p_1 \ p_2	$p(k_1, k_2)$	p
$p(k_1, k_2)$	$(1 - k_1 - k_2 - c - d_1) k_1 - (1 - p)(p - c - d_1)$ $(1 - k_1 - k_2 - c - d_2) k_2 - (1 - p)(p - c - d_2)$	0 0
p	0 0	$pk_1 + (p - c - d_1) \frac{1-p-k_1-k_2}{2}$ $pk_2 + (p - c - d_2) \frac{1-p-k_1-k_2}{2}$

Table 4: A best reply invariant transformation of Table 3

The bimatrix game of Table 4 results from Table 3 by subtracting the non-equilibrium payoff from the equilibrium payoff for a given strategy of the other seller, i.e. after such a transformation the non-equilibrium payoff for a given strategy of the other player is 0. The mixed strategy equilibrium in Table 4 is the same as in Table 3. Thus both games have the same best reply structure, i.e. the same stability sets (the sets of mixed strategy vectors to which every component of a pure strategy vector is a best reply). By best reply invariance we can thus solve the game in Table 4 instead of the one in Table 3.

p_1 \ p_2	$p(k_1, k_2)$	p
$p(k_1, k_2)$	X 1	0 0
p	0 0	1 Y

Table 5: An isomorphic transformation of Table 4 where

$$X = \frac{(1 - k_1 - k_2 - c - d_1)\, k_1 - (1 - p)\,(p - c - d_1)}{pk_1 + (p - c - d_1)\,\frac{1 - p - k_1 - k_2}{2}} \tag{A.3}$$

and

$$Y = \frac{pk_2 + (p - c - d_2)\,\frac{1 - p - k_1 - k_2}{2}}{(1 - k_1 - k_2 - c - d_2)\, k_2 - (1 - p)\,(p - c - d_2)}. \tag{A.4}$$

Finally, the game of Table 5 results from Table 4 by positively affine transformations of payoff functions, i.e. by an isomorphic transformation. If $X = Y$ would hold, isomorphic invariance in the form of symmetry invariance would prescribe the mixed strategy equilibrium as the solution. If, however, $X \neq Y$ monotonicity prescribes (p_1^*, p_2^*) for $X > Y$ and (p_1, p_2) for $Y > X$ as the solution. A change from a game with $X^0 = Y^0$, where no strict equilibrium is the solution, to $X > X^0 = Y^0$ can be seen as strengthening the strict equilibrium (p_1^*, p_2^*) since player 1's incentive to coordinate on (p_1^*, p_2^*) is increased. Monotonicity requires that such strengthening induces (p_1^*, p_2^*) as the solution. Now the condition $X > Y$ is equivalent to

$$\prod_{i=1}^{2} \left[(1 - k_1 - k_2 - c - d_i) k_i - (1 - p)(p - c - d_i) \right] > \prod_{i=1}^{2} \left[p k_i + (p - c - d_i) \frac{1 - p - k_1 - k_2}{2} \right]. \tag{A.5}$$

or equivalently

$$\prod_{i=1}^{2} \left\{ (c + d - p)(1 - p) - k_i \left[c + d - p(k_1, k_2) \right] \right\} > \prod_{i=1}^{2} \left\{ (c + d - p) \frac{p(k_1, k_2) - p}{2} - p k_i \right\} \tag{A.6}$$

revealing a complicated dependence on the various parameters k_1, k_2, $d = d_1 = d_2$, and p with $p < p(k_1, k_2)$.

Case A.2: $p > p(k_1, k_2)$

As for the other case we first state the condition under which $p_1 = p_2 = p$ is an equilibrium and then explore the conditions for payoff and risk dominance of (p_1^*, p_2^*) over (p_1, p_2) for the cases of symmetric timing dispositions (M, M) and (m, m). In the asymmetric cases again the payoff dominant equilibrium will be selected.

The indicator function 1_A assumes the value 1 on A and 0 otherwise. The constellation $p_1 = p_2 = p$ is an equilibrium if and only if

$$p(1 - p) - (c + d_i)(1 - p - k_i) \cdot 1_{\{1 - p - k_1 > 0\}} < p \frac{1 - p + k_i - k_j}{2}$$

for $i = 1, 2$ and $j \neq i$ or

(A.2.A) $1 - p > k_i$ for $i = 1, 2$

and

(A.2.B) $(c + d_i) > \frac{p}{2}\left(1 + \frac{k_j}{1-p-k_i}\right)$ for $i, j = 1, 2$ with $i \neq j$.

As mentioned earlier, the multiplicity of equilibria is due to the assumption that a seller i with the lower price must serve the whole market. If total demand exceeds his capacity, i.e. condition (A.2.A) is fulfilled, then the cost of the excess demand $1 - p - k_i$ might be higher than the additional surplus resulting from underbidding the common price. For this (A.2.B) is a necessary and sufficient condition. The payoffs of all price constellations p_i with $p_i = p(k_1, k_2)$ or $p_i = p$ are again represented as a 2 x 2-bimatrix game in Table 6. As in Table 3 the cost of k_i is neglected. Clearly (p_1^*, p_2^*) and (p, p) are both strict equilibria of this game.

p_1 \ p_2	$p(k_1, k_2)$	p
$p(k_1, k_2)$	$(1 - k_1 - k_2)\, k_1$ $(1 - k_1 - k_2)\, k_2$	$(1 - k_1 - k_2)(k_1 + k_2) - (c + d_1)\, k_2$ 0
p	0 $(1 - k_1 - k_2)(k_1 + k_2) - (c + d_2)\, k_1$	$p\frac{1-p+k_1-k_2}{2}$ $p\frac{1-p-k_1+k_2}{2}$

Table 6: The 2 x 2-bimatrix game for $p > p(k_1, k_2)$

The strict equilibrium (p_1^*, p_2^*) with $p_1^* = p_2^* = p(k_1, k_2)$ payoff dominates (p_1, p_2) with $p_1 = p_2 = p > p(k_1, k_2)$ when

$$(1 - k_1 - k_2)\, k_i > p\frac{1 - p + k_i - k_j}{2} \text{ for } i, j = 1, 2 \text{ and } i \neq j. \tag{A.7}$$

For risk dominance of (p_1^*, p_2^*) one needs again that $X > Y$ where now

$$X = \frac{(1 - k_1 - k_2)\, k_1}{p^{\frac{1-p+k_1-k_2}{2}} - (1 - k_1 - k_2)\,(k_1 + k_2) + (c + d_1)\, k_2} \tag{A.8}$$

and

$$Y = \frac{p^{\frac{1-p+k_2-k_1}{2}} - (1 - k_1 - k_2)\,(k_1 + k_2) + (c + d_2)\, k_1}{(1 - k_1 - k_2)\, k_2}. \tag{A.9}$$

To illustrate the chances that (p_1^*, p_2^*) payoff dominates (p_1, p_2) assume $k_1 = k_2 = k$ so that (A.7) simplifies to

$$(1 - 2k)\, 2k > p\,(1 - p)\,. \tag{A.10}$$

Thus payoff dominance typically depends on whether (p_1^*, p_2^*) or (p_1, p_2) generates the larger total revenue. In other words: Only capacity vectors (k_1, k_2), whose sums do not exceed the monopoly supply of $1/2$, cannot be payoff dominated by price vectors (p_1, p_2) with $p_1 = p_2 = p > p\,(k_1, k_2)$.

A larger sum $c + d_1 = c + d_2$ reduces X and increases Y. It thus does not only improve the chances of an alternative strict equilibrium (p_1, p_2) according to (A.2.B), but also that this alternative solution risk dominates the solution (p_1^*, p_2^*).

By this we only wanted to illustrate how to derive a unique solution of the price competition subgames and on which parameters it will depend on whether the equilibrium (p_1^*, p_2^*) with $p_1^* = p_2^* = p\,(k_1, k_2)$ is selected or not. A complete solution for all possible subgames would have to rely on a (too) complicated case distinction.