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Robotization and labor factor as part of price competition on minimal information

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ABSTRACT
The introduction of Robotization deteriorates the amount of work factor required in a production process. To model this idea, we propose an index of new technologies that is non-zero and less than unity. We compete two companies that use various new technologies. The results obtained invalidate the paradox of Solow which says in substance: « you can see the computer age everywhere except in the statistic productivity ».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*.

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I. INTRODUCTION

The introduction of new technologies of information and communication drives to an automation more and more pushed in the production process, commercialization and distribution. These evolutions allow us to raison a question on the impact of Robotization on working factor.

Automation of the production results from four effects:

- The substitution of capital by work with direct consequence, the reduction of number of workers if the production remains at a constant level;
- The increase of the company's market shares ;
- The rise of qualified jobs in the conception and the manufacturing of automatons (which can be of foreign origin or not) ;
- The creation of local jobs which role is to install robots and ensure their maintenance where appropriate.

The variation of these effects according to the geographical space and the sector of activity explains the diversity of analyses which go from the certainty that the « robot kills employment » at the rise of a « new shared prosperity».

It is important to reveal that the debate of the impact of technology on employment is not new. The idea according to which technology destroys jobs was worn it the 19th century by Ned Ludd and his « companions ». Theses English workers bitterly considered that the use of new machines to weave could replace human labor. The « Luddies riot » in many regions of North England in the early 1810, ended with the massive destruction of these machines.

Nowadays, the increasing use of robots and the spread of the digital lead to a new wave of worry (Askenazy, 2011) certainly, but contribute to improve the productivity of companies (Aubert, 2014).

Results of many studies on the impact of automation on employment diverge.

On the one hand, the finding is alarming, while the other, we put before the creation of new jobs due to Robotization.

The consulting firm (Roland Berger, 2014) projected the destruction of about three millions jobs on the horizon 2025. Another study conducted by Frey and Osborne (2013) estimated that 47 % of american jobs are at risk of being replaced by robots in 10 to 20 years.

A contradictory study defended the idea of the creation of 450 000 to 800 000 new jobs between 2017 and 2020 due to automation (Metra Martech, 2013), without specifying the number of destroyed jobs.

Results of Eurobaromètre conducted in 2012 by the European Commission showed the attitude of French citizens on this split debate. Indeed, three quarters among them estimated that the robot will end up replacing human; at the same time, 90 % of them are convinced of their utility in the realization of difficult and dangerous tasks for the man.

Jeremy Rifkin (1996) in his book entitled « The end of work » estimates that the more an economy is productive, the more the level of unemployment is high. In other words, it means that we work in an effective way, the more the amount of workers used decreases.

Clearly, when a company invests in the acquisition of new technology, it expects to reduce the amount of factor used and thus, reduce production costs.

With the Robotization, the number of workers will certainly decrease, but men will not disappear from factories. Implementation tasks will be abandoned to while control and maintenance tasks will be preserved.

Our approach is completely different: it is microeconomic where we put in competition two companies which diversely use new technologies, the aim being to detect the most competitive.

II. THE IMPACT OF NICT ON WORK FACTOR THROUGH A SERIES OF EXAMPLES

2.1. Virtual assistant

A virtual assistant or conversational robot is a computer program whose aim is the simulation of a smart conversation with human. This technique is already used by 80 % of companies in developed countries in their Webmarketing strategy. This conversation can be of an audio or text form. These applications more and more appear in Web sites or in instant messengers (Facebook, Messenger and others) and are notably used to handle customer relationship management.

The virtual assistant ensures un a 7 days on 7 service, 24 hours on 24 and it is appreciated for different reasons : dissemination of information nearby internets users, visitors assistance in their order taking, response to questions for ongoing orders and mostly conditions concerning returned goods, information and / or partners assistance by intranet or extranet. 30 % of virtual assistant users take place in the evening or at night, out of switchboard opening hours. To EDF (Electricité de France) Individuals, virtual assistance named Laura, answers up to an average of 10 000 questions per day on billing, opening or contracts modification, etc.

2.2. Delivery Robots

In China, the delivery robot is currently replacing the traditional delivery man under some conditions. It an autonomous machine with wheels, equipped of GPS, cameras and radars. Consignees are more and more numerous to receive parcels, meals and other from robot whose height is similar to a small washing machine, at a speed of about 3 km / h. A client among many others, delighted with the prowess of this machine, however regrets that it could not deliver at the door of the apartment as the traditional deliver man was used to do.

The consumer selects products to be delivered via a mobile phone and pays online. The supermarket which receives the order places the goods into the robot which will deliver in 3 to 4 minutes time at the foot of the building located at about 200 meters. To collect his package, the consignee clicks on the link via his mobile phone to unlock the safe. It is noted that in China, 52 % of inhabitants do their purchases online versus 14 % in the rest of the world.

The highest speed of this robot is 12 km / h and cannot work 24 hours on 24. Thus, the human deliverer is not totally ousted from the job market and continues to partially play his role.

In the light of these two examples, and some others that we did not developed here, we suppose that the amount of work due for production of an extra output unit has dropped compared to traditional economy, that is to say, the one involving NICT. Consequently, new technologies mentioned upper contribute to reduce costs production for all type of company operating in any business sector (primary, secondary or tertiary).

III. THE ANALYSIS OF THE TRADITIONAL STRUCTURE OF PRODUCTION COSTS FOR A COMPANY

In this section, we present the traditional structure (where the work factor and the capital factor are not distorted because of new technologies impact**)** production costs for the company depend on capital factor and work factor on the one hand, and the expression of the function of production costs depends on the quantities offered by the company, on the other hand.

3.1. Production costs for the company in traditional economy

3.1.1. Production costs in general

Generally, when a company envisages to introduce a given level of output in the market, it does the inventory of different combinations of factors that will allow it to reach that level of output. What is interesting for this company, is to find the less expensive combination (aim of profit maximization, for instance) when the factors prices are given.

The company generally has many production factors of which two are often retained in the study of the function of cost[1] : the capital and the work.

When a company decides to simultaneously vary all its factors in the research of a given output, we will talk of long duration production costs. On the other hand, when at least one of the factors is fixe, we will talk of short duration production costs. In this study, we may be looking at the short duration analysis, where only work factor and capital factor will be considered.

3.1.2. Some characteristics of production costs in traditional economy

Fixed and variable costs of production are generally high in contrary to the new economy where internet contributes to reduce production costs (that will studied at section 3). The factor mobility is less strong, the dissemination of information is slower, the clientele network is less extensive compared to the one of the new economy, etc. (NJOCKE M., 2010)

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

3.2.1. The traditional cost function and the production function

The traditional cost function is heard as, a cost function where work factor and capital factor are not distorted because of the effect of new technologies.

We will consider that a given company i is, confronted to a linear cost function of the form of:

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

We will consider that this company is subject to the constraint of the production function of type Cobb-Douglas:

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

The variables and parameters intervening in the function of cost and production are:

- K and L respectively represent the capital factor and the work factor;
- CF_i represents fixed costs supported by the company i ;
- $A_i > 0$ is an efficiency parameter (the more A_i is high, the more quantities produced are higher and this is possible whatever the combination of factors);
- α_i represents the capital cost or the interest rate;
- β_i represents the salary or the remuneration of work factor;
- $v_i = e_{q_i/K} = \dfrac{\frac{dq_i}{q_i}}{\frac{dK}{K}}$ represents the partial elasticity of output in relation to capital or to input K ;
- $s_i = e_{q_i/L} = \dfrac{\frac{dq_i}{q_i}}{\frac{dL}{L}}$ represents the partial elasticity of output in relation to work or to input L.

3.2.2. The cost function of company i in relation to quantities produced q_i in absence of NICT

It is useful to give the cost function expression in relation to quantities produced, in the sense that when we seek to maximize the profit of company i, thisprofit has as explanatory variable, the quantity produced. We shall therefore minimize the variable cost ($CV_i = \alpha_i K + \beta_i L$) under the constraint of the function of production ($q_i = A_i K^{v_i} L^{s_i}$).

Let's form the Lagrangien: $£(K, \mathrm{L}, \lambda) = \alpha_i K + \beta_i L + \lambda(q_i - A_i K^{v_i} L^{s_i})$. The resolution of equation system including different partial derivatives of lagrangien in relation to K, L et λ results on the traditional function in absence of NICT.

[1] There is a production cost called opportunity cost which represents the best return we give up by affecting ressources otherwise.

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

IV. THE ANALYSIS OF THE PRODUCTION COSTS STRUCTURE IN PRESENCE OF NEW TECHNOLOGIES.

4.1 Discussion around the new function of cost in presence of NICT

Examples highlighted above show that NICT can sensibly upset the structure of production costs because the amount of factors used decrease considerably. To model this idea, we suggest the class of the following cost function: $CT_i = \alpha_i K^{u_i} + \beta_i L^{t_i} + CF_i$ (4), which goes up a conversion of power type.

By awarding to t_i the value 1 ($t_i = 1$) and to u_i the value 1 ($u_i = 1$), we find the function of simple linear cost, either: $CT_i = \alpha_i K + \beta_i L + CF_i$

It is a form of cost of function that we analyzed in the case of traditional economy (not taking into consideration NICT) in the previous paragraph.

In a previous study[2], we showed that the amount of capital due for the production of a unit of output dropped in presence of NICT in relation to traditional economy; so we assumed that the way to work in new economy remained the same compared to traditional economy. This seemed to be a very strong hypothesis for the work factor had to be adapted to new form of capital factor. The reasoning « all things remaining equal », led us to consider the class of the following cost of function: $CT_i = \alpha_i K^{u_i} + \beta_i L + CF_i$ (5), assuming that t_i is equal to ($t_i = 1$) unit.

In this study, we will assume that the capital factor does not suffer any impact in the presence of NICT; this assumption can to some extent, seem to be a strong hypothesis for the capital factor should in principle adapt to the new form of work factor; but like we said, we will work in the hypothesis «all things remaining equal ». The dominant variable is the work factor (L). Resuming the example of virtual assistant or the delivery du robot, we observe that the number of workers decrease with the NICT in compared to the traditional situation, that is, without NICT. To model this idea, we will deform the function of cost through a coefficient noted t_i, which represents the index of NTIC such as $0 < t_i \leq 1$. When t_i tends towards zero, we will say that the company uses more and more NICT and when t_i tends towards one, we will say that the company uses less and less NICT. We will adopt the following class function: $CT_i = \alpha_i K + \beta_i L^{t_i} + CF_i$ (6),

Let's remind that u_i represents the index of new technologies affected to capital factor, while t_i represents the index of new technologies affected to work factor.

We equally admit that α_i (the cost of capital K or interest rate) and β_i (the remuneration of work factor L) know no change; their values do not change when we go from traditional economy to economy involving new technologies.

We equally consider that the company i is always confronted to the same function of production of type Cobb-Douglas: $q_i = A_i K^{v_i} L^{s_i}$ (2)

(We once more apply the reasoning «all things remaining equal »).

[2] NJOCKE M., NJOCKE G., (2017): « New Information and Communication Technologies and the Competitiveness of Companies within the Framework of a Cournot duopoly », Journal of Economics and Development Studies.

The parameter t_i in the equation (6) expresses the simple idea that the amount of work due for the production a unit of output decreased in the function of cost in presence of NICT. In the following, we will call t_i, the index or the parameter of NICT.

4.2.The function of cost of the company i in relation to quantities produced q_i in presence of NICT

Company i is confronted to the following function of cost:

$CT_i^* = C(K,L) = \alpha_i K + \beta_i L^{t_i} + CF_i^*$ (6), and it is subject to the constraint of the function $q_i = q(K,L) = A_i K^{v_i} L^{s_i}$ (2) of type Cobb-Douglas.

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

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

Let's form the Lagrangien :

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

The resolution of equation system including different partial derivatives of lagrangien in relation to K, L and λ results tothe new function of cost in presence of NICT depending on des quantities produced. Whether:

$$CT_i^*(q_i) = \beta_i\left(1 + \frac{t_i v_i}{s_i}\right)\left(\frac{1}{\left(A_i^{\left(\frac{1}{s_i + t_i v_i}\right)}\left(\frac{\beta_i t_i v_i}{\alpha_i s_i}\right)^{\left(\frac{v_i}{s_i + t_i v_i}\right)}\right)}\right)^{t_i} q_i^{\left(\frac{t_i}{s_i + t_i v_i}\right)} + CF_i^* \quad (7)$$

4.3.Examination of equations of total costs of the company i in presence and in absence of NICT

The traditional function of cost without taking into consideration NICT is:

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

The function of cost taking into consideration NICT is:

$$CT_i^*(q_i) = \beta_i\left(1 + \frac{t_i v_i}{s_i}\right)\left(\frac{1}{\left(A_i^{\left(\frac{1}{s_i + t_i v_i}\right)}\left(\frac{\beta_i t_i v_i}{\alpha_i s_i}\right)^{\left(\frac{v_i}{s_i + t_i v_i}\right)}\right)}\right)^{t_i} q_i^{\left(\frac{t_i}{s_i + t_i v_i}\right)} + CF_i^* \quad (7)$$

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

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

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

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

$$CT_i^*(q_i) = \beta_i D_i^* E_i^* q_i^{\left(\frac{t_i}{s_i+t_i v_i}\right)} + CF_i^* \quad (7)$$

Let's compare the total cost in absence of NICT noted $CT_i(q_i)$, and the total cost in presence of NICT noted $CT_i^*(q_i)$

- We previously showed that fixed costs in presence of NICT were lower than the fixed costs in absence of NICT. Whether: $CF_i^* \le CF_i$
- Let's compare D_i et D_i^*

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

We admitted that $t_i < 1$, this implies $\frac{v_i}{s_i} > \frac{t_i v_i}{s_i}$

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

- Let's now compare these expressions $q_i^{\left(\frac{1}{v_i+s_i}\right)}$ and $q_i^{\left(\frac{t_i}{s_i+t_i v_i}\right)}$ appearing respectively in equations (3) and (7).

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

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

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

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

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

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

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

<u>Note</u>: thereafter, we will evoke the competition between companies i and j. The examination of equations of cost in presence and in absence of NICT is analogous to the one of company j .Parameters concerning company j are obtained by inversion (replacement) of the index i by the index j. So, we will have:

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

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

V. PRICE COMPETITION: THE BERTRAND MODEL

This model puts in competition two companies which propose a price to consumers, qualified as « price takers ». Bertrand (1883) criticizes the model of Cournot who considers that the two duopolists have constant and equal unit costs (In the original version, this unit cost is zero). Bertrand criticizes Cournot on a dual aspect: first, the behavior of the firms is not optimal for they could expand (hypothesis rejected with the difficulties encountered); secondly, the decisions variables to Cournot are quantities, while to Bertrand, there are prices (Friedman, 1977).

The hypothesis of atomicity of agents (price equal to marginal cost and profit zero) is questioned by Bertrand because for him, with only two companies, the outcome is perfect competition result (price equal to marginal cost and profit is zero) : this is Bertrand paradox.

We considered two companies i and j with the following characteristics[3] :

- Company i has the confidence of the banks (lower capital cost), high marginal productivity of labor, that is to say more qualified workers (high salaries) and high investments in R&D (high fixed costs).
- Company j does not have the confidence of the banks (high capital cost), lower marginal productivity of labor[4], that is to say less qualified workers (low salairies) and low investments in R&D (low fixed costs). We adopted the following scoring:

[3] An example of two companies which verify these characteristics: a company located at the north (developed country) and the other at the south (developing country). The company located at the north will have the confidence of banks, the high marginal productivity of labor and investments in R&D important compared to the company located at the south which will face banks mistrust, lower marginal productivity of labor and investments in R&D lower. We could have considered the case where the companies have the same characteristics. But, it is an interesting framework analysis on minimal information, given the fact that market shares would be identical.

- α_i and α_j respectively represent the capital cost or interest rate that are supported by companies i and j.
- β_i and β_j respectively represent the remunerations of labor factor in companies i and j.
- CF_i and CF_j respectively represent fixed costs for companies i and j whose differences are essentially explained by the different level in R&D.

If we consider $CT_i = \alpha_i K + \beta_i L^{t_i} + CF_i$, total cost of the company i and $CT_j = \alpha_j K + \beta_j L^{t_j} + CF_j$, the total cost of the company j, the previous hypothesis result in the following inequalities:

- $\alpha_i < \alpha_j$: the company i has the confidence of the banks, its cost of credit is lower than the one of the company j : the company i presents better credit repayment (anticipated profits for instance, being more important) nearby a bank compared to the company j.
- $\beta_i > \beta_j$: employees of the company i are more « efficient[5] » than employees of the company j ; the employees of company i thus have higher wages.
- $CF_i > CF_j$: we considered that some components of fixed costs such as rent, buildings, electricity costs, bying furniture (desks and chairs), and maintenance costs are nearly the same for the two companies. We assumed that R&D are higher at the company which has a high marginal productivity of labor (higher wages). Consequently, fixed costs at company i will be higher than fixed costs at company j.

We considered that for each company of these companies, its production function did not change when passing from traditional economy towards economy taking into consideration NICT for the sake of simplicity. So the respective functions of production of these companies i and j are:

$$q_i = q(K, L) = A_i K^{v_i} L^{s_i} \text{ with } A_i, v_i, s_i \in \Re_*^+ \text{ and } v_i + s_i < 1$$

$$q_j = q(K, L) = A_j K^{v_j} L^{s_j} \text{ with } A_j, v_j, s_j \in \Re_*^+ \text{ and } v_j + s_j < 1$$

We assumed that company i is characterized by a high capital intensity (that is to say the capital per worker $\frac{K}{L}$ is very important or high; in the reverse the company j is characterized a low capital intensity (the capital per worker $\frac{K}{L}$ is less important).

This is reflected in an elasticity of the product (of output) in relation to capital, noted $e_{q_i/K} = v_i$, higher in the company i than the elasticity of the product in relation to capital, noted $e_{q_i/L} = s_i$, in the company j. So, we will have: $v_i > v_j$.

Likewise, we assumed that the elasticity of the product in relation to work is higher in the company j than the elasticity of the product in relation to work in the company i. So, we will have: $s_j > s_i$.

The parameters t_i and t_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 amount of capital due for the production of a unit of output is less important.

[4] We choose the hypothesis here that salairies are low because the marginal productivity labor is low. But, it could be that the marginal productivity labor is high, but wages are low due to less powerful unions during wage negociations.

[5] Wage can be of equal performance but receive different level of remuneration due to different capacities of unions during wage negociations.

- When this parameter will tend towards zero, we will say that the company uses more of new technologies.
- When this parameter will tend towards one, we will say that the company uses less of new technologies.
- When this parameter is equal to the unit, we will say that the company is characterized by costs of production in traditional economy. I other words,itwill not use new technologies.
- This parameter cannot take the value zero, for if that was the case, this would simply mean that the company does not use work factor, according to the function of cost that we propose.

Say that $t_i < t_j$, implies that the company i uses more of new technologies than the company j.

VI. ALGEBRAIC AND NUMERICAL RESOLUTION OF THE BALANCE OF BERTRAND TAKING INTO CONSIDERATION OF NTIC[6]

6.1 Algebraicresolution

The functions of cost of these companies i and j are respectively:

$$CT_i^*(q_i) = \beta_i D_i^* E_i^* q_i^{\left(\frac{t_i}{s_i + t_i v_i}\right)} + CF_i^*$$

$$CT_j^*(q_i) = \beta_j D_j^* E_j^* q_j^{\left(\frac{t_j}{s_j + t_j v_j}\right)} + CF_j^*$$

Let's assume that the demand functions of companies i and j are respectively:

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

The variables p_i and p_j are respectively the prices charged by the companies i and j, and the variables q_i and q_j, the corresponding quantities offered.

<u>Question</u>: what are the prices p_i and p_j charged by the producers i and j and what are the profits and the resulting quantities?

The function of profit of company i is:

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

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

The reaction function of company i is:

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

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

The function of profit of company j is:

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

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

[6] The resolution of the balance of Bertrand balanced with the consideration of NICT is a general case. To find this resolution without taking into consideration NICT, we should award value to unit parameter t_i and t_j.

The reaction function of company j is:

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

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

The solution of the balance of Bertrand is given by the resolution of the system below in p_i and p_j. It can also be obtained graphically by the intersection of reaction functions.

$$\begin{cases} -4p_i + p_j + 12 + 2\beta_i D_i^* E_i^* \left(\frac{t_i}{s_i + t_i v_i} \right) \left(-2p_i + p_j + 12 \right) \left(\frac{t_i}{s_i + t_i v_i} - 1 \right) = 0 \\ \\ -4p_j + p_i + 12 + 2\beta_j D_j^* E_j^* \left(\frac{t_j}{s_j + t_j v_j} \right) \left(-2p_j + p_i + 12 \right) \left(\frac{t_j}{s_j + t_j v_j} - 1 \right) = 0 \end{cases} .$$

6.2 Numericalresolution

We will calculate the different equilibria of Bertrand starting from the seven pairs of index of new technologies for the two companies.

The seven pairs of index of new technologies that we obtained in this study are: $(t_i, t_j) = (1,1)$, $(t_i, t_j) = \left(1, \frac{1}{3}\right)$, $(u_i, u_j) = \left(\frac{1}{3}, 1\right)$, $(t_i, t_j) = \left(\frac{1}{3}, \frac{1}{3}\right)$, $(t_i, t_j) = \left(\frac{1}{3}, \frac{1}{5}\right)$, $(t_i, t_j) = \left(\frac{1}{3}, \frac{1}{7}\right)$ et $(t_i, t_j) = \left(\frac{1}{7}, \frac{1}{7}\right)$.

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's award particular values to these parameters respecting these inequalities:

$\alpha_i = 1$, $\alpha_j = 2$, $\beta_i = 5$, $\beta_j = 1$, $CF_i^* = CF_i = 10$, $CF_j^* = CF_j = 5$, $v_i = \frac{1}{2}$, $v_j = \frac{3}{8}$, $s_i = \frac{1}{4}$ and $s_j = \frac{4}{8}$

6.2.1. Positive and negative effect of NICT on the competitiveness of companies

On minimal 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 more intensely compared to a competitor, for its price lower and its profit more important while the price of the competitor is high and its profit low. In the reverse, the effect will be negative for the company which will use less new technologies compared to its competitor. We see it when we pass from the initial situation 1 to situations 2, 5, and 6, where the company j uses more of new technologies than the company i : The competition of the company j is improved in these conditions while the one of i is deteriorated. These cases are the following:

Case	Pairs of NICT $(t_i ; t_j)$	Pairs of price[7] $(p_i ; p_j)$	Pairs of profit $(\Pi_i ; \Pi_j)$
1	$(t_i ; t_j) = (1;1)$	$(p_i ; p_j) = (5{,}494; 7{,}739)$	$(\Pi_i ; \Pi_j) = (1{,}365; 4{,}665)$

[7] These pairs of price are calculated with the help of Matlab software.

2	$(t_i\,;t_j)=\left(1;\frac{1}{3}\right)$	$(p_i\,;\,p_j)=(7{,}864;5{,}743)$	$(\Pi_i\,;\Pi_j)=(0{,}665;37{,}228)$
5	$(t_i\,;t_j)=\left(\frac{1}{3};\frac{1}{5}\right)$	$(p_i\,;\,p_j)=(4{,}261;4{,}212)$	$(\Pi_i\,;\Pi_j)=(2{,}815;24{,}710)$
6	$(t_i\,;t_j)=\left(\frac{1}{3};\frac{1}{7}\right)$	$(p_i\,;\,p_j)=(4{,}243;4{,}142)$	$(\Pi_i\,;\Pi_j)=(2{,}603;25{,}456)$

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

Case	Pair of NICT $(t_i\,;t_j)$	Pair of price $(p_i\,;\,p_j)$	Pairs of profit $(\Pi_i\,;\Pi_j)$
3	$(t_i\,;t_j)=\left(\frac{1}{3};1\right)$	$(p_i\,;\,p_j)=(5{,}102;7{,}609)$	$(\Pi_i\,;\Pi_j)=(14{,}545;3{,}840)$

6.2.2.Saturation effect of NICT on the competitiveness of a company

When a company starts using new technologies in an intensive way (specifically the company j), on minimal information, we observe that its price evolves less proportionately compared to the increase of new technologies. These are the following situations:

Case	Pairs of NICT $(t_i\,;t_j)$	Pairs of price $(p_i\,;\,p_j)$	Pairs of profit $(\Pi_i\,;\Pi_j)$
5	$(t_i\,;t_j)=\left(\frac{1}{3};\frac{1}{5}\right)$	$(p_i, p_j)=(4{,}261;\ 4{,}212)$	$(\Pi_i\,;\Pi_j)=(2{,}815;24{,}710)$
6	$(t_i\,;t_j)=\left(\frac{1}{3},\frac{1}{7}\right)$	$(p_i\,;\,p_j)=(4{,}243;4{,}142)$	$(\Pi_i\,;\Pi_j)=(2{,}603;25{,}456)$

These saturation effects are calculated in the tables 1 and 2 below retracing the evolution of the price of company j at the balance of Bertrand in relation to the index of NICT t_j, and this for a given value $\bar{t_i}=\frac{1}{2}$. In this study, we will assimilate the marginal productivity of work, noted $\frac{\Delta p_j}{\Delta L^{t_j}}$ à $\frac{\Delta p_j}{\Delta t_j}$ for $t_j^1 > t_j^2 \Rightarrow L^{t_j^1} > L^{t_j^2}$. It is true that the more the amount of work will be high, the more the absolute value of the expression $L^{t_j^1} - L^{t_j^2}$ will be higher than the absolute value of expression $t_j^1 - t_j^2$. But what matters here, independently of these possible deviations is to know if the price increases or decreases, that is to say if the productivity is negative or positive. In this model, when it will be negative, it means that the productivity decreases, and when it will be, it means that the productivity increases.

<u>Table 1</u>: Evolution of the price charged by the company j at the balance of Bertrand in relation to the index of NICT t_j and this for a given value $\bar{t_i}=\frac{1}{3}$.

Variation of the index of new technologies t_j of company j and this for a given value $\bar{t_i}=\frac{1}{3}$ of the	Variation of the price p_j charged by the company j at the balance of Bertrand	Variation rate of the price p_j in relation to the index of NICT t_j	Variation rate of the slope $\frac{\Delta p_j}{\Delta t_j}$ in relation to the index of NICT t_j :

company i		$\frac{\Delta p_j}{\Delta t_j} = \frac{p_j^2 - p_j^1}{t_j^2 - t_j^1}$	$\frac{\Delta\left(\frac{\Delta p_j}{\Delta t_j}\right)}{\Delta t_j} = \frac{\Delta^2 p_j}{\Delta (t_j)^2}$
$t_j = 1$	$p_j \approx 7{,}739$	-	-
$t_j = \frac{1}{3}$	$p_j \approx 4{,}480$	4,889	-
$t_j = \frac{1}{5}$	$p_j \approx 4{,}212$	2,010	21,593
$t_j = \frac{1}{7}$	$p_j \approx 4{,}142$	1,225	13,738

Table 1 shows that the more company j uses NICT, the more its price charged is low, and this drop is achieved at a decreasing rate as revealed at the third column of this table.

<u>Table 2</u>: Evolution of the profit of company j at the balance of Bertrand in relation to the index of NICT t_j and this for a given value $\bar{t_i} = \frac{1}{3}$.

Variation of the index of new technologies t_j of company j and this for a given value $\bar{t_i} = \frac{1}{3}$ of company i	Variation of the profit $\prod_j$ of company j at the balance of Bertrand	Variation rate of the profit $\prod_j$ in relation to the index of NICT t_j : $\frac{\Delta \prod_j}{\Delta t_j} = \frac{\prod_j^2 - \prod_j^1}{t_j^2 - t_j^1}$	Variation rate of the slope $\frac{\Delta \prod_j}{\Delta t_j}$ in relation to the index of NICT t_j : $\frac{\Delta\left(\frac{\Delta \prod_j}{\Delta t_j}\right)}{\Delta t_j} = \frac{\Delta^2 \prod_j}{\Delta (t_j)^2}$
$t_j = 1$	$\prod_j \approx 4{,}665$	-	-
$t_j = \frac{1}{3}$	$\prod_j \approx 22{,}508$	- 26,765	-
$t_j = \frac{1}{5}$	$\prod_j \approx 24{,}710$	- 16,515	- 76,875
$t_j = \frac{1}{7}$	$\prod_j \approx 25{,}456$	- 13,055	- 60,550

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

The different equilibria obtained in situation of minimal information make appear that the Solow paradox is not verified since the use of new technologies is accompanied by an increase of the productivity that is done at a decreasing rate, that is to say a productivity which increases slower. In other words, we observe that as company j uses NICT, it becomes more competitive for its price is low, while its profit increases at a decreasing rate as shown at the third column of table 2.

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

Still on minimal information, when two companies go in for a technological race, that is to say when they intensively use new technologies, it appears that the effect on the competitiveness of the companies is nil or neutral in the sense that none of them is forewarned. The pricesremainalmostidentical (Cas 4 and 7).

Case	Pairs of NICT $(t_i\,;t_j)$	Pairs of price $(p_i\,;p_j)$	Pairs of profit $(\Pi_i\,;\Pi_j)$
4	$(t_i, t_j) = \left(\frac{1}{3}, \frac{1}{3}\right)$	$(p_i, p_j) = (4{,}486;\ 5{,}165)$	$(\Pi_i\,;\Pi_j) = (5{,}767; 21{,}801)$
7	$(t_i, t_j) = \left(\frac{1}{7}, \frac{1}{7}\right)$	$(p_i, p_j) = (4{,}098;\ 4{,}106)$	$(\Pi_i\,;\Pi_j) = (9{,}651; 24{,}876)$

Table 3 : Summary of differentresultat

(t_i, t_j)	(p_i, p_j)	(q_i, q_j)	(Π_i, Π_j)
Case 1 : (1 ; 1)	(5,494 ; 7,739)	(8,751 ; 2,016)	(1,365 ; 4,665)
Case 2 : $\left(1; \frac{1}{3}\right)$	(7,864 ; 5,743)	(2,015 ; 8,378)	(0,665 ; 37,228)
Case 3 : $\left(\frac{1}{3}; 1\right)$	(5,102 ; 7,609)	(9,405 ; 1,884)	(14,545 ; 3,840)
Case 4 : $\left(\frac{1}{3}; \frac{1}{3}\right)$	(4,327 ; 4,480)	(7,826 ; 7,367)	(3,629 ; 22,508)
Case 5 : $\left(\frac{1}{3}; \frac{1}{5}\right)$	(4,261 ; 4,212)	(7,690 ; 7,837)	(2,815 ; 24,710)
Case 6 : $\left(\frac{1}{3}; \frac{1}{7}\right)$	(4,243 ; 4,142)	(7,656 ; 7,959)	(2,603 ; 25,456)
Case 7 : $\left(\frac{1}{7}; \frac{1}{7}\right)$	(4,098 ; 4,106)	(7,910 ; 7,886)	(9,651 ; 24,876)

Result 1: When the two companies do not use NICT (case 1), company j of South (developing country) wins on his counterpart i of North (developed country) for its price is lower ($p_j \prec p_i$) and its profit higher: ($\prod_j \succ \prod_i$). This situation is due to particular advantageous characteristics for company j, notably lower fixed costs ($CF_j \prec CF_i$), lower wages ($\beta_j \prec \beta_i$), lower elasticity of the product in relation to capital ($v_j \prec v_i$).

Result 2: When both use in the same proportions (case 4 and case 7), none of them seems to stand out; prices and market shares being almost identical. The profit of company j seems to be higher compared to the one of company i due to particular advantageous characteristics of company j. We will say that, the effect is neutral.

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

Result 4: The effect is negative for company j which uses less compared to its opponent i (case 3)

Result 5: When fixed the level of NICT utilization of a company, notably company i ($\bar{u}_i = \frac{1}{3}$), by varying the level of utilization of NICT by the opponent company j, in the sense of a more pronounced use, we observe an effect of saturation. This is justified by the drop of its price charged at a decreasing rate and the increase of its profit at a decreasing rate.

VII. CONCLUSION AND PERSPECTIVES

In this study, we evaluated the effects of new technologies on the competitiveness of companies in a competitive environment. It appeared that these effects were related to the level of information detained by opponents. *On minimal information (no opponent knows the function of reaction of the other):*

a) *The use of new technologies has a* <u>*benefic effect*</u> *for the company which uses them more intensely compared to its opponent, for while its price, its profit increase ; the reverse effect is observed at its opponent that is the increase of its price and drop of its profit.*

b) *When the two companies go in for a technological race, that is to say an intensive use of new technologies, it appears that the effect on the competitiveness of companies is* <u>*nil*</u> *that is so far none of them is advantaged. Prices of the marketremainingalmostidentical.*

This neutrality at the level of the prices nevertheless confers an advantage to the company j in terms of profit that could be explained by particular advantageous characteristics: higher remunerations at company i compared to remunerations at company j, higher R&D at company which has high marginal productivity of labor (higher wages, so $CF_i > CF_j$).

c) *Results obtained shows that the intensive use (one-sided or not) of new technologies, beyond a certain level, does not improve the competitiveness of a company, likely because of the* <u>*saturation effect*</u>*.*

The last column of table 2 reveals that the profit will be maximum if only the second variation of profit of company j in relation to its index of new technologies is negative ($\frac{\Delta^2 \prod_j}{\Delta(u_j)^2} \prec 0$).

The seek of the point of inflexion will allow us to find level of use of new technologies. This issue will be tackled in a subsequent work.

This perverse effect of NICT (or saturation effect) raises the issue of the determination of the optimal level of new technologies of a company in a competitive environment.

The results we have achieved depend closely on the assumptions we have adopted:

- Firstly, the idea that the NICT only affected the labor factor in the function of cost. In a subsequent study, we will try to deform both factors at the same time, and see how the intensive use of new technologies could affect or modify the competitiveness of companies in a competitive environment.
- On the other hand, we have assumed that the competitiveness was a price competition (duopoly of Bertrand). It could equally be interesting to study, in a future work, the duopoly of Edgeworth.

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