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Observability, Commitment and Flexibility

Marcel Boyer, Armel Jacques, Michel Moreaux

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Observability, Commitment and Flexibility*

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Résumé / Abstract

Nous montrons que la possibilité qu'ont, ou non, les entreprises d'observer leurs choix technologiques respectifs a des impacts significatifs sur les technologies qu'elles adopteront à l'équilibre. Selon les caractéristiques de l'industrie, la valeur stratégique de la flexibilité technologique peut être positive ou négative, et il est parfois préférable d'observer plutôt que d'être observé, parfois plus profitable d'être observé que d'observer.

We show that whether observing technological choices made by competitors is possible or not has significant impacts on the equilibrium technological configurations. Depending upon the industry characteristics, the strategic value of technological flexibility may be either positive or negative, and it is sometimes better to observe than to be observed, and sometimes to be observed than to observe.

Mots Clés : Flexibilité, observabilité, duopole

Keywords : Flexibility, observability, duopoly

JEL : D43, L13

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1 INTRODUCTION

In a recent issue of this journal, Boyer and Moreaux (1997) [BM] studied the choice of flexible manufacturing systems in a duopoly framework in which the technological decisions, typically long run decisions, are taken in the first stage, whereas the output decisions, typically short run decisions, are taken in the second stage. They assumed that, before choosing its level of production, each firm could observe the long run technological choice of its rival and they showed how flexibility choices depended on six industry characteristics: the expected size of the market (μ), the variability in the level of demand (V), the differential investment cost for a flexible technology (H), the slope of the demand function (β), the capacity of an inflexible factory (x) and the marginal cost of production (c).

They argued that low market volatility combined with intermediate market size favored inflexible technologies; that large values of either volatility or size favored flexible technologies; and that low or intermediate values of both favored the coexistence of flexible and inflexible technologies. They also showed the possibility of flexibility traps in which the firms choose flexible technologies while they could both make more profits by choosing inflexible ones. Such traps could appear in industries characterized by low volatility and intermediate size. Finally, they characterized the paths of technological flexibility adoption: first, as function of market size increases, holding constant the volatility of demand, and then as function of demand volatility increases, holding constant the expected size of the market.

In this paper, we study the relaxation of the assumption that firms can observe the choice of technologies made in the first stage before competition in production levels takes place. We will show how observability of technological choices affect the equilibrium configuration of technologies. Studying the role of observability has two objectives: first, there exist industries where it is not easy to observe the technological choice of one's competitor; second, the comparison between these two polar cases will allow us to clearly define and measure the strategic value of flexibility.

When each firm's technological choice is observed by its rival (in the closed loop game – CL), that choice can act as a credible commitment to a particular production behavior in the second stage. Two factors then influence the choice of the technological flexibility level: the chosen technology should be well adapted to the expected size and volatility of demand, the efficiency factor, but the chosen technology could also influence the production behavior of the competitor in the second stage, the strategic factor. When technological choices are not observed (in the open loop game – OL), the strategic factor above does not appear. As suggested by Vives (1989), the comparison of equilibria obtained under the two observability conditions will allow us to characterize the strategic value of flexibility

We recall the BM model in section 2 and we proceed with the comparison of the OL and CL game frameworks in section 3. Section 4 is devoted to an intermediate case where one and only one firm observes the technological choice of its rival. Finally, we conclude in section 5.

2 THE MODEL

As mentioned above, BM propose a two stage duopoly game in which the firms choose simultaneously their respective technology in the first stage and compete à la Cournot in the second stage, once the technological choices have been observed. Demand is linear and represented by $p = \max\{0,\ \alpha - \beta Q\}$ where α is a random variable distributed over the interval $[\underline{\alpha}, \overline{\alpha}]$, with mean μ and variance V and $\underline{\alpha}$ large enough to allow both firms to be active in the second period.[1] The value of α is assumed to be observed by both firms before production takes place. Only two technologies are available, with i standing for the inflexible technology and f for the flexible technology. The inflexible technology can only be used to produce at full capacity $q = x$ at a total variable cost cx while the flexible technology can be used to produce any quantity $q \geq 0$ at a total variable cost of cq. The differential investment cost between the flexible and the inflexible technologies is H, the cost of the inflexible technology being set at 0 for simplicity. The first stage subgame perfect payoffs are given by:

$$\Pi^1(f,f) = \Pi^2(f,f) = \frac{1}{9\beta}\left[V + (\mu - c)^2\right] - H \tag{1}$$

$$\Pi^1(i,f) = \Pi^2(f,i) = \frac{1}{2}x\left(\mu - \beta x - c\right) \tag{2}$$

$$\Pi^1(f,i) = \Pi^2(i,f) = \frac{1}{4\beta}\left[V + (\mu - \beta x - c)^2\right] - H \tag{3}$$

$$\Pi^1(i,i) = \Pi^2(i,i) = x\left(\mu - 2\beta x - c\right) \tag{4}$$

[1] See Boyer, Jacques and Moreaux (1998b) for a model allowing bankruptcy.

3 THE COMPARISON OF CL AND OL GAMES

The CL game is analyzed by BM and their main results are summarized in Proposition 1:

Proposition 1: *The subgame perfect Nash equilibria of the CL game are as follows:*
a) both firms choose inflexible technologies if

$$H \geq \max\left\{\frac{1}{4\beta}V+\frac{9}{4}\beta\left[x-\frac{1}{3\beta}(\mu-c)\right]^2, \frac{1}{9\beta}V+\frac{1}{2}\beta\left[x-\frac{1}{3\beta}(\mu-c)\right]^2-\frac{1}{6}\left[x-\frac{1}{3\beta}(\mu-c)\right](\mu-c)\right\}$$

b) both firms choose flexible technologies if

$$H \leq \min\left\{\frac{1}{4\beta}V+\frac{9}{4}\beta\left[x-\frac{1}{3\beta}(\mu-c)\right]^2, \frac{1}{9\beta}V+\frac{1}{2}\beta\left[x-\frac{1}{3\beta}(\mu-c)\right]^2-\frac{1}{6}\left[x-\frac{1}{3\beta}(\mu-c)\right](\mu-c)\right\}$$

c) one firm chooses the flexible technology and the other the inflexible technology if

$$\frac{1}{4\beta}V+\frac{9}{4}\beta\left[x-\frac{1}{3\beta}(\mu-c)\right]^2 \geq H \geq \frac{1}{9\beta}V+\frac{1}{2}\beta\left[x-\frac{1}{3\beta}(\mu-c)\right]^2-\frac{1}{6}\left[x-\frac{1}{3\beta}(\mu-c)\right](\mu-c)$$

d) both firms choose the same technology, either flexible or inflexible, if

$$\frac{1}{4\beta}V+\frac{9}{4}\beta\left[x-\frac{1}{3\beta}(\mu-c)\right]^2 \geq H \geq \frac{1}{9\beta}V+\frac{1}{2}\beta\left[x-\frac{1}{3\beta}(\mu-c)\right]^2-\frac{1}{6}\left[x-\frac{1}{3\beta}(\mu-c)\right](\mu-c).$$

In the OL game, firms do not observe the technological choice of their competitor and therefore it is as if each firm chooses simultaneously in stage 1 a technology and a production decision function to be applied in stage 2 after observing the state of demand parameter α. The relevant strategies are as follows.

– If a firm is flexible and expects its competitor to be flexible, it produces $q(\alpha) = \frac{\alpha - c}{3\beta}$ in the second stage; we call this strategy $S1 : (f,\ q = \frac{\alpha - c}{3\beta})$.

– If a firm is flexible and expects its competitor to be flexible and to beleive that the firm is inflexible, the firm produces $q(\alpha) = \frac{\alpha + x\beta - c}{4\beta}$ in the second stage; we call this strategy $S4 : (f,\ q = \frac{\alpha + x\beta - c}{4\beta})$.

– If a firm is flexible and expects its competitor to be inflexible, then it produces $q(\alpha) = \frac{\alpha - x\beta - c}{2\beta}$ in the second stage; we call this strategy $S2 : (f,\ q = \frac{\alpha - x\beta - c}{2\beta})$.

– If a firm is inflexible, it can only produce at $q = x$ in the second period, whatever the technology of the other firm; we call this strategy $S3 : (i,\ q = x)$.

We will show that three equilibria are possible in the OL game: $(S1, S1)$, $(S2, S3)$ (and the symmetric $(S3, S2)$) and $(S3, S3)$. In any other case, at least one firm would not be on its best reply. We must characterize the best response function $BR(\cdot)$ of a firm to different strategy choices of its competitor.

THE BEST RESPONSE TO $S1 : (f,\ q = \frac{\alpha - c}{3\beta})$.

If firm 2 plays $S1$, then firm 1 can be flexible with strategy $S1$ or be inflexible with strategy $S3$. If firm 1 plays $S3$, then

$$
\begin{aligned}
q_1 &= x, \qquad q_2 = \frac{\alpha - c}{3\beta}, \qquad p = \frac{2\alpha - 3x\beta + c}{3}, \\
\pi_1 &= x\frac{2\alpha - 3x\beta - 2c}{3}, \qquad E(\pi_1) = x\frac{2\mu - 3x\beta - 2c}{3}
\end{aligned}
$$

Given (1), $S1 = BR(S1)$ iff

$$
\frac{1}{9\beta}\left[V + (\mu - c)^2\right] - H \ \geq \ x\frac{2\mu - 3x\beta - 2c}{3} \tag{5}
$$

THE BEST RESPONSE TO $S2 : (f,\ q = \frac{\alpha - x\beta - c}{2\beta})$.

If firm 2 plays $S2$, then firm 1 can be inflexible with strategy $S3$ or be flexible with strategy $S4$. If firm 1 plays $S4$, then

$$
\begin{aligned}
p &= \frac{1}{4}(\alpha + x\beta + 3c), \qquad \pi_1 = \frac{1}{16\beta}(\alpha + x\beta - c)^2 - H, \\
E(\pi_1) &= \frac{1}{16\beta}\left[V + (\mu + x\beta - c)^2\right] - H
\end{aligned}
$$

Given (2), $S3 = BR(S2)$ iff

$$\frac{1}{2}x\left(\mu - \beta x - c\right) \geq \frac{1}{16\beta}\left[V + \left(\mu + x\beta - c\right)^2\right] - H \tag{6}$$

THE BEST RESPONSE TO $S3$: $(i,\ q = x)$.

If firm 2 plays $S3$, then firm 1 can be flexible with strategy $S2$ or be inflexible with strategy $S3$. Given (3) and (4), we have $S2 = BR(S3)$ iff

$$\frac{1}{4\beta}\left[V + \left(\mu - x\beta - c\right)^2\right] - H \geq x\left(\mu - 2\beta x - c\right),$$

that is, iff

$$\frac{1}{4\beta}\left[V + \left(\mu - 3x\beta - c\right)^2\right] - H \geq 0 \tag{7}$$

Condition (7) turns out to be the condition under which inflexibility is the best response to inflexibility in the CL game. Hence, the possibility to observe or not the technological choice of the other firm does not affect this condition and therefore the equilibrium (i, i) emerges for efficiency reasons only and not for strategic reasons. These results are summarized in Proposition 2:

Proposition 2: *The subgame perfect Nash equilibria of the OL game are as follows:*
a) both firms choose flexible technologies if

$$H \leq \frac{1}{16\beta}\left[V + \left(\mu + x\beta - c\right)^2\right] - \frac{1}{2}x\left(\mu - \beta x - c\right)$$

b) one firm chooses the flexible technology and the other the inflexible technology or both firms choose flexible technologies if

$$\frac{1}{16\beta}\left[V + \left(\mu + x\beta - c\right)^2\right] - \frac{1}{2}x\left(\mu - \beta x - c\right) \leq H \leq \frac{1}{9\beta}\left[V + \left(\mu - c\right)^2\right] - x\frac{2\mu - 3x\beta - 2c}{3}$$

c) one firm chooses the flexible technology and the other the inflexible technology if

$$\frac{1}{9\beta}\left[V + \left(\mu - c\right)^2\right] - x\frac{2\mu - 3x\beta - 2c}{3} \leq H \leq \frac{1}{4\beta}\left[V + \left(\mu - 3x\beta - c\right)^2\right]$$

d) both firms choose inflexible technologies if

$$\frac{1}{4\beta}\left[V + (\mu - 3x\beta - c)^2\right] \leq H.$$

The equilibria for the CL and the OL games are represented on Figure 1 with parameter values $\beta = 1$, $x = 1$, $c = 0.2$, and $H = 0.1$ (the minimum value of $\underline{\alpha}$ allowing both firms to be active in the second stage is then 2.2).

[INSERT FIGURE 1 HERE]

We obtain 8 different regions in the (μ, V)-space:
– In A: the CL equilibrium is (i, i); the OL equilibrium is (i, i).
– In B: the CL equilibrium is (i, f) $[(f, i)]$; the OL equilibrium is (i, f) $[(f, i)]$.
– In C: the CL equilibrium is (i, f) $[(f, i)]$; the OL equilibria are (i, f) $[(f, i)]$ and (f, f).
– In D: the CL equilibrium is (i, f) $[(f, i)]$; the OL equilibrium is (f, f).
– In E: the CL equilibrium is (f, f); the OL equilibrium is (f, f).
– In F: the CL equilibrium is (f, f); the OL equilibria are (i, f) $[(f, i)]$ and (f, f).
– In G: the CL equilibrium is (f, f); the OL equilibria are (i, f) $[(f, i)]$.
– In H: the CL equilibria are (i, i) and (f, f); the OL equilibrium is (i, i).

The structure of the equilibria of the OL game is as follows. If the volatility of demand V is low and the capacity x of an inflexible factory is close to the quantity chosen by a duopoly in a competition à la Cournot, then the inflexible technology is chosen by both firms. If V increases or if x moves away from the Cournot equilibrium quantity, then one of the two firms adopts the flexible technology. If V increases even more or if x moves even farther from the Cournot equilibrium quantity, then the other firm adopts a flexible technology too. However, there are zones where the OL game accepts several types of equilibria: in C and F, we have two equilibria, namely (i, f) $[(f, i)]$ and (f, f). Multiple equilibria appear because a flexible firm can play two different strategies, $S1$ and $S2$. In these zones, $S1 = BR(S1)$ but $S3 = BR(S2)$ so the best response to flexibility depends on the production decision function followed by the flexible firm.

The comparison between equilibria of the CL game and equilibria of the OL game shows two particularly interesting zones where the CL and OL games result in different technological configurations for the industry. In zone D on Figure 1 the equilibrium of the CL game is (i, f) $[(f, i)]$ and the equilibrium of the OL game is (f, f). In the CL game, one firm chooses inflexibility for strategic reasons. However, if its competitor could not observe its technological choice, the firm would choose a flexible technology. In that zone, the capacity x of an inflexible firm is larger than the expected production level of a flexible firm. By choosing inflexibility, a firm can therefore commit to produce more in the second stage of the game, hence reducing in equilibrium the expected production of the other firm: the strategic value of flexibility is *negative* in region D. In region G, the equilibrium of the CL game is (f, f) while the equilibrium in the OL game is (i, f) $[(f, i)]$. In this region, the expected production level of a flexible firm is larger than the capacity x of an inflexible one. By choosing flexibility, a firm increases its expected production level in stage 2 and therefore decreases the expected production of the other flexible firm: the strategic value of flexibility is *positive* in region G. There are two other zones (C and F) where we can observe similar differences but in these two zones, the OL game accepts several equilibria, making the comparison less striking.

The flexibility trap present in region H in the CL game does not appear in the OL game. In the CL game, if one firm is flexible then the other firm chooses flexibility too: flexibility is a best response to flexibility and (f, f) is therefore an equilibrium. In this region the expected production of a flexible factory is greater than the capacity of an inflexible factory. So choosing flexibility when the other firm is flexible decreases the expected production of the other firm. However we are in a flexibility trap because both firms would be more profitable in the alternative (i, i) equilibrium. In the OL game, the strategic value of flexibility disappears since technological choices are not observable: the best reply to flexibility becomes inflexibility and the only equilibrium is (i, i). Hence, non observability prevents the occurrence of the flexibility trap.

The paths of technological flexibility adoption, as either market size or demand volatility increases, depend on the conditions of observability. Using the approach of BM mutatis mutandis, we find that the timing of adoption may be advanced or postponed depending on the particular region considered. If the inflexible factory capacity is large compared with the expected size of the market, that is, if $\mu \leq 3\beta x + c$, flexibility has a negative strategic value; therefore, as demand volatility increases, the jump from an asymmetric flexibility configuration to (f, f) happens earlier in the OL game. If the inflexible factory capacity is small compared with the expected size of the market, that is, if $\mu \geq 3\beta x + c$, flexibility has a positive strategic value and the jump from an asymmetric flexibility configuration to (f, f) is postponed in the OL game. Similarly, as the market size grows for a given demand volatility level, the jump from (f, f) to (i, f) happens earlier while the jump from (i, f) to (f, f) is postponed in the OL game.

4 THE ASYMMETRIC OBSERVATION GAME

Let us now consider the intermediate case where firm 2 [firm 1] can [cannot] observe the technological choice of firm 1 [firm 2] before playing the Cournot competition stage 2 game. This game has no subgame. We assume that for the second stage of the competition, firm 2 takes full advantage of its information set. This implies that: the best response test for firm 1 playing OL strategies is the set of conditions given for the CL strategies; the best response test for firm 2 playing CL strategies is the set of conditions given for the case of OL strategies (see section 3 above).[2] With this set of best replies, we obtain the following asymmetric observability equilibria which can also be represented on Figure 1:

– In A and H, the equilibrium is (i, i).
– In B and C, equilibria are (i, f) and (f, i).
– In D, the equilibrium is (i, f).
– In E, the equilibrium is (f, f).
– In F, the equilibria are (f, i) and (f, f).
– In G, the equilibrium is (f, i).

In regions A, B and E, equilibria are the same in the OL and CL games; so they do not change in asymmetric observability case. In area C, the equilibria of the asymmetric observability game are the same as in the CL game. The configuration (f, f) which is an equilibrium in the OL game is not an equilibrium in the asymmetric observability game. If firm 2 chooses flexibility then firm 1 chooses inflexibility which induces firm 2 to decrease its production in most states of demand. In region D, the unique equilibrium of the asymmetric observability game is (i, f). One may wonder then whether the best position in this region D is to observe or be observed. The answer depends on the parameter values; for low volatility, the best technology is the inflexible one and it is therefore better to be observed than to observe; but for high volatility, the best technology is the flexible one and it is therefore better to observe

[2] Boyer, Jacques and Moreaux (1998a) give more justifications about this definition of a robust equilibrium in this kind of situation.

than be observed.[3] In region F, there are two Nash equilibria of the asymmetric observability game, namely (f,f) and (f,i) and it is better to be flexible than inflexible. It is therefore better to be observed than to observe. In region G, there is an unique Nash equilibrium (f,i). The best technology is the flexible one and therefore, as in area F, it is better to be observed. In region H, the unique equilibrium is (i,i). The fact that one of the firm does not observe its competitor's technological choice prevents the occurrence of the flexibility trap. So this intermediate observability structure is profitable for both firms in region H while in regions D, F and G, one firm gains at the expense of the other one.

5 CONCLUSION

We have shown in this paper that whether observability of technological choices is possible or not has significant impacts on technological choices and on the adoption timings of flexible technologies as market grows or as volatility of demand increases. We have been able to make more precise the meaning of the strategic value of flexibility and we showed that this value can be positive or negative depending on the industry parameters. In contexts where one and only one firm observes the technological choice of its competitor, we showed that it is sometimes better to observe than be observed and sometimes better to be observed than observe. This might be the basis of a theory of industrial intelligence understood as a deliberate attempt at observing the choices of the competitor as well as at making one's choices exposed to the eyes of the competitor.

[3]The equation of the border of these two zones is:

$$\frac{1}{4\beta}\left[V+(\mu-\beta x-c)^2\right]-\frac{1}{2}x\,(\mu-\beta x-c)-H=0.$$

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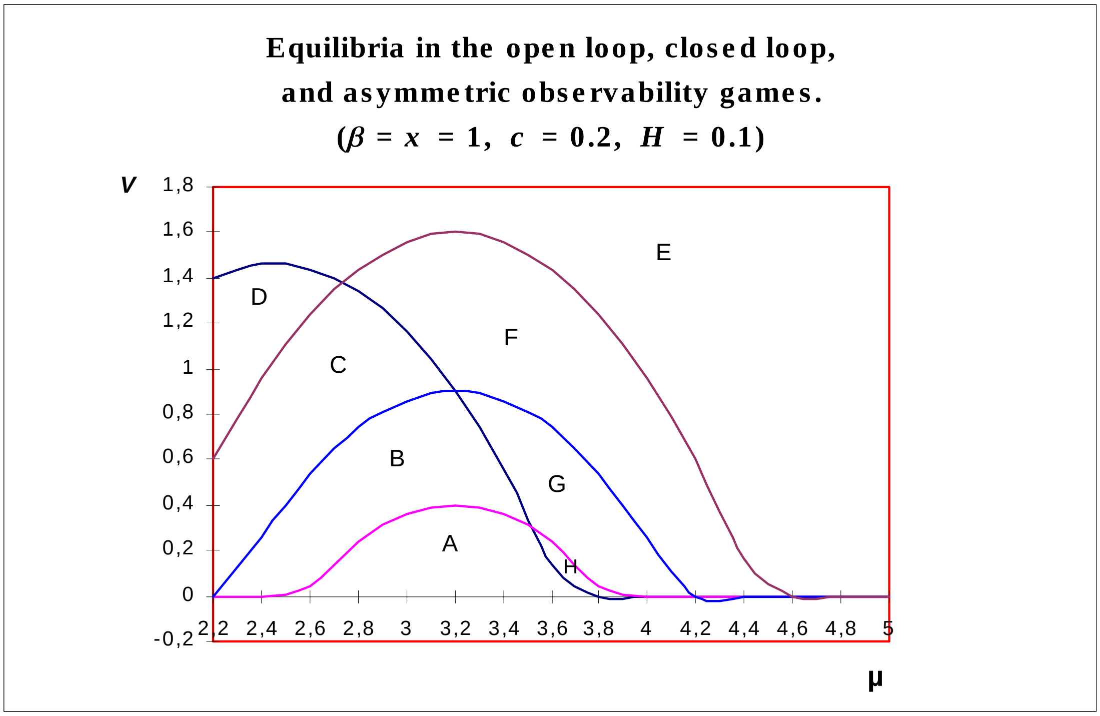

Equilibria in the open loop, closed loop,
and asymmetric observability games.
(β = x = 1, c = 0.2, H = 0.1)
V
1,8
1,6
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0,4
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Figure 1:

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