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New Information and Communication Technologies and the Competitiveness of Companies within the Framework of a Cournot duopoly

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Abstract

We evaluate the effects of New Information and Communication Technologies (NICTs) on the competitiveness of enterprises in a competitive environment, using a restricted Cournot duopoly model where two companies scramble for market shares. We consider two situations: a minimal information competition and an asymmetric information competition. The potential effects of NICTs on the competitiveness of an enterprise are varied: they could be positive, negative, neutral, or without importance beyond a certain level of usage. NICTs prove to be a necessary factor in the improvement of the competitiveness of an enterprise, but it cannot be considered sufficient. This analysis put to evidence the Solow Paradox that '*one sees the computer age everywhere except in productivity statistics*'.Other than the endogeneity of technological progress and flexibility between capital and labour, this study provides another explanation of the Solow Paradox,that is, information *asymmetry*.

Keywords: Cost of Production, Follower, Index of New Technologies, Leader, Productivity

1. Introduction

We try to define the concept of new economy which refers to an economy where information plays a dominant role (Mucchielli, 2006). According to Bosserelle (1994), one of the main innovations was the steam engine during first half of the XIX^{th}century; the railway during second half of theXIX^{th}century; the car, chemical and electrical industries during first half of thexx^{th} century; the rise and decline of fordism, i.e. of a major innovation in the techniques of mass production (gains in productivity) during second half of XX^{th}century. After the invention of writing, followed by the advent of the printing press, the orientation towards a society based on information was marked by the electric telegraph, the telephone and radio communications. At the same time, television and the Internet associated images, text voice while also becoming accessible on the mobile telephone that also plays the role of camera (Arthaut, 2006).

Information and Communication Technologies (ICTs), also known as New Information and Communications Technologies (NICTs) refer to all the techniques used in the treatment and transmission of information, particularly computer science, the Internet and telecommunications (Réseaux, 2003). Between the years 1974 and 1975, the common word was «information technologies» (and not technologies of information). This period is marked by a debate on «the computerisation of the society» requested by former French president Giscard d'Estaing. In the years 1980, this concept is found under the name «technologies information» or «technologies of communication», often associated to a particular use, especially education (Brousseau and Rallet, 1997).

It is as from the 1990s that this concept adopted the meaning retained in this paper; it takes the form of «New Information and Communications Technologies», «Information and Communication Technologies», «New Information Technologies», etc. (Gadrey, 2000).

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NICT generally refer to the set of the instruments which favour the treatment, diffusion of information and the spread of knowledge. Computers and programs play a crucial role in the conversion, storage and management of this information (Le Goff, Dang Nguyen; 2000). The variation of initials (NICT, NIT, ICT) is a proof that its semantics remains unclear. From this evolution, we retain that the association of the terms «technology» and «information» is far from recent given that communication makes use of the voice, gestures, writing, etc. The application of ICTs to these functions requires the use of the telegraph, telephone, radio, television, and books. This is what could contradict the «N» in NICT. On the other hand, this concept can be closely linked to computer science which is strictly defined as the automatic treatment of information. However, the logic of computer science is above all in the treatment of certain logical functions like calculations for example. The calculator which is the ancestor of the computer cannot really be regarded as a form of data processing. The computer, the digitalisation of data and electronics constitute the basis of the near total of NICTs; this is what justifies the «N» of NICTs given that these applications are recent. Consequently, it is not easy to give a strict definition of NICT.

The miniaturisation of the components making it possible to produce «multifunctional» machines at affordable prices has been made possible thanks to the bringing together of computer science and telecommunications in the last decade of the XXth century (*Gollac., Greenan and Hamon–Cholet, 2000)*. In companies and administrations, communication was done by the means of paper before computerisation. All information was transmitted by writing through the use of informative newspapers and often remained confined in the services concerned. When this information became targeted, the use of notice boards and information mails were common, the various units being closed on them. It is important to highlight that the development of the means of mass communication like television, radio, press, and cinema made it possible to establish a close communication with users. The digitalization of signals makes it possible to constitute a technological base of data for the development of exchange transiting through the interface of screens of microcomputers. All this information can be stored in the form of codes using a multi-media disc. This possibility of being able to store information of various nature (written, sound and fixed or animated image) starts a social revolution insofar as information becomes accessible to all henceforth (*Gadrey, Zarifian, 2002)*. Internet network created in 1969 by American soldiers allows a user with a computer equipped with a modem to communicate with correspondents at any point of the world. After the soldiers, the scientific community adopted this network.

New Information and Communications Technologies are largely used in companies, although unequally according to their size.[3] In 1987, computer science was used by 26 % of employees (Gollac, 1989). This proportion increased to 39 % in 1993, then to 51% in 1998 (Cézard and Vinck, 1998). In 1997, all industrial companies in France, having more than 50 employees were already using computer science (Gollac, Greenan and Hamon-Cholet, 2000). At the beginning of the year 2000, 80% of industrial companies with more than 20 paid employees used microcomputers connected in networks, as against 63% in 1997 and 32% in 1994. Moreover, 75% of these companies use numerical lines, 90% are equipped with mobile telephones and two thirds use the Internet. 69% of companies with over 500 employees use integrated management software packages allowing human resource management, financial management, accounting management, sales, distribution, supplies and electronic trade (Feuvrier and Heitzman, 2000). The price of microcomputers witnessed a progressive fall in recent years.[4] As an example, the super computer of brand CRAY 1, designed to perform 100 million instructions per second was sold at 60 million francs at the beginning of the 1980s, and required additional costs (large engine room, air-conditioning equipments, etc). In 1996, a microcomputer of this power based on Pentium 100 costs 6000 times less than the CRAY 1. At the level of the information system, we witness a rise of the productivity of labour for the typing of information. The delocalisation of production comes to reinforce this idea of reduction of 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 company and personnel management, there is less hierarchy in the organisation; the management of human resources is optimal: recruitment and management of careers is easier (*Léo and Philippe, 2000)*.
At the commercial level, the extension of the potential market (electronic trade) leads to a fall of the costs of provisioning and improves the public image of the company (*Goff, Dang Nguyen, 2000)*.

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[3] Reseaux (2003): Les NTIC en petites entreprises, vol 21 (212)

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

Asymmetrical information will make it possible to distinguish two types of agents: an agent having information on its competitor called leader, and an agent not having information on its competitor called follower (Krugman P. and Wells R., 2009). We will particularly find that in a competitive environment, the use of new technologies is not beneficial for the company whose reaction function is known, whatever its level of utilization of the factor NICT (whether it uses it more or less than the leader). If information is asymmetrical and the level of production of the follower decreases substantially, the productivity of the follower (loser) company, when it uses new technologies can either improve in spite of the fall of its output, or worsen. It will appear in this study that the production and productivity of a company decreases when it is follower, whereas it increasingly uses new technologies: this is to some extent the manifestation of the Solow paradox. Robert Solow, an American economist and Nobel Prize laureate of economics in 1987 finds that an increasing use of new technologies in the economy does not automatically lead to an increase in productivity contrarily to what we would have thought.[5]This finding leads to what is called the Solow paradox. This paradox is often formulated as follows: «*You can see the computer age everywhere except in the productivity statistics*».

Many empirical[6] studies (econometric models) on the economy of the United States of America have attempted to bring answers to the Solow paradox. Some of these empirical studies are based on the comparison between the French and American economies in order to check the validity or not of this paradox (Gilles F. and L'Horty, 2003). In France, it is found that the labour productivity for the period going from 1990 to 1995 (with more use of new technologies), is lower compared to the period going from 1974 to 1989: This clearly shows the manifestation of the Solow paradox (Greenan N., Mairesse J., 2000).

In the United States, since 1995 (with an increased use of new technologies), productivity is greater compared to the period preceding the year 1995. This show that this paradox is no longer verified in the United States. However, many studies relating to the period of before 1995 do not find any significant correlation between the use of new technologies and productivity (Brynjolfsson, E and Saunders, Adam, 2009). Generally, two reasons are advanced to explain the Solow paradox. The first reason is the endogeneity of technical progress: it is supposed that new technologies take time to become effective. In other words, time is necessary for new technologies to have an impact on productivity. The second reason is related to the relationship which exists between new technologies and the organisation of production. One needs for example, a strong flexibility of the labour and capital factors to efficiently face the fluctuations of demand on the market. These two reasons, according to many authors explain the Solow paradox which, once more, conveys the idea that an intensive use of new technologies is not accompanied by an increase in productivity.

Our approach is very different: it is of a microeconomic nature where we put in competition two companies that use new technologies differently. It is within this framework of analysis that we try to understand the reasons for which the use of new technologies could not be accompanied by an improvement in competitiveness, i.e. by an increase in the market share, profits and productivity. The question of the impact of NICTs on the performance of companies will lead us on the one hand, to determine the conditions under which NICTs could be a source of improvement of the competitiveness of companies, and this question will make it possible, on the other hand, to bring another explanation to the Solow paradox; this other explanation being, in this study, the knowledge of the reaction function of a company by its competitor.

2. Impact of NICTs on the structure (or form) of the total cost function: an illustration of the impact of NICTs on variable and fixed costs through a series of examples

2.1. The portable computer

The portable computer today plays a multitude of functions and this, in an increasingly faster way compared to the old generations of machines.

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[5]Productivity is defined as the relationship between the volume (or the value) of production and the quantity of factors (capital, labour, etc). The total productivity of factors is defined as a weighted average of the indices of productivity.

[6]A review of studies on the American economy can be found in Brynjolfsson and Yang (1996); and a review of studies on the French economy in Greenan and Mairesse (1999).

A new machine is equivalent to two (or even more) old machines in term of usage of time; one spends less time than previously and we consider this as a fall of the quantity of capital (and thus a drop in variable cost).

2.2. Electronic commerce

Electronic commerce, unlike traditional commerce leads to lower variable and fixed costs of production. The acquisition of a commercial counter on the internet will cost less than that of a traditional commercial counter: the existence of «walls», salesmen or women not being necessary in electronic commerce. The «walls» here refer to the buildings and expenses related to the maintenance of these buildings. These are fixed costs and they are significantly lower in the case of electronic trade.

2.3. Electronic messaging and the exchange of files (ftp).

Electronic messaging on the global scale, commonly called e-mail makes it possible for subscribers to communicate internally and externally at a low variable cost: a user in Douala pays the same price to send an e-mail to Yaoundé or Paris, whether the receivers are associates, employees, customers, etc. The electronic mail now presents itself as a complement to the fax in companies while being an economic mode of communication. The Internet also allows the transfer of files (ftp: file transport protocol) whose electronic volume is important. This allows for example a team geographically dispersed to meet and work by sending documents on any support (written, sound or video): This is the principle of virtual offices. Once more, in the case of NICTs, the fixed costs (virtual offices) are almost null compared to the traditional economy with high fixed costs (real offices).

2.4. Videoconference

Videoconferencing comprises of two techniques: the first being the videophony which allows seeing and dialoguing with the interlocutor and the videoconferencing which allows meetings with several people (terminals). There are several applications of the videoconferencing such as educational television (remote training that allows the reduction of the costs of training students), the telemedicine which enables medical experts to exchange information and render health services remotely and thus reduce the cost of health services.

2.5. The internet, advertising and marketing.

2.5.1. The internet and advertising

Rather than paying pages of publicity spots or send prospection files to its potential customers, the company sends them computerised messages which are relatively less expensive. If we consider that the more advertising is done, the greater the sale of the produced quantities, then the publicity expenditure is avariable cost. We thus witness a fall in variable costs (from the point of view of the factor capital).

2.5.2. The internet and marketing

Today, the main factor that determines success is no longer the size of the company, but its reaction speed. The production cycles are continuously being shortened in order to meet the needs of the market. In fact, there are the companies that will be able to benefit from this new era that will be more performing on the market. The internet allows the company to have a commercial presence on the world market and its use (the internet) is the key of the development of the company, if not its survival. In fact, the internet offers companies the means of selling and promoting their products in a globally and develop their market without having to support significant commercial costs (these various costs are cited above). Moreover, the internet offers companies the means of acquiring information necessary for the management of their business in an unlimited manner. Technical, economic and commercial information is available free and many companies start to reduce their research expenditure, which are regarded here as fixed costs. In the light of these examples, we note that the quantity of capital required for the production of an additional unit of output has dropped, compared to the traditional economy i.e. the economy that does not integrate NICTs. Consequently, the new technologies mentioned above contribute to reduce production costs for all types of companies operating in any branch of industry (primary, secondary or tertiary).

3. Analysis of the traditional structure of production costs of the company

In this section, we present the traditional structure (where the labour and capital factors are not distorted because of the effect of new technologies) of the production costs of the company following the capital and labour factors on the one hand, and the expression of the function of the cost of production in terms of the quantities supplied by the company, on the other hand.

3.1. Production costs of the company in the traditional economy

3.1.1. Production costs in general

In a general manner, when a company plans to put on the market a given level of output, it makes an inventory of the various combinations of factors which will enable it to reach this level of output. In doing this, it tries to find the least expensive combination (objective of maximisation of profit for example) when the prices of these factors are given. The company generally has several factors of production of which two are very often retained in the study of its performance index:[7]capital and labour. When a company decides to simultaneously change all its factors in the quest for a given output, we talk of a change in production costs in the long run. On the other hand, when at least one of the factors is fixed, we talk of short run production costs. In the framework of this study, we do a short run analysis where only the factors labour and capital are taken into account.

3. 1. 2. Some characteristics of the production costs in the traditional economy

The fixed costs of production are generally high, contrary to the new economy where the internet contributes to reduce production costs (which we analyze in section 3). It should also be noted that in the traditional economy, to produce a certain quantity of wheat for example, four tractors were required whereas in the new economy, to produce the same quantity requires far less. The mobility of factors is less, the diffusion of information slower; the network of customers is restricted compared to that of the new economy, etc.

3.2. The cost function of company i in the absence of NICTs

3.2.1. The traditional cost function and the production function

By traditional cost function, we mean a cost function where the labour and capital factors are not deformed by the effect of new technologies. Consider a given company i that is faced with a linear cost function of the form:

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

Supposing that this company is subjected to the constraint of a Cobb-Douglas type production function:

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

The variables and parameters intervening in the production and costfunctions are:

- K and L representing the factors capital and labour respectively;
- CF_i represents the fixed costs supported by the company i
- $A_i > 0$ is a parameter of efficiency (the higher A_i is, the more the produced quantities are higher and this whatever the combination of factors);
- α_i the represents the cost of capital or the interest rate;
- β_i represents wages or the income of the labour factor;
- $v_i = e_{q_i/K} = \dfrac{\frac{dq_i}{q_i}}{\frac{dK}{K}}$ represents the partial elasticity of the product (of the output) relative to the factor capital or the input K.

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[7] There is a production cost known as opportunity cost which represents the best output lost up by allocating resources otherwise

- $s_i = e_{q_i/L} = \dfrac{\frac{dq_i}{q_i}}{\frac{dL}{L}}$ represents the partial elasticity of the product (of the output) relative to the factor labour or the input L.

3.2.2. The cost function of company i relative to the quantities produced q_i in the absence of NICTs

It is useful to give the expression of the cost function as a function of the produced quantities, given that when we seek to maximize the profit of the company i, this profit has as explanatory variable the quantity produced. To do this, we minimize the variable cost ($CV_i = \alpha_i K + \beta_i L$) under the constraint of the production function ($q_i = A_i K^{v_i} L^{s_i}$). Let us form the Lagrangian:£$(K, L, \lambda) = \alpha_i K + \beta_i L + \lambda(q_i - A_i K^{v_i} L^{s_i})$The resolution of the system of equations containing the different partial derivatives of the Lagrangian relative to K, L and λ gives the traditional cost function in the absence of NICTs.

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

4. Analysis of the structure of production costs in the presence of new technologies.

4.1. Discussions on the new cost function in the presence of NICTs

The series of examples presented in paragraph 1 above supposes that NICTs can appreciably offset the structure of production costs. On the one hand, these examples suppose that wewitness a fall in fixed costs in the presence of NICTs. If CF_i denotes 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 $CF_i^* \leq CF_i$. This inequality simply means that fixed costs are lower in a context of NICT compared to the traditional economy.

In addition, these same examples suppose that the variable costs in a context of NICT are less than the variable cost in a traditional economy: the levels (or quantities) of the factors capital and labour required for the production of a unit of output has dropped compared to the traditional economy (not taking into account NICTs). It is supposed that the modification of the structure (or form) of total costs consists in considering the following class of cost functions[8] : $CT_i = \alpha_i K^{u_i} + \beta_i L^{t_i} + CF_i$ By attributing the value 1 to u_i and t_i ($t_i = 1$ $u_i = 1$), we obtain the simple linear cost function, i.e.: $CT_i = \alpha_i K + \beta_i L + CF_i$

It is this form of cost function which we analysed within the framework of the traditional economy (not taking into account NICTs) in the previous paragraph. If $u_i \neq 1$or $t_i \neq 1$, the cost function (4) undergoes a transformation of the power type. We consider that the factor labour does not undergo any transformation in the presence of NICT.This means that the way of working in the traditional economy and the economy with NICT is the same: this hypothesis can to a certain extent seem a strong hypothesis given that labourmust adapt in theory to the new form of capital, but as we said, we also work following the assumption of «all things being equal».

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8 Note that there can exist a class of costfunctions other than that which we have chosen to name.

We suppose that t_i is equal to 1. In our analysis, the dominating variable is capital (K). Going back to the example of videoconferencing, the company with branches positioned in different geographical areas can use this technique to reduce its production costs in the form of costs of displacement. Before NICTs, these costs of displacement represent a significant share in its administrative expenditures. This expenditure is regarded as capital (K) obtained not with personal funds, but through a loan from a bank practicing a given interest rate. With NICT, the number of people required to move is in a clear reduction and consequently, the related expenditure: this is for example a saving of resources (K) which the company is no more obliged to borrow from a bank at a fixed interest rate. To model this idea, we deform the cost function using the coefficient u_i which represents the index of NICT such that $0 < u_i \leq 1$. When u_i tends towards zero, it is said that the company uses NICT more intensively and when u_i tends towards one, we say that the company uses NICT less intensively. Thus the new total cost function of the company i in the presence of NICT becomes:

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

We also suppose that α_i (the cost of capital K or the interest rate) and β_i (income of the labour factor L) do not witness any change; their values do not change when we go from the traditional economy to the economy with new technologies.

We also consider that the company i is always confronted with the same Cobb-Douglass type production function:

$$q_i = A_i K^{v_i} L^{s_i} \qquad (2)$$

The parameter u_i in equation (5) expresses the simple idea that the quantity of capital required for the production of a unit of output dropped in the cost function in the presence of NICTs. In the rest of the document, we refer to u_i as the index or parameter of NICTs.

4.2. The cost function of company i as function ofthe quantities produced q_i in the presence of NICT.

The 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 it is subjected to the constraint $q_i = q(K,L) = A_i K^{v_i} L^{s_i}$ (2) which isof a Cobb-Douglas type.

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

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

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

The resolution of the system of equations made up of the different partial derivatives of the Lagrangian with respect to K, L and λ gives the new cost function in the presence of NICTs as a function of the produced quantities i.e:

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

4.3. Examination of the equation of the total cost of company i in the presence and absence of NICTs.

The traditional cost function without taking into account 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 that takes into account NICT is:

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

Given that

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

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

The total costs without and with new information and communication technologies respectively become:

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

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

Let us compare the total cost in absence of NICT written $CT_i(q_i)$, and the total cost in the presence of NICT written $CT_i^*(q_i)$

- We previously showed that the fixed costs in the presence of NICT were lower than the fixed costs in the absence of NICT. i.e: $CF_i^* \leq CF_i$

- Let us compare D_i and D_i^*

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

We supposed that $u_i < 1$, this implies $\frac{s_i}{v_i} > \frac{s_i u_i}{v_i}$

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

- Let us now compare the expressions $q_i^{\left(\frac{1}{v_i+s_i}\right)}$ and $q_i^{\left(\frac{u_i}{v_i+s_i u_i}\right)}$ appearing respectively in equations (3) and (6).

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

$CF_i^* \le CF_i$ and $D_i^* < D_i$ 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 say that $CT_i^*(q_i) < CT_i(q_i)$

The index of new technologies u_i thus leads to a formal modification of the total cost function through:

(a) The slope of the cost function

(b) The cost at the origin represented here by the fixed cost

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

<u>Note</u>: Afterwards, we introduce competition between the companies i and j. The examination of the cost equations in the presence and absence of NICTs is similar to that of the company j. The parameters concerning company are obtained by inversion (replacement) of the index by the index . Thus, we obtain:

$$D_j = \left(1+\frac{s_j}{v_j}\right) \quad D_j^* = \left(1+\frac{s_j u_j}{v_j}\right)$$

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

5. The duopoly model

We consider two companies i and j in a Cournot duopoly situation[9]. We suppose that the consumers have a demand function $q = q_i + q_j = f(p)$ where q_i and q_j are the quantities supplied by companies i and j at a given price p . The two companies i and j have cost functions $CT_i(q_i)$ and $CT_j(q_j)$ respectively, with given characteristics. We suppose the two companies i and j have the following characteristics[10]: The company i has the esteem of banks (low 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). The company j does not have the esteem of the banks (high cost of capital), a low marginal productivity[11]of labour, 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 are the costs of capital or the interest rates represents which the companies i and j respectively bear. - β_i and β_j are the factor incomes of labour in the respective companies i and j - CF_i and CF_j are the fixed costs in the companies i and j respectively, whose variations will be explained primarily by the different levels of R&D. If $CT_i = \alpha_i K^{u_i} + \beta_i L + CF_i$ denotes the total cost of company i and $CT_j = \alpha_j K^{u_j} + \beta_j L + CF_j$ the total cost of company j , the preceding hypotheses yield the following inequalities:

-: $\alpha_i < \alpha_j$ the company i has the confidence of banks. Its cost of credit is lower than that of the company *j*: the company i has better guarantees of refunding its loan (the level of anticipated profits for example, being higher) to the bank compared to the company j .

-: $\beta_i > \beta_j$. The employees of company i are more *«performing[12]»* than those of the company j . The employees of the company i consequently have higher wages.

-: $CF_i > CF_j$ we consider that certain components of fixed costs such as the rents of the buildings, the expenses on electricity, the purchase of furniture (offices and chairs), the maintenance costs are the same in the two companies. We suppose that R&D costs are higher in the company which has a higher marginal productivity of labour (higher wages). Consequently, the fixed costs in the company i will be higher than the fixed costs in company j The parameters u_i and u_j respectively represent the index (or the parameter) of NICT for the companies i and j . The index of new technologies reflects the idea that the quantity of capital required for the production of a unit of output is lover.

- When this parameter tends towards zero, it is considered that the company uses more new technologies.
- When this parameter tends towards one, it is considered that the company uses less new technologies.
- When this parameter is equal to one, it is considered that the company is characterised by production costs in the traditional economy. In other words, it will not use new technologies.
- This parameter will not be able to take the value zero because if such this was the case, this will boil down to saying that the company does not use the factor capital, according to the cost function which we propose.

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[9]In the Cournot duopoly, competition is based on the market share. It could have been possible to consider this analysis using the Bertrand duopoly. In the Bertrand duopoly, the two companies manufacture distinguishable but sufficiently substitutable goods. In this case (which is not rare), competition is based on prices

[10]An example of two companies that verify these characteristics: A company found in the north (developed country) and the other found in the south (developing country). The company in the north will have the confidence of banks, a higher marginal productivity of labour and higher investments in R&D compared to the company in the south. We could have considered the case where the companies have the same characteristics, but this is not interesting in the presence of minimum information, given that the market shares will be the same and in the case of asymmetrical information, the results will be symmetrical to a change in the position of leader and follower.

[11]The hypothesis is made here that wages are low because the marginal productivity of labour is low. But the marginal roductivity of labour could be high, but the low wages persist because of powerless trade unions during the wage negotiations

[12]The employees can be equal performances but receive different levels of remuneration because of the capacities different from the trade unions during the wage negotiations.

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

6. The effects of NICT on the competitiveness of the companies in minimal information.

They appear four different effects appear (positive effect, negative effect, neutral effect, saturation effect):

6.1. Positive or negative effect of NICT on the competitiveness of a company

In a situation of minimum information (no competitor knows the reaction function of the other), the use of new technologies has a beneficial effect for the company which uses them intensely compared to its competitor because its share of the market and its profit increase while the share of the market and the profit of the competitor decrease. Conversely, the effect will be negative for the company which uses new technologies less compared to its competitor. This is seen when one goes from the initial situation 1 to situations 2, 4, and 5, where the company j uses more new technologies than the company i. The competitiveness of the company j improves under these conditions while that of the company i worsens. These situations are as follows:

Situations	Couples of NICT	Couples of production[13] $(q_i\,;q_j)$
1	$(u_i\,;u_j)=(1;1)$	$(q_i\,;q_j)=(44{,}715;72{,}033)$
2	$(u_i\,;u_j)=\left(1;\frac{1}{2}\right)$	$(q_i\,;q_j)=(42{,}141;77{,}935)$
4	$(u_i\,;u_j)=\left(\frac{1}{2};\frac{1}{4}\right)$	$(q_i\,;q_j)=(65{,}576;67{,}030)$
5	$(u_i\,;u_j)=\left(\frac{1}{2};\frac{1}{8}\right)$	$(q_i\,;q_j)=(65{,}484;67{,}219)$

On the other hand, in situation 3, the effect is beneficial for the company i:

Situation	Couple de NTIC $(u_i\,;u_j)$	Couple de production $(q_i\,;q_j)$
3	$(u_i\,;u_j)=\left(\frac{1}{2};1\right)$	$(q_i\,;q_j)=(69{,}115;59{,}978)$

6.2. The saturation effect of NICT on the competitiveness of a company

When one of the companies launches itself into the intensive use of new technologies (the company j), in minimum information, we find that its share of the market evolves less than proportionally compared to the increase in new technologies. These situations are as follows:

Situations	Couple of NICT $(u_i\,;u_j)$	Couples of output $(q_i\,;q_j)$
4	$(u_i\,;u_j)=\left(\frac{1}{2};\frac{1}{4}\right)$	$(q_i,q_j)=(65{,}576;\ 67{,}030)$
5	$(u_i,u_j)=\left(\frac{1}{2},\frac{1}{8}\right)$	$(q_i,q_j)=(65{,}484;\ 67{,}219)$

[13] These couples of production are calculated using the software "Scientific Workplace 3.0". An example of resolution of these equilibriums is in the appendix.

These saturation effects are calculated in table 1 below that gives the evolution of the quantity supplied by the company j at the Cournot-Nash equilibrium according to the index of NICT u_j, and this for a given value $\bar{u}_i = \frac{1}{2}$.

In this study, we will assimilate the marginal productivity of the capital, denoted with $\frac{\Delta q_j}{\Delta K^{u_j}}$ to $\frac{\Delta q_j}{\Delta u_j}$ since $u_j^1 > u_j^2 \Rightarrow K^{u_j^1} > K^{u_j^2}$. It is true that the higher the capital will be, the more the absolute value of the expression $K^{u_j^1} - K^{u_j^2}$ will be higher than the absolute value of the expression $u_j^1 - u_j^2$. What is important here, independently of these possible variations is to know if the output increases or decreases, i.e. if the productivity is positive or negative. In this model, when it is positive, this will mean that the productivity decreases, and when it is negative, this will mean that productivity increases.

<u>Table 1</u>: Evolution of the quantity supplied by the company j at the Cournot-Nash equilibrium according to the index of NICT u_j and this for a given value $\bar{u}_i = \frac{1}{2}$.

Variation of the index of the new technologies of the company and this for a given value $\bar{u}_i = \frac{1}{2}$ of the company i	Variation of the quantity supplied q_j by the company j to the Cournot-Nash equilibrium	Rate of variation of the output q_j relative to the index of NTIC u_j:	Rate of variation of the slope $\frac{\Delta q_j}{\Delta u_j}$ relative to the index of NICT u_j: $\frac{\Delta\left(\frac{\Delta q_j}{\Delta u_j}\right)}{\Delta u_j} = \frac{\Delta^2 q_j}{\Delta (u_j)^2}$
$u_j = 1$	$q_j \approx 59{,}978$	-	-
$u_j = \frac{1}{2}$	$q_j \approx 65{,}898$	$-11{,}84$	-
$u_j = \frac{1}{4}$	$q_j \approx 67{,}03$	$-4{,}528$	$-29{,}248$
$u_j = \frac{1}{8}$	$q_j \approx 67{,}219$	$-1{,}512$	$-24{,}128$

The various equilibriums obtained in situation of minimum information reveal that the paradox of Solow is not verified since the use of new technologies is accompanied by an increase in productivity which is done at a decreasing rate, i.e. productivity which increases less quickly.

6.3. Neutral effect of NICT on the competitiveness of a company

Still in situation with minimum information, when the two companies engage themselves in a technological race, i.e. in a very intensive use of new technologies, it appears that the effect on competitiveness of the companies is null or neutral insofar as none of them is favoured. The market shares remain almost identical (situations 6 and 7):

Situations	Couples of NICT	Couples of production
6	$(u_i, u_j) = \left(\frac{1}{2}, \frac{1}{2}\right)$	$(q_i, q_j) = (66{,}147;\ 65{,}898)$
7	$(u_i, u_j) = \left(\frac{1}{8}, \frac{1}{8}\right)$	$(q_i, q_j) = (66{,}680;\ 66{,}641)$

7. Effects of NICT on the competitiveness of companies in asymmetrical information

7.1. The company i is a leader and the company j is a follower while considering certain variations in the couple of indices of NICT (u_i, u_j) at the benefit of company j

7.1.1. Negative effect on the competitiveness of a company (for the follower)

In asymmetrical information (one of the competitors knows the reaction function of the other), the use of new technologies is not beneficial for the company whose function of reaction is known, whatever its degree of utilization of NICT (whether it uses it more or less than the leader). Here, we witness the Solow paradox which reflects the idea that a use of new technologies is not always accompanied by an increase in productivity. This fall in the productivity of the follower, in spite of an increasing use of NICT is illustrated in table 2.

<u>Table 2</u>: Evolution of the quantity supplied by the company when it is follower, at the Stackelberg equilibrium according to the index of NICT u_j and this for a given value of $\bar{u}_i = \frac{1}{2}$

Variation of the index of new technologies u_j of the company j (follower), and this for a given value $\bar{u}_i = \frac{1}{2}$ of the company i	Variation of the quantity supplied q_j by the company j (follower) at the Stackelberg equilibrium.	Rate of variation of the output q_j relative to the index of NICT u_j: $\frac{\Delta q_j}{\Delta u_j} = \frac{q_j^2 - q_j^1}{u_j^2 - u_j^1}$	Rate of variation of the slope $\frac{\Delta q_j}{\Delta u_j}$ relative to the index of NICT u_j:
$u_j = 1$	$q_j \approx 52{,}465$	-	-
$u_j = \frac{1}{4}$	$q_j \approx 1{,}307$	68,211	-
$u_j = \frac{1}{8}$	$q_j \approx 1{,}068$	1,912	530,392

According to table 2 above, we find that the increasing (higher) use of new technologies ($u_j \to 0$) is accompanied by a reduction in the output of the company j for a fixed level of the index of new technologies of the competitor i. The productivity of the company j (follower) compared to the index of NICT u_j (understood here as a lesser capital requirement), i.e. $\left(\frac{\Delta q_j}{\Delta u_j}\right)$ decreases. Column 3 of table 2 reveals this reduction. This enables us to paraphrase Solow: «one see machines everywhere except in productivity statistics». This paradox is explained here by detrimental asymmetrical information for the follower. When one passes from the initial situation 1' to the situation 2', we find that the follower company uses more new technologies than the leader company, but it is the leader company that has a greater share of market. These situations are as follows:

Situations	Couples of NICT	Couples of production
1'	$(u_i, u_j) = (1,1)$	$(q_i, q_j) = (84{,}347;\ 52{,}465)$
2'	$(u_i, u_j) = \left(1, \frac{1}{2}\right)$	$(q_i, q_j) = (193{,}428;\ 0{,}807)$

We find the same thing when we go from the situation 4' to the situations 5' and 6': the follower does not stop its losses when it decides to use NICT intensively. These situations are as follows:

Situations	Couples of NICT	Couples of production
4 '	$(u_i, u_j) = \left(\frac{1}{2}, \frac{1}{2}\right)$	$(q_i, q_j) = (193{,}372;\ 0{,}871)$
5 '	$(u_i, u_j) = \left(\frac{1}{2}, \frac{1}{4}\right)$	$(q_i, q_j) = (194{,}806;\ 1{,}307)$
6 '	$(u_i, u_j) = \left(\frac{1}{2}, \frac{1}{8}\right)$	$(q_i, q_j) = (196{,}376;\ 1{,}068)$

7. 1.2. Effect of saturation on the competitiveness of a company (for the follower)

Still in asymmetrical information, the results obtained show that the intensive use (unilateral or not) of new technologies beyond a certain threshold, does not improve the competitiveness of the follower (probably because of an effect of saturation). We notice that there is no significant modification of the market shares; in certain cases, we even find a slight reduction on of market share for the follower: the fact that it uses using new technologies intensively does not improve its situation. It can use all the windscreensit wants but this will change nothing. These situations are as follows:

Situations	Couples of NICT	Couples of production
5 '	$(u_i, u_j) = \left(\frac{1}{2}, \frac{1}{4}\right)$	$(q_i, q_j) = (194{,}806;\ 1{,}307)$
6 '	$(u_i, u_j) = \left(\frac{1}{2}, \frac{1}{8}\right)$	$(q_i, q_j) = (196{,}376;\ 1{,}068)$

7.2. The company i is follower and the company j is a leader while considering certain variations of the couple of indices of NICT (u_i, u_j) at the benefit of company j

7.2. 1. Positive effect on the competitiveness of the company (for the leader)

In a situation of asymmetrical information (one of the competitors knows the reaction function of the other), the use of new technologies is beneficial for the company which knows the reaction function of the competitor. When we go from the initial situation 1" to situations 2", 3", 4", 5", 6" and 7", we find that it is the leader company which has a greater part of the market because it knows the reaction function of its competitor, whatever is the level of use of NICT of the leader and the follower. These situations are as follows:

Situations	Couples of NICT	Couples of production
1"	$(u_i, u_j) = (1,1)$	$(q_i, q_j) = (43{,}196;\ 94{,}559)$
2"	$(u_i, u_j) = \left(1, \frac{1}{2}\right)$	$(q_i, q_j) = (38{,}985; 103{,}627)$
3"	$(u_i, u_j) = \left(\frac{1}{2}, 1\right)$	$(q_i, q_j) = (0{,}465; 196{,}634)$

4 "	$(u_i,u_j)=\left(\frac{1}{2},\frac{1}{2}\right)$	$(q_i,q_j)=(0{,}486;196{,}612)$
5 "	$(u_i,u_j)=\left(\frac{1}{2},\frac{1}{4}\right)$	$(q_i,q_j)=(0{,}48941;196{,}608)$
6 "	$(u_i,u_j)=\left(\frac{1}{2},\frac{1}{8}\right)$	$(q_i,q_j)=(0{,}48979;196{,}606)$
7 "	$(u_i,u_j)=\left(\frac{1}{8},\frac{1}{8}\right)$	$(q_i,q_j)=(0{,}756;198{,}081)$

7. 2.2. Effect of saturation on the competitiveness of a company (for the leader)

Still in a situation of asymmetrical information, the results obtained show that the intensive use (unilateral or not) of new technologies, beyond a certain threshold, does not improve competitiveness of the leader (probably because of an effect of saturation). It is found that there is no significant modification of market shares; we even find in certain cases, a slight reduction ofthe market share of the leader. The market share of the leader decreases whereas it uses new technologies more intensively. These situations are as follows:

Situations	Couples of NICT	Couples of production
4 "	$(u_i,u_j)=\left(\frac{1}{2},\frac{1}{2}\right)$	$(q_i,q_j)=(0{,}486;196{,}612)$
5 "	$(u_i,u_j)=\left(\frac{1}{2},\frac{1}{4}\right)$	$(q_i,q_j)=(0{,}48941;196{,}608)$
6 "	$(u_i,u_j)=\left(\frac{1}{2},\frac{1}{8}\right)$	$(q_i,q_j)=(0{,}48979;196{,}606)$

8. Conclusion and prospects

In this study, we evaluate the effects of new technologies on the competitiveness of companies in a competitive environment. We find that these effects are a function of the level of information (minimal or asymmetrical) which the competitors possess:

a) *In a situation of minimum information (no competitor knows the reaction function of the other), the use of new technologies has a beneficial effect for the company which uses NICT more intensely than its competitor, because its share of the market and its profit increase while the share of market and the profit of the competitor decrease.*

b) *Still in a situation of minimum information, when the two companies engage themselves in a technological race, i.e. in the very intensive use of new technologies, it appears that the effect on competitiveness of the companies is null since none of them is favoured. Market shares remain almost identical.*

c) *In a situation of asymmetrical information (one of the competitors knows the reaction function of the other), the use of new technologiesis not beneficial for the company whose function of reaction is known, whatever its degree of utilisation of NICT (Whether it uses them more or less than the leader). Here, we witness the Solow paradox which conveys the idea that the use of new technologies is not always accompanied by an increase in productivity.*

d) *In a situation of asymmetrical information and minimum information, the results obtained show that the intensive use (unilateral or not) of new technologies beyond a certain threshold does not improve the competitiveness of a company, probably because of an effect of saturation.*

This perverse effect of NICT (or effect of saturation) raises the question of the determination of the optimal level of new technologies of a company in a competitive environment. This question will be the subject of future studies.

In asymmetrical information, the reaction time is more highlighted in the new economy, unlike in the traditional economy. This means that the adaptability toproductionof one week for example in the traditional economy could be equivalent to an adjustment in production for a period less than one week in the new economy, which could explain why the follower in the economy with NICT loses more (no matter its level of utilisationof the factor NICT) compared to its situation in the traditional economy. Another finding from this study is that in a competitive environment such as a Cournot duopoly, the specific advantageous characteristics (confidence of banks, higher marginal productivity of labour, higher investments in R&D) of a company in the presence of NICT are not sufficient determinants to be able to guarantee a greater markets hare market, profits and productivity. One of the main determinants in the acquisition of a greater markets hare is the knowledge of the function of reaction of the competitor in a situation of asymmetrical information. In fact, for a given company, we conclude that whatever the level of utilization of new technologies of the competitor, if the reaction function of this competitor is known, it is systematically losing.

Moreover, this analysis makes it possible to understand the Solow paradox which is further esxplained by asymmetrical information.

Finally, if NICT appear as a useful factor for the improvement of the competitiveness of a company, it cannot be regarded as a sufficient factor for the improvement of its competitiveness. The results we reach are based on the hypothesis that we adopted:

- On the one hand, the idea that the NICT affect only the factor capital in the cost function and not the labour factor. In a future study, we will try same to deform the two factors and examine how the intensive use of new technologies could affect or modify the competitiveness of companies in a competitive environment.
- Also, we supposed that competition is mainly a competition by the quantities (duopoly of Cournot). It would also be interesting to study in future research this competitiveness when the goods are not homogeneous but rather close substitutes (the model of Bertrand or competition by prices).

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Appendix: Numerical example of the application ofCournot-Nash equilibriums[14]

In this appendix, we show the resolution of a Cournot-Nash equilibrium. The other equilibrium are resolved in the same manner, the difference residing in the variation of the couple of NICT (u_i, u_j) where u_i represents the index of new technologies of the company i and u_j, the index of new technologies of the company j. We calculate the different Cournot-Nash equilibriums going from the seven couples of new information technologies for the two companies.

The seven couples of indices we have retained in this study are: $(u_i, u_j) = (1{,}1)$, $(u_i, u_j) = \left(1, \frac{1}{2}\right)$, $(u_i, u_j) = \left(\frac{1}{2}, 1\right)$, $(u_i, u_j) = \left(\frac{1}{2}, \frac{1}{2}\right)$, $(u_i, u_j) = \left(\frac{1}{2}, \frac{1}{4}\right)$, $(u_i, u_j) = \left(\frac{1}{2}, \frac{1}{8}\right)$ et $(u_i, u_j) = \left(\frac{1}{8}, \frac{1}{8}\right)$.

We previously established the following inequalities:

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

Let us attribute to these parameters the following specific values:

$\alpha_i = 1$, $\alpha_j = 2$, $\beta_i = 10$, $\beta_i = 1$, $CF_i^* = CF_i = 100$, $CF_j^* = CF_j = 50$, $v_i = \frac{1}{2}$, $v_j = \frac{3}{8}$, $s_i = \frac{1}{4}$ and $s_j = \frac{4}{8}$

To simplify the analysis, we also suppose that $A_i = A_j = 1$. We recall that A_i and A_j representin the production function ($q_i = A_i K^{v_i} L^{s_i}$ for i and $q_j = A_j K^{v_j} L^{s_j}$ for j) the efficiency parameters: This means that the higher A_i (or A_j) is, the higher the quantities produced are, whatever the combination of factors.

We are also going to suppose that the inverse demand function (i.e. price) is:

$$P = f^{-1}(q) = f^{-1}(q_i + q_j) = \frac{1}{a}(q_i + q_j) - \frac{b}{a}$$

Giving values to a and b:

$a = -2$ and $b = 200$ (for example), the inverse demand function becomes:

$$P = -\frac{1}{2}(q_i + q_j) + 100$$

Recall that the functions[15]of cost (with and without the use of NICT) of the duopolies i and j are:

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[14]All the results of the Cournot-Nash equilibriums are obtained using the software «Scientific workplace 3.0»

[15] Proofs of these functions are developed in my doctorate thesis; we just recopied the main algebraic results while maintaining the numbering of the equations.

$$CT_i(q_i) = \alpha_i D_i E_i q_i^{\left(\frac{1}{v_i + s_i}\right)} + CF_i$$ (3) without taking into account NICT

$$CT_i^*(q_i) = \alpha_i D_i^* E_i^* q_i^{\left(\frac{u_i}{v_i + (s_i u_i)}\right)} + CF_i^*$$ (6) when taking into account NICT

$$CT_j(q_j) = \alpha_j D_j E_j q_j^{\left(\frac{1}{v_j + s_j}\right)} + CF_j$$ (3') without taking into account NICT

$$CT_j^*(q_j) = \alpha_j D_j^* E_j^* q_j^{\left(\frac{u_j}{v_j + (s_j u_j)}\right)} + CF_j^*$$ (6') when taking into account NICT

We have considered that:

$$D_i = 1 + \frac{s_i}{v_i},\ D_j = 1 + \frac{s_j}{v_j},\ D_i^* = 1 + \frac{s_i u_i}{v_i},\ D_j^* = 1 + \frac{s_j u_j}{v_j},$$

$$E_i = \frac{1}{A_i^{\left(\frac{1}{v_i + s_i}\right)} \left(\frac{s_i \alpha_i}{v_i \beta_i}\right)^{\left(\frac{s_i}{v_i + s_i}\right)}}\ ;\ E_j = \frac{1}{A_j^{\left(\frac{1}{v_j + s_j}\right)} \left(\frac{s_j \alpha_j}{v_j \beta_j}\right)^{\left(\frac{s_j}{v_j + s_j}\right)}}$$

$$E_i^* = \left(\frac{1}{A_i^{\left(\frac{1}{v_i + (s_i u_i)}\right)} \left(\frac{s_i \alpha_i u_i}{v_i \beta_i}\right)^{\left(\frac{s_i}{v_i + (s_i u_i)}\right)}}\right)^{u_i}\ ;\ E_j^* = \left(\frac{1}{A_j^{\left(\frac{1}{v_j + (s_j u_j)}\right)} \left(\frac{s_j \alpha_j u_j}{v_j \beta_j}\right)^{\left(\frac{s_j}{v_j + (s_j u_j)}\right)}}\right)^{u_j}$$

$(u_i, u_j) = (1,1)$ **: none of the two companies uses NICT**.

What do the corresponding cost functions if we replace A_i, A_j, α_i, α_j, β_i, β_j, s_i, s_j, v_i, v_j by their values?

Firstly, D_i, D_j, E_i and E_j become:

$$D_i = 1 + \frac{1/4}{1/2} = 1 + \frac{1}{2} = \frac{3}{2}\ ;\ D_j = 1 + \frac{4/8}{3/8} = 1 + \frac{4}{3} = \frac{7}{3}$$

$$E_i = \frac{1}{1^{\left(\frac{1}{1/2 + 1/4}\right)} \left(\frac{1/4\,(2)}{1/2\,(10)}\right)^{\left(\frac{1/4}{1/2 + 1/4}\right)}} = \frac{1}{\left((1)\frac{1}{20}\right)^{1/3}} = 20^{1/3}$$

$$E_j = \frac{1}{1^{\left(\frac{1}{3/8+4/8}\right)}\left(\frac{4/8\,(2)}{3/3\,(1)}\right)^{\left(\frac{4/8}{3/8+4/8}\right)}} = \frac{1}{(1)\left(\frac{8}{3}\right)^{4/7}} = \left(\frac{3}{8}\right)^{4/7}$$

After the intermediary calculations of D_i, D_j, E_i and E_j, the cost functions (3) and (3') of the companies i and j become:

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

$$= 1\left(\frac{3}{2}\right)20^{1/3} q_i^{\left(\frac{1}{1/2+1/4}\right)} + 100 = \left(\frac{3}{2}\right)20^{1/3} q_i^{4/3} + 100$$

$$CT_j(q_j) = \alpha_j D_j E_j q_j^{\left(\frac{1}{v_j+s_j}\right)} + CF_j \qquad (3')$$

$$= (2)\frac{7}{3}\left(\frac{8}{3}\right)^{4/7} q_j^{\left(\frac{1}{3/8+4/8}\right)} + 50 = \frac{14}{3}\left(\frac{3}{8}\right)^{4/7} q_j^{8/7} + 50$$

In order to determine the Cournot-Nash equilibrium when $(u_i, u_j) = (1,1)$, we first determine the reaction functions of the two companies; These functions then enable us to determine the quantities supplied by these companies at the Cournot-Nash equilibrium. The profits of the companies i and j are such that:

$$\Pi_i = Pq_i - CT_i(q_i) = \left(-\frac{1}{2}(q_i + q_j) + 100\right)q_i - \left(\left(\frac{3}{2}\right)20^{1/3} q_i^{4/3} + 100\right)$$

$$= -\frac{1}{2}q_i^2 - \frac{1}{2}q_i q_j + 100q_i - \left(\frac{3}{2}\right)20^{1/3} q_i^{4/3} - 100 \qquad (7)$$

$$\Pi_j = Pq_j - CT_j(q_j) = \left(-\frac{1}{2}(q_i + q_j) + 100\right)q_j - \left(\frac{14}{3}\left(\frac{3}{8}\right)^{4/7} q_j^{8/7} + 50\right)$$

$$= -\frac{1}{2}q_i q_j - \frac{1}{2}q_j^2 + 100q_j - \frac{14}{3}\left(\frac{3}{8}\right)^{4/7} q_j^{8/7} - 50 \qquad (8)$$

Setting the appropriate derivatives equal to zero:

$$\frac{d\Pi_i}{dq_i} = -q_i - \frac{1}{2}q_j + 100 - \frac{4}{3}\left(\frac{3}{2}\right)20^{1/3} q_i^{1/3} = 0 \Leftrightarrow -q_i - \frac{1}{2}q_j + 100 - (2)20^{1/3} q_i^{1/3} = 0$$

$$\frac{d\Pi_j}{dq_j} = -\frac{1}{2}q_i - q_j + 100 - \left(\frac{8}{7}\right)\frac{14}{3}\left(\frac{3}{8}\right)^{4/7} q_j^{1/7} = 0 \Leftrightarrow -\frac{1}{2}q_i - q_j + 100 - \frac{112}{21}\left(\frac{3}{8}\right)^{4/7} q_j^{1/7} = 0$$

The corresponding reaction functions are obtained by setting the first derivative of profit of each company with respect to quantity equal to zero. i.e.:

$$\frac{d\prod_i}{dq_i} = 0 \Leftrightarrow -q_i - (2)20^{1/3} q_i^{1/3} + 100 = \frac{1}{2} q_i \Leftrightarrow -2\left(q_i + (2)20^{1/3} q_i^{1/3}\right) + 200 = q_j$$

This equation represents the reaction function of company i.

$$\frac{d\prod_j}{dq_j} = 0 \Leftrightarrow -q_i - \frac{112}{21}\left(\frac{3}{8}\right)^{4/7} q_j^{1/7} + 100 = \frac{1}{2} q_i \Leftrightarrow -2\left(q_j + \frac{112}{21}\left(\frac{3}{8}\right)^{4/7} q_j^{1/7}\right) + 200 = q_i$$

This equation represents the reaction function of company j.

The Cournot-Nash solution is obtained by the resolution of the system of equations given by reaction functions, i.e.:

$$\begin{cases} -2\left(q_i + (2)20^{1/3} q_i^{1/3}\right) + 200 = q_j \\ -2\left(q_j + \frac{112}{21}\left(\frac{3}{8}\right)^{4/7} q_j^{1/7}\right) + 200 = q_i \end{cases}$$

Wethusobtain $q^{cn_1} = \left(q_i^{cn_1}, q_j^{cn_1}\right)$with:

$$\begin{cases} q_i^{cn_1} \approx 44{,}715 \\ q_j^{cn_1} \approx 72{,}033 \end{cases}$$