

RENT DISSIPATION IN REPEATED ENTRY GAMES:
SOME NEW RESULTS

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Abstract

Two player infinitely repeated entry games are revisited using a new Markov equilibrium concept. The idea is to have an incumbent facing a hit and run entrant. Rent dissipation no longer necessarily holds. It will not when competition is tough in case of entry. Similarities and differences with previous approaches are analyzed. Several economic illustrations are discussed.

JEL classification: C73, D43, L12.

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1 Introduction¹

This paper revisits the dynamics of potential competition in a natural monopoly context. In such situations an incumbent is repeatedly facing an entrant. Rent dissipation ordinarily prevails (see among others Fudenberg and Tirole, 1987 and Wilson, 1992). The intuitive idea behind rent dissipation is a rational expectations argument (Farrell, 1986). In Maskin and Tirole (1988) and in Ponsard (1991) a proper game analysis confirms the rational expectations intuition. These results provide some formal grounds to contestability theory (Baumol et al., 1982).

Contestability is an important benchmark in applied industrial organization. Originally designed for the airline industry it has been applied to many sectors such as telecoms or electricity. The main idea is to restructure the industry to reduce the length of commitments and the possible sunk costs, which is

equivalent to have the discount factor go to one in a repeated entry game. Other economic characteristics play no role.

Many economists have challenged this view (for survey articles see Brock, 1983 or Shepherd, 1984). Two criticisms are directly relevant for this paper: why should the incumbent remain passive against a hit and run strategy? why is it that the intensity of competition in case of entry plays no role in the argument? The first question refers to a theoretical issue which can only be handled in a game framework. The second question (first pointed out in Dasgupta and Stiglitz, 1986) refers to empirical matters. Indeed, Sutton (p. 35, 1991) provided ample evidence that "a very sharp fall in price suffices to deter entry and maintain a monopoly outcome".

This paper provides a game theoretic formalization of hit and run strategies in an infinite horizon: if the incumbent makes a mistake, the equilibrium path is such that the entrant comes *in*, makes some money and then *leaves*. Equilibrium paths are such that the intensity of competition in case of entry plays a major role².

More specifically, rent dissipation need not necessarily prevail.³ In this approach rent dissipation depends on the monopoly rent relative to the cost of entry: when this ratio is high rent dissipation occurs and when it is low it does not. Consequently, the tougher the competition in case of entry the more likely rent dissipation fails to hold.

In addition to rent dissipation, selection is also analyzed. Selection means that only the more efficient firm can remain a permanent incumbent (selection was introduced in Gromb et al., 1997, in which finitely repeated *asymmetric* entry games were first analyzed). Selection is an important economic property to look for since it encourages innovation and the search for competitive advantage. In a dynamic context it seems preferable to the static productive efficiency criteria. The empirical results reported by Scherer (1992) and Gerovski (1995) indeed show that most entries occur after large innovations. It is proved that equilibrium paths satisfy selection if the asymmetry between the two firms is high enough.

These results on rent dissipation and on selection can be conveniently summarized through a new and interesting taxonomy of competitive situations. Depending on its economic characteristics, a given situation may be qualified as typical of:

excess-competition: if a more efficient incumbent were to choose to deter entry forever, it would have to dissipate all of its profits;

under-competition: a less efficient incumbent can deter entry forever and make stationary positive profits;

selection: a less efficient incumbent is not able to deter entry forever and

²There are formalizations of this idea in the context of two stage games (see for instance Henry, 1988, Sutton, 1991 chap 2, or d'Aspremont and Motta, 2000) but to the author's knowledge none in the infinite horizon context. In the two stage models, the firms cumulative pay-offs are zero by construction.

³See Boyer et al., 2003, for a recent contribution in which rent dissipation does not prevail. Their argument is based on capacity constraints and is unrelated to the current discussion.

make stationary positive profits, but a more efficient incumbent may.

At the formal level, the adopted Markov equilibrium concept extends the one used by Maskin and Tirole (1988).⁴ The idea is to relax the stationarity assumptions which they impose on the strategies. This relaxation is motivated by the results obtained in Gromb, Ponsard and Sevy (1997).⁵ There it was shown that when one firm is more efficient than the other, at equilibrium, the less efficient firm cannot remain a permanent incumbent in a long enough game. This suggests that the stationarity assumption is too strong and is the reason for the drawback of the MT approach pointed out in Lahmandi et al. (1996) namely, that the less efficient firm can remain a permanent incumbent and, moreover, that its stage rent is higher than what the more efficient firm would obtain were it the permanent incumbent. Yet, the GPS approach, when extrapolated to infinitely repeated games, has drawbacks of its own. The issue remained open.

The paper is organized as follows. Section 2 introduces the class of infinitely repeated entry games under study. Various solution concepts may be used to analyze these games. In section 3 the new Markov solution concept is defined. Similarities and differences with previous approaches are detailed in the appendix. Section 4 studies the mathematical properties of the proposed solution concept: the given finite time horizon for incumbency of the hit and run firm is the key parameter. It is proved that when an equilibrium exists it is necessarily unique, that this firm would prefer to play in a game in which its given time as an incumbent is as long as possible but that when this given time exceeds some bound such an equilibrium may no longer exist. Whenever there is no such bound the situation is one of rent dissipation. A necessary and sufficient condition for such a bound to exist is obtained. In section 5, the conditions for rent dissipation are interpreted and a new taxonomy of situations is introduced, economic illustrations are detailed in the appendix. Section 6 concludes with open questions that should be studied to improve our understanding of the proposed solution concept.

2 The game Γ_∞^δ

Various game forms may be used to capture the idea of short run commitments in a natural monopoly context. For convenience, our model is very similar to the one introduced in GPS. Denote Γ_∞ such an entry game.

Denote the two firms player 1 and player 2. Let i be anyone of the two players and $j \neq i$ be the other one.

The game Γ_∞ is constructed from two one stage Stackelberg entry games, denoted $G(1)$ and $G(2)$. The game Γ_∞ consists of a sequence of such one stage games $(G(i^1), G(i^2), \dots, G(i^k), \dots)$ in which any i^k may be either 1 or 2 depending on the actual moves selected along the way⁶.

⁴to be later referred to as the MT approach. Originally designed for entry games, this approach has been extended to any extensive game (Maskin and Tirole, 2001).

⁵to be later referred to as the GPS approach.

⁶Strictly speaking the game under study is not a repeated game since the stage game varies

Each game $G(i)$ is played as follows:

step 1: the first player to move is player i , it is called *the incumbent*, player i may either select a move x_i in \mathfrak{R} or move *out*;

step 2a: if player i selects x_i at step 1 then player j may either select *in* (with respective payoffs for i and j : $d_i(x_i), -C_j(x_i)$) or *out* (with respective payoffs : $v_i(x_i), 0$) ;

step 2b: if player i selects *out* at step 1 then player j may either select a move x_j in \mathfrak{R} or move *out*;

step 3 : if player i selects *out* at step 1 and player j selects x_j at step 2b then player i may either select *in* (with respective payoffs : $-C_i(x_j), d_j(x_j)$) or *out* (with respective payoffs : $0, v_j(x_j)$);

step 4: if player i selects *out* at step 1 and player j selects *out* at step 2b then the game Γ_∞ stops (with respective payoffs : $0, 0$).

Moreover the actual play of $G(i)$ determines the incumbent in the next $G(i')$ to be played :

- player i' is again player i if this sequence is (x_i, out) or (out, x_j, in) ;
- player i' is player j if the sequence is (x_i, in) or (out, x_j, out) .

- Denote $i^+(i)$ the next stage incumbent determined according to this transition rule.

The payoffs in the game are the sum of the stage payoffs using a discounted factor δ . Attention is focused on δ close to 1.

This completely specifies Γ_∞^δ .

The functions v_i, C_i, d_i respectively stand for stage monopoly profits, entry costs and exit payoffs. For $i \in (1, 2)$ it is assumed that v_i is strictly increasing, C_i strictly decreasing and d_i non positive.

For Γ_∞^δ to be of economic interest it is assumed that :

$$C_j^{-1}(0) > v_i^{-1}(0)$$

$$C_i^{-1}(0) > v_j^{-1}(0)$$

The first inequality means that the static “limit price” of player i , $C_j^{-1}(0)$, should be higher than player i ’s “average cost”, $v_i^{-1}(0)$, otherwise player i is definitely barred from entry (the situation is one of “bockaded entry”). Similarly for player j .

For mathematical convenience it will be further assumed that the functions v_i and C_i have derivatives and that these derivatives are uniformly bounded away from zero and from infinity. It is believed that this technical assumption may be relaxed without affecting the results.

Two classes of games shall be of special interest.

The class of *symmetric* entry games in which $v_1 = v_2$ and $C_1 = C_2$. The economic issue is *rent dissipation* : at equilibrium, does the stage payoff of the incumbent $v_i(x_i)$ converge to zero when the discount factor goes to one ?

among two distinct ones. However, folk theorems apply and some form of Nash selection is required.

The class of *asymmetric* entry games in which $v_1 = v_2 + \Delta f$ in which Δf is a constant, and $C_1 = C_2$. The economic issue is *selection* : suppose $i^1 = 2$, then is it true that for all $\Delta f > 0$, at equilibrium, player 1 is the long run incumbent i.e., for all $k \geq k^*$, $i^k = 1$, whatever the discount rate close enough to one ?

Interpretation

Consider a standard Stackelberg model such as Dixit (1980). The leader commits to some move q_L then the follower reacts with q_F . The entry barrier is constructed in such a way that the profit of the follower is not positive. Denote the two players profits $h_L(q_L, q_F)$ and $h_F(q_L, q_F)$. With our notations $C_F(q_L) = -\max_{q_F} h_F(q_L, q_F)$ and $v_L(q_L) = h_L(q_L, q_F)$ when the follower does not enter. In a static model the optimal entry preventing commitment maximizes $v_L(q_L)$ under the constraint $\max_{q_F} h_F(q_L, q_F) \leq 0$ that is, $C_F(q_L) \geq 0$. In the context of a repeated entry game with short term commitments this is not enough since the follower takes into account the future stream of profits he could obtain acting as a leader in the next Stackelberg game, etc. There are several ways to precisely define such a dynamic entry game (Eaton and Lipsey, 1980, Maskin and Tirole, 1988, Ponsard, 1991).

The selected game form has several advantages: the endogeneity of leadership is key, the game has no simultaneous moves which avoids multiplicity of stage equilibria, it is easier to track than alternate move models, players are encouraged to move *in* to avoid stopping the game and the results can be extended with some effort to the other game forms.

3 The selected Markov equilibrium concept

The game Γ_∞^δ has many Nash equilibria ranging from predatory behavior (one player behaves as an unconstrained monopolist if incumbent and always moves *in* if not, and the other always stays *out*) to collusive behavior (the two players alternate as incumbent using tit for tat as a threat). Such equilibria are not illustrative of hit and run competition.

This section proposes a new Markov equilibrium concept, to be denoted as *SME* for *selected Markov equilibrium*, among more general Markov approaches.

Markov strategies depend on the way the state variable is defined. The state variable precises the stakes of a given stage game G . It of course says who is the incumbent. A time variable will be included in the state variable to capture the non stationarity of the hit and run behavior.

The general Markov approach

Let

- t be the discrete time variable;
- θ be the state variable, $\theta = (i, t)$ which means that $G(i)$ is the stage game to be played;
- (z_1^θ, z_2^θ) stand for the decisions in $G(i)$ given θ and (Z_1, Z_2) stand for the strategies ;

- $G_1^\theta(z_1^\theta, z_2^\theta)$ and $G_2^\theta(z_1^\theta, z_2^\theta)$ stand for the two players' respective stage payoffs in $G(i)$ given θ and (z_1^θ, z_2^θ) ;
- $\theta^+(z_1^\theta, z_2^\theta) = (i^+, t^+)$ be the next stage state variable given θ and (z_1^θ, z_2^θ) where i^+ is defined according to the rules of Γ_∞^δ and t^+ is to be defined later;
- δ be the discount rate ;
- (Y_1, Y_2) be a Markov equilibrium when it exists ;
- $\pi_1(Y_1, Y_2 | \theta)$ and $\pi_2(Y_1, Y_2 | \theta)$ refer to the players discounted equilibrium payoffs given an initial state θ and an equilibrium (Y_1, Y_2) .

Definition 1 *Markov equilibria*⁷ are such that :

$$\pi_1(Y_1, Y_2 | \theta) = \text{Max}_{z_1^\theta} [G_1^\theta(z_1^\theta, y_2^\theta) + \delta\pi_1(Y_1, Y_2 | \theta^+(z_1^\theta, y_2^\theta))]$$

$$\pi_2(Y_1, Y_2 | \theta) = \text{Max}_{z_2^\theta} [G_2^\theta(y_1^\theta, z_2^\theta) + \delta\pi_2(Y_1, Y_2 | \theta^+(y_1^\theta, z_2^\theta))]$$

By construction, these Markov equilibria are refinements of Nash equilibria of Γ_∞^δ . They need not be perfect since they may depend on past moves through the variable t .

In the MT approach there is no such time variable, the GPS extension to infinitely repeated games provides some hints on how to design the time variable, this is done in the SME approach (see appendix for the formalizations of MT and GPS).

The SME approach

This approach relies on the following assumptions:

- the two players are exogeneously distinguished. One player is called player L (for *long term* incumbent) and the other player is called player S (for *short term* player to be seen as the hit and run player). No assumption is made at this point as regards the relative efficiency of L versus S .
- an integer n is exogeneously given and let $t = 0, 1 \dots n$.
- when the game is in state $\theta = (i, 0)$, if $i^+ = L$ then $t^+ = 0$ but if $i^+ = S$ then $t^+ = 1$.
- when the game is in state $\theta = (S, t)$ with $1 \leq t < n$, if $i^+ = S$ then $t^+ = t + 1$ but if $i^+ = L$ then $t^+ = 0$.
- when the game is in state $\theta = (S, n)$, $t^+ = 0$ whether $i^+ = L$ or S .

⁷This system of equations is known as the Shapley recursive equations for recursive games (Shapley, 1953)

For a given value of the parameter n , the following proposition gives sufficient conditions to obtain such a Markov equilibrium. Existence and uniqueness will be addressed later.

Proposition 2 *Let y_L and y_S^t for $t \in \{0, 1, 2, \dots, n\}$ be a solution (if it exists) of the following system denoted Φ_δ^n :*

$$\begin{aligned} -C_L(y_S^t) + v_L(y_L)\delta(1 - \delta^{n-t})/(1 - \delta) &= 0 & \text{for } t \in \{0, 1, 2, \dots, n\} \\ -C_S(y_L) + \sum_{t=1}^n \delta^t v_S(y_S^t) &= 0 \end{aligned}$$

and

$$v_L(y_L) \geq 0$$

$$\sum_{t'=t}^{t'=n} \delta^{t'-t} v_S(y_S^{t'}) \geq 0 \quad \text{for } t \in \{1, 2, \dots, n\}$$

but

$$\sum_{t'=0}^{t'=n} \delta^{t'} v_S(y_S^{t'}) < 0$$

Then the following moves in Γ_∞^δ are a Markov equilibrium:

- if $\theta = (L, 0)$ player L plays $x_L = y_L$ and player S plays out iff $x_L \leq y_L$

(in case player L moves out then player S also moves out);

- if $\theta = (S, 0)$ player S plays out then player L plays $x_L = y_L$ and player S

plays out iff $x_L \leq y_L$

(in case player S plays x_S player L moves out iff $x_S \leq y_S^0$);

- if $\theta = (S, t)$ with $t \neq 0$ player S plays $x_S = y_S^t$ and player L plays out iff $x_S \leq y_S^t$

(in case player S moves out then player L plays $x_L = y_L$ and player S plays out iff $x_L \leq y_L$).

Proof of this proposition is in the appendix.

Such an equilibrium may be interpreted as follows.⁸ The state $\theta = (L, 0)$ is an absorbing state in which L remains a permanent incumbent using a stationary strategy, L 's equilibrium stage payoff is non negative in that state. If he makes a mistake, S moves *in* and the next stage is $\theta = (S, 1)$, then S stays as an incumbent for n stages using a non stationary strategy designed to make L patient until S moves *out*. Player S 's total equilibrium payoff in $\theta = (S, 1)$ exceeds his entry cost in $\theta = (L, 0)$ given that L made a mistake, furthermore S 's total equilibrium payoff remains non negative along the way. At the state $\theta = (S, 0)$ player S 's best move is *out* because it is not worthwhile for him to make L patient for $n + 1$ stages. If S makes a mistake along the way, L moves *in* and the next state is $\theta = (L, 0)$.

A key feature of this equilibrium is that it is the long time incumbent's best strategy to wait until the hit and run player moves *out* and not to aggressively fight against him. This is because it is the hit and run player's best strategy to eventually move *out*. Similarly as in GPS, one would like the length of the hit and run period (the parameter n) to be endogeneously determined. It will be proved later that player S 's total equilibrium payoff in state $\theta = (S, 1)$ is increasing in n . It is proposed to select the most appropriate n as the highest integer for which such a Markov equilibrium exists.

⁸These ideas go back to Louvert, 1998.

4 Properties of SME's for a given n

This section addresses the mathematical properties of SME's for a given n . Some preliminary comments are in order.

Our attention is focused on the case δ close to 1. It will be proved that if the system Φ_δ^n has a solution it is necessarily unique. For mathematical simplicity, the proof is made on the limit system Φ_1^n derived from Φ_δ^n when δ goes to 1. The same arguments would apply to Φ_δ^n when δ is close to 1. Because Φ_δ^n is continuous in δ its unique solution when δ goes to 1 converges to the unique solution of Φ_1^n . The properties of the solution of Φ_1^n are studied and used to infer the properties of the solution of Φ_δ^n which describes a SME.

To avoid ambiguity the solution of Φ_1^n when it exists is indexed by n such as $y_L(n)$ and $y_S^t(n)$ for $t \in \{0, 1, 2, \dots, n\}$. The *stage rent* for player L refers to $v_L(y_L(n))$ and the *total rent* for player S refers to $\sum_{t'=1}^{t=n} v_S(y_S^{t'}(n))$.

Lemma 3 *When δ goes to 1 the limit system Φ_1^n of the system Φ_δ^n defined in Proposition 4 is such that:*

$$\text{for } t \in \{0, 1, 2, \dots, n\} \quad -C_L(y_S^t) + (n-t)v_L(y_L) = 0 \quad (1)$$

$$-C_S(y_L) + \sum_{t'=1}^{t=n} v_S(y_S^{t'}) = 0 \quad (2)$$

and

$$v_L(y_L) \geq 0 \quad (3)$$

$$\text{for } t \in \{1, 2, \dots, n\} \quad \sum_{t'=t}^{t'=n} v_S(y_S^{t'}) \geq 0 \quad (4)$$

but

$$\sum_{t'=0}^{t'=n} v_S(y_S^{t'}) < 0 \quad (5)$$

The proof of this lemma is straightforward.

Theorem 4 Φ_1^n admits at most one solution for large enough n .

Proof of this theorem is in the appendix.

Theorem 5 *If there exists a solution respectively in Φ_1^m and in Φ_1^n with $m > n$ then $y_L(m) \leq y_L(n)$.*

Proof. Suppose $y_L(m) > y_L(n)$ then $v_L(y_L(m)) > v_L(y_L(n))$. Since C_L is strictly decreasing this implies for all $t \in \{0, 1, 2, \dots, n\}$:

$$y_S^{m-t}(m) < y_S^{n-t}(n)$$

so that

$$\sum_{t'=n}^{t'=0} v_S(y_S^{m-t'}(m)) < \sum_{t'=n}^{t'=0} v_S(y_S^{n-t'}(n))$$

For $t \in \{n+1, \dots, m\}$ we still have $y_S^{m-t}(m) < y_S^0(n)$ and, because of (5) we also certainly have $v_S(y_S^0(n)) < 0$ then

$$\sum_{t'=m-1}^{t'=0} v_S(y_S^{m-t'}(m)) \leq \sum_{t'=n}^{t'=0} v_S(y_S^{m-t'}(m))$$

Then

$$\sum_{t=m-1}^{t=0} v_S(y_S^{m-t}(m)) < \sum_{t=n}^{t=0} v_S(y_S^{n-t}(n))$$

By construction the left hand side should be greater or equal to zero while the right hand side should be strictly negative thus a contradiction. ■

Theorem 6 *Suppose there is a solution in Φ_1^n for all values of n then:*

$$\lim_{n \rightarrow \infty} v_L(y_L(n)) = 0$$

$$\lim_{n \rightarrow \infty} \sum_1^n v_S(y_S^t(n)) = C_S(v_L^{-1}(0))$$

$$\lim_{n \rightarrow \infty} y_S^1(n) = x^*$$

in which x^* is uniquely defined as: Φ

$$\int_{x^*}^{C_L^{-1}(0)} v_S(x) \frac{dC_L}{dx}(x) dx = 0$$

Proof of this theorem is in the appendix.

Corollary 7 *If there is a solution in Φ_1^n for arbitrarily large values of n it is necessary that:*

$$v_S(x^*) + C_S(v_L^{-1}(0)) \leq 0$$

and if

$$v_S(x^*) + C_S(v_L^{-1}(0)) < 0$$

there is a solution for arbitrarily large values of n .

Proof. Consider the first part. Using (5), for all n we have $v_S(y_S^0(n)) + C_S(y_L(n)) < 0$ so that at the limit we certainly have $v_S(x^*) + C_S(v_L^{-1}(0)) \leq 0$.

As for the second part the above theorem in fact proves that in the construction of theorem 6 for n large enough \hat{y}_S^1 converges to x^* as \hat{y}_L goes to $v_L^{-1}(0)$; since $v_S(x^*) + C_S(v_L^{-1}(0)) < 0$ it must be that (5) will be satisfied and a solution is obtained. ■

These results may be used to infer properties of a SME in Γ_∞^δ with δ close to 1. For a given n , the two systems Φ_1^n and Φ_δ^n are close to each other. If Φ_1^n has a unique solution so does Φ_δ^n and this solution is a SME of Γ_∞^δ . Observe that, as soon as $\delta < 1$, Φ_δ^n cannot have a solution for arbitrarily large values of n . This is easily seen by contradiction considering the constraints that $\lim_{n \rightarrow \infty} \sum_{t=1}^{t=n} \delta^t v_S(y_S^t) = v_S(y_S^1)$ would have to satisfy. Denote by n_δ the largest integer for which Φ_δ^n has a solution. The following corollary summarizes the main result of the paper: it provides a condition to obtain rent dissipation in Γ_∞^δ when δ goes to 1 using SME as the solution concept.

Theorem 8 Suppose $v_S(x^*) + C_S(v_L^{-1}(0)) < 0$, then $\lim_{\delta \rightarrow 1} v_L(y_L(n_\delta)) = 0$.

Proof. If $v_S(x^*) + C_S(v_L^{-1}(0)) < 0$, Φ_1^n has a solution for arbitrarily large n , this proves that $\lim_{\delta \rightarrow 1} n_\delta = \infty$. Theorem 8 says that $\lim_{n \rightarrow \infty} v_L(y_L(n)) = 0$. Since $\lim_{\delta \rightarrow 1} n_\delta = \infty$, whatever n the solution of Φ_1^n and of Φ_δ^n can be made arbitrarily closed so that $\lim_{\delta \rightarrow 1} v_L(y_L(n_\delta)) = 0$. ■

5 Economic analysis of the SME solution

Recall the results for δ close to 1. If Γ_∞^δ has a SME of duration n , it is unique. If there are SME's with respective durations n and m , the hit and run player should select the longest one to maximize its total rent. A condition is provided to obtain rent dissipation in Γ_∞^δ , in which case the hit and run player would at the limit stay indefinitely.

In the remaining part of this paper it will be assumed that the hit and run player selects the maximal duration for which Φ_δ^n has a solution, letting δ go to 1. This seems as a natural assumption to make since by doing so the hit and run player selects the duration of his stay to his best advantage. In the concluding section this particular selection among SME's is further argued.

By construction this defines *the SME solution* of the limit game Γ_∞^1 , the economic properties of which we want to now discuss.

Come back to symmetric and asymmetric entry games. Recall that a symmetric game is such that $v_1 = v_2$ and $C_1 = C_2$ and that an asymmetric game may be derived from a symmetric one such that $v_1 = v_2 + \Delta f$, in which Δf is a constant, and $C_1 = C_2$. If $\Delta f \geq 0$ player 1 is said to be *strong* and player 2 *weak*, and vice et versa.

Consider first the issue of rent dissipation in symmetric games. Theorem 8 proves that if there is rent dissipation with SME in Γ_∞^1 , the relative time horizon for S can be extended to infinity, the stage rent $v(y_L)$ goes to zero and the total rent $\sum_1^n v(y_S^t(n))$ goes to $C(v^{-1}(0))$; this solution is consistent with both MT and GPS. Yet, one major difference should be pointed out. There need not always be rent dissipation in Γ_∞^1 .

This result suggests that the analysis of potential competition should be revisited : the issue of short time commitment is no longer sufficient and more attention should be given to other structural characteristics of the situation.

We proceed as follows. Firstly, the rent dissipation issue in symmetric games is discussed. Secondly, a taxonomy of competitive situations is introduced to analyze asymmetric ones.

5.1 Rent dissipation in symmetric games

Consider the special case in which v and C are linear functions.

Proposition 9 *If v and C are linear functions then rent dissipation prevails if $v_S(C_L^{-1}(0)) > C_S(v_L^{-1}(0))$ while no rent dissipation prevails if $v_S(C_L^{-1}(0)) < C_S(v_L^{-1}(0))$.*

Proof. The equation that defines x^* is $\int_{x^*}^{C^{-1}(0)} v(x) \frac{dC}{dx}(x) dx = 0$. Because of the linearity of the v and C functions, x^* is the symmetric of $C^{-1}(0)$ with respect to $v_S^{-1}(0)$ so that $v_S(x^*) = -v_S(C_L^{-1}(0))$. Then the result follows from corollary 9. ■

Qualitatively speaking, this proposition says that the entry cost should be high enough with respect to the monopoly profit for rent dissipation to occur. It can be directly applied to the case of short run price commitment. This form of competition is illustrative of the very notion of contestability (Baumol et al 1982). Generally speaking, the stage game may be described as follows:

- firm i is the incumbent and sets a price p_i ;
- firm j decides to enter or not, if it does enter it sets a price $p_j = p_i - s$ in which s is a strictly positive function which may depend on p_i ;
- if firm j did not enter, firm i payoff is $R(p_i) - f$ in which R is the monopoly revenue function with $R' > 0$ and $R'' < 0$ and f a stage fixed cost;⁹
- if firm j did enter, firm j payoff is $R(p_i - s) - f$, and firm j will play first at the next stage;
- there are no commitments from one stage to the next one except the fact that the order of moves is endogeneously determined.¹⁰

The symmetric entry game is thus defined with

$$\begin{aligned} v(p) &= R(p) - f \\ C(p) &= -(R(p - s) - f) \end{aligned}$$

In this framework contestability can be captured by letting ε go to zero and one would expect that the incumbent price be forced to average cost i.e. to the price p_{ac} such that $R(p_{ac}) - f = 0$. Such is not the case with SME. Consider the simple case of constant switching cost that is, $s = cst$.

Proposition 10 *In an entry game with short run price commitments and constant switching costs, if this switching cost is close to zero, there is no rent dissipation.*

Proof. Since s is close to zero we may use linear approximations of the v and C functions around the value $p = p_{ac}$. Denote by p_l the value of p such that $C(p_l) = 0$. We certainly have p_l close to p_{ac} . According to proposition 12

⁹Ordinarily the revenue function $R(p)$ has a maximum (at the unconstrained monopoly price); we assume that ε is small enough so that $C^{-1}(0)$ be less than this maximum so that v is indeed increasing on the relevant range of analysis. This assumption may be relaxed without affecting the results.

¹⁰This form of competition has been formalized as an entry game in Ponsard (1991). There the simultaneous version was considered and a forward induction argument was used to select among equilibria. In the sequential version this argument is superfluous.

the ratio $v(p_l)/C(p_{ac})$ relative to 1 characterizes the situation. We may write $v(p_l)/C(p_{ac}) = -(v(p_l) - v(p_{ac}))/((p_l - p_{ac}))(C(p_{ac}) - C(p_l))/(p_{ac} - p_l)$ so that $v(p_l)/C(p_{ac})$ is close to $-v'(p_{ac})/C'(p_{ac}) = R'(p_{ac})/R'(p_{ac} - s) < 1$ since $R'' < 0$. ■

This form of competition may be qualified as *tough*. A *softer* form of competition would correspond to a case in which the cost of entry is lower (and the static limit price higher). Eventually, rent dissipation would occur. A detailed example is given in the appendix.

5.2 A taxonomy of competitive situations

Rent dissipation may or may not occur in symmetric games. This generates an interesting taxonomy for the general case of asymmetric games in which one player is more efficient than the other.

Definition 11 *A competitive situation is said to be one of*

under-competition: if $L = \text{weak}$ and $S = \text{strong}$ there exists n^ such that Φ_1^n has no solution for all $n > n^*$*

(a less efficient incumbent can deter entry forever and make stationary positive profits);

selection: if $L = \text{weak}$ and $S = \text{strong}$ there always exist a solution in Φ_1^n for all n large enough

but if $L = \text{strong}$ and $S = \text{weak}$ there exists n^ such that Φ_1^n has no solution for all $n > n^*$*

(a less efficient incumbent is not able to deter entry forever and make stationary positive profits, but a more efficient incumbent may);

excess-competition: whether $L = \text{weak}$ or $L = \text{strong}$ there always exist a solution in Φ_1^n for all n large enough

(if an incumbent were to choose to deter entry forever, it would have to dissipate all of its profits).

A general comparative statics result always holds. If there is *excess-competition* in a symmetric game i.e., there is rent dissipation, then in the associated asymmetric game in which the long-term player is more and more efficient (increasing Δf), at some point, his rent will become strictly positive. Conversely, if there is *under-competition* in a symmetric game then in the associated asymmetric game in which the long-term player is less and less efficient (decreasing Δf), at some point, his rent will be fully dissipated.

Proposition 12 *Take $v_L = v + \Delta f$, $v_S = v$ and $C_L = C_S = C$. Denote $H(\Delta f) = v_S(x^*) + C_S(v_L^{-1}(0))$ then:*

- if $H(0) < 0$ there exists some $\Delta F > 0$ such that for all $\Delta f > \Delta F$ we have $H(\Delta f) > 0$;

- if $H(0) > 0$ then there exists some $\Delta F' < 0$ such that for all $\Delta f < \Delta F'$ we have $H(\Delta f) < 0$.

Proof. Consider the first statement, in $H(\Delta f) = v_S(x^*) + C_S(v_L^{-1}(0))$ observe that the first term does not depend on Δf since x^* is defined from the equation $\int_{x^*}^{C_L^{-1}(0)} v_S(x) \frac{dC_L}{dx}(x) dx = 0$ is independent of Δf . As for the second term we certainly have $v_L^{-1}(0)$ strictly decreasing in Δf so that, since C_S is a decreasing function and since we are assuming that its derivative is uniformly bounded away from zero this provides the result. Reversing the argument we obtain the second statement. ■

Excess-competition refers to the case in which a difference in efficiency is not rewarded by an increase in profitability. *Under-competition* refers to the case in which a less efficient firm may sustain with a strictly positive profit. *Selection* is what one would expect under Schumpeterian competition. An economic illustration in which this taxonomy prevails is given in the appendix.

6 Discussion

The major result of this paper is that whether or not commitments are short-term no longer dominates the other economic characteristics in the analysis of rent dissipation. To obtain rent dissipation, it is no longer sufficient that the discount factor goes to 1.

These new results are obtained through a Markov equilibrium concept which embeds the hit and run idea. The results are derived under fairly general assumptions.

This approach suggests that potential competition is not very effective in markets in which competition is tough while it may if it is soft. In the former case the cost of entry is too high relative to the monopoly profit and, at equilibrium, a hit and run player cannot stay long enough to force the incumbent to average cost, in the latter case it may. This contradicts the standard results of contestability but it is well in line with more traditional views on entry.

The SME approach requires some further theoretical work. In this last section some open question are pointed out.

Question 1: There may be other Markov equilibria which are consistent with the proposed definition of the state variable. Full characterization would be helpful. This has been obtained with the MT approach.

Question 2: In corollary 9 it is suspected that the condition $v_S(x^*) + C_S(v_L^{-1}(0)) \leq 0$ is not only necessary but also sufficient.

Question 3: For the proposed taxonomy, it should be true that in case of *under-competition*, when a weak player may remain with a strictly positive rent indefinitely, a strong player may also. This is more difficult than it may seem and does not follow from proposition 13.

Question 4: A more interesting issue concerns the fact that our assignment of player 1 and player 2 to the respective L or S positions may be considered as arbitrary. A more formal approach might be to have a preliminary stage at which each player decides how long he could stay, say n_1 for player 1 and n_2 for player 2. The choices n_1 and n_2 are then revealed and an infinitely repeated game $\Gamma_\infty^{n_1, n_2}$

is played in which each player can only use hit and run strategies according to the number of stages decided at the preliminary stage. Using a Markov formalization similar to the present one, it is suspected that the equivalent of theorem 7 holds (i.e., given n_i the best response $n_j(n_i)$ is the highest n_j for which the entry game $\Gamma_{\infty}^{n_1, n_2}$ has an equilibrium). If this were indeed the case, our taxonomy could be stated as follows :

- *selection*: only the strong player would select to stay infinitely (the limit equilibria in $\Gamma_{\infty}^{n_1, n_2}$ with respect to large values of (n_1, n_2) would have $n_1^* = \infty, n_2^* < \infty$, where player 1 is the strong player) ;

- *under-competition*: either player could select to stay infinitely but if one does, the other would not wish to, the preliminary game would be similar to a battle of the sexes game (there would be two limit equilibria $\Gamma_{\infty}^{n_1, n_2}$ with $n_1^* = \infty, n_2^* < \infty$ and $n_1^* < \infty, n_2^* = \infty$) ;

- *excess-competition*: either player would select to stay infinitely whatever the other one does, the preliminary game would be similar to a prisoner dilemma game (formally $\Gamma_{\infty}^{n_1, n_2}$ would have no limit equilibrium with respect to large values of (n_1, n_2) , the best response $n_1(n_2)$ being ∞ and vice versa, while both equilibrium payoffs in a game $\Gamma_{\infty}^{n_1, n_2}$ would decrease as (n_1, n_2) increases).

Answers to these questions would provide a better understanding of the SME concept and of the associated taxonomy.

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8 Appendix

8.1 Other Markov equilibria

Each Markov approach amounts to interpret Γ_∞^δ as a specific stochastic game (see figures 1 to 4).

The MT approach (*figure 2*)

The strategies of the players depend only on the first component of θ that is, who is the current incumbent. Provided that δ is sufficiently close to one,

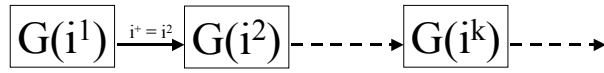


Figure 1: The game Γ_∞^δ

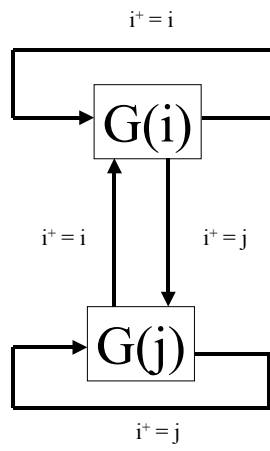


Figure 2: The game Γ_∞^δ in the MT approach

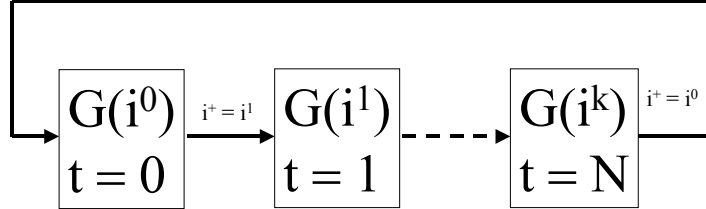


Figure 3: The game Γ_∞^δ in the GPS approach

the following proposition holds (Maskin and Tirole, 1988)¹¹:

Proposition 13 *Let y_1 and y_2 be the solution, proved to exist and to be unique, of the following system of two equations.¹²*

$$\text{for all } i \neq j \in \{1, 2\} \quad -C_i(y_j) + \delta v_i(y_i)/(1 - \delta) = 0$$

then the following moves in $G(i)$ generate a Markov equilibrium:

player i plays $x_i = y_i$

player j plays out if and only if $x_i \leq y_i$.

This Markov equilibrium satisfies rent dissipation but not selection.

An equilibrium path may be interpreted as follows: anyone of the two players, whether it is the more efficient one or not, may remain as a permanent incumbent. In case he makes a mistake, the other player moves *in* and stays as the future permanent incumbent.

The GPS approach (*figure 3*)

This refinement makes explicit use of the time variable. Let N be an integer exogeneously given. The following transition rule is adopted:

¹¹Maskin and Tirole's analysis is carried out on a specific Cournot model but their Markov approach can be directly applied to the class of entry games defined in this paper. While they identify other Markov equilibria, the focus in their paper is on the one characterized by proposition 2.

¹²In the following three propositions, we should more precisely write $y_i(\delta)$, the dependency of y_i on the discount factor δ is left out to simplify the notations.

- $t^+ = t \bmod(N + 1)$.

A Markov equilibria may be constructed as a direct extension of GPS for finite games. Denote Γ_k a finite entry game where k here refers to the maximal number of times the stage games $G(i)$ may be repeated. The notation $\Gamma_k(1)$ and $\Gamma_k(2)$ makes precise who is the initial incumbent in Γ_k . Observe that any such game $\Gamma_k(i^1)$ is a finite perfect information game so that it has a unique perfect equilibrium. Provided that δ is sufficiently close to one, the following proposition holds.

Proposition 14 *In any asymmetric entry game, for all $\Delta f > 0$ (i.e. player 1 is more efficient than player 2) let an integer N and two sequences y_1^t and y_2^t for $t \in \{0, 1, 2 \dots N\}$ be the solution, proved to exist and be unique, of the following system of equations:*

$$\begin{aligned} & \text{for all } i \neq j \in \{1, 2\} \\ & -C_i(y_j^N) = 0 \\ & -C_i(y_j^t) + \sum_{t'=t+1}^{t'=N} \delta^{t'-t} v_i(y_i^{t'}) = 0 \quad \text{for } t \in \{0, 1, 2 \dots N-1\} \\ & \text{and} \\ & \sum_{t'=t}^{t'=N} \delta^{t'-t} v_2(y_2^{t'}) \geq 0 \quad \text{for } t \in \{1, 2 \dots N\} \\ & \text{but} \\ & \sum_{t=0}^{t=N} \delta^t v_2(y_2^t) < 0. \end{aligned}$$

*Then the unique perfect equilibrium in $\Gamma_k(2)$ is such that:*¹³

for $1 \leq k \leq N$ player i plays $x_i = y_i^k$ and player j plays out if and only if $x_i \leq y_i^k$

for $k = 0$ player 2 plays out, then player 1 plays $x_1 = y_1^0$ and player 2 plays out if and only if $x_1 \leq y_1^0$.

In the game $\Gamma_k(2)$ the less efficient player may maintain as a permanent incumbent if and only if $k \leq N$. This proposition (Gromb et al., 1997) allows to construct the unique perfect equilibrium of any game $\Gamma_k(i^1)$ whatever its length $k > N + 1$ using a backward induction argument. Indeed, since the initial equilibrium move for player 2 in $\Gamma_{N+1}(2)$ is *out* then in terms of payoffs, we have $\Gamma_{N+1}(2) \equiv \Gamma_{N+1}(1)$ with a zero equilibrium payoff for player 2, so that, $\Gamma_{N+2}(2) \equiv \Gamma_1(2)$ while $\Gamma_{N+2}(1) \equiv \Gamma_1(1) + \Gamma_{N+1}(1)$. Let $k = (N + 1)q + r$ with $r < N + 1$, then $\Gamma_k(i^1)$ will be played as a game $\Gamma_r(i^1)$ followed by q times $\Gamma_{N+1}(1)$ games.

This equilibrium satisfies both rent dissipation and selection.

To construct the Markov equilibrium in Γ_∞^δ consistent with the adopted transition rules, go as follows: decompose the game Γ_∞^δ into finite sequences of $N + 1$ stages, within each such sequences use the strategies of Γ_{N+1} , this is feasible since the state variable says where the players stand within each sequence. Clearly, if one player uses such a strategy, there is no way for the other to obtain a higher payoff than the one he gets through his Markov strategy.

¹³For simplicity only the equilibrium path is described, the best response after non equilibrium moves is easily completed.

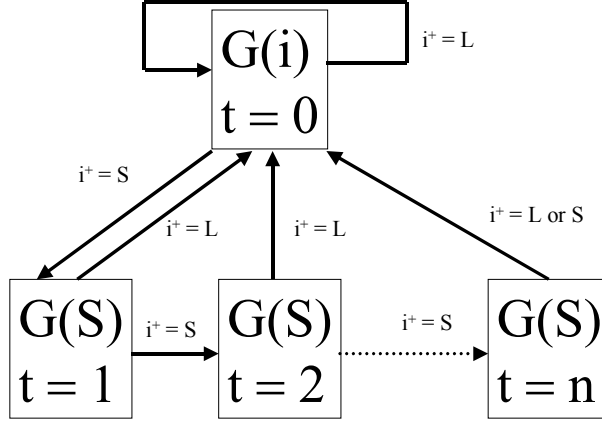


Figure 4: The game Γ_∞^δ in the SME approach

This Markov equilibrium can be interpreted as follows: only the more efficient player may remain as a permanent incumbent, if he makes a mistake then the other player (the less efficient one to be seen as the hit and run player) moves *in* and stays *in* (at most N stages) until $t = 0$.

This equilibrium has at least three limitations. Firstly, the strategy of the efficient player should be stationary and not cyclical. Secondly, after a mistake, the number of stages the hit and run player may stay *in* should not depend on where the players stand on the cycle. Thirdly, it seems awkward to rely on a finite game to define the relevant N used to construct the solution of an infinite horizon game. In this approach, the time variable says too much.

The SME approach (*figure 4*)

8.2 Proofs

Proof. (Proposition 2) Let (Z_L, Z_S) be the Markov strategies as defined in the proposition. The associated paths are as follows:

- if $\theta = (L, 0)$ the path is : $((y_L, out), (y_L, out), \dots)$;
- if $\theta = (S, 0)$ the path is : $((out, y_L, out), (y_L, out), (y_L, out), \dots)$;
- if $\theta = (S, t)$ with $t \neq 0$ the path is: $((y_S^t, out) \dots (y_S^n, out), (out, y_L, out), (y_L, out) \dots)$;

The corresponding non negative discounted payoffs are easily computed as follows: $\pi_L(Z_L, Z_S \mid \theta = (L, 0)) = \pi_L(Z_L, Z_S \mid \theta = (S, 0)) = v_L(y_L)/(1 - \delta)$

$$\begin{aligned}
\pi_L(Z_L, Z_S \mid \theta = (S, t)) &= \delta^{n+1-t} \pi_L(Z_L, Z_S \mid \theta = (L, 0)) \\
&= v_L(y_L) \delta^{n+1-t} / (1 - \delta) \text{ for } t \in \{1, 2 \dots n\} \\
\pi_S(Z_L, Z_S \mid \theta = (S, t)) &= \sum_{t'=t}^n \delta^{t'-t} v_S(y_S^{t'}) \quad \text{for } t \in \{1, 2 \dots n\} \\
\pi_S(Z_L, Z_S \mid \theta = (S, 0)) &= \pi_S(Z_L, Z_S \mid \theta = (L, 0)) = 0
\end{aligned}$$

Part I : Z_L is a best response to Z_S .

Let $\theta = (L, 0)$

- if player L selects $x_L \leq y_L$ player S moves *out* so that $\theta^+ = (L, 0)$, then player L discounted payoff is $v_L(x_L) + \delta \pi_L(Z_L, Z_S \mid \theta = (L, 0))$

which is maximized at $x_L = y_L$ to be $\pi_L(Z_L, Z_S \mid \theta = (L, 0))$;

- if player L selects $x_L > y_L$ player S moves *in* so that $\theta^+ = (S, 1)$, then player L discounted payoff is

$d_L(x_L) + \delta \pi_L(Z_L, Z_S \mid \theta = (S, 1)) = d_L(x_L) + \delta^{n+1} \pi_L(Z_L, Z_S \mid \theta = (L, 0)) < \pi_L(Z_L, Z_S \mid \theta = (L, 0))$ since $d_L(x_L) \leq 0$ and $\delta < 1$;

- if player L moves *out* player S also moves *out* and the game ends with zero payoff for player L ;

- this shows that $x_L = y_L$ is a best response.

Let $\theta = (S, t)$ for $t \in \{0, 1, 2 \dots n\}$

- if player S selects $x_S \leq y_S^t$ then by moving *out* player L gets $\delta \pi_L(Z_L, Z_S \mid \theta = (S, t))$ for $t \in \{0, 1, 2 \dots n-1\}$, and $\delta \pi_L(Z_L, Z_S \mid \theta = (L, 0))$ for $t = n$ so that his payoff may directly be written as $\delta^{n+1-t} \pi_L(Z_L, Z_S \mid \theta = (L, 0))$, while by moving *in* he gets $-C_L(x_S) + \delta \pi_L(Z_L, Z_S \mid \theta = (L, 0))$

since $-C_L(x_S) \leq -C_L(y_S^t)$ we have :

$$-C_L(x_S) + \delta \pi_L(Z_L, Z_S \mid \theta = (L, 0)) \leq -C_L(y_S^t) + \delta \pi_L(Z_L, Z_S \mid \theta = (L, 0))$$

by construction $C_L(y_S^t) = v_L(y_L) \delta (1 - \delta^{n-t}) / (1 - \delta)$ and $\pi_L(Z_L, Z_S \mid \theta = (L, 0)) = \delta v_L(y_L) / (1 - \delta)$ so that

$$-C_L(y_S^t) + \delta \pi_L(Z_L, Z_S \mid \theta = (L, 0)) = \delta^{n+1-t} \pi_L(Z_L, Z_S \mid \theta = (L, 0))$$

hence player L 's best response is to move *out*;

- if player S select $x_S > y_S^t$ the same argument but with $-C_L(x_S) > -C_L(y_S^t)$ shows that player L 's best response is to move *in*;

- if player S moves *out* then, using the argument given for $\theta = (L, 0)$ it is clear that player L should play $x_L = y_L$.

Part II : Z_S is a best response to Z_L .

Let $\theta = (L, 0)$

- if player L selects $x_L \leq y_L$ by moving *out* player S gets $\pi_S(Z_L, Z_S \mid \theta = (L, 0)) = 0$, while if he moves *in* he gets $-C_S(x_L) + \delta \pi_S(Z_L, Z_S \mid \theta = (S, 1))$.

Since $-C_S(x_L) \leq -C_S(y_L)$ we have

$$-C_S(x_L) + \delta \pi_S(Z_L, Z_S \mid \theta = (S, 1)) \leq -C_S(y_L) + \delta \pi_S(Z_L, Z_S \mid \theta = (S, 1))$$

by construction $C_S(y_L) = \sum_{t'=1}^n \delta^{t'-1} v_S(y_S^{t'})$ and $\pi_S(Z_L, Z_S \mid \theta = (S, 1)) = \sum_{t'=1}^n \delta^{t'-1} v_S(y_S^{t'})$

so that

$$-C_S(y_L) + \delta \pi_S(Z_L, Z_S \mid \theta = (S, 1)) = 0$$

hence player S 's best response is to move *out*;

- if player L select $x_L > y_L$ the same argument but with $-C_S(x_L) > -C_S(y_L)$ shows that player S 's best response is to move *in*;

- if player L selects *out* and player S moves *out* the game ends and player S gets 0, if player S selects $x_S > y_S^0$, by the Markov assumption player L moves *in* and player S discounted payoff is $d_S(x_S) + 0 \leq 0$, if player S selects $x_S \leq y_S^0$ player L moves *out* and $\theta^+ = (S, 1)$ but in that case player S discounted payoff is strictly negative since $v(x_S) \leq v(y_S^0)$ and $\sum_{t'=0}^{t=n} \delta^{t'} v_S(y_S^{t'}) < 0$,

hence player S 's best response is to move *out*.

Let $\theta = (S, t)$ for $t \in \{0, 1, 2 \dots n\}$

- if player S selects moving *out* or $x_S > y_S^t$ (in which case player L moves *in*) he gets 0;

- if player S selects $x_S \leq y_S^t$ player L plays *out* and player S discounted payoff is $v_S(x_S) + \delta \pi_S(Z_L, Z_S \mid \theta = (S, t + 1 \bmod n + 1))$

which is maximized at $x_S = y_S^t$ to be $\sum_{t'=t}^{t=n} \delta^{t'-t} v_S(y_S^{t'})$; by construction this expression is non negative if t is different from 0, and strictly negative if $t = 0$, consequently player S best response is $x_S = y_S^t$ for $t \in \{1, 2 \dots n\}$ but *out* for $t = 0$. ■

Proof. ¹⁴ (Theorem 4) The proof runs as follows. Firstly prove that conditions (1-2-3-4) of Φ_1^n have a unique solution. Secondly, check whether condition (5) is satisfied: if it is, the unique solution of Φ_1^n is obtained, if it is not Φ_1^n has no solution.

To prove the first part, for all $x_L \in [v_L^{-1}(0), C_S^{-1}(0)]$, define the function $W(x_L) = C_S(x_L) - \sum_1^n v_S(x_S^t)$ in which the sequence (x_S^t) is derived from x_L through (1) that is,

$$-C_L(x_S^t) + (n - t)v_L(x_L) = 0 \quad \text{for } t \in \{0, 1, 2 \dots n\}$$

then, show that $W(x_L)$ is negative (step 1) then positive (step 2) and that its derivative is strictly positive (step 3) so that there is a unique solution to the equation $W(x_L) = 0$. Indeed:

Step 1: if $x_L = v_L^{-1}(0)$ then $W(x_L) < 0$

In that case $x_S^t = C_L^{-1}(0)$ for all t so that $W(v_L^{-1}(0)) = C_S(v_L^{-1}(0)) - n v_S(C_L^{-1}(0))$

by assumption $v_S(C_L^{-1}(0)) > 0$ so that for n large enough $W(v_L^{-1}(0)) < 0$.

Step 2: if $x_L = C_S^{-1}(0)$ then $W(x_L) > 0$

Since C_L is strictly decreasing, the sequence (x_S^t) is a strictly increasing sequence bounded by $C_L^{-1}(0)$. Since v_S is strictly increasing this implies that $\sum_1^n v_S(x_S^t)$ is certainly negative for n large enough so that $W(C_S^{-1}(0)) = -\sum_1^n v_S(x_S^t)$ is certainly positive.

Step 3: $\frac{dW}{dx_L} > 0$

We have

$$\frac{dW}{dx_L} = \frac{dC_S}{dx_L} - \sum_{t=1}^n \left(\frac{dv_S}{dx_S^t} \cdot \frac{dx_S^t}{dx_L} \right)$$

¹⁴I am indebted to Rida Laraki for providing the argument for this proof.

Using (1) we get:

$$\frac{dx_S^t}{dx_L} = (n-t) \frac{dv_L}{dx_L} / \frac{dC_L}{dx_S^t}$$

By substitution it follows that:

$$\frac{dW}{dx_L} = \frac{dC_S}{dx_L} - \frac{dv_L}{dx_L} \sum_{t=1}^{t=n} ((n-t) \frac{dv_S}{dx_S^t} / \frac{dC_L}{dx_S^t})$$

By assumption $-\frac{dv_S}{dx_S^t} / \frac{dC_L}{dx_S^t}$ is uniformly bounded away from zero by ε so that

$$\frac{dW}{dx_L} \geq \frac{dC_S}{dx_L} + \frac{dv_L}{dx_L} \frac{n(n-1)}{2} \varepsilon$$

Since $\frac{dv_L}{dx_L}$ is bounded away from zero and since $\frac{dC_S}{dx_L}$ is bounded away from $-\infty$ we certainly have $\frac{dW}{dx_L} > 0$ for n large enough.

Hence for a given n large enough there is a unique solution to $W(x_L) = 0$ that is, to (2). This solution is in $]v_L^{-1}(0), C_S^{-1}(0)[$ so that (3) is also satisfied. Denote \hat{y}_L this solution and (\hat{y}_S^t) for $t \in \{0, 1, 2, \dots, n\}$ the associated sequence obtained through (1). Observe that (4) is satisfied as well : since v_S is increasing the function $\sum_{t'=t}^{t'=n} v_S(\hat{y}_S^{t'})$ is bell shaped with respect to t so for all t we have:

$$\sum_{t'=t}^{t'=n} v_S(\hat{y}_S^{t'}) \geq \text{Min}(\sum_1^n v_S(\hat{y}_S^t), v_S(\hat{y}_S^n)) = \text{Min}(C_S(\hat{y}_L), v(C_S^{-1}(0))) > 0$$

because $\hat{y}_L < C_S^{-1}(0)$ implies $C_S(\hat{y}_L) > 0$ while $\hat{y}_S^n = v(C_S^{-1}(0)) > 0$ by construction.

It is now a simple matter to check whether (5) holds or not. If it does a complete solution to Φ_1^n is obtained, if it does not there cannot be a solution for that value of n since conditions (1) through (4) have a unique solution. ■

Proof. (Theorem 6) Parts 1 and 2 of the theorem are easily proved.

Indeed, suppose $v_L(y_L(n)) \geq \varepsilon > 0$ for all n , then using (1) the sequence $(y_S^t(n))$ is a strictly increasing sequence defined backwards from $y_S^n(n) = C_L^{-1}(0)$ so (4) cannot hold for large n hence $\lim_{n \rightarrow \infty} v_L(y_L(n)) = 0$. Then Part 2 follows from (2).

Part 3.

First of all, given that $\frac{dC_L}{dx}$ is bounded away from infinity and from zero and that $v_S(x)$ is bounded away from zero, there exists a unique $x^* < C_L^{-1}(0)$ such that

$$\int_{x^*}^{C_L^{-1}(0)} v_S(x) \frac{dC_L}{dx}(x) dx = 0$$

For all $x \leq C_L^{-1}(0)$ define $F(x) = \int_x^{C_L^{-1}(0)} v_S(u) \frac{dC_L}{du}(u) du$, the function F is such that $F(x) > 0$ iff $x < x^*$.

We now show the convergence of $y_S^1(n)$ to x^* .

Using (1) and (2) we get :

$$\begin{aligned} C_S(y_L(n))v_L(y_L(n)) &= \sum_{t=1}^{t=n} v_S(y_S^t(n))v_L(y_L(n)) \\ &= \sum_{t=1}^{t=n} v_S(y_S^t(n)) [C_L(y_S^{t-1}(n)) - C_L(y_S^t(n))] \end{aligned}$$

When $v_L(y_L(n))$ is small this non negative expression is close to $F(y_S^1(n))$.¹⁵ This proves that $y_S^1(n)$ cannot be far below x^* . Using (2) and (5) for the two sequences n and $n+1$, it is clear that $y_S^1(n+1)$ and $y_S^1(n)$ cannot be far apart either. More precisely:

$$|y_S^1(n+1) - y_S^1(n)| \leq -\text{Min}\left(\frac{dC_L}{dx}(y_S^1(n)), \frac{dC_L}{dx}(y_S^0(n))\right)v_L(y_L(n))$$

Since $\frac{dC_L}{dx}$ is bounded away from infinity, $\lim_{n \rightarrow \infty} |y_S^1(n+1) - y_S^1(n)| = 0$, this is enough to prove that $y_S^1(n)$ converges to some limit and this limit can only be x^* since $\lim_{n \rightarrow \infty} C_S(y_L(n))v_L(y_L(n)) = \lim_{n \rightarrow \infty} C_S(y_L(n)) \lim_{n \rightarrow \infty} v_L(y_L(n)) = C_S(0).0 = 0$. ■

8.3 Economic illustrations of potential competition

Two economic models of entry are analysed. In both models *under-competition* prevails when competition is tough in case of entry.

8.4 Competition through short run price commitments

Consider the specific price model detailed in Ponsard (1991), the switching cost s is not constant. Still the situation remains one of *under-competition* when s is small. But, if s is not close zero, we may have *excess-competition*. How tough price competition is is the key factor.

More precisely, let ω be a parameter to be interpreted as a price cross elasticity. The demand D_i to firm i is defined as follows :

$$\begin{array}{ll} 0 \leq p_i \leq p_j - (1 - p_j)/\omega & D_i(p_i, p_j) = D_i^m(p_i) = 1 - p_i \\ p_j - (1 - p_j)/\omega \leq p_i & D_i(p_i, p_j) = D_i^d(p_i, p_j) \\ p_i \leq p_j + (1 - p_j)/(1 + \omega) & = (1 + \omega)(1 - p_i + \omega(p_j - p_i))/(1 + 2\omega) \\ \underline{p_j + (1 - p_j)/(1 + \omega) \leq p_i} & D_i(p_i, p_j) = 0 \end{array}$$

¹⁵**Proof.** Make the change of variable from x_S to $u = C_L(x_S)$. As t goes from 1 to n , x_S increases from $y_S^1(n)$ to $y_S^n(n)$ and u from $u^1(n) = C_L(y_S^1(n))$ to $u^n(n) = C_L(y_S^n(n)) = 0$ but $u^{t-1}(n) - u^t(n)$ remains t independant and equals $v_L(y_L(n))$, let $\Delta u(n) = v_L(y_L(n))$.

We may then write

$$v_L(y_L(n))\sum_{t=1}^{t=n} v_S(y_S^t(n)) = \sum_{t=1}^{t=n} v_S(C_L^{-1}(u^t(n)))\Delta u(n)$$

For large values of n we have

$$\sum_{t=1}^{t=n} v_S(C_L^{-1}(u^t(n)))\Delta u(n) \approx \int_{u^1(n)}^0 v_S(C_L^{-1}(u))du = \int_{y_S^1(n)}^{C_L^{-1}(0)} v_S(x) \frac{dC_L}{dx}(x)dx.$$

■

The demand function is piece wise linear with a kink when the regime changes from a monopoly to a duopoly one. The higher ω the smaller the duopoly range in which $D_i = D_i^d$ and the tougher the price competition (ε close to zero corresponds to large ω).

Firm i incurs a stage fixed cost f if and only if it produces. There is no variable cost. Consequently player i 's profit as a function of the prices (p_i, p_j) writes:

$$\begin{aligned} \text{if } D_i(p_i, p_j) > 0 & \quad \pi_i(p_i, p_j) = D_i(p_i, p_j) \cdot p_i - f \\ \text{if } D_i(p_i, p_j) = 0 & \quad \pi_i(p_i, p_j) = 0 \end{aligned}$$

The stage game $G(i)$ is :

- player i is the incumbent, player i may either select a move p_i with $0 \leq p_i \leq 1$, or move *out* i.e., he proposes no price ;
- if player i selects p_i then player j may select *in*, in this case this means that he sets a price p_j which is his best response to p_i in terms of revenue that is, *without taking account of his fixed cost* ; denote $p_j(p_i)$ this best response, then the players respective payoffs are $(\pi_i(p_i, p_j(p_i)), \pi_j(p_i, p_j(p_i)))$; or he may select *out* with respective payoffs $(D_i^m(p_i) \cdot p_i - f, 0)$;
- etc.

The exit payoff which is $d_i(p_i) = \pi_i(p_i, p_j(p_i))$ is certainly non positive for all relevant p_i .

Summing up the monopoly profit function v is such that :

$$v(p) = D^m(p) \cdot p - f = (1 - p)p - f$$

and the entry cost C is defined as¹⁶

$$C(p) = -\text{Max}_{p_j} (D_j(p, p_j) \cdot p_j) + f$$

Our attention will be limited to symmetric games. We want to investigate whether there is *under* or *excess-competition* depending on the two parameters ω and f . This depends on the sign of $v(p^*) + C(v^{-1}(0))$ in which p^* is defined by

$$\int_{p^*}^{C^{-1}(0)} v(p) \frac{dC}{dp}(p) dp = 0$$

Observe that the function C is not differentiable when the regime goes from the monopoly one to the duopoly one, but this is for only one point and has no bearing for the integral. Still we cannot obtain p^* from an analytical formula and a numerical analysis has to be made to characterize the competitive situation.¹⁷ Figure 6 summarizes the results. In this table, *UC* refers to *under-competition*, *EC* refers to *excess-competition*.

¹⁶This makes the calculation of $C^{-1}(0)$ somewhat cumbersome.

¹⁷The corresponding calculations may be obtained from the author upon request.

f							
0,225	UC	UC	UC	UC	UC	UC	UC
0,200	UC	UC	UC	UC	UC	UC	UC
0,175	EC	UC	UC	UC	UC	UC	UC
0,150	EC	EC	EC	UC	UC	UC	UC
0,125	EC	EC	EC	EC	EC	UC	UC
0,100	EC	EC	EC	EC	EC	EC	UC
w	4	6	8	10	12	14	20

Figure 5: The taxonomy for the price model

The positions of *UC* and *EC* in the table clearly suggests a pattern. The situation is always one of *under-competition* when f is high (which is consistent with traditional economics) or when w is large (which is not). The higher f the lower w to obtain *under-competition*. Such a context may be qualified as tough since the profit to be made is structurally low because of f and the price competition is high because of w . On the opposite side the case of *excess-competition* corresponds to simultaneous low values of f and w , a context of less intense competition for the reverse reasons. This confirms the interpretation obtains with the previous example : structural factors related to the degree of toughness of competition do impact potential competition, the tougher the competition, the more likely it is that the incumbent may secure a positive rent.

8.5 Competition through durable capital

Consider the profit and entry cost functions defined as follows :

$$v(x) = \pi^m x - f$$

$$C(x) = (\pi^m - \pi^d)(H - x)$$

Define symmetric and asymmetric games from these v and C functions.

This model may be interpreted as a reformulation¹⁸ of the Eaton and Lipsey model (1980). There firms compete through plants which become obsolete after H units of time. The strategic decision for the incumbent consists in early replacement of its own plant. By doing so the incumbent prevent an entrant to preempt its market. Each time it sets a new plant, a firm incurs a fixed cost f . Operating costs are assumed to be zero. If both firms are in the market simultaneously, their duopoly flow of revenue is π^d per unit of time. If only one is present, its flow of revenue is π^m . For consistency we certainly have $\pi^m > 2\pi^d$ and $\pi^m H \geq f$ so that $0 \leq v^{-1}(0) = f/\pi^m \leq H$. For simplicity also assume that

¹⁸See Gromb et al (1997) for details on this reformulation.

$\pi^d H \leq f$. Note that Δf may be interpreted as the difference in the fixed costs of the two firms.

In our framework a new stage game occurs each time a plant is set up, then $G(i)$ is such that:

- player i is the incumbent, player i may either select a move x_i with $0 \leq x_i \leq H = C^{-1}(0)$, i.e. he sets at what time he will replace his plant, or if he will move *out* that is, he will decide not to set a new plant ;

- if player i selects x_i then player j may select *in*, i.e. player j will preempt player i by setting up his own plant exactly before the selected time x_i (with respective payoffs for i and j : $d_i(x_i), -C_j(x_i)$; indeed player j 's plant will be operating under a duopoly situation for the remaining life time of player i 's plant that is, $H - x_i$ units of time ; this entry cost is the opportunity cost that need be subtracted from player j 's next stage profit when he will be playing as the incumbent); or player j may select *out* (with self explanatory payoffs $v_i(x_i), 0$);

- etc.

Beware that the plant life time goes with the moves within a stage game $G(i)$ while the discrete time in Γ_∞^δ goes with the setting of new plants.

Note that the exit payoff is $d_i(x_i) = \pi^m x_i + \pi^d (H - x_i) - f$ which is maximized and positive for $x_i = H$. Our Markov construction in state $(S, 0)$ should be adapted to let player S capture this exit payoff rather than simply moving out.¹⁹

Corollary 15 *The game of competition through durable capital has a SME for arbitrary large values of n (i.e. there is rent dissipation for the long-term incumbent):*

$$\begin{aligned} \text{for } L = \text{strong and } S = \text{weak, iff} \quad & \Delta f < (H\pi^m - f)\pi^d / (\pi^m - \pi^d); \\ \text{for } L = \text{weak and } S = \text{strong, iff} \quad & -(H\pi^m - f)\pi^d / \pi^m < \Delta f. \end{aligned}$$

Proof. Consider the first case that is, $v_L(x_L) = \pi^m x_L - f + \Delta f$ and $v_S(x_S) = \pi^m x_S - f$ and $C_1 = C_2 = C(x) = (\pi^m - \pi^d)(H - x)$.

Proposition 11 may be used. We have $v_L^{-1}(0) = (f - \Delta f) / \pi^m$ and $C^{-1}(0) = H$.

Then $-v_S(C^{-1}(0)) + C(v_L^{-1}(0)) = f - H\pi^m + (\pi^m - \pi^d)(H\pi^m - f) / \pi^m + \Delta f(\pi^m - \pi^d) / \pi^m = -\pi^d(H\pi^m - f) / \pi^m + \Delta f(\pi^m - \pi^d) / \pi^m$

which is indeed negative iff $\Delta f < (H\pi^m - f)\pi^d / (\pi^m - \pi^d)$.

The second case that is, $v_L = \pi^m x - f$ and $v_S = \pi^m x_i - f + \Delta f$ and C unchanged, is obtained through similar calculations. ■

Fix π^m , H and f and let π^d and Δf vary. Depending on the values of $(\pi^d, \Delta f)$ the type of competition lies in different zones that may be depicted in a diagram (see figure 5). This illustrates the taxonomy. The corresponding zones are interpreted as follows:

¹⁹In state $\theta = (S, 0)$ player S plays $x_S = H$ and player L moves *out* iff $x_S \leq y_S^0$. The sequence (y_S^t) is now defined such that $-C_L(y_S^t) + (n+1-t)v_L(y_L) = 0$ to take into account this change of strategies in $\theta = (S, 0)$. The other (in)equations in system Σ_1 are revised accordingly. This does not affect the mathematical properties of the SME.

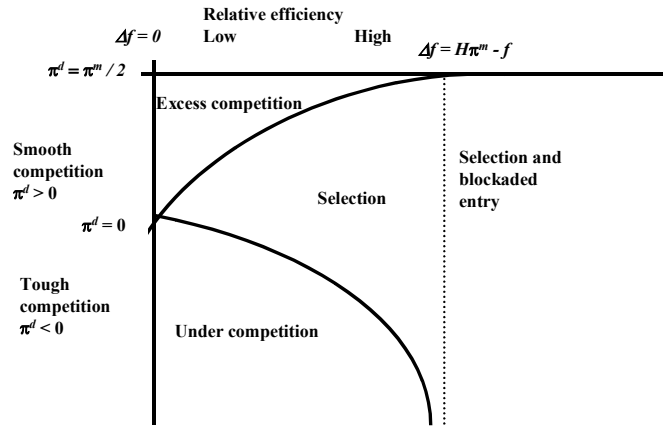


Figure 6: The taxonomy for the Eaton and Lipsey model

- *selection* is obtained whatever π_d as long as Δf is large enough ; observe that for $\Delta f > H\pi^m - f$ the least efficient firm is barred from the market anyway (blockaded entry);
- *excess-competition* prevails for $\pi_d > 0$ and small enough Δf ;
- *under-competition* prevails for $\pi_d < 0$ and small enough Δf .

Rent dissipation does not always prevail. The toughness of competition in the case of entry is the structural factor that matters : it directly determines the ratio of the entry cost relative to the monopoly profit. With a negative duopoly revenue the incumbent is able to secure a positive stage rent.

With GPS, selection always occurs as soon as $\Delta f > 0$. With SME it only occurs with Δf large enough (except at the singular point $\pi^d = 0$).

These results seem to make economic sense.

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