Attempt of modelling the Technnological Acceleration

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Abstract :

In this paper, we study the technological acceleration whithin a new frame work wich extends models used in the literature. The objective of our research is then to construct a global model of evaluation of the technological acceleration by two methods of physical science. Firstly, we will try to formulate the equation of propagation of the technological acceleration and to find out the variable upon which it depends by drawing our inspiration from the model of undulatory physics. Secondly, we will borrow the model of dynamic physics (kinematics and Newtonian dynamics) in order to be clarified on the evaluation and measure of the technological acceleration. Kinematics and Newtonian dynamics will serve to quantify the technological advance of an industry or of a country which will make it possible to inform the decision makers about the state of health of their technology and to guide them in their ulterior strategic choices.

Key words: Technological Acceleration- Physics Models – Dynamics of the Technological Acceleration- Patents.

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Attempt of Modelling the Technological Acceleration

"In fact, dialectic is only the science of general laws of the movement and of the development of nature of human society and of thought». F.Engels.

1 - General Presentation.

Speaking about the thechnological dynamics leads us to evoke its first origines. The premisses of technology date back to ancient civilisations such as the Pharaonic or phenician times, and it is then that the first technical bases were established. The genesis of mathematics and geometry in ancient Greek attest the birth of a learned discourse on what would be ulteriorly known as "technology". Since then, and throughout different periods, technology has known such an evolution whose rate varied depending on the socio-economic contexts.

The industrial revolution in England marks, however, the start of what we call technological acceleration and which we will define as the state of activation (by training, diffusion and management) which renders the mechanisms of research, of development, of invention, and of innovation quicker in order to improve industrial performances. Technological acceleration draws its source from the social environement from which it emerges. Its continuity is henceforward ensured by management (the technological development). The technological acceleration is expressed by the reduction of the life cycle of the products and of the procedures of manufacturing (increase of the number of patents).

The invention of thermic energy in the 18 th century, of electricity in the 19 th century, of electronics in the 20 th century, as well as many other techniques have incessantly given consecutive pushes to the technical acceleration. In other terms -as was formulated by C.E.K MEES(1946) : The temporal scale of human progress is surely not linear. The technical progress is increasing much faster than time goes by; and may be that the most adequate chronological scale for the history of science and technology would be the ones whose subdivision are proportional to the logarithm of their distancing from the present time.

The rate of the technological acceleration, which has aroused the interest of a great number of contemporary economists, shows, however, certain inadequacies at the modelling level. Given its richness, this theme allows, by studying it, to embrace rich and various disciplines which cannot let the researchers in economy unconcerned. Nevertheless, when one wants to treat the technological acceleration, one cannot neglect the so luxuriant economics literature on this theme, which compells our contribution to treat the subject otherwise.

We will, then, try in this work to formulate in scientific terms the technological acceleration by relying on ulterior approaches particularly the ones made by specialized economists in innovation. the descriptive introduction of the agents adopting the logic of the technological acceleration will be dependant on the knowledge, on the competence, and on the financial means expended in the past, in the present, or which may be developed in the future.

Our approach will consist of finding a simplified writing which will make it possible to study the technological acceleration as a physical phenomenon, meanwhile we will try to avoid all mathematical problems liable to thwart this endeavour. To report in simple terms such a complex situation as the one of the technological acceleration and its representative elements is no easy enterprise, neither theoretically nor practically. In order to face the requirements related to the representation of the phenomenon by calculation, we will be compelled to have recourse to approximations.

The objective of our research is, then, to construct a global model of evaluation of the technological acceleration by two methods of physical science. Firstly, we will try to formulate the equation of propagation of the technological acceleration and to find out the variable upon which it depends by drawing our inspiration from the model of undulatory physics. Secondly we will borrow the model of dynamic physics (kinematics and Newtonian dynamics) in order to be clarified on the evaluation and measure of the technological acceleration. Kinematics and Newtonian dynamics will serve to quantify the technological advance of an industry or of a country in order to guide the decision makers to be informed about the state of health of their economy.

1.1 Formulation of the Propagation of the Technological Acceleration :

It is essential that a question be asked : where are we to search for the origine of the ideas which are liable to guide us to undulatory mechanics in order to explain the phenomenon of technological acceleration ?

The developments of the schumpeterian theory are essentially based on the fundamental hypothesis that the economical progress propagates in the form of waves of innovative contractors, by a radiation which is realized discontinuously at the level of the quality and quantity of the inventions.

The concept of creative destruction- according to Schumpeter contains the essence of the explanation we provide about the technological acceleration. Were we to exclude the idea of creative destruction which is so dear to schumpeter, we would render it impossible or at least difficult to understand the technological acceleration. According to Schumpeter(1942), it is the change of the industrial process that is incessanty revolutionizing the economic structure inside, by continuonsly destructing its old elements whereas new elements are being continuonsly created. This process of Creative Destruction constitutes the fundamental datum of capitalism: it is of it that capitalism consists at the end of the analysis, and all capitalist enterprise is to be fit to it willy-nilly.

The waves are only functions which propagate in the form of streams with maximal and minimal amplitudes, the enterprises fill their slot in the market depending on their technological weight (innovation) and see the value of their innovations fluctuating according to the competition (see diagram A). The technological acceleration phenomenon can be interpreted thanks to the undulatory nature of the innovations among enterprises.

An economic milieu is susceptible to propagate gradually the disruption caused by an innovation. In physics, this phenomenon is known as waves. This concept has been fit to the different problems of physics as is noted by M. Alfonso & E.J.Finn(1970) : " the physician has extended the use of the concept and has applied it to a great number of phenomena which are not the same as the objective image of a wave on the surface of water but which obey to the same mathematical description". All the waves are numerous spatiotemporal phenomena and vary according to a defined physical variable F. A wave propagates in a speed V in the sens of the positive Xs and defined with a function G of a variable (t-x /v). This is summed up in the equation:

$$F= G (t-x / v).$$

Our work will be limited to the study of the relationship to which the wave associated to the technological acceleration obeys; the amplitude of this wave in any point M of the economic space is naturally a function of these x, y, z, and t coordinates, supposing that:

x = the level of the invention of the products to study.

y = the number of competing enterprises which are situated in the space in question .

z = the sales stemming from the products incorporating the concerned innovation.

In a point m of the axis ox , the amplitude f (x,t) of the wave will have an identical expression, with the exception of a delay θ by the wave to move from O to M. We express the latter according to the covered distance .

$$F(x,t)= a \sin 2 \pi \nu (t-\theta) = a \sin 2 \pi (\nu t-x/\lambda).$$

With: $\nu = 1/T = \omega /2 \pi$ $\lambda = 2 \pi /k.$ $\theta /T= x/ \lambda$.

a= represents the level of the research on the domain to be studied.

ν= is the frequency of the innovations in the concerned technological domain.

t-θ = is the time of diffusion of the technology in question.

- We derive F(x,t) by x:

$\partial F(x,t)/ \partial x= -2 \pi /\lambda (\cos 2 \pi (\nu t-x/\lambda))$

$\partial'' F(x,t)/ \partial'' x= -4\pi^2 a /\lambda^2 \sin 2 \pi (\nu t-x/\lambda).$

- We derive F(x,t) by t:

$\partial F(x,t)/ \partial t= 2\pi \nu a \cos 2\pi (\nu t-x/ \lambda).$

$\partial'' F(x,t)/ \partial t''= -4\pi^2 \nu^2 a \sin 2 \pi (\nu t-x/ \lambda).$

the speed of propagation of the wave : $vo = \lambda \nu$.

By eliminating $\sin 2\pi (\nu t - x/\lambda)$ from the above equations, we obtain the differential equation of the second rate with constant coefficients of the propagation of the technological acceleration along the axis ox :

$$\partial'' F/ \partial x'' = (1 / vo^2) \partial'' F/ \partial t''.$$

The propagation of the wave associated to our dimension should then satisfy the equation:

$$\partial'' F/ \partial x'' + \partial'' F/ \partial y'' + \partial'' F / \partial z'' = (1 / vo^2)\partial'' F / \partial t''.$$

$$\Delta F= (1/ vo^2) \partial'' F/ \partial t''.$$

Δf is a " laplacian " operator of the function f .

$F= a \sin (2 \pi \nu t).$

$\Delta F = \Delta a \sin(2 \pi \nu t)$.

$$\Delta a + 4(\pi^2 \nu^2 / vo^2)a = 0.$$

Finally, the equation of propagation of the wave of the technological acceleration depends only on its amplitude, that is to say the level, the frequency, and the speed of the scientific research. The latters are closely linked to the degree of management of technology. Relativity and wave are an inseparable couple in physics. The same thing applies to the wave of the technological acceleration, the propagation of the wave has a consecutive effect on the behavior of the offers. Either it amplifies derives, or nullifies them.

⇓INVENTION ⇑

Pressure of R & D — Pressure of survival

INNOVATION ⇒ — **⇒ PRODUCT**

Pressure of the market

Diagram A: The characteristics of the wave of the technological acceleration.

1-2 - Dynamics of the Technological Acceleration:

The system of dynamics of the technological acceleration is not the concern of probabilities only. Its condition develops according to a determinist equation, and is determined only by the specifications of its initial and final conditions. When this system meets another with which it engages in a mutual interaction, it undergoes transformations which may require that the significative variables involved in its modelling be calculated.

As to our modelling, we will use the deterministic way in the evolution of the technological acceleration. We will start from the hypothesis of the accomplishment of both the initial and final conditions of the evolution of the system in question.

The mathematical image of the technological acceleration may be summed up in the concept of discontinuity. It has the passing of time as its image. We may schematize time by abscissa curves and the intensity of the determinants of the technological acceleration by ordinate ones (R & D, patents, competition, the technological development, training, diffusion, management, etc...). As far as we are concerned, we will limit ourselves to the quantifiable elements which are included in our definition of the technological acceleration.

The technological acceleration is a spaciotemporal fact, and its phenotypes and genotypes are well determined in the developed countries, which allows us to adopt a physical-science approach. In this perspective, we can make reference to M. faber & J.L.R. Props(1991) who believe that physics is entirely concerned in the evolution of phenotypes, which explains its success as well as the interest of other disciplines to it by the adoption of its models. The parallelism which we will adopt between the physical acceleration and the technological acceleration may be considered with all the intention deserved by a new model which tries to present the scientific ways in the domain of economy.

We will first clarify the acceleration in physics, then we will apply it to technology.

1-2-1 The physical acceleration:

It is in mechanics that mathematics and the physical reality meet. It is by studying mechanics that physicians learn to schematize real phenomena and to provide theoretical descriptions. We will consequently appeal to classical mechanics alone given the difficulty of grasping relativist mechanics and to find a correlation between quantium and economic variables on the one hand, and on the other hand the inadequacy of the statistics involved in the quantum model of the technological acceleration which constitutes a real problem to such a process. The notion of physical acceleration has first appeared in the works of Galileo who has proved that it is the variation of speed which leads to the notion of acceleration.

Let us take as an example any race (horses, cars, bycicles, ...), we say that a body goes faster than another when it takes to it less time to cover the same distance, the notion of speed includes information on direction in which the boby moves. Speed is then a measurable magnitude since distance and time are measurable magnitudes.

There are different sorts of speeds in physics: if the quotient of the distance by time is constant as to its magnitude on the trajectory, the movement is said, then, to be rectitinear and uniform; otherwise, that is to say in case speed were not constant, it would then be a matter of acceleration. This acceleration is, by definition, equal to the ratio of speed to time.

The relation of the acceleration given by kinematics is:

$$\gamma = dV/\, dT.$$

γ= acceleration. dV = variation of speed. dT = variation of time .

Formulating the acceleration may be achieved otherwise by applying the fundamental principle of Newtonian classical dynamics. It is the relation between the sum of the forces, masses , and acceleration:

$$\Sigma F = \gamma \Sigma M.$$

F= force. M= mass. γ= acceleration.

1-2-2 The Technological Acceleration.

Were we to apprehend the mechanisms of the technological acceleration, the synthesis of the history of techniques and the analysis of economic theories will be required. Economic analysis aims to quantify the economic phenomena and to formalize the description of the stakes in the mechanisms. In order that the modelling of the technological acceleration be achieved, we have first to try to find the representative variables; otherwise, we will be compelled to have recourse to the variables schematizing the reality to be analyzed. Our topic now faces two problems: the first is that it is quite difficult to get the statistical values of a number of variables which we would like to incorporate in our model, and the second is that the reality of the technological acceleration is of such a complexity that we cannot apprehend it except at the expense of such a simplicity which may turn out to be costly.

1-2-2-1. The Approach of the Technological Acceleration by Kinematics.

Kinematics allows to appreciate the condition of the technological acceleration of a country or any technological area without any lingering on its part on the forces influencing the technological acceleration. What counts is only the outputs of the technological acceleration by basing our work on only one reference: the patents, given the importance of their role in the economic development and of their contribution in the technological acceleration.

There are many economists who are interested in the statistical studies achieved by J. Schmookler(1966) who is one of the most famous scientists who have studied the different areas (petroleum, industry, railways conception, building ...) and traced a graph representing in abscissa curves years (one century) and in ordinate curves the number of inventions and production in capital goods. Schmookler's graph shows that the inventions follow the investments and do not precede them. Everyday ameliorations are often carried out by profit, and only innovation confers the transforming action to the invention. Also, it should be noted that it is only through the economic innovations that the effects of productivity increase can be expressed, that new resources can be created, and that conditions of life can be ameliorated. There is then nothing surprising about finding out the existence of different legal weapons aiming to protect the inventor. The patent -one of these weapons- is often used by firms as a weapon of a strategic nature. The preoccupation of the political powers of developed countries is to promote their position with regard to other competing countries. The patent grants its holder the privilege to monopolize a limited span of time as well as a remuneration. The scope of this remuneration can only originate from an industrial exploitation and its great social usefulness.

The patent allows the protection of inventions against competitors and the avoidance that they present the same product on the market. The continuous increase of inventions, quasi-exponential of the curve of patents, is one of the fundamental elements of the illustration of the technological acceleration. As such, we cite Pierre Rousseau (1965): "humanity, at the end of this twentieth century, consumes inventions at an accelerated rate, it swallows them up more and more quickly and each year it needs even more".

Accoding to Bernard Bobe(1991), there are at least five reasons which necessitate innovation :

- the speed of the technological evolution.
- the speed of evolution of the market.
- the vivacity of international competence.
- transfers of technologies due to the increasing internationalization.

The area of the technological acceleration is rigorously shown in the developed countries mainly Japan, France, Germany,and the USA. The technological positions of these countries may be evaluated by a study of the number of applications for patent registration.

B. Amable and E.M. Mouhoud (1990) made an analysis of the comparative advantages of the six most industrialized countries, particularly the USA, Japan, France and Germany, in the three technological areas, i.e. low technology, medium technology, and high technology. France, Japan, the USA, and Germany have a comparative advantage as to the rest of the world and developed countries in the domains of medium and high technology. There has appeared a change of situation as soon as they tried to extend the analysis on the comparative advantages of the countries under study with the OCDE zone, i.e. the area where competition is tough particularly by the mechanism of patents. Japan has comparative advantages as to the OCDE countries on the level of middle and high technology since the early seventies and up to now. As to Germany, it has comparative advantages only on the level of high technology with regard to the OCDE. The situation of France is represented in a serrated curve as far as high technology is concerned; however, it has a comparative advantage in the area of low technology and a clear-cut disadvantage on the level of medium technology. As far as the United States are concerned, there is a clear-cut comparative advantage with regard to the OCDE countries that appears on the level of medium technology as well as on the level of high technology.

We realize that the evolution of patent registration (1980-1990) of the USA emphasizes a clear-cut superiority with regard to the remaining countries in the period under study, it is realized by a yearly patent registration of the order of 33 %; followed by Japan with an annual increase of 21% in the same period. As to Germany it was late until 1985 compared to France, and since then, it moved ahead of this latter. During the period under study the registered patents are of the order of about 50 %. France occupies the third position in the span of time from 1980 to 1984, but it has moved to the fourth position since 1985. The increase of the registered patents by France from 1980 to 1990 was of 3% only. Were we to establish a parallelism with the study of B. Amable and E.M. Mouhoud, we will realize that the countries which have advantages in the areas of medium and high technologies (these technologies require more protection by patents) are in a positive correlation with the level of the registered patents.

1-2-2-2. The Approach of the Technological Acceleration by Dynamics.

At this level, we will have recourse to the analytical method developed by Léontief since 1942. This analysis is known under different names: input-output, physics flux between areas... This method ows its intellectual paternity to F. Quesnay's economic chart; the interdependences amongst the flux of activities of all the productive areas of economy had to be brought to the fore in such a way that the sum of outgoings would be equal to receipts.

The indicators of the effort of the technological acceleration are presented on the level of inputs as:

1. expenditures of research and development
2. learning in Arrow (1962) and Rosenberg's (1982) sens.
3. employment of researchers.
4. degrees of management of technologies.

The indicators of the effort of the technological acceleration on the level of outputs are presented as :

1. the number of registered patents.
2. the total amount of the total export from which we substract the total of the raw materials.

Research and development represent, then, the representative and quantifiable input for the technological acceleration; as to the output, it is represented by the number of patents.

So that we be able to formalize the relation of the equation of the technological acceleration, we will suppose that we have the abitity to know at any time the characteristics of its forces, i.e. the patents and their costs as well as the masses of expenditures of R&D.

$$\Sigma\Sigma\ Bij\ Pij = \gamma\Sigma\Sigma\ (R\&D)ij.$$

Equation of the dynamics of technology.

- Bij is the number of patents of industry i in a period j.
- Pij is the cost of the patents Bij.
- (R&D)ij is the total of expenditures of the research-development of the industry i at a time j .
- γ is the technological acceleration of the industry i in the period under study.

$$\gamma = \Sigma\Sigma\ Bij\ Pij / \Sigma\Sigma\ (R\&D)ij.$$

γ will allow to measure more precisely the intensity of the technological acceleration in the different branches of activities or in the whole economy of a given state.

The mastery of the technological acceleration has become a major necessity for the preoccupied countries about their development given its impact on economy and society in general, even if its price has become too high to run into remarkable inventions (consider the case of the NASA in the USA). The knowledge and competence of the developed countries are practically the same and the superiority of one of them does not last long given the technological development. Inventions are succeding one another in a considerable progression and the increase of the number of publications and inventions is more important from year to year thanks to the forces and pressures of the market; their conception and circulation do not last long (see diagram B); we are rather witnessing a lessening of the period separating the invention from its introduction in industry under the pretext of profit and survival of the enterprises. We are witnessing a new era of democratization of the means of conveying information, namely by internet, and their repercussions will have the effect of a snowball on the technological acceleration by the interaction and widened fertilization of the technological pieces of information in particular.

CONCLUSIONS :

In this modelling, we have tried to formulate scientifically the technological acceleration by dipping into the sources of economy and physical science. Firstly, the equation to which the wave of the technological acceleration was identified. Secondly, the dynamics of the technological acceleration was apprehended by two different methods: kinematics and classical dynamics. The former considers technology only on the level of the output by means of the patents; as to the latter, it deals with the forces governing the technological acceleration at the level of input and also at the level of output. The boundaries of the model which has just been presented may be limited to two points: the first point is focused on the inadeqacies of the statistics which concern the data of the research; as to the second point , it is related to the method of classical mechanics which seems to be a means of simplification of the technological acceleration.

F. RESEARCH→→→ F. DEVELOPMENT →→→→ F.SALE

INVENTION →→→ INNOVATION→ →→→→ MARKET

V.inv V.inn V.MAR t1

↑ ↓ E.competition

↓ V.comp.t2

P. new product ↓ E.imitation

↓V.qtt t3

↑ ↓V.inn.minor

V.qlt4.

Diagram B: the interactions of the areas of the technological acceleration.

Notations :

F: force, P: pressure, Vinv: value of invention, Vinn: value of innovation, E: effect, Vmart1: value of technology at the market at a time t1, Vcomt2 : value of technology at a time t2, which stems from competition. Vqtt t3 =value of technology at a time t3, being dictated by the quatity of its offer. Vqlt4: at a time t4 demarcation is achieved by quality as a consequence of minor innovations.

The last step is the firm survival which is conditioned by the realization of a new product and consequently, the loop of the interaction of the areas of the technological acceleration is looped.

We note that : Vinv > Vinn > Vmar t1 > Vcon t2 > Vqtt t3 > Vql t4.

References :

ALFONSO M.& FINN E.J., « Physique générale », Tome II, Champs et ondes, Edition du renouveau pédagogique, I.N.C, Momtréal, Paris, 1970.

AMABLE B. & MOUHOUD M., « Changement technique et compétitivité internationale : une comparaison de six pays industriels », in Revue d'Economie Industrielle, n°54, 1990.

ARROW K., « The Economic Implications of Learning by Doing », in Review of Economic Studies, n°29, 1962.

BOB B., « Diagnostic de la fonction R&D, leçon Japonaise », in Revue Francaise de Gestion, Sept-OCT. 1991.

ENGELS F., « Anti-dürhing », Editions sociales, 1973.

FABER.M & PROOPS J.L., « Evolution in Biology, Physics, and Economics », in Evolutionary Theories of Economic and Technological Change, SAVIOTTI P.P.& METCALFE. J.S., Harwood academic publishers, 1991.

LEONTIEF W., « The Structure of American Economy 1919-1939 », 2nd edition, Oxford University Press, 1951.

MEES C.E.K., « The Path of Science », New York, 1946.

ROSENBERG N., « Inside the Black Box : Technology and Economics », Cambridge University Press, 1982.

ROUSSEAU P., « L'invention est une aventure », Edition Hachette, 1965.

SCHMOOKLER J., « Invention and Economics Growth », Harvard University Press, Cambridge, Massachussets, 1966.

SCHUMPETER J.A., « Capitalism, Socialism, and Democracy », Harper & Row, 1942.