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Original Paper

Perfect Games and New ICTs within the Framework of a Bertrand Duopoly

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Abstract

We assess the impact of new information and communication technologies (ICT) on the competitiveness of enterprises in a competitive environment using as restricted model, the Bertrand duopoly where two firms engage in price competition. We consider the case of competition with minimum information.

We find that he effects of ICT on business competitiveness vary and can be: positive, negative, neutral or irrelevant beyond a certain threshold of use.

Keywords: index of new technologies, productivity, minimum information

1. Introduction

We start by determining the scope of the concept of new economics which refers to an economy where information plays an important role (Mucchielli, 2006).

According to Bosserelle (1994), the main innovations registered include the steam engine in the first half of the XIX th century; the railway in the second half of the XIX th century; automobile, chemical and electrical industries during the first half of the XX th century; the growth and decline of fordism, i.e. a major innovation in mass production techniques (productivity gains) during the second half of the XX th century.

With the discovery of writing and the coming of the printing press, the move towards an information based society was electrical telegraph, the telephone and radiotelephone. At the same time, the television and the internet linked images to text and speech while becoming accessible on mobile phones which also play the role of camera (Arthaut, 2006).

Information and communication technologies (ICT), also referred to as New Information and Communication Technologies (NICT) are the set of techniques used in the processing and transfer of information, especially computer science, the internet and telecommunications (Réseaux, 2003).

In the years 1974 and 1975, the common vocabulary is “information technology” (and not of information). This period is marked by a debate on “the computerization of the society” ordered by French former president Giscard d’Estaing.

In the 1980s, this concept takes the names “technologies of information” or “technologies of communication”, usually related to a particular use, mainly education (Brousseau & Rallet, 1997).

It is from the 1990s that this concept became a description of the item being and takes the names; “New Information and Communication Technologies”, “Information and Communication Technologies», «New Information Technologies”, etc. (Gadrey, 2000).

NICT generally refer to a set of instruments that facilitate the processing and transfer of information and sharing of knowledge. Computers and softwares play an important role in the transformation, storage and management of this information (Le Goff & Dang Nguyen, 2000). The changes in the initials (NICT, NIT, ICT) shows that its semantics is still unclear.

From this historical evolution, we can say that the association of the terms “technology” and “information” is far from recent, given that communication uses voice, actions, writing, etc. The application of ICT to these different functions uses the telegraph, the telephone, radio, television and textbooks. This is what appears to contradict the “N” in NICT. On the other hand, this concept can be closely linked to computer science which is defined in the strict sense as the automated processing of information. However, the logic of computer science is found mainly in the processing of certain logical functions like calculations. The calculator, which can be considered as the predecessor of the computer cannot really be considered as an information processing tool. The computer, data digitisation and electronics make up the basis of almost all NICT. This is what justifies the “N” in NTIC given that these applications are recent. However, it is not easy to have a precise definition of NICT.

The miniaturization of components allowing to produce “multifunctional” machines at affordable prices was possible thanks to the linking of computer science and of telecommunications in last decade of the twentieth (Gollac, Greenan, & Hamon-Cholet, 2000).

In firms and administrations before computerisation, communication was done by means of paper work. All information was transmitted by writing with the aid of informative journals and remained often confined in the services concerned. When this information became targeted, notice boards and information mails were used since there was not much communication between the services. It is important to highlight that development of mass communications such as television, radio, press, and cinema enabled the establishment of close communication with users.

The digitisation of signals enables the construction of a technological database for the development of exchange transiting through the interface of the screens of microcomputers. All this information can be stored in the form of codes with the aid of a multimedia disc. This possibility of being able to stock the information of various forms (written, sound, and fixed or motioned pictures) starts-up a social revolution given that information henceforth becomes accessible to all (Gadrey & Zarifian, 2002).

The internet network created in 1969 by the American military enables a user with a computer equipped with a modem, to communicate with correspondents at any point of the world. After these military men, the scientific community acquired this network.

New information and communication technologies are widely used in firms, although unequally due to their size (Note 1). In 1987, computer science was used by 26% of wage earners (Gollac, 1989). This proportion increased to 39% in 1993, then to 51% in 1998 (Cézard & Vinck, 1998). In 1997, all industrial companies in France, having more than 50 employees were already using computer science (Gollac, Greenan, & Hamon-Cholet, 2000). At the beginning of the year 2000, 80% of industrial companies with more than 20 employees used microcomputers connected in networks, as against 63% in 1997 and 32% in 1994. Also, 75% of these companies use numerical lines, 90% are equipped with mobile phones, and two thirds use the internet. 69% of firms of more 500 employees use integrated management software packages that enable the management of human resources, financial management, accounting management, sales, distribution, procurement and electronic trade (Feuvrier & Heitzman, 2000). The prices of microcomputers witnessed an increasing decline in recent years (Note 2). For example, the CRAY 1 brand super-computer designed to execute 100 million instructions per second was sold at 60 million francs in the beginning of the eighties and required operation costs (large computer hall, air conditioning, etc.). In 1996, a micro-computer with this same abilities based on a Pentium 100 costs 6000 times less than the CRAY 1.

At the level of the information systems, they witnessed an increase in the productivity of labour for the collection of information. The relocation of production comes to reinforce this idea of reduction in production costs. The availability of information ensures a better knowledge of the environment and thus improves the efficiency of decision-making (Duguet, 2000).

At the level of the structure of the firm and of management of personnel, there is less hierarchy in the organisation; the management of human resources is optimal: easy recruitment and carrier management (Léo & Philippe, 2000).

At commercial level, the extension of the potential market (through electronic trade) leads to a fall in procurement costs and improves the brand image of the firm (Goff & Dang Nguyen, 2000).

In a previous study, we go from the crucial hypothesis that the introduction of NICT comes to change the nature of the traditional cost function in the sense that the amount capital for the production of a unit of output has decreased.

2. The Effects of NICT on the Nature of the Total Cost Function: An Illustration of the Impact of NICT on Variable and Fixed Costs Using a Series of Examples

2.1 E-commerce

E-commerce unlike traditional trade leads to lower variable and fixed costs of production. The acquisition of a counter on the internet is less expensive than that of a traditional commercial shop since buildings and sales people are not necessary in the case of e-commerce.

Buildings in this context refer to the costs of constructing and maintaining walls. These are fixed costs, which are very low in the case of e-commerce.

2.2 Electronic Mails and the Exchange of Files (FTP)

Electronic mails at the global level, commonly referred to as emails enable subscribers to communicate both internally and externally at a lower variable cost: a user in Douala pays the same price to send an email to Yaoundé or Paris, regardless of whether the correspondent is an associate, an employee, a customer, etc.

Emails thus already appear as a substitute to fax in companies while being a cheap form of communication.

The internet also enables the transfer of files (through ftp or file transport protocol) of a large electronic size. This enables a team dispersed geographically to meet and work by sending themselves documents on any format (written, sound or video): this is the principle of virtual offices. It appears once again that in the case of NICT, the fixed costs (virtual offices) are almost negligible compared to traditional offices (with real office buildings).

Video-conferencing makes use of two techniques: the first is being the videophone that allows one to see and communicate with others and the second being video-conference that enables the holding of meetings with several persons (terminals).

There are several applications of video-conferencing such as distance learning (remote training that enables the reduction of the training costs of students), telemedicine which enables medical professionals to exchange information and bring remote healthcare at a lower cost.

2.3 The Internet, Advertising and Marketing

Rather than paying for advertising spots or sending marketing files potential clients, the firm sends them relatively less expensive computerised messages. If we consider that the making of publicity increases the quantities sold, then advertising costs appear as variable costs. We therefore witness a drop in variable costs with the internet (from the point of view of the capital factor).

Today, the decisive factor in success is no longer the size of the firm but its speed of reaction. Production cycles are increasingly becoming shorter in order to meet market needs. It is the firms which will be able to take advantage of this new order which will be most competitive on the market. Internet allows, to the firm to have a commercial presence on the worldwide market and its use (Internet) is the key of a development of the firm otherwise of its survival. In fact, Internet gives to firms the means to sell and to promote their products in a planetary way; and to develop their market without credit to support important commercial expenses (these different costs were recalled higher). Of more Internet offer to firms, means to acquire information, in a limitless way, of all kinds necessary for the management of their business. Technical, economic and commercial information is available free and many firms begin reducing their research expenses; these research expenses are considered here to be fixed costs.

3. The Analysis of the Traditional Structure of the Cost of Production of the Firm

In this section, we introduce the traditional structure (where the labour and capital factors are not

distorted by new technologies) production costs of the firm according to the labour and capital factors on one hand, and the expression of the function of production cost according to quantities supplied by the firm, on the other hand.

3.1 The Production Costs of the Company in the Traditional Economy

3.1.1 Production Costs in a General Manner

In a general manner, when a firm plans to put on the market a given level of output, it takes an inventory of the different combinations of factors which will allow it to attain this level of output. What is important for her is to find the least expensive combination (in view of profit maximisation, for example) when the prices of these factors are given.

The firm generally has several factors of production, two of which are very often retained in the study of its cost function (Note 3): capital and labour.

When a firm decides to simultaneously vary all its factors in its quest for a given output, we talk about long run production costs. On the other hand, when at least one of the factors is fixed, then we talk of short run production costs. In this study, we carry out a short run analysis where only the labour and capital factors are considered.

3.1.2 Some Characteristics of Production Costs in Traditional Economy

In the traditional economy, the fixed costs of production are generally high compared to the new economy where the internet contributes to a reduction in production costs (as will be shown in section 4). Also, in the traditional economy, to produce a given quantity of wheat for example, four tractors were needed while in new economy, to produce the same quantity, less needed. The mobility of factors is lower, the communication of information slower, and the network of customers is less wide relative to that of the new economy.

3.2 The Cost Function of the Firm i in the Absence of NICT

3.2.1 The Traditional Cost Function and the Production Function

The traditional cost function refers to a cost function where the labour and capital factors have not been distorted by new technologies.

We consider that the company i faces a linear cost function of the form:

$$CT_i = C(K,L) = \alpha_i K + \beta_i L + CF_i \quad (1)$$

We also consider that the company faces a Cobb-Douglass type production function given by:

$$q_i = q(K,L) = A_i K^{v_i} L^{s_i} \quad (2)$$

Where the variables and parameters in the cost function are:

- K and L which respectively stand for the capital and labour factors;
- CF_i represents the fixed costs born by company i;
- $A_i > 0$ is an efficiency parameter (the greater the value of A_i, the greater the quantities produced irrespective of the combination of factors);
- α_i represents the cost of capital or interest rate;
- β_i represents wages or the reward to the labour factor;
- $v_i = e_{q_i/K} = \dfrac{\dfrac{dq_i}{q_i}}{\dfrac{dK}{K}}$ represents the partial elasticity of the output relative to the input capital K;

$s_i = e_{q_i/L} = \dfrac{\dfrac{dq_i}{q_i}}{\dfrac{dL}{L}}$ represents the partial elasticity of output relative to the input labour L.

3.2.2 The Cost Function of Company i in Terms of the Quantities Produced q_i in the Absence of NICT

It is important to give the cost function in terms of the quantities produced since when we seek to maximise the profit of company i, this profit is expressed in terms of the quantity produced. To do this, we minimise the variable cost function ($CV_i = \alpha_i K + \beta_i L$) under the production cost constraint ($q_i = A_i K^{v_i} L^{s_i}$).

The Lagrangian function is: $£(K, \mathrm{L}, \lambda) = \alpha_i K + \beta_i L + \lambda(q_i - A_i K^{v_i} L^{s_i})$. The solving of the system of equations made up of the first derivatives of the Lagrangian function relative to K, L and λ yields the traditional function in the absence of NICT.

This equation is: $$CT_i(q_i) = \alpha_i\left(1+\frac{s_i}{v_i}\right)\frac{1}{\left(A_i\left(\frac{s_i\alpha_i}{v_i\beta_i}\right)^{s_i}\right)^{\left(\frac{1}{v_i+s_i}\right)}} q_i^{\left(\frac{1}{v_i+s_i}\right)} + CF_i$$

4. Analysis of the Structure of Production Costs in the Presence of

4.1 Discussion of the New Production Cost Function in the Presence of NICT

The series of examples discussed in section 2 above suppose that NICT can reasonably change the structure of production costs.

Firstly, these examples suppose that there is a fall in fixed costs in the presence of NICT. If CF_i represents the fixed costs of company i in the traditional economy i.e. in the absence of NICT and CF_i^* the fixed costs of company i in the new economy, then we can suppose that n $CF_i^* \leq CF_i$.

This inequality simply means that fixed costs are lower in a NICT environment relative to the traditional economy.

Furthermore, these same examples suppose that the variable costs in a NICT context are lower than those in a traditional economy: the levels (or quantities) of labour and capital factors required for the production of a unit of output have fallen relative to the traditional economy (that does not use NICT). We suppose that the modification of the structure (or form) of total costs can be illustrated using the following class of cost functions (Note 4): $CT_i = \alpha_i K^{u_i} + \beta_i L^{t_i} + CF_i$

By giving u_i the value 1 and t_i the value 1 ($u_i = 1$, $t_i = 1$), we obtain the simple linear cost function: $CT_i = \alpha_i K + \beta_i L + CF_i$

This is the form of the cost function we analysed in the framework of the traditional economy (that does not use NICT) in section 3.

If $u_i \neq 1$ or $t_i \neq 1$, the cost function $CT_i = \alpha_i K^{u_i} + \beta_i L^{t_i} + CF_i$ (4), undergoes a transformation of the power function form.

We suppose that the labour factor undergoes no transformation in the presence of NICT; this supposes that the method of working in the traditional economy and in the economy with NICT are the same:

this hypothesis can be considered to be unrealistic since the labour factor generally adapts itself to the nature of the capital factor; but we work under the hypothesis of «all things being equal». Following this hypothesis, we attribute to t_i the value 1 $(t_i = 1)$

In our analysis, the dominant variable is the capital factor (K). By considering the example of videoconferencing, the parent company with branches in different geographical areas can use this technique to reduce its production costs, especially its costs of displacement.

Before the arrival of NICT, these displacement costs represented a large proportion of operation costs. These costs being considered as a form of capital (K) sometimes obtained not through equity capital but through loans from a bank with a fixed interest rate.

With the coming of NICT, the number of people required to move drastically reduces, as well as the costs of displacement: this is for example a saving of resources (K) that the company is no longer obliged to borrow at a fixed interest from a bank. To incorporate this idea into our model, we transform the cost function using a coefficient u_i, which has NICT indices such that $0 < u_i \leq 1$. When u_i approaches zero, the company is using NICT intensively and u_i approaches 1, the company is using NICT less intensively.

Thus, the new total cost function in the presence of NICT becomes:

$$CT_i^* = \alpha_i K^{u_i} + \beta_i L + CF_i^* \tag{5}$$

We suppose that α_i (the cost of capital K or interest rate) and β_i (the reward for the labour factor *L*) remain unchanged: their values do not change when we go from the traditional economy to one with new technologies.

We also suppose that company faces the same Cobb-Douglass type production function:

$$q_i = A_i K^{v_i} L^{s_i} \tag{2}$$

(We once again apply the notion of "all things being equal").

The parameter u_i in equation (5) simply expresses the idea that the quantity of capital required for the production of a unit of output has fallen in the cost function in the presence of NICT. In the rest of this study, u_i is referred to as the NICT index or parameter.

4.2 The Cost Function of Company i in Terms of Quantity Produced q_i in the Presence of NICT

Company *i* is faced with the following cost function:

$CT_i^* = C(K,L) = \alpha_i K^{u_i} + \beta_i L + CF_i^*$ (5), and is subjected to the constraint given by the function $q_i = q(K,L) = A_i K^{v_i} L^{s_i}$ (2) which is of a Cobb-Douglas type.

The programme of the company (producer) i in the presence of NICT is such that:

Min $CV_i^* = \alpha_i K^{u_i} + \beta_i L$ subject to the constraint $q_i = A_i K^{v_i} L^{s_i}$

The Lagrangian is:

$£(K,L,\lambda) = \alpha_i K^{u_i} + \beta_i L + \lambda\left(q_i - A_i K^{v_i} L^{s_i}\right)$

The solution of the system of equations made up of the different partial derivatives of the Lagrangian function relative to K, L and λ yields the new cost function in terms of quantities produced, in the presence of NICT. This equation is:

$$CT_i^*(q_i)=\alpha_i\left(1+\frac{s_iu_i}{v_i}\right)\left(\frac{1}{\left(A_i^{\left(\frac{1}{v_i+s_iu_i}\right)}\left(\frac{s_i\alpha_iu_i}{v_i\beta_i}\right)^{\left(\frac{s_i}{v_i+s_iu_i}\right)}\right)}\right)^{u_i} q_i^{\left(\frac{u_i}{v_i+s_iu_i}\right)}+CF_i^* \quad (6)$$

4.3 Analysis of the Total Cost Equation of Company i in the Presence and in the Absence of NICT

The traditional cost function without NICT is:

$$CT_i(q_i)=\alpha_i\left(1+\frac{s_i}{v_i}\right)\left(\frac{1}{A_i^{\left(\frac{1}{v_i+s_i}\right)}\left(\frac{s_i\alpha_i}{v_i\beta_i}\right)^{\left(\frac{s_i}{v_i+s_i}\right)}}\right)q_i^{\left(\frac{1}{v_i+s_i}\right)}+CF_i \quad (3)$$

The cost function with NICT is:

$$CT_i^*(q_i)=\alpha_i\left(1+\frac{s_iu_i}{v_i}\right)\left(\frac{1}{\left(A_i^{\left(\frac{1}{v_i+s_iu_i}\right)}\left(\frac{s_i\alpha_iu_i}{v_i\beta_i}\right)^{\left(\frac{s_i}{v_i+s_iu_i}\right)}\right)}\right)^{u_i} q_i^{\left(\frac{u_i}{v_i+s_iu_i}\right)}+CF_i^* \quad (6)$$

Substituting $D_i=\left(1+\frac{s_i}{v_i}\right); E_i=\frac{1}{A_i^{\left(\frac{1}{v_i+s_i}\right)}\left(\frac{s_i\alpha_i}{v_i\beta_i}\right)^{\left(\frac{s_i}{v_i+s_i}\right)}}$

$$D_i^*=\left(1+\frac{s_iu_i}{v_i}\right)\ ;\ E_i^*=\left(\frac{1}{\left(A_i^{\left(\frac{1}{v_i+s_iu_i}\right)}\left(\frac{s_i\alpha_iu_i}{v_i\beta_i}\right)^{\left(\frac{s_i}{v_i+s_iu_i}\right)}\right)}\right)^{u_i}$$

The total cost functions with and without the use of NICT respectively become :

$$CT_i(q_i) = \alpha_i D_i E_i q_i^{\left(\frac{1}{v_i + s_i}\right)} + CF_i \quad (3)$$

$$CT_i^*(q_i) = \alpha_i D_i^* E_i^* q_i^{\left(\frac{u_i}{v_i + s_i u_i}\right)} + CF_i^* \quad (6)$$

Lets compare the total cost function in the absence of NICT $CT_i(q_i)$, with that with the use of NICT written $CT_i^*(q_i)$

- We have previously shown that the fixed costs in the presence of NICT are less than the fixed costs in the absence of NICT. Thus: $CF_i^* \leq CF_i$

- Lets compare D_i and D_i^*

$$D_i = \left(1 + \frac{s_i}{v_i}\right) \; ; \; D_i^* = \left(1 + \frac{s_i u_i}{v_i}\right)$$

Given that $u_i < 1$, we deduce that $\frac{s_i}{v_i} > \frac{s_i u_i}{v_i}$

We can thus conclude that $D_i^* < D_i$

- Lets now compare the expressions $q_i^{\left(\frac{1}{v_i + s_i}\right)}$ and $q_i^{\left(\frac{u_i}{v_i + s_i u_i}\right)}$ that respectivement appear in equations (3) and (6).

We have $\frac{1}{v_i + s_i} > \frac{u_i}{v_i + s_i u_i}$ since $u_i < 1$. Thus $q_i^{\left(\frac{1}{v_i + s_i}\right)} > q_i^{\left(\frac{u_i}{v_i + s_i u_i}\right)}$

$CF_i^* \leq CF_i$; $D_i^* < D_i$; and that $q_i^{\left(\frac{1}{v_i + s_i}\right)} > q_i^{\left(\frac{u_i}{v_i + s_i u_i}\right)}$

We can therefore say that $CT_i^*(q_i) < CT_i(q_i)$

The index of new technologies u_i therefore leads to a modification of the form of the cost function through:

(a) The slope of the cost function $\left(\alpha_i D_i^* E_i^* < \alpha_i D_i E_i\right)$

(b) The y-intercept at the origin represented by the fixed cost $CF_i^* \leq CF_i$

(c) The degree of the monomial q_i: $q_i^{\left(\frac{u_i}{v_i+s_iu_i}\right)} < q_i^{\left(\frac{1}{v_i+s_i}\right)}$

Note: In the rest of the study, we introduce competition between companies i and j. The analysis of the cost functions in the presence and absence of NICT is similar to that of company j. The parameters concerning company j are obtained by the replacement of index i by index j. Thus, we have:

$$D_j = \left(1+\frac{s_j}{v_j}\right);\ D_j^* = \left(1+\frac{s_ju_j}{v_j}\right);\ E_j = \frac{1}{A_j^{\left(\frac{1}{v_j+s_j}\right)}\left(\frac{s_j\alpha_j}{v_j\beta_j}\right)^{\left(\frac{s_j}{v_j+s_j}\right)}}\quad E_j^* = \left(\frac{1}{A_j^{\left(\frac{1}{v_j+s_ju_j}\right)}\left(\frac{s_j\alpha_ju_j}{v_j\beta_j}\right)^{\left(\frac{s_j}{v_j+s_ju_j}\right)}}\right)^{u_j}$$

4.4 Characteristics of the Parameters of the Cost Functions of Companies i and j

We consider companies i and j with the following characteristics (Note 5):

- Company i has the confidence of the banks (lower cost of capital), a high marginal productivity of labour, i.e. more qualified workers (high wages) and high investments in R&D (high fixed costs).

- Company j does not have the confidence of banks (high cost of capital), has a low marginal productivity of labour (Note 6), i.e. less qualified workers (low wages) and low investments in R&D (low fixed costs). We adopt the following notations:

- α_i and α_j respectively stand for the cost of capital or interest rates borne by the companies i and j.

- β_i and β_j respectively stand for the reward of the labour factor in companies i and j.

- CF_i and CF_j respectively stand for the fixed costs in companies i and j with differences mainly owing to the levels of R&D.

If $CT_i = \alpha_i K^{u_i} + \beta_i L + CF_i$ represents the total cost of company i and $CT_j = \alpha_j K^{u_j} + \beta_j L + CF_j$ that of company j, the previous hypotheses lead to the following inequalities:

- $\alpha_i < \alpha_j$: Company i has the confidence of banks meaning its cost of loans is lower than that of company j: company i has better chances of reimbursing its loan (expected profits for example being greater) from a bank relative to j.

- $\beta_i > \beta_j$: the workers of company i are more "*performing* (Note 7)" than those of company j; the workers of company i therefore have higher wages.

- $CF_i > CF_j$: We have considered that certain components of fixed costs like the rents of buildings, electricity charges, cost of furniture (office furniture and chairs), and maintainance costs are relatively the same in the two companies. We consider that R&D is higher in the company that has a higher

marginal productivity of labour (higher salaries). As a result, the fixed costs in company i are higher than the fixed costs in company j.

The parameters u_i and u_j respectively represent the NICT indices (or parameters) for companies i and j. He new technologies index reflects the idea that the quantity of capital required for the production of a unit of output is lower.

- When this parameter is close to zero, this means that this company uses NICTs more intensively.
- When this parameter is close to 1, this means that the company uses NICTs less intensively.
- When this parameter is equal to 1, we say that the company is characterised by production costs in the traditional economy. In other words, it doesn't use new technologies.
- This parameter cannot the value zero because this would mean the company doesn't use any capital following the cost function used.

To say that $u_i < u_j$, implies that company i uses more new technologies than company j.

5. Algebraic and Numeric Determination of the Bertrand Equilibrium with NICT

5.1 Algebraic Solution

The cost function of company i is: $CT_i^*(q_i) = \alpha_i D_i^* E_i^* q_i^{\left(\frac{u_i}{v_i + s_i u_i}\right)} + CF_i^*$

The cost function of company j is: $CT_j^*(q_j) = \alpha_j D_j^* E_j^* q_j^{\left(\frac{u_j}{v_j + s_j u_j}\right)} + CF_j^*$

Lets consider that the demand functions of companies i and j be given by:

$q_i = -2p_i + p_j + 12$ and $q_j = -2p_j + p_i + 12$

The variables p_i and p_j are the prices practiced by companies i and j, and the variables q_i and q_j, the corresponding quantities supplied.

What are the prices p_i and p_j charged by producers i and j and what are the profits and outcome quantities?

The profit function of company i is:

$$\prod_i = p_i q_i - CT_i^*$$

$$= p_i\left(-2p_i + p_j + 12\right) - \alpha_i D_i^* E_i^*\left(-2p_i + p_j + 12\right)^{\left(\frac{u_i}{v_i + s_i u_i}\right)} - CF_i^*$$

The reaction function of company i is:

$$\frac{\partial \prod_i}{\partial p_i} = -2p_i + p_j + 12 - 2p_i - \alpha_i D_i^* E_i^*\left(\frac{u_i}{v_i + s_i u_i}\right)\left(-2p_i + p_j + 12\right)^{\left(\frac{u_i}{v_i + s_i u_i} - 1\right)}.(-2) = 0$$

$$= -4p_i + p_j + 12 + 2\alpha_i D_i^* E_i^*\left(\frac{u_i}{v_i + s_i u_i}\right)\left(-2p_i + p_j + 12\right)^{\left(\frac{u_i}{v_i + s_i u_i} - 1\right)} = 0$$

The profit function of company j is:

$$\prod_j = p_j q_j - CT_j^*$$

$$= p_j\left(-2p_j + p_i + 12\right) - \alpha_j D_j^* E_j^* \left(-2p_j + p_i + 12\right)\left(\frac{u_j}{v_j + s_j u_j}\right) - CF_j^*$$

The reaction function of company j is:

$$\frac{\partial \prod_j}{\partial p_j} = -2p_j + p_i + 12 - 2p_j - \alpha_j D_j^* E_j^* \left(\frac{u_j}{v_j + s_j u_j}\right)\left(-2p_j + p_i + 12\right)\left(\frac{u_j}{v_j + s_j u_j} - 1\right).(-2) = 0$$

$$= -4p_j + p_i + 12 + 2\alpha_j D_j^* E_j^* \left(\frac{u_j}{v_j + s_j u_j}\right)\left(-2p_j + p_i + 12\right)\left(\frac{u_j}{v_j + s_j u_j} - 1\right) = 0$$

5.2 Numerical Solution

The seven sets of indices of NICT retained in this study are:

1) $(u_i, u_j) = (1,1)$, 2) $(u_i, u_j) = \left(1, \frac{1}{2}\right)$, 3) $(u_i, u_j) = \left(\frac{1}{2}, 1\right)$, 4) $(u_i, u_j) = \left(\frac{1}{2}, \frac{1}{2}\right)$,

5) $(u_i, u_j) = \left(\frac{1}{2}, \frac{1}{4}\right)$, 6) $(u_i, u_j) = \left(\frac{1}{2}, \frac{1}{8}\right)$ and 7) $(u_i, u_j) = \left(\frac{1}{8}, \frac{1}{8}\right)$.

We previously established the following inequalities:

$\alpha_i < \alpha_j$, $\beta_i > \beta_j$, $v_i > v_j$, $s_i < s_j$ and $CF_i > CF_j$

Let us attribute to these parameters the following values that satisfy the inequalities above:

$\alpha_i = 1$, $\alpha_j = 2$, $\beta_i = 10$, $\beta_j = 1$, $CF_i^* = CF_i = 10$, $CF_j^* = CF_j = 5$, $v_i = \frac{1}{2}$,

$v_j = \frac{3}{8}$, $s_i = \frac{1}{4}$ and $s_j = \frac{4}{8}$

Here, we carry out a numerical resolution for a given set of indices if new technologies. The other solutions are obtained by simply varying the values of the u_i and u_j. Thus:

$(u_i, u_j) = (1,1)$**: No company uses NICT**

$D_i^* = \frac{3}{2}$; $D_j^* = \frac{7}{3}$; $E_i^* = 20^{1/3}$; $E_j^* = \left(\frac{3}{8}\right)^{4/7}$; $\alpha_i = 1$; $\alpha_j = 2$; $v_i = \frac{1}{2}$;

$v_j = \frac{3}{8}$; $s_i = \frac{1}{4}$; $s_j = \frac{4}{8}$.

The reaction function of company i becomes:

$$-4p_i + p_j + 12 + 2(1).\frac{3}{2}.(20)^{1/3}\left(\frac{1}{\frac{1}{2}+\frac{1}{4}(1)}\right)\left(-2p_i + p_j + 12\right)^{\frac{1}{0,5+0,25}-1} = 0$$

$$\Leftrightarrow -4p_i + p_j + 12 + 3.(20)^{1/3}.\frac{4}{3}.\left(-2p_i + p_j + 12\right)^{1/3} = 0$$

$$\Leftrightarrow -4p_i + p_j + 12 + 4.(20)^{1/3}.\left(-2p_i + p_j + 12\right)^{1/3} = 0$$

The reaction function of company j becomes:

$$-4p_j + p_i + 12 + 2(2).\frac{7}{3}.\left(\frac{3}{8}\right)^{4/7}\left(\frac{1}{\frac{3}{8}+\frac{4}{8}}\right)\left(-2p_j + p_i + 12\right)^{\frac{1}{3/8+4/8}-1} = 0$$

$$\Leftrightarrow -4p_j + p_i + 12 + \frac{28}{3}.\left(\frac{3}{8}\right)^{4/7}.\frac{8}{7}.\left(-2p_i + p_j + 12\right)^{1/7} = 0$$

$$\Leftrightarrow -4p_j + p_i + 12 + \frac{32}{3}.\left(\frac{3}{8}\right)^{4/7}.\left(-2p_i + p_j + 12\right)^{1/7} = 0$$

The Bertrand solution is obtained by solving the system of equations given by the reaction function:

$$\begin{cases} -4p_i + p_j + 12 + 4.(20)^{1/3}.\left(-2p_i + p_j + 12\right)^{1/3} = 0 \\ -4p_j + p_i + 12 + \frac{32}{3}.\left(\frac{3}{8}\right)^{4/7}.\left(-2p_j + p_i + 12\right)^{1/7} = 0 \end{cases}$$

Which is the price couple: $(p_i, p_j) = (8{,}368\ ;\ 7{,}069)$

Which yields the quantity couple (Note 8): $(q_i, q_j) = (2{,}333\ ;\ 6{,}230)$ and the profit couple: $(\Pi_i, \Pi_j) = (-3{,}076\ ;\ 17{,}483)$

6. Effects of NICT in the Presence of Minimum or Perfect Information

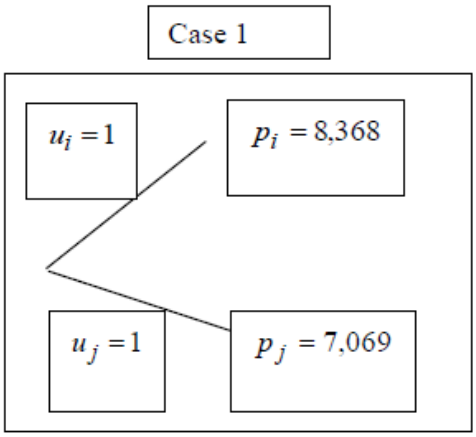
We obtain four effects (positive effect, negative effect, neutral effect, saturation effect):

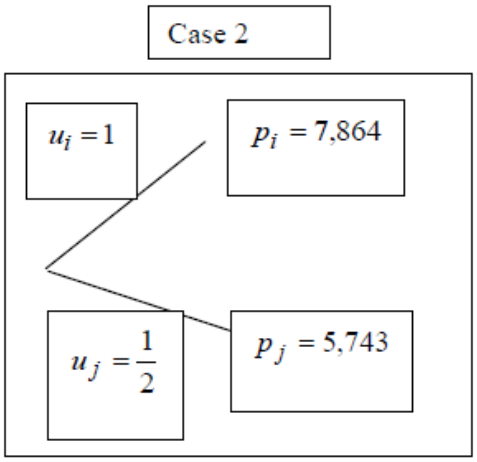
6.1 Positive or Negative Effect of NICT on the Competitiveness of the Company

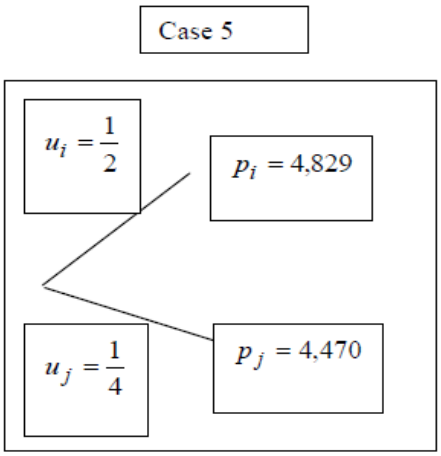
In the presence of minimum information (no competitor knows the reaction function of the other), the use of NICT has a beneficial effect for the company using it more intensively relative to the competitor since its price is lower.

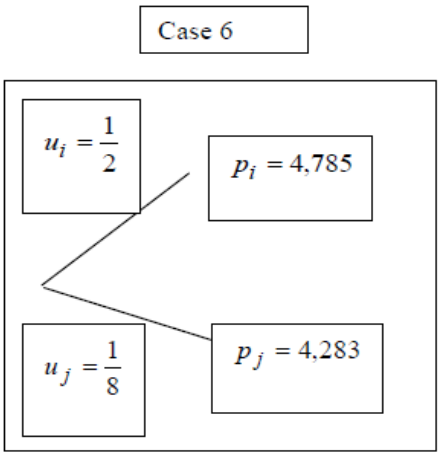
Conversely, the effect is negative for the company using less NICT relative to its competitor and thus a higher price.

These cases are presented below (Note 9):

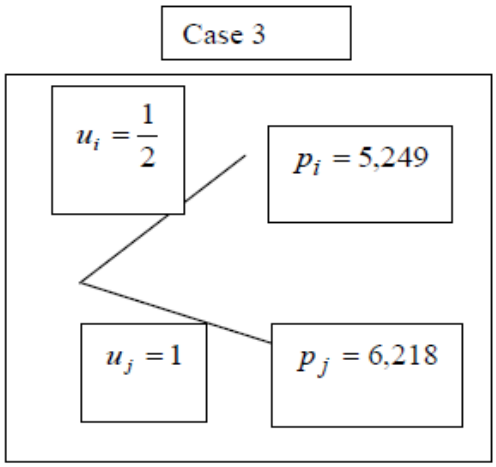








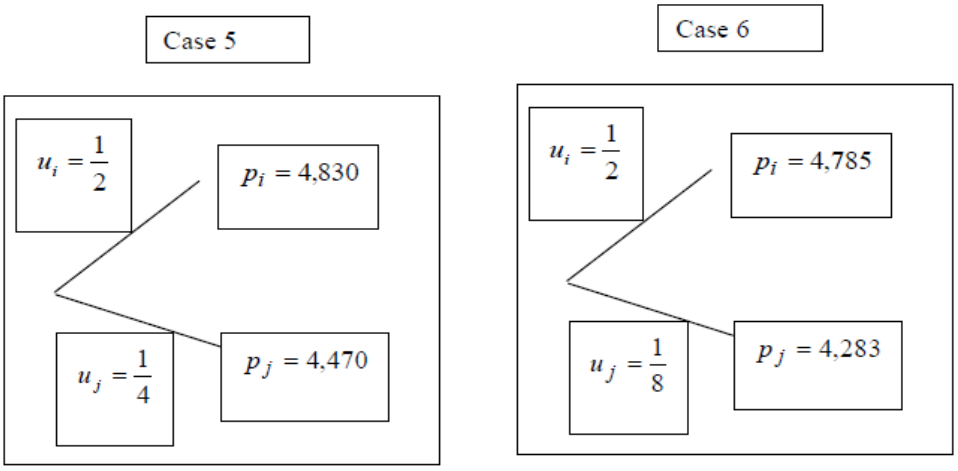
However, in case 3, the effect is beneficial for company i:



6.2 Saturation Effect of NICT on the Competitiveness of a Company

When one of the companies engages into the intensive use of NICT (company j), in the case of minimum information, we find that its price evolves less than proportionally to the increase in new

technologies : This is the movement to case 5 having as couple of NICT indices, $(u_i, u_j) = \left(\frac{1}{2}, \frac{1}{4}\right)$ corresponding to the price couple $(p_i, p_j) = (4{,}830;\ 4{,}470)$, *to* case 6 having as couple of NICT indices, $(u_i, u_j) = \left(\frac{1}{2}, \frac{1}{8}\right)$ corresponding to the couple of prices $(p_i, p_j) = (4{,}785; 4{,}283)$. These cases are represented as follows:



The saturation effects are calculated in the table below which presents the evolution of the price of company j at the Bertrand equilibrium in terms of the NICT index u_j, for a given value $\bar{u}_i = \frac{1}{2}$. In this study, we are going to consider the marginal productivity of capital, written $\frac{\Delta p_j}{\Delta K^{u_j}}$ as equal to $\frac{\Delta p_j}{\Delta u_j}$ since $u_j^1 > u_j^2 \Rightarrow K^{u_j^1} > K^{u_j^2}$. Although as the quantity of capital increases, the absolute value of the expression $K^{u_j^1} - K^{u_j^2}$, will be greater than that of $u_j^1 - u_j^2$, what is important here, regardless of these possible differences is to know if the price increases or reduces, i.e. if productivity is positive or negative. In this model, when it is positive, this would imply that productivity increases and when it is negative, this would imply that productivity reduces.

Table 1. Evolution of the Price of Company j at the Bertrand Equilibrium in Terms of the NICT Index u_j for $\bar{u}_i = \frac{1}{2}$

Variation in the index of new technologies u_j of company j for a given value $\bar{u}_i = \frac{1}{2}$ of company i	Variation in price p_j by company j at the Cournot Nash equilibrium	Rate of change of price p_j relative to the NICT index u_j : $\frac{\Delta p_j}{\Delta u_j} = \frac{p_j^2 - p_j^1}{u_j^2 - u_j^1}$	Rate of change of the slope $\frac{\Delta p_j}{\Delta u_j}$ relative to the NICT index u_j : $\frac{\Delta\left(\frac{\Delta p_j}{\Delta u_j}\right)}{\Delta u_j} = \frac{\Delta^2 p_j}{\Delta (u_j)^2}$
$u_j = 1$	$p_j \approx 6{,}218$	-	-
$u_j = \frac{1}{2}$	$p_j \approx 5{,}051$	2,334	-
$u_j = \frac{1}{4}$	$p_j \approx 4{,}470$	2,324	0,04
$u_j = \frac{1}{8}$	$p_j \approx 4{,}283$	1,496	6,624

Table 2. Evolution of the Profit of Company j at the Bertrand Equilibrium in Terms of the NICT Index u_j for $\bar{u}_i = \frac{1}{2}$

Variation in the index of new technologies u_j of company j for a given value $\bar{u}_i = \frac{1}{2}$ of company i	Variation in profit $\prod_j$ by company j at the Cournot Nash equilibrium	Rate of change of profit $\prod_j$ relative to the NICT index u_j : $\frac{\Delta \prod_j}{\Delta u_j} = \frac{\prod_j^2 - \prod_j^1}{u_j^2 - u_j^1}$	Rate of change of the slope $\frac{\Delta \prod_j}{\Delta u_j}$ relative to the NICT index u_j : $\frac{\Delta\left(\frac{\Delta \prod_j}{\Delta u_j}\right)}{\Delta u_j} = \frac{\Delta^2 \prod_j}{\Delta (u_j)^2}$
$u_j = 1$	$\prod_j \approx 8{;}870$	-	-
$u_j = \frac{1}{2}$	$\prod_j \approx 15{,}808$	- 13,876	-

$u_j = \frac{1}{4}$	$\prod_j \approx 21{,}979$	- 24,684	43,232
$u_j = \frac{1}{8}$	$\prod_j \approx 25{,}219$	- 25,920	9,888

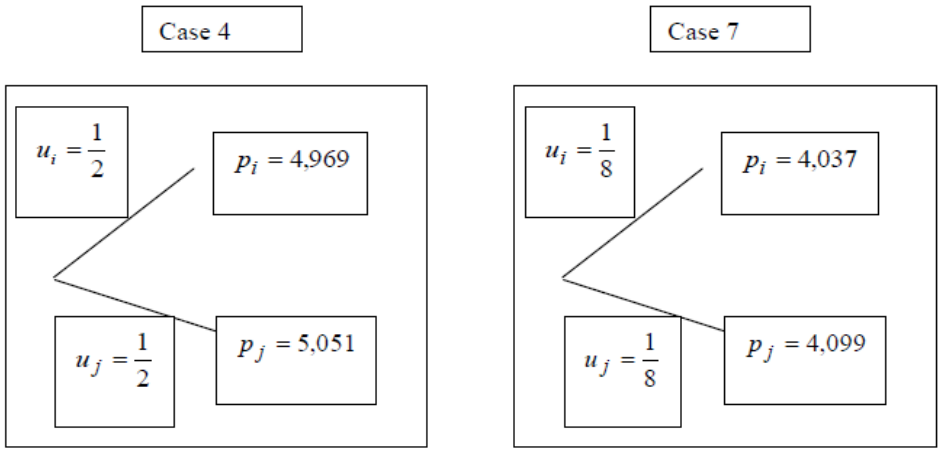
Table 1 shows that the more company *j* uses ICT, the more his practiced price is low, and this drop is done at a decreasing rate as revealed by the third column of this table.

Table 2 on the other hand, shows that the more company *j* uses ICT, the more its profit is high and this rise is done at a decreasing rate.

The different equilibriums obtained in a situation of minimum information show that the Solow paradox is not verified since the use of new technologies is accompanied by an increase in productivity which takes place at a decreasing rate. This shows that productivity increases at a slower rate.

6.3 Neutral Effects of NICT on the Competitiveness of Companies

Remaining in the situation of minimum information, when both companies engage in a technological race, i.e. in the intensive use of new technologies, we find that the effect on competitiveness is null or neutral since no company benefits. The prices of both companies remain the same (Cases 4 and 7):



Case 4 corresponds to the couple of indices $(u_i, u_j) = \left(\frac{1}{2}, \frac{1}{2}\right)$ having as corresponding couple of prices $(p_i, p_j) = (4{,}969\ ;\ 5{,}051)$. Case 7 corresponds to the couple of indices $(u_i, u_j) = \left(\frac{1}{8}, \frac{1}{8}\right)$ having as corresponding couple of prices $(p_i, p_j) = (4{,}037\ ;\ 4{,}099)$.

Table 3. Summary of the Main Results

(u_i, u_j)	(p_i, p_j)	(q_i, q_j)	(Π_i, Π_j)
Case 1 : (1 ; 1)	(8,368 ; 7,069)	(2,333 ; 6,230)	(-3,076 ; 17,483)
Case 2 : $\left(1; \frac{1}{2}\right)$	(7,864 ; 5,743)	(2,015 ; 8,378)	(-4,517 ; 26,844)
Case 3 : $\left(\frac{1}{2}; 1\right)$	(5,249 ; 6,218)	(7,720 ; 4,813)	(17,113 ; 8,870)
Case 4 : $\left(\frac{1}{2}; \frac{1}{2}\right)$	(4,969 ; 5,051)	(7,113 ; 6,867)	(12,785 ; 15,808)
Case 5 : $\left(\frac{1}{2}; \frac{1}{4}\right)$	(4,830 ; 4,470)	(6,810 ; 7,890)	(10,763 ; 21,979)
Case 6 : $\left(\frac{1}{2}; \frac{1}{8}\right)$	(4,785 ; 4,283)	(6,713 ; 8,219)	(10,131 ; 25,219)
Case 7 : $\left(\frac{1}{8}; \frac{1}{8}\right)$	(4,037 ; 4,099)	(8,025 ; 7,839)	(21,616 ; 22,216)

Result1: when the two companies do not use ICT (case 1), company *j* of the south region (developing country) wins over its counterpart *i* of north region (developed country) for its price is lower($p_j \prec p_i$), its market share and its profit are higher: ($q_j \succ q_i$) and ($\prod_j \succ \prod_i$). This situation is due to special advantageous characteristics for company *j*, notably the lower fixed costs ($CF_j \prec CF_i$), lower salaries ($\beta_j \prec \beta_i$), the elasticity of the product compared to capital is lower ($v_j \prec v_i$).

Result 2: When they two use them at the same proportion (case 4 and case 7), none of them seems to have an upper hand; prices and market shares being nearly identical. The profit of company *j* seems higher compare to company *i* simply due to special advantageous characteristics for company *j*. In this case, we will say that the impact is neutral.

Result 3: The impact is positive for company *j* which uses more new technologies compare to its opponent *i* (case 2, 5, and 6)

Result 4: The impact is negative for company *j* which uses less ICT compare to its opponent *i (case 3)*

Result 5: When there fix the level of ICT utilization of companies, notably company i

($\bar{u}_i = \frac{1}{2}$), by varying the level of ICT utilization of the opponent company *j* , in the sense of a more pronounced utilization , we observe an impact of congestion. This justifies the drop of practiced price at a decreasing rate and rise of profit at a decreasing rate.

7. Conclusion

In this study, we evaluate the effects of new technologies on the competitiveness of companies in a competitive environment. We find four main effects in the situation of minimum information:

a) *When a competitor does not know the reaction function of the other, the use of new technologies benefits the company that uses it more intensively than its competitor since its price is lower.*

b) *When both companies engage in a technological race, i.e. in an intensive use of new technologies, the effect on the competitiveness of companies is null since no company benefits and the prices remain identical.*

c) *The results obtained show that the intensive use (unilateral or not) of new technologies beyond a given threshold does not improve the competitiveness of the firm, a likely reason for this being a saturation effect.*

This unexpected negative effect of NICT (or saturation effect) raises the question of the optimal level of new technologies for a company in a competitive environment. This question will be addressed in a future study.

The last column of Table 2 shows that profit will be maximum if only $\frac{\Delta^2 \prod_j}{\Delta(u_j)^2} \prec 0$

The search of the point of inflection will allows us to find the threshold of utilization of new technologies. This question will be addressed in a subsequent study.

The results obtained in this study are closely related to the assumptions made: The idea that NICT affects only the capital factor in the cost function and not the labour factor. In our future studies, we will assume that it affects the labour factor and analyse how the intensive use of NICT affects and modifies the competitiveness of firms in a competitive environment.

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Notes

Note 1. Réseaux, (2003) : Les NTIC en petites entreprises, vol 21 (212).

Note 2. Régis Arthaut (2006), «La consommation des ménages en TIC depuis 45 ans : un renouvellement permanent», division synthèse des biens et services, Insee, n °1101.

Note 3. There exists a production cost referred to as opportunity cost which represents the best alternative forgone by allocating resources elsewhere.

Note 4. Note that there are other classes of cost functions different from that in (4).

Note 5. An example of two companies that meet these characteristics: A company based in the North of the country (developed country) and the other in the south (developing country). The company in the north will have the confidence of banks, a high marginal productivity of labour, and higher investments in R&D relative to the company in the south that is feared by banks, has a lower marginal productivity of labour and a low level of investments in R&D. We could have considered the case where the companies have the same characteristics but, it is not an interesting framework in the case of minimum information given that the market shares will be equal.

Note 6. We make the assumption that wages are low because the marginal productivity of labour is low. But it could happen that the marginal productivity of labour is high but wages remain low due to the lack of bargaining power of workers associations during the setting of wages.

Note 7. Workers can be of equal performance but recieve different wages due to differences in the bargaining powers of professional organisations during the negosiation of wages.

Note 8. The couple of quantities is obtained by substituting p_i and p_i in the demand functions of the two companies mentioned earlier. The resolution of the system of equations is obtained using the software Matlab.

Note 9. Among these cases, we insert the case where no company uses NICT. We find that it is company j that benefits since its price is lower and its production cost lower than that of company i.