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THE NEW ENDOGENEOUS GROWTH THEORY VERSUS A PRODUCTIVITY REGIME APPROACH :

ONE CENTURY OF AMERICAN ECONOMIC HISTORY REVISITED

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Contents

Will the new endogenous growth theory deliver a deep and genuine understanding about economic development and specially the stages of American growth, hegemony and possibly decline?

Is there any synthetic and convincing explanation about the American productivity slow-down and similarly the SOLOW paradox, according to which innovations are to be seen everywhere in our daily life ... but not at all in the U.S. productivity statistics?

Is the regulation approach so wrong when it explains the productivity problems by the demise of the Fordist regime and the progressive loss of technological leadership by American manufacturers ?

The present paper proposes some tentative answers to these three issues, via a methodological discussion of conventional growth theory, a survey of the literature about technical change and industrial organization and an econometric studies of the determinants of aggregate labor productivity from 1890 to 1987. The basic objective is to detect long run relationship through cointegration techniques, along with special tests of possible structural change of productivity regimes. Consequently the argument develops as follows.

First, productivity regimes are situated in recent discussions on productivity slowdown, endogenous growth and the "régulation" theory (Section I). The theoretical bases for the existence of productivity regimes instead of long run stable production functions are presented and discussed (Section II). Then some statistical and econometric problems are investigated: clearly, the recent advances in time series analysis brings some tools specially convenient for testing the existence of long run relationships between productivity and selected economic and social variables (Section III). Consequently, these principles are implemented for the U.S. economy over the period 1869–1889 for a very simple set of explaining factors: capital deepening and increasing returns to scale. The hypothesis of a unique and stable relationship is rejected, whereas stability tests diagnose the succession of four periods with varying impact of both the capital:labor ratio and the size of the economy (Section IV). But the notion and effectiveness of productivity regimes need more detailed investigations in two directions. First, a series of variables measuring the constitution of the American market, process and product innovation, and government investment are added to the previous macroeconomic variables: capital:labor ratio and employment. Secondly, the robustness of the four preceding periods is assessed and related to a direct chronology of the source of innovation and technical change in the U.S., which roughly confirms the previous chronology: 1890–1920, 1921–1933, 1934–1964, 1965–1989 (Section V). These results which are surprisingly consistent, and provide a significant support for the notion of productivity regime, by contrast to conventional production functions, are then compared with previous attempt to specify technological epoques for the the U.S. (Section VI). Nevertheless, they call for further elaboration and investigations, which are briefly sketched out by concluding remarks (Section VII).

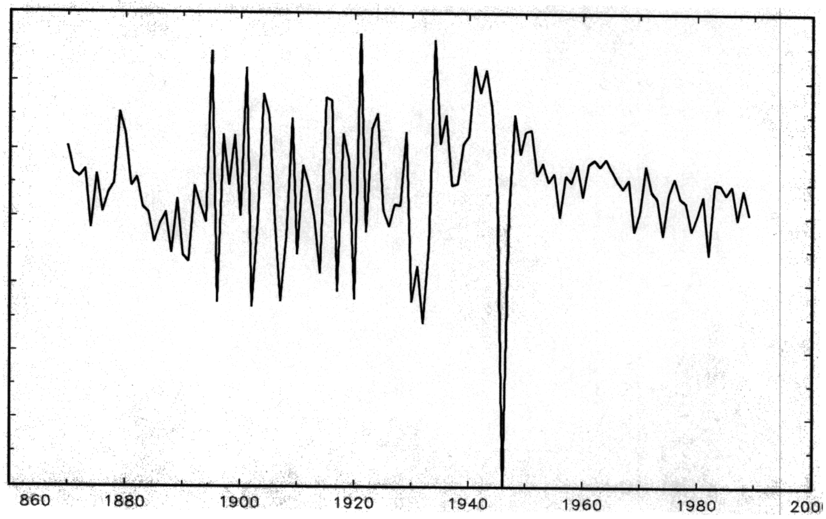
1 CAN HISTORY ENLIGTHEN THE CURRENT PRODUCTIVITY PARADOX?

Contemporary theoreticians and policy makers have focused their analyses upon short run disequilibria from the early 1970's to the mid-1980's. In the so called new classical theory, all economic dynamics are reduced to individual reactions to unexpected shocks. This feature is common to most of the research, even along neo-Keynesian lines. In a striking parallel, economic policies have devoted much efforts in order to foster the efficiency and short run flexibility of labor and financial markets, under the hypothesis or belief that a series of optimal decisions from period to period will automatically lead to the fastest growth and therefore a significant improvement in living standards.

Since the mid-1980's, it is more and more widely recognized that one of the major challenges addressed to the American society relates to the poor productivity performance of this country: after having forged ahead, the United States would be falling behind (M. ABRAMOVITZ, 1989, pp. 220–241). New competitors, such as Europe and Japan, would be now exploring the technological frontier, at least in some key sectors. The threat does not concern only the U.S. external competitiveness, but simultaneously the very destiny of the American dream about an ever increasing welfare. In a recent and synthetic book, W.J. BAUMOL, S.A.B. BLACKMAN and E.N. WOLFF (1989) point out: "...the long run productivity growth can make an enormous contribution to living standards, and there is no substitute for productivity growth in this respect ...". Many statistical studies on households incomes have confirmed a drastic change in the ways of maintaining family living standards: by a larger participation of women to the labor force and by longer hours and no so much through an inrease in real after tax wages (M. REICH, 1991).

1.1 Still an American productivity puzzle

E.F. DENISON (1967, 1979) made pioneering work in investigating the roots of total factor productivity dynamics, both in the U.S. and in industrialized countries. Nevertheless, he documented a significant slowdown after 1973 or even 1969 without any success in finding out a satisfactory reason for such an evolution: the residual term remains important and unexplained in spite of a multitude of factors brought into the analysis. This failure might be attributed to the very methodology of growth accounting and still more its necessary reliance upon marginal productivity theory. An alternative view adopts a purely statistical approach: is this contemporary slowdown so extraordinary with respect to the long run historical American record? A graph providing the rate of hourly productivity since 1870 exhibits mitigated evidences (Figure 1). On one side, the variability is such that the productivity rate during the last two decades lies inside the range delimited by secular patterns of evolution for this variable. Such an evidence has recurrently been put forward for example by A. MADDISON (1982, 1991). But on the other side the period from 1945 until now does not look like the previous ones. The fluctuations are far milder and starting from the end of World War II, from cycle to cycle, one observes a rather clear adverse trend in productivity gains, at odds with an opposite upward evolution from 1890 to 1922 and even possibly 1942.



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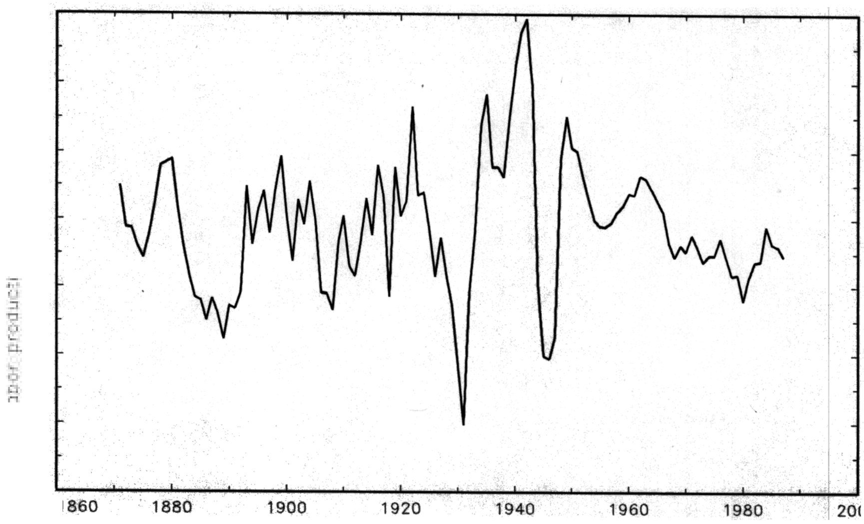

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Therefore from an economic point of view, something has to be explained: the recent years do not exhibit "productivity as usual", not to speak of the discrepancies between the U.S., Japan and Western Europe. Consequently, most other authors have preferred a whole spectrum of different methods which rely neither upon pure accounting nor mere statistical analyses but consist in deriving from economic theories testable hypotheses which can be confronted with time series or cross-sectional data, at the macro, sector and, ultimately, micro level.

But until now the numerous researches along these lines have not delivered any grand interpretation but only a series of caveats. Yes, the U.S. economy becomes more and more tertiary ... but per se this structural change does not explain a considerable fraction of the aggregate productivity slowdown (W.J. BAUMOL et al., 1989). Of course, many European countries have caught up, but this is not a reason for a declining American performance (J.G. WILLIAMSON, 1991). The oil shocks and counter-shocks do explain some ups and downs in the medium term productivity and growth ... but they do not suffice to capture why productivity performances still differ across advanced capitalist economies (F. LARSEN and J. LLEWELLYN, 1986).

Consequently, it is not a surprise if during the last few years more innovative explanations and theories have been worked out and tested against the American data. By nature and since long, capitalism has reacted by innovating to the very unbalances and contradictions this mode of production permanently creates. The very first and evident explanation of the productivity slowdown is then that inventions and more importantly their conversion into profitable economic activities have lost part of their impetus. Clearly, the United States have experienced a significant decline in the share of R.&D. expenditures in GNP from 1967 to 1979, whereas West Germany and Japan have not cut their efforts (D.C. MOWERY and N. ROSENBERG, 1989). Nevertheless, this interpretation only captures a limited fraction of the dynamics of productivity. Firstly, econometric studies suggest that the elasticity of production with respect to the stock of knowledge delivered by the cumulation of past R.&D. expenditures is generally significant but rather small (J. MAIRESSE and M. SASSENOU, 1991). Secondly, it is hard to believe from the direct observation of a multiplicity of process and product innovations that technical change has been exhausted during the last decade. But then a new paradox emerges: for instance, computers are to be seen everywhere ... except in the official productivity statistics! (R. SOLOW, 1988).

1.2 The new endogenous growth theory at bay in front of the SOLOW's paradox

The growth theory had been quite neglected during the 1970's, even though the reduction in growth rates and recurring instabilities clearly called for novel investigations in this area. Only post-Keynesians, Marxists, radicals or "régulationists" have continued their analyses about the long run trends of modern capitalist economies. Within mainstream economics, a renewed interest has been observed after the semi-seminal articles by P. ROMER (1986, 1987, 1990). He elaborated a model centered upon the compatibility of intertemporal optimization of individuals who are facing and simultaneously creating externalities due to innovations which can be appropriated by followers. P. ROMER gave thus a Marshallian solution to what general equilibrium theorists used to consider as a dead end: the existence, but not the optimality of a pure market equilibrium in the presence of dynamic increasing returns to scale.

This author simultaneously tried to confront the predictions of his models with the stylized facts derived from at least two centuries of growth. Since any new knowledge makes easier subsequent innovations along the same path, growth is unlimited even if labor and natural resources are limited. Looking at cross-national data since the emergence of Dutch capitalism, P. ROMER initially found that from one historical period to another, there is an upward trend in productivity growth rates. He also found that the conventional neoclassical production function and consequently growth theory systematically underestimates the contribution of capital to productivity.

Thus the new endogenous growth theory provides conflicting interpretations about the American productivity slowdown. On the one side, it can be attributed to the deceleration in capital deepening, itself related to the low saving propensity of this country. This could explain why the relative performance of the U.S. has declined with respect to Japan or European countries, which have invested much more in productive and intangible capital. On the other side, the long run perspective delivers an opposite prediction: given that after World War II, the U.S. was technologically leading in the quasi totality of sectors, given the advance in basic and applied research, the growth rate of productivity should have been superior to those of Germany or Japan, provided the catching up effect is removed.

Consequently the new theories add a new mystery to the American productivity puzzle: given its initial advance, North America should never have been caught up by its followers, but, on the contrary, should have widen its productivity differential. For the time being this theory is still too crude to give a convincing and straight forward explanation for the relative performance of the O.E.C.D. countries and especially the deterioration of the position of the U.S. since two decades.

1.3 Are SSA and the regulationist interpretations obsolete?

Analysts in the Marxian tradition have continuously emphasized the role of capitalist institutions in channeling the contradictory process of accumulation. Both the Social Structure of Accumulation (SSA) and the Regulation Approach (RA) share this concern and have investigated the reasons why the post-World War II period has been so dynamic in terms of improvement in productivity, living standards and general stability. Basically, the struggles in the firm as well as in the political arena have led to genuine social compromises, which in turn make innovation and technical change more or less coherent with the coercive laws of accumulation. Among these institutional changes, a special emphasis has been put upon the capital-labor accord for SSA or the wage-labor nexus for RA, along with a new State-citizen accord for SSA, somehow paralleled by the institutionalized compromise put forward by the regulationists.

Nevertheless, different reasons for the end of the long boom are put forward by these two approaches. For SSA, the near full employment reached during the mid-1960's reinforced the bargaining position of workers as well as of minorities, triggering the equivalent of a profit squeeze, which in turn has introduced inflationary pressures, most of the time validated by the Central Bank. The Reagan years would then be a period of a tentative restoration of work discipline, via a monetarist cold bath, deregulation and anti-union strategies. The productivity slowdown is therefore related to first structural factors, i.e. the rise of the costs incurred in order to maintain the corporate order, second to the unfavorable impact of Reaganomics upon capacity utilization and ultimately total factor productivity (S. BOWLES, D. GORDON and T. WEISSKOPF, 1989, 1990).

For RA, the roots of the crisis of Fordism, i.e. the post-World War II accumulation regime has to be found in the structural limits inherent to this regime, from its productive side: the very diffusion and deepening of capital substitution finally hits some social and economic barriers, which dampens productivity growth. Given the three years wage contracts binding during the 1960's, nominal wages initially follow their track but are finally revised a few years after the productivity slowdown (M. JUILLARD, 1988). The related shifts in the demand regime and the productivity regime lead either to instability (R. BOYER, 1988), or to a decline in the long run growth path (R. BOYER, 1989). In other advanced countries, the pattern is generally different since the precise compromises and work organizations are not the same and some had still a productivity gap to close. Nevertheless, the slowdown is common to quasi all, since the international system diffuses the American inflation and disequilibria to developed and developing countries.

Criticisms to SSA and RA have abounded and concern both their theoretical underpinnings and historical relevance. Basically, R. BRENNER and M. GLICK (1991) and M. DE VROEY and J. CARTELIER (1989) have argued that the RA does not deliver any theoretical breakthrough and neglects the so called coercive laws governing any capitalist mode of production, whatever its precise institutional settings. The problem is that very few such laws are actually exhibited by these authors and its precisely the aim ... and may be the merit of RA to coin intermediate concepts which would reconcile MARX seminal hints with what another century and the succession of structural crises and long run boom has learnt to radical scholars (R. BOYER, 1989). The debate is too large to be addressed in this paper.

On the contrary, it aims at replying to a series of recurring and severe doubts about the congruence between the stylized facts put forward by the regulationnists and specially M. AGLIETTA (1982) and the common knowledge built by economic historians who have been studying intensively U.S. capitalism. R. BRENNER and M. GLICK (1991, pp. 51–61) challenge the whole periodisation, since they diagnose much more continuity than discontinuities in technical change and in the accumulation process. "Long before the era of taylorist-Fordist transformations, new machines, representing enormous advances in productive efficiency, had been more or less regularly—though certainly not continually—coming into use" (p. 59).

One of the major findings of the present paper is precisely to present rather rigorous econometric tests which tend to suggest that even though the mechanization process is an inner tendency within each capitalist development mode, its rhythm and impact on productivity varies a lot from one historical epoch to another. In other words, quality of mechanization turns into contrasted quantitative evolutions, i.e. productivity regimes. Conversely the dynamism or alternatively the structural crisis generated by a regime might trigger technological and/or institutional transformations, therefore affecting the qualitative configuration of the system. This is the core of the regulationist message, right or wrong (M. AGLIETTA, 1982; R. BOYER, 1990). Still more extensive and intensive accumulation are not mythical concepts, since they can be precisely and adequately defined. The statistical analysis presented in this paper suggests that the results are more supporting this view than destroying it.

Just in passing, this idea of technological epochs is not a total novelty. Even in the tradition originating from the seminal paper on empirical production functions for the American economy (C.W. COBB and P.H. DOUGLAS, 1928), the long run stability of such functions has been challenged. For example, conventional CHOW's tests deliver three technological epochs: 1890–1918, 1919–1937, 1938–1958 (M. BROWN and J. POPKIN, 1962) and this chronology resists to the change of the production function from a Cobb-Douglas to a C.E.S. (M. BROWN and J.S. de CANI, 1963). One of the objectives of this paper is to apply contemporary methods in testing for structural change. Nevertheless, the emphasis is not put upon production functions, which are valid only for the short run and not for the long run but rather upon productivity regimes, since the movement along a production funciton and its continuous shifts by innovation and competition cannot be disentangled and therefore have to be jointly estimated.

This message or at least warning seems to have been forgotten by most growth theorists and productivity analysts. The semi-new endogenous growth theory still persists in postulating one unique regime valid from the Mayflower times until the space age: this makes deductive reasoning possible ... but does not necessarily add to the relevance of the theory. On the contrary, SSA and RA have already undertaken the study of productivity regimes. D.M. GORDON (1991) finds out that the drive system does not have the same properties as the capital-labor accord system and that the phasing out of the first one does coincide exactly with the rise of the second. Similarly, M. JUILLARD (1988) has shown that the period since 1950 is not homogeneous and experienced first a decline in productivity and, a few years later, an equivalent downward shift into the equation describing wage formation. In a sense, this paper tries to go a step further with respect to these early attempts. So doing, it responds also to some of the other criticisms of RA.

2 FROM CONVENTIONAL PRODUCTION FUNCTIONS TO PRODUCTIVITY REGIMES

The existence of aggregate production functions has triggered lively and sometimes hot discussions during the 1960's, around the so-called two Cambridge controversy about the measure of capital. This debate has generally left out a parallel and no less important issue: looking at time series data, can one disentangle between substitution along a given production function and shift of this function under the impact of technical change. The present section will deal mainly with the empirical relevance of this debate in the light of the trends of the productivity in the United States since 1869.

2.1 The complex relationship between production function and technical progress function

Let us suppose that the aggregation problem from firm level to sector and then global variables has been solved for a given period of time (L. JOHANSEN, 1969). This delivers isoquant describing which level of capital and labor have to be combined in order to get a given volume of production. Then, given the relative price of these two factors, private optimization will lead to an optimum, i.e. an efficient state, provided that marginal productivities are decreasing. If now, technical change takes place and introduces new techniques of production, it is no more possible to disentangle how the new optimum derives from a shift in relative prices or from a change in the production function. Usually, conventional neoclassical theory (R.M. SOLOW, 1957) as well as growth accounting (E.F. DENISON, 1967) is bound to arbitrarily decompose the movement along an isoquant and the shift of this isoquant. If one assumes that factors are paid at their marginal productivity, the isocost line is a first order approximation for the isoquant, in such manner that:

$$Q_t = \mu N_t + (1 - \mu) K_t$$

Consequently, the impact of technological change is captured by relating actual production Q_t^* to Q_t, i.e. the capacity of production obtained by combining the current level of factors with the technique observed in the previous period:

$$A_t = Q_t / [\mu N_t + (1 - \mu) K_t]$$

But alternatively, one could consider that the very impact of innovations is to change the relative productivity of each factors and therefore try to estimate the equivalent of a Cobb-Douglas function with varying parameters μ_t. In such a case, the variation in the bias $[\mu_t / (1 - \mu_t)]$ of technical change replaces an estimate of its intensity A_t. Actually, a brief survey of the econometric estimates for the U.S. economy exhibits such a two fold strategy: R.M. SOLOW (1957) and E.F. DENISON (1967) prefer to estimate A_t whereas M. BROWN and J.S. De CANI (1962, 1963) and R.W. RESEK (1963) only investigate the direction and non-neutrality of technical change, i.e. μ_t.

Such a dilemma is not easy to disentangle in applied work. An elegant solution may consist in testing simultaneously a production function and an expression for technical change, which yields usually to the adoption of exponential trends for A_t, which allows an estimate of continuously varying elasticities for labor and capital, with eventually no constraint imposing constant returns to scale. But let us note that the very specification of technological trends might have a drastic impact upon the estimates of these elasticities (R. BOYER, M. JUILLARD, 1992).

One possible way of getting an intuitive idea of the direction of technical change is to plot over time the observations of K/Q versus L/Q, i.e. the amount of capital and labor required to produce one unit of output. The reader will have recognized the plane un which isoquants corresponding to a given production function are usually drawn.

In the absence of technical change, the observations should be distributed along one isoquant according to shifts in relative prices. On the other hand, if there is technical change and that the saving rate is constant, traditional growth theory leads us to expect to

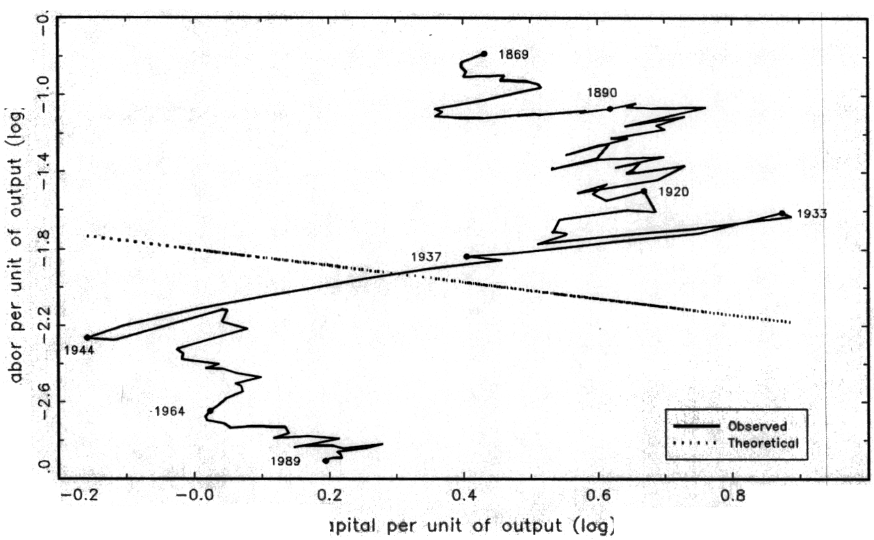

Figure 3: Theoretical and observed isoquants

see the economy moving toward a balanced growth path and the observations of capital and labor by unit of output should migrate toward a vertical line on which $K/Q/$ is constant. This is one of the stylized facts of traditional growth theory. Figure 3 provides such a diagram for the private aggregate American economy from 1869 to 1989: none of the polar cases described above appears.

From 1869 to 1929, labor intensity continuously declines, whereas the capital:output ratio is roughly constant, in spite of rather sharp fluctuations, due to the succession of business cycles.

2. From 1930 to 1944, a sharp decline in the capital:output ratio is associated with a significant increase in labor productivity. Far from being an isoquant this curve is upward sloped, which means that both capital and labor productivity can be very significantly increased, due to either rapid technological innovation or organizational change, each of them being associated to the shift to a war economy.

3. From 1945 to 1989, a new regime seems to emerge: the capital:output ratio does not go back to pre-World War II levels, and is kept quasi-constant, whereas labor productivity increases at a rapid rate. This regime is quite different from the first one since a cumulative increase in labor productivity is obtained by a far lower capital:output ratio. This unprecedented improvement is not clearly explained, if noticed for a long time, for example by L. CAUSSAT (1981) and more recently by G. DUMENIL and D. LEVY (1991b). Possibly a drastic internal reorganization of firms, an increase in shift work and a new stage of mechanization, as shown by the increase in the share of equipment in total investment, explain this transition.

From a purely empirical point of view, it is not easy to disentangle the short run production

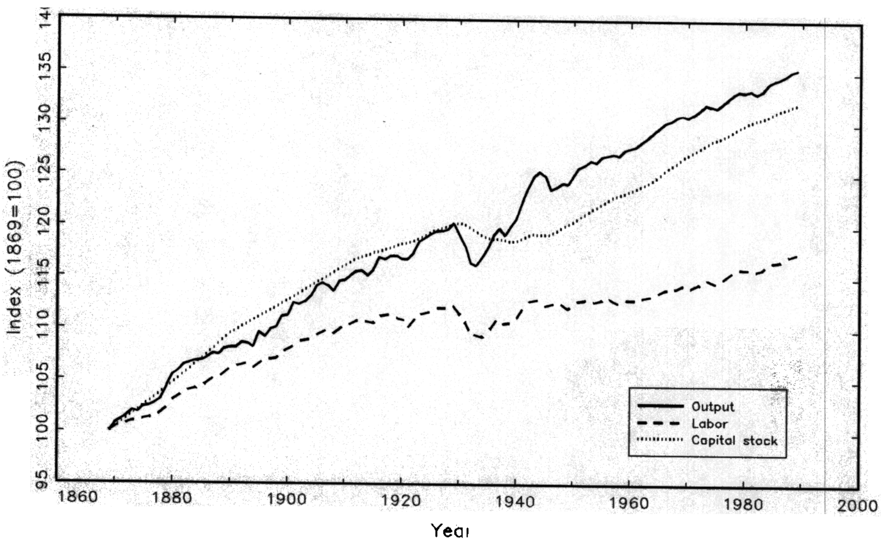

Figure 4: Index of production, hours of work and capital stock (1869=100)

possibilities from their continuous shift when time elapses. But this not the single problem to be solved.

2.2 From Joan ROBINSON to Paul ROMER: capital as the engine of technical change

Imagine now that we want to investigate the so called capital:labor substitution problem and plot an index of production, labor and capital quantities as in Figure 4. Two striking results emerge. First, in the very long run production is more closely related to capital than to labor and one does not find the configuration expected by COBB and DOUGLAS (1928) and according to which the logarithm of GDP would lie between the logarithm of labor and capital at a distance proportional to the their income share. The second surprise is that this relation is rather loose and breaks down during one or two decades casting some doubt about the stability of any production function.

Therefore estimating the simple labor productivity equation consistent with a Cobb-Douglas production function with constant return to scale

$$\ln(Q/N) = a \ln(K/N) + b \tag{3}$$

would probably not provide results anywhere close to the theoretical elasticities expected in a pure production function. However, the coefficients might well represent the mix with a technical progress function.

From a theoretical point of view this would, for example, be coherent with the two following hypotheses: the existence of a production function:

$$\ln(Q/N) = a_1 \ln(K/N) + b_1 \tag{4}$$

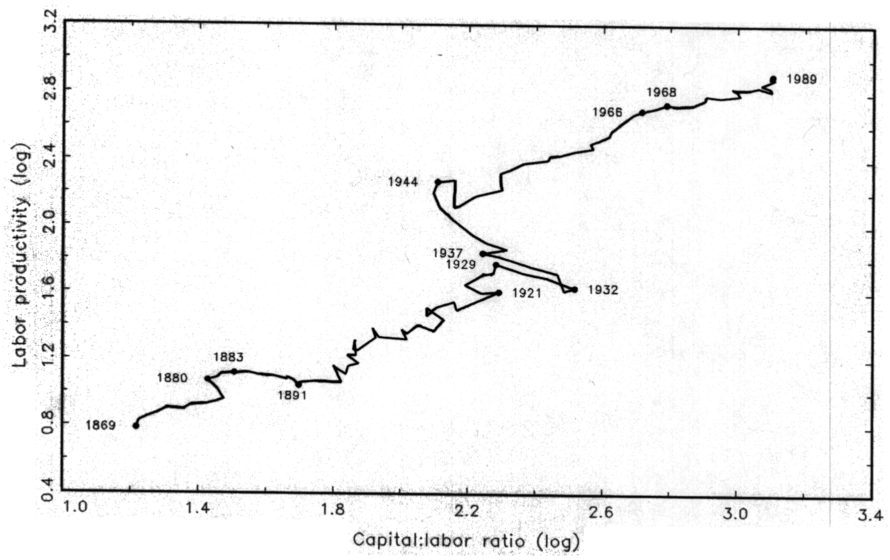

Figure 5: Labor productivity and capital:labor ratio

and, simultaneously, an improvement of technologies according to the rate of capital formation, due to learning by doing effects in the equipment good sector:

$$b_1 = a_2 \ln(K/N) + b_2 \tag{5}$$

Under such hypotheses, an OLS estimate of a so-called Cobb-Douglas function would deliver an hybrid result: $a = a_1 + a_2$ and there would be no way of identifying a_1 and a_2, if there is endogenous technical change. We apparently find the same result that P. ROMER (1986) puts forward in order to justify his and Chicago economists' astute rediscovery of external increasing returns to scale: each firm only invests for capturing private returns, but, in so doing, it creates new know-how which is equivalent to a public good.

In this respect, P. ROMER is right after all! But J. ROBINSON had already made the same point twenty years ago, along with N. KALDOR, and had added a second point at odds with the neoclassical vision of the world. The joint evolution of labor productivity and mechanization are not necessarily universal laws but typically historical ones, limited to capitalism. SSA and RA would add: limited to a specific accumulation regime. The plot of labor productivity and the capital:labor ratio gives a suggestive example of such an historicity (Figure 5). One notices again that the long run elasticity is nearest from unity than from the profit share that this relation experienced deep historical changes: a sudden shift during World War II and afterward a quasi-continuous decline in this elasticity which becomes very small during the 1970's and 1980's. The first stylized fact of P. ROMER first article is invalidated: no clear tendency to an acceleration of productivity and knowledge happens but a succession of phases during which some radical innovations deliver first impressive results and then run progressively into more and more acute problems due to the very fact that the exploration of any break-through encounters or provokes new emerging unbalances, which can no more be solved within the current paradigm.

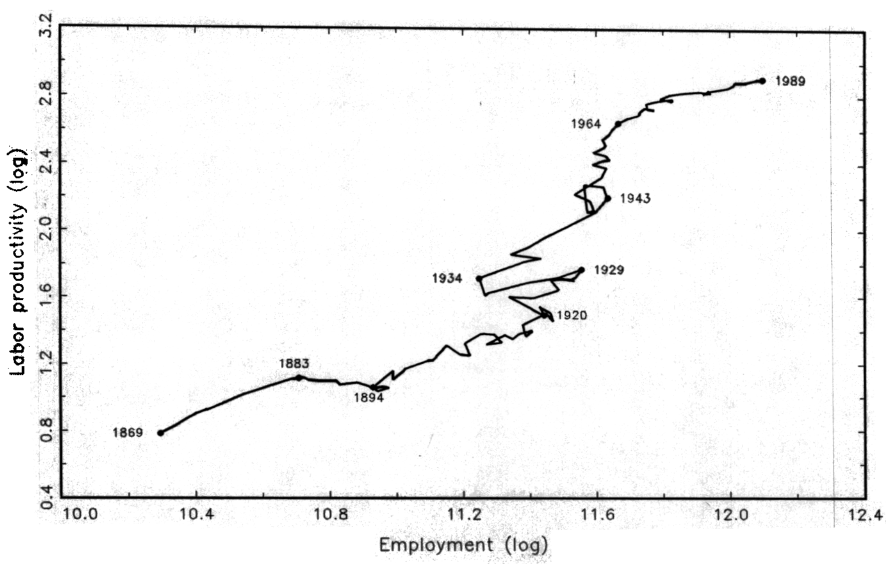

Figure 6: Labor productivity and hours of work

The uneven development of the impact of capital deepening upon labor productivity is obvious in the case of the U.S. economy, since three contrasted periods can be specified (Figures 5 and 6):

1. From 1869 to 1929, a rather smooth pattern takes place with a close relation between the two variables, the related elasticity is closer too one than 0.3 and therefore technical change seems associated to capital.

2. The second period is quite atypical: a fast and large improvement of productivity is obtained via a significant reduction of capital per hour, which suggests a paradigmatic change and/or a drastic revision in organization principles. Furthermore, the macroeconomic context is affected first by the 1929 crash and then by the shift to a war economy. Rather than a new regime, this period may be best considered as a period of transition.

3. Finally, from 1945 to 1989, a third period is characterized by a new relation between productivity and capital. Note that the apparent elasticity of capital and labor progressively decreases toward rather limited values. Once more this a possible evidence for regime exhaustion. The configuration is also clearly different from the first period. This conforts us in the idea that the Great Depression and World War II preside to the emergence of a new regime and are not a cataclysm followed by a return to previous normality.

2.3 Global and monotonous technical progress versus local and path-dependent technological change

The conventional theory of production functions is unsatisfactory for another series of reasons. Basically, technology is introduced in a totally abstract way, mainly as a geometrical transformation of a simple analytical function. After all, the various definitions for neutrality precisely refer to homothetical or afine transformations of the static aggregate production function: one gets respectively, SOLOW, HICKS or HARROD neutrality definitions. The solution is mathematically impeccable and elegant indeed ... but poorly relevant from a technological or economic standpoint.

In fact, the assumption is quite strong since it infers that technical change has general properties which remain constant across sectors, processes and that they do vary through time. For instance, will the labor saving bias be the same in the railroad, chemical, textile or machine tools industry? The specialists would object that this is a purely *ad hoc* hypothesis designed to solve some problems in growth theory and warrants the existence of a stable steady path. The econometric analysis shows that this simplifying device is rather rejected for the American economy.

But this objection is not the only one. In a long neglected article, P. DASGUPTA and J. STIGLITZ (1969) have pointed that any set of innovations is basically local in the following sense: engineers only discover the shape of the production capability frontier in a very limited range along the technological paradigm. For example, what is learnt about the oil engine does not tell anything about the opportunities of cars propelled by an electrical engine. Furthermore, today's discoveries do not provide any certain information about what will be found tomorrow, but affect only the *a priori* probability distribution. If any one could perform such a perfect forecast, one would master the very laws of history, all natural laws, and their economic implementation. This criticism, once applied to a vulgar conception of Marxist materialism, bears equally on most of the simplest versions of the neoclassical theory of technical change.

The neo-schumpeterian and evolutionary analyses provide a convincing alternative to such a dead end. At every moment of time, firms only have precise information about the techniques that they actually use or less relevant ones about their competitors. When they decide to innovate, they take a risk: they may find out a more profitable product or process, but they may also end up in an inferior state by comparison with their routine technique (R.R. NELSON and S.G. WINTER, 1982). Since such a choice cannot be enlighten by impossible computations over not yet known states of the nature, the engineers and managers have to rely upon the equivalent of rules of thumb, informed by all the relevant information available to decision makers at a reasonable cost, but limited by their cognitive and computational actual capabilities. Such a tentative representation cannot be exclusively individual since the decisions taken accordingly have to be roughly compatible with the joint and simultaneous decisions of other firms: may be experts, the emergence of technical norms, the diffusion of patents or simply the imitation within a technological community or even and industrial district finally shape the equivalent of a paradigm in basic science. What to search for—reduction of labor costs, energy saving, optimization of information, standardization or customization ...—, how to fulfill these objectives and, on the contrary, where not to look for are the very basic issues that any technological paradigm help to solve at a relative low cost compared to what would be needed in a totally rational approach with complete information (G. DOSI, 1982).

This framework which derives from many researches emanating from the economics and history of techniques (B. GILLES, 1970; D.C. MOWERY and N. ROSENBERG, 1989; R.R.

NELSON, 1992) has four major advantages for our purpose:

From global, the technical change becomes local, not in the geographical sense but due to the fact that only a very limited number of potential innovations are explored at any given period of time: the ones which are in line with the prevailing paradigm, itself function of the economic environment and dominant social relations. This apparently invalidates any grand and atemporal production function. Consequently, it might be erroneous to infer any global and long run transformation in factor elasticities or technical change neutrality from a given local transformation occurring at a given historical period.

2. Since engineers and managers try to improve techniques around a given set of technologies and in accordance with the prevailing paradigm, path-dependency might occur as a significant pattern of technological change. It is easier to improve along known expertise than to launch brand new innovations. Consequently, the success of a cluster of innovations makes further success more likely along the same broad technologies. Path-dependency is more likely when increasing returns to scale prevail as a key feature of division of labor in modern economies (B. ARTHUR, 1989; P. DAVID, 1988). This feature definitely links the short run elasticity with the evolution through time of technological intensity and bias.

3. Adding these two features, production capabilities exhibit a strong historical flavor. For each historical epoch, there is a definite way to reap increasing returns to scale associated with the division of labor: technical division of tasks within the firm, deepening of the social division via mechanization, constitution of a large and growing internal market, building of transport infrastructures or telecommunication network externalities and finally the spill-over effects associated with the advance of basic knowledge. All these mechanisms have not the same impact upon productivity trends. A cursory survey of history of techniques (B. GILLES 1971; A. HOUNDSHELL, 1986; R.R. NELSON, 1992; R. BOYER and G. SCHMEDER, 1990) suggests that contrasted forms of division of labor have taken place and probably delivered quite different productivity trends.

4 The historical transformation concerns a socio technical regime itself. First, a cluster of radical and interdependent innovations generate unprecedented productivity gains. Then, they are diffusing, they mature and, after some threshold, encounter marginal decreasing returns and are overcome by superior techniques deriving from a new wave of technological change. Consequently, within a technical paradigm, a logistic (G. DUMENIL and D. LEVY, 1991b) type evolution takes place in such a manner that one rarely observes the steady growth rate that neo-classicists are fond of. In the medium-long run, the inner logic of a productivity regime deliver an evolution pattern with first an acceleration and then a deceleration. In the very long run, technological paradigms replace one another and not any natural or economic law warrant that their long run trends are the same.

2.4 The notion of production regime: Some theoretical considerations

It is time now to define more rigorously what is a production regime. Basically, such a regime supposes some predictable trends in sector share of investment in production and a given mix between the substitution of capital and labor and a technical production function. This definition clearly takes into account that a shift along a given isoquant cannot be disentangled from the shift of this isoquant due to technical change. This factor is not at all exogenous since firms react to competition, profit trends, relative prices and even class struggle by trying to develop new techniques in very precise directions, either in labor saving or in workers control and division or in energy saving. According to the relative importance of these factors different productivity regimes will emerge.

Of course a productivity regime is fundamentally a macroeconomic concept. Consequently, how do firms behave in order to fulfill the regularity it implies? Basically, every manager, engineer, technician tries to decide investment and organization in accordance with the prevailing socio-technical paradigm, and in reaction with the main macroeconomic variable such as profit rate, real interest rate, taxation and long run expectations. Therefore, the aggregation of all these decisions is rather easy given that the same pattern and sometimes the same expectations are shared all over the various sectors of the economy. If not, technological change would follow a sort of white noise as some real business cycle theoreticians suppose but which is not in line with the findings of the experts in technological change.

But, this is not a purely technical and economic concept. In fact, most of the institutional forms of capitalism play a role in shaping aggregate production capabilities. For example, the nature of competition will set the share of demand among firms and consequently the distribution of the technology used which does not necessarily follow the pattern of global cost minimization, as would be implied by pure and perfect competition (L. JOHANSEN, 1972). Similarly, average productivity is not a simple matter of technology, since labor is not a pure commodity under the direct control of managers: according to the prevailing industrial relations, workers will have different interests in working hard and taking care of quality. Consequently, the size of welfare benefits, the level of employment and the relative bargaining power of workers and managers will play a role in actual productivity. This basically destroys the fiction which is at the core of conventional production functions. Recently, the so-called efficiency wage theories have recognized the importance of such a factor. This is not a simple short run phenomena since the direction and intensity of workers struggle can affect the pattern of mechanization, organization and therefore technical change (A. LIPIETZ, 1982).

Finally, each productivity regime has its own inner dynamic, which explains how frequently neo-Schumpeterian and the evolutionary economists formalize technical change as a logistic process. But, this is far too mechanical for many other factors affecting the speed of obsolescence of a given technological paradigm, which rarely exhibits the nice regularities which are typical of a conventional diffusion process.

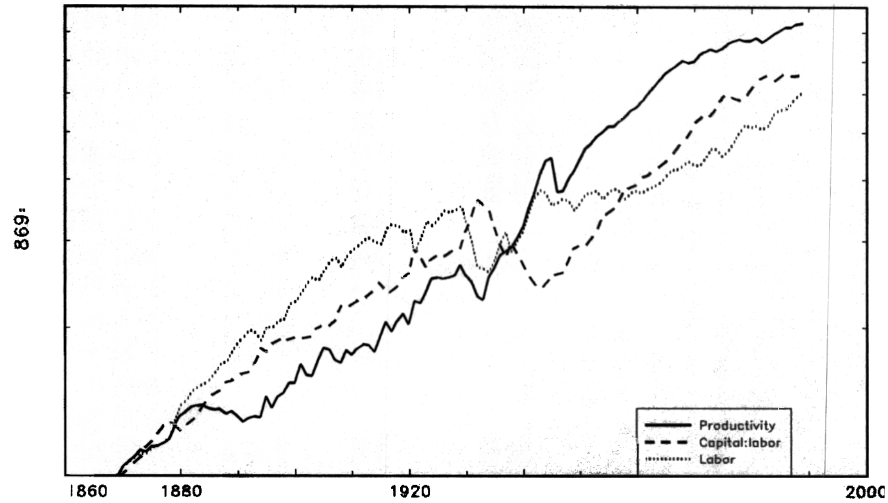

Figure 7: Index of labor productivity, hours of work and capital:labor ratio (1869=100)

2.5 A first look at American productivity regimes

These ideas can be used in order to enlighten the American evolution since the Civil War. Before any sophisticated econometric tests, let us provide three stylized facts in favor of the succession of different productivity regimes in this country:

Looking at the joint evolution of apparent labor productivity and the capital per hour worked in Figure 7, no steady long run relation stands out. Not only the pre-World War I trends are quite atypical, and the inter-war period is totally paradoxical, but the post-World War II era exhibits a third configuration with smooth fluctuations of these two variables along with a progressive deceleration of the productivity trend. One observes the succession of regimes as well as the maturation of the Fordist one.

2. A relation seems also to prevail between labor productivity and the level of employment. If we suppose that the size of the manpower is a key variable for the ability to extend the division of labor (B. ROWTHORN, 1975), this relation may indirectly describe the role of the extension of markets on productivity, as implied by A. SMITH, A. YOUNG and N. KALDOR and G. MYRDAL. Looking at Figure 6, it is however clear that such a relationship is not stable in the long run. Quite on the contrary, an irregular logistic curve describes a cumulative diffusion of the so-called American system, then its high efficiency from the mid-1930's until the early 1960's and finally the progressive exhaustion of its potentialities. This is an evidence for a shift from a very intensive accumulation regime to a rather extensive one after the mid-1960's.

3. Although no relation between labor productivity on the one hand and the capital:labor ratio and hours worked on the other seems to be stable on the entire period from 1869 to 1989, such a relation seems however to be valid during sub-periods. At first

glance, one configuration would exist from the 1890's until the eve of the Depression, combining the beneficial effects of market expansion and mechanization, when the three variables grow more or less at the same speed.Huge disruptions occur during the Depression and World War II, when spectacular productivity gains are obtained despite a decrease in the capital:labor ratio.

After World War II, as the path of productivity accelerates, there is no return to the previous configuration: productivity and the capital:labor ratio grow now much faster than employment. After the mid-1960's, this model unravels in turn and leaves the stage to possibly yet another regime.

2.6 An initial model for labor productivity

All these theoretical and descriptive evidences have now to be checked more carefully by using rigorous methods and tests. The above discussion suggests to start with a productivity equation which provides for the influence of both mechanization and the expansion of the market.

$$\ln(Q/N) = \beta_0 + \beta_1 \ln(N) + \beta_2 \ln(K/N) + e \qquad (6)$$

where Q/N denotes the net output per hour worked in the private economy in 1982 dollars. N represents the hours worked in the private economy and K/N, the net fixed private capital in 1982 dollars per hour worked. These data are as described in G. DUMENIL and D. LEVY (1991c). e is the usual stochastic error term.

As underlined in Section 2.2, despite its formal correspondence with a Cobb-Douglas function, this equation should not be understood as a function of production but as a technical progress function and the elasticities β_1 and β_2 should not be interpreted as in the usual production function context.

No time trend is introduced in the regression, because we want to constrain the effect of technical change on labor productivity to pass either through the capital:labor ratio or the scale of employment. The capital:labor ratio carries the idea that technical change necessary for improvement in labor productivity is in part embodied in capital and correspond to the mechanization of production. The level of employment translates both increasing returns associated with the extension of the market and, because employment itself displays a increasing trend, the general effects of improvement in knowledge and organization which would be otherwise picked-up by a linear trend. Note however that in our specification the general improvement in knowledge manifests itself only to the extent that employment is indeed growing.

The estimation results for the period 1869–1989 and 1890–1989 figure in Table 1. The reason to start with these two periods has to do with the amount of information entering in the data before 1890. As it is well known and documented in G. DUMENIL and D. LEVY (1991c), data before this date must be partly interpolated. Furthermore, carefull examination of Figures 7 and 6 for this period reveals relations wich are smoother than later. It was therefore important to us to analyze the data on the longer period available and to establish from the start the effects on the results of the inclusion of the observations between 1869 and 1889. As it turns out, the effects are dramatic.

ESTIMATION RESULTS			
		1869-1989	1890-1989
Constant		-3.374	-13.035
		(1.300)	(1.621)
Hours of work		0.258	1.173
		(0.136)	(0.161)
Capital:labor ratio		1.032	0.648
		(0.118)	(0.111)
$\overline{R}^2$		0.8887	0.9054
D.W.		0.0530	0.0540
		Cointegration tests	
D.F.		-1.5010	-0.9885
ADF(3)		-1.9145	-0.9537
		Tests of structural change	
CUMSUM	forward	($p<0.05$)	($p<0.05$)
	backward	($p<0.05$)	($p<0.05$)
CUMSUM SQUARE	forward	0.474	0.405
	backward	0.370	0.440
T test	forward	7.352	3.493
		(p=0.000)	(p=0.000)
	backward	-0.894	-5.774
		(p=0.373)	(p=0.000)
Wilcoxon	forward	5688	3218
		(p=0.000)	(p=0.000)
	backward	3054	1035
		(p=0.220)	(p=0.000)
Number of runs	forward	11	16
		(p=0.000)	(p=0.000)
	backward	17	17
		(p=0.000)	(p=0.000)
Modified Von Neuman	forward	0.038	0.053
	backward	0.042	0.067

Table 1: Estimation results

If we include the data between 1869 and 1889, the elasticity of the capital:labor ratio is almost equal to unity and the elasticity of labor is 0.25. When these data are omitted, the relative importance of the two elasticities is totally reversed: 0.65 for the capital:labor ratio and 1.17 for employment. This shows that, as expected, the relation is extremely unstable. As explained below, it seems difficult, using our framework, to give an acceptable account of the earlier period and we end up eliminating the observations between 1869 and 1889 for the next step, on the ground that either the measurement errors are too important or that the productivity determinants that we are after are not yet well established during this period.

Before turning to the statistical tests which allow us to rigorously evaluate the long run properties and the stability of this equation, it is necessary to provide some backgound on the conceptual link between long-run relations and cointegration and on statistical tests for the statility of regression coefficients.

3 STABILITY AND UNICITY OR REGIME CHANGE?

3.1 How to detect long run relations?

For relatively obvious reasons of immediate preoccupations, economic analyses and the econometrics associated with them have been until recently more concerned with short run adjustments than with long run properties. It is exact that short term models have indeed long run properties, but, in practice, long run properties were more something that one checked out after the analysis rather than imposed at the conception of the model. Recent developments in the theory of cointegration (R.F. ENGLE and C.W.J. GRANGER, 1987; R.F. ENGLE and B.S. YOO, 1987) have provided a new methodology to represent long run relations and a way of testing for the existence of such relations. In the context of growth economics and without entering into unsavory technical details, two or more variables may be said cointegrated if, although they are exhibiting a trend, their relationship is stationary through time. Consumption and income are a typical example: even if the propensity to consume may vary in the short run, in the long run it should be fixed, because it is unthinkable that an economy experiences an ever growing or ever shrinking propensity to consume. In more technical terms, this means that, in an equation of cointegration, the stochastic error term must be stationary.

The methodological consequences of this approach to long run relations are that these relations should be tested in the levels to which they are enounced rather than in first difference or in growth rate and that the residuals of the regressions should be tested for stationarity. The tests for stationarity are versions of the by now well known unit root tests.

Looking for elements of invariance and structures is essential to the apprehension of reality by the human mind. However, nothing warrants that these structures should remain invariant forever. In economics, the historicity of economic mechanisms has usually been of interest mostly to the heterodox traditions, being even a constitutive element of the Marxist approach. The neo-classical tradition focused rather on the permanence of individuals behavior, leaving mostly out of the field of economics the historicism associated with societal phenomenons. In the theory of growth, the long run could only be thought as balanced growth, which is little more than the reproduction of the same structure on an expanded scale.

Understandably enough, the study of what is usually called in this context structural change has not been one of the central domain of research of the profession. There are two ways of thinking structural change. In the first one, there exists structures or models which are stable, but have validity for a certain period only. Then another model prevails. This is the approach of *regimes* and that is the one which is followed in the remaining of this paper. The other approach is to think an hyper-model according to which basic structures are evolving. The simplest of this type of model postulates that a parameter is a linear function of time. That has been the way technical change has been introduced in the neo-classical function of production, leading to the estimation of, for example, the rate of growth of total factor productivity. More sophisticated members of this category would be evolutionary models and, in statistic, variable parameter models. The two approaches are not necessarily as separate as presented above. In particular, it would be hard to argue that a given regime succeeds to a previous one without some period of transition deprived of a fixed structure.

Recently, many authors following NELSON and PLOSSER (1982) have argued that rather than representing the evolution of economic variables as stochastic around a linear trend, they were in fact following a non-stationary stochastic trend. This approach has the merit of better recognizing the amplitude of change affecting macroeconomic time series over many decades. However, as PERRON (1989) has shown, one or two major events may be responsible for this characteristic of the time series. One can therefore think long run relationships as a succession of regimes more or less stable, interrupted by great shocks. These watershed events would be much greater in amplitude than than the regular stochastic components of the time series.

As far as econometrics are concerned, it is indeed possible that there exist long run, cointegrated, relations, but that these relations be only valid for a given period. Methodologically, it is a rather important point, because the logic of the tests for cointegration would most probably leads one to reject the hypothesis of cointegration on the sample as a whole, if in fact two different relations existed for two sub-periods.

If one entertains the possible existence of different regimes, the proposed methodology is to first ascertain the stability of the equation under investigation, then, if the stability is rejected, to try to determine the exact duration of the periods for which an equation is stable. It is only then that cointegration could really be established or disproved.

3.2 What about structural change?

If it is possible to come up with a model general enough so as structural change appears as the coefficients of the equation changing value from period to period, different models for different periods simplify in a single equation with different values of the parameters for different periods.

The stability of the coefficients of an equation is then analyzed by a battery of tests proposed by J.M. DUFOUR (1982). All of them exploit the properties of recursive residuals.

Recursive residuals are nothing but the standardized error of forecast one period ahead when one runs the regression iteratively, adding the observations of the sample one by one. If the model is stable, the recursive residuals should be distributed symmetrically around zero and the tests of stability attempt to detect departure from this pattern. It should be noted that in the context of non-stationary time series, such tests of stability are somewhat related to tests of cointegration. In particular, a relation which is not cointegrated would almost surely lead to the rejection of the hypothesis of stability, because the distribution of the statistics of the tests of stability under the null hypothesis assumes that the error term is stationary.

If the equation is considered as unstable, attention must now turn to determining possible break points. The technique used here was first proposed by GOLDFELD and QUANDT and consists in introducing dates of break as parameters into the likelihood function corresponding to the equation. The break points are then estimated through maximum likelihood.

Several problems with this method must be mentioned. As it is necessary to have at least as many observations for a period as there are parameters in the equation, very small periods can not be detected through this method. More generally, because maximum likelihood estimators benefit only asymptotically of optimal properties, short periods should be regarded with some healthy suspicion. The break points obtained through the maximum likelihood estimator should therefore be more considered as indicative than as absolute truth. This information should be used in combination with the plot of the recursive estimates of the parameters and a priori information on crisis and historical turning points. Let us see how this comes together when applied to the model outlined in Section 2.6

4 CAPITAL DEEPENING AND INCREASING RETURNS: FOUR PERIODS

In Section 2.6, Table 1, we reporte regression results for an equation explaining labor productivity as function of mechanization and expansion of the scale of production. Two periods of estimation are considered: 1869–1989 and 1890–1989. First, we formally investigate whether this equation statisfies the properties of cointegration and stability of the coefficients, then, provided that those properties are not statisfied we go on trying to isolate sub-periods where the regression is indeed stable.

4.1 The absence of any long run stable relation

Results of the tests of cointegration and of stability are presented in Table 1. The test entitled D.F. is a simple test of Dickey-Fuller applied to the residuals of the regression. ADF(3) is an augmented test of Dickey-Fuller where possible autocorrelation is taken into account, in this case, with 3 lagged periods. None of the tests can reject the hypothesis of a unit root in the residuals, so rejecting the hypothesis of cointegration.

The tests of stability of the coefficients investigate various patterns in the distribution of the recursive residuals. Forward recursive residuals indicate that one started with the earlier data adding then more and more recent observations to the sample. Backward recursive

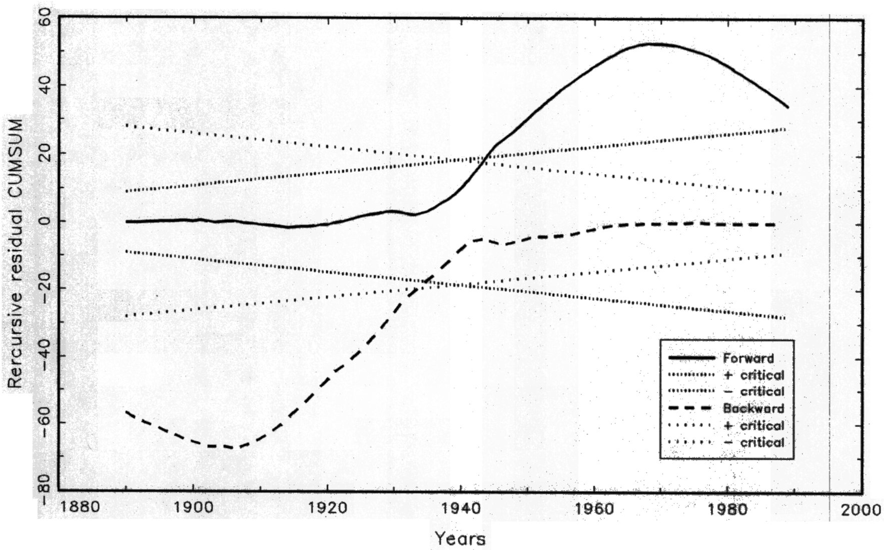

Figure 8: CUMSUM of the recursive residuals: 1890–1989

residuals means that one started with the most recent data and then one proceeded to add older and older observations.

The results of the CUMSUM test are better described graphically. Figure 8 displays the CUMSUM of both the forward and the backward residuals for the period 1890–1989. Note that the crossing of the critical lines only indicate the occurence of instability before the date of the crossing, it doesn't by itself inform on the date of the break. For the other tests, both the value of the relevent statistic and the level of significance of the test (p-value), when available, are provided.

As could already be expected from the inspection of Figures 5, 6 and 7, both the hypothesis of cointegration and the hypothesis of stability of the coefficients are rejected at a very high level of significance, and that for the longer and for the shorter period under consideration. This means that instability is not brought chiefly by the questionable data from 1869 to 1889, but exists also during the XXth century. Paradoxically, the earlier data introduce a greater level of variability of the residuals which results in stability being accepted in the longer period for some of the tests with the backward residuals.

Given the instability of the equation, it is interesting to examine the evolution of the recursive estimates of the coefficients themselves. Note however that the interpretation of these graphs becomes difficult after the first change occurs for any coefficient, because, past this date, the equation is misspecified and the consequences are not always easy to decipher. Figure 9 displays the recursive estimates of the employment elasticity. It is to be expected that wide changes occur at both end of the graph when very few observations are taken into account. Going forward, a small drop occurs after 1920 and then a massive increase after 1940. When one starts with recent data and add previous ones, the coefficient seems to be slowly diminishing until 1940, when again a huge change occurs.

The evolution of the elasticity of the capital:labor rartio is no less remarquable (Figure 10). There is a sharp increase in the estimated value as soon as 1920, rather than after

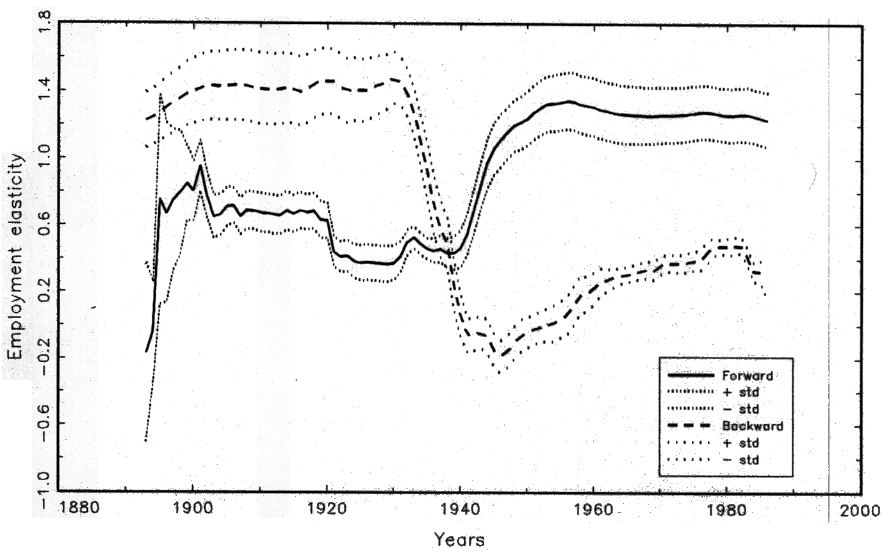

Figure 9: Recursive estimates of employment elasticity

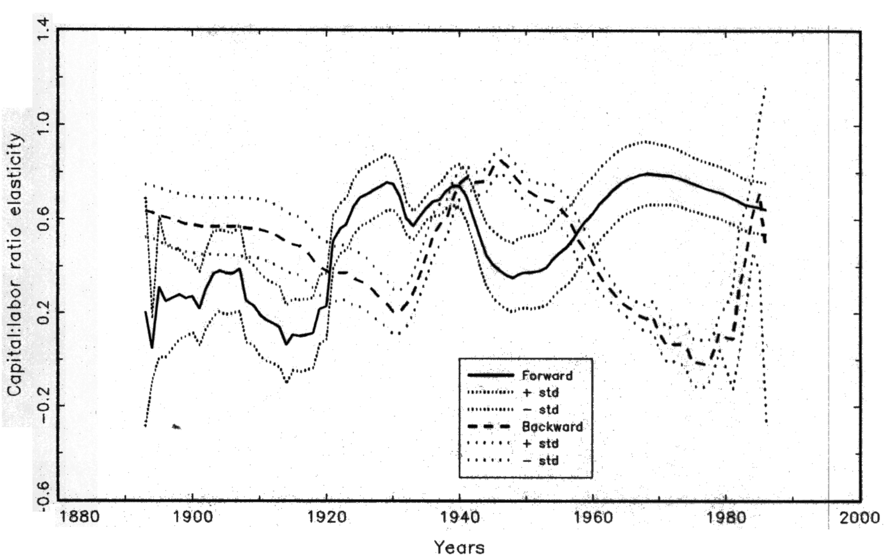

Figure 10: Recursive estimates of capital:labor elasticity

1940 as in the case of the elasticity of employment. After this period, the values oscillate at a higher level than at the beginning. Going backward, the data for the 1950's and 1960's are obviously of a different nature than the one obtained for the 1970's and the 1980's.

4.2 1869–1989: Three break points

The next step is then to try to distinguish sub-periods between 1869 and 1989 for which the model is stable. The general methodology here is to introduce the date of the breaks as parameters in the likelihood function and to choose the dates which maximize this function. One of the particularity, or shortcoming, of the method is that it can't distinguish periods shorter than the number of parameters to be estimated in the equation. Periods which appear as lasting for a number of years equivalent to the number of coefficients plus one correspond therefore to this border condition rather than to a true maximum of the likelihood function.

In a first round of experiment on the period 1869–1989, trying to distinguish seven sub-periods, several very short periods, corresponding to the above border condition, appeared for the earlier years. As mentioned above, this could come from measurement errors in the data or from the fact that no relationship of the form envisaged here can explain the movement of labor productivity during those early years. In any case, for the remaining of the paper, we decided to avoid the difficulty altogether by restricting our original sample to the period going from 1890 to 1989.

Through the method of the maximum likelihood, four distinct periods are put in evidence: from 1890 to 1920, from 1921 to 1934, from 1935 to 1964, and from 1965 to 1989. The model is then reestimated, by letting each parameter free to change value between each period. It becomes then possible to test which changes are significant and to eliminate the insignificant ones. The final results figure in Table 2.

In the first period, productivity growth is obtained both through the increase of the capital:labor ratio and the extension of the production as measured by employment. The second period—a transition period, quite short, between 1921 and 1934—appears as marked by a significant increase in the elasticity of the capital:labor ratio. The third period could be described as typical of what has been called 'Fordism'. The elasticity of both the capital:labor and of employment shows a dramatic increase. The fourth period could be called the crisis of the previous one. The changes go in the opposite direction: the elasticity of the two explanatory variables collapses.

4.3 Some puzzles

Several remarks are in order. The break dates suggested by the regression are not necessarily the same as one would guess upon examination of the univariate graphs or even the bivariate relations (productivity/capital:labor ratio and productivity/labor, see Figures 5 and 6). Note that the 1920's are regrouped together with the depression years in a single transition period and that the regression for this period can hardly pretend to be more than an *ad hoc* device to deal with these transition years. It remains that a higher efficiency of mechanization is what seems to distinguish the 1920's from earlier years.

ESTIMATION RESULTS				
Model I	1890-1920	1921-1933	1934-1964	1965-1987
Constant	-6.295	-6.295	-21.424	-1.122
Hours of work	0.639	0.639	1.918	0.277
	(0.026)	(0.026)	(0.063)	(0.050)
Capital:labor ratio	0.217	0.286	0.639	0.248
	(0.044)	(0.036)	(0.050)	(0.049)
$\overline{R}^2$	0.9966			
D.W.	1.476			
Model II	1890-1920	1921-1933	1934-1964	1965-1987
Constant	-0.164	-0.164	-13.788	-1.911
Hours of work			1.05	0.246
			(0.100)	(0.070)
Capital:labor ratio		0.179	0.719	0.285
		(0.039)	(0.052)	(0.059)
Railroad freight	0.227	0.190	0.190	
	(0.023)	(0.024)	(0.024)	
Copyrights	0.078	0.078	0.078	0.078
	(0.038)	(0.038)	(0.038)	(0.038)
Patent applications (inventions)			0.103	
			(0.036)	
Gross public investment			0.123	0.123
			(0.036)	(0.036)
Business failure rate	-0.037	-0.037	-0.037	-0.037
	(0.011)	(0.011)	(0.011)	(0.011)
$\overline{R}^2$	0.9976			
D.W.	1.535			

Table 2: Estimation results for four regimes

In the same manner, the exceptional years of World War II are regrouped with the later period, dating the beginning of what is often referred to as the *post-war regime* as soon as 1934. The years of war are remarkable because they display the introduction of methods of production which are both capital and labor saving, and that these productivity advantages are conserved at the end of the war. Of course, the capital:labor ratio starts again its march forward but at a lower level in comparison with the period before the Depression. The effect is in fact more acute for structures than for equipment and must be on some extend linked to the massive introduction of shift work.

The end of the post-war regime is dated in 1964–65. Even if such dates are more indicative than the precise dating of a watershed event, it is a few years before the actual slowdown in productivity growth, as if the engine started to have problems before the car actually slows down.

In order to shed more light on the dynamic of each regime, in a second step, we add other explanatory variables to the model. As it is impractical to carry in parallel the search for break dates and the search for significant variables, we simply accept the periods isolated in the first part of this paper.

5 SOCIO-TECHNICAL SYSTEMS GENERATE PRODUCTIVITY REGIMES

If productivity regimes express themselves via macroeconomic variables, they are not restricted to this only set, since quite on the contrary many direct measures of network externalities, innovation, public investment are available and can be plugged into the equation. Once obtained, the new estimates are to be compared with the teaching of major surveys of technical change and industrial organization for the American economy.

5.1 Railways, innovations and public investment: contrasted historical evolutions

The purpose to add variables to the initial model is to try to explain better how the general development of the economy, described by the growth of employment in the first model, affects labor productivity. Several dimensions are explored.

The development of the scale of the economy is associated with the size of the market as reflected by transportation. We use ton-miles of railroad freight as an indicator (see Figure 11). The very important role of railroad in the building of the industrial structure of the U.S. corresponds to the faster rate of growth before the Depression. After World War II, railroad freight grows at a much slower pace.

General infrastructures provided by the state are approached by the gross investment of the government. If we exclude the years of the Depression and of World War II, the trend is almost identical from the beginning of the century until the peak of the Vietnam War, then the tendency is durably reversed.

The invention and research dimension of the process of technical change is captured by the number of copyrights and of patent applications for inventions (see Figure 12). Copyright is probably a concept broader than one would like to track the process of innovation

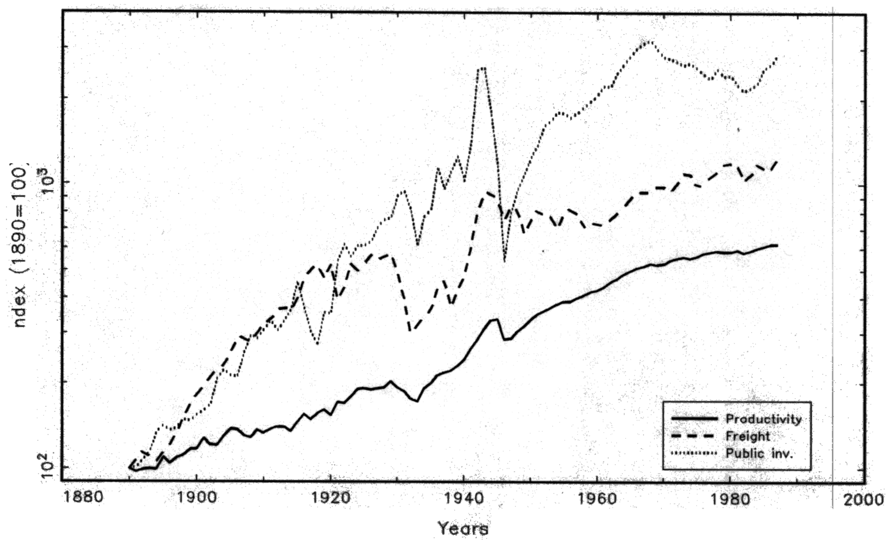

Figure 11: Index of labor productivity, railroad freight (ton/miles), and public investment

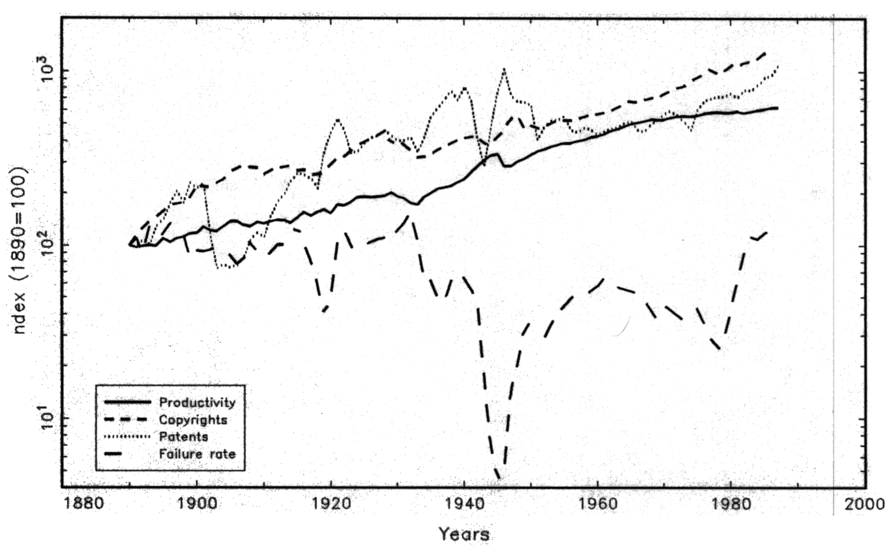

Figure 12: Index of labor productivity, copyrights, applications for patent (invention), and failure rate (1895=100)

with productive applications, but its smoother trend maybe a better indicator of the cumulative effect of intellectual activities. Patent applications for invention, on the contrary display a much more accidented trajectory. Note however that both variables seem to indicate a faster growth toward the end of the period.

Business failure rate could be an indicator of the intensity of inter-capitalist competition as well as a short term indicator of cyclical nature which would capture the employment cycle or labor hoarding throughout economic slowdown. As it appears in the results, it is the latter effect which dominates. It is remarkable that the average failure rate was larger for all the period before the Depression than after World War II, indicating clearly an important modificiation in the way that inter-capitalist competition regulates economic activity. In this respect, the surge in the business failure rate despite the increase in the number of businesses in the 1980's is all the most remarkable.

5.2 A confirmation: four technological epochs

Using basically the four sub-periods established in the first exercise, these variables were added into the previous model. However, the last period must stop in 1987 rather than 1989 because of unavailable data in the supplementary variables. It was then again possible to test which variable belongs to which regime and which coefficient changes in a significant manner (see Table 2). Basically, the same evolution of the key parameters is observed, but a more detailed account of the factors involved is given, and for example, the role of the capital:labor ratio can be disentangle from the role of infrastructures and complemented with the impact of two measures of innovations.

The effect of two variables doesn't seem to change significantly over the entire period: the copyrights which, as expected, contributes positively to productivity and the business failure rate which enters with a negative sign. This result combined with the information displayed in Figure 12 should be interpreted as capturing cyclical effects: when the economic activity slows down and the failure rate goes up, production adjusts faster than employment and labor productivity decelerates or even diminishes. This is the well known employment cycle in the short run. With its negative sign, we can consider that business failure rate adjusts on some extend for short cycles.

In the first period, 1890–1920, railroad freight and copyrights capture entirely the effects described in the first model by the capital:labor ratio and employment. This underlines the contributions of scale of markets and innovation during this period.

As in model I, the second period, 1921–1933, is characterized by an increase in the role of the captial:labor ration which, in this model, enters the equation with an elasticity of 0.18.

In the third period, 1934–1964, all the variables play a role to some extend. Because the scale effects directly captured by employment in the first model are now shared with freight, copyrights, patents and government investment, the elasticity of employment is less: 1.05 instead of 1.92. However it remains quite important. Patent applications for inventions enter the model only in this period and the effects of government investment manifest themselves in the two last periods. Quite remarkably, the elasticity of the capital:labor ratio remains similar to the one in the first model: 0.72 here instead of 0.64. This would indicate that the mechanization dimension is somewhat orthogonal to scale and innovation.

Again, the fourth period, 1965–1987, is marked by the decline in the elasticity of employment and of the capital:labor ratio. Furthermore, railroad freight drops out of the equation. This conforts us in the idea that the recent period represents an exhaustion of the technological dynamism manifest in the previous one.

To judge the importance of the contribution of each of the variables to productivity growth, we can compute the change accounted for by the increase of each of them in every period ($b_i \Delta x_i$). It figures with the average growth rate of each variable in Table 3. Note that this approach has its drawbacks because the results are highly influenced by the particular circumstances of the initial and final year of each period.

In the first model, except during the transition years of 1921–1933, the contribution of the scale of production is more important than the contribution of the capital:labor ratio. As mention earlier, due to the specification of the equation, the employment variable captures more than the sole effects of returns to scale. However, from period to period, the importance of the capital:labor ratio for productivity growth is clearly increasing. In the second model, the contribution of each variable gives us a more complete picture of each regime.

5.2.1 The age of railways and inventors

From 1890 to 1920, productivity growth is chiefly associated with the development of railroad freight. The contribution of copyrights is much smaller. As should be expected from a cyclical indicator, the contribution from the decline in failure rate between the beginning and the end of the period contributes very little to productivity growth.

Transition and Depression

The 1920's and the Depression mark the crisis and the end of the previous regime. As for the simple model, tracking these tormented years is more difficult. The positive contribution of the capital:labor ratio is almost exactly balanced by the negative effects of decrease in freight. Copyrights and business failures play no role at all although that there elasticity is significant.

A Fordist regime

The new regime put in place at the end of the Depression has markedly different characteristics from the previous ones. Employment contributes to more than half the increase productivity growth. The role of freight is also important, but less than in the first period. The contribution of the capital:labor ratio increases on the contrary from the previous period. Government investment offers a similar contribution. Copyrights and patents contributes finally relatively little to the large growth rate of productivity during this period.

5.2.4 A long crisis and convergence toward an extensive growth regime

Since the late 1960's, the Fordist engine misfires. Labor productivity growth crawls to a mere 0.98 percent despite a return to higher rate of mechanization. The relative contribution

CONTRIBUTION TO PRODUCTIVITY GROWTH OF EACH EXPLANATORY VARIABLE				
Average rate of growth of the variables				
	1890-1920	1921-1933	1934-1964	1965-1987
Labor productivity (actual)	1.43	0.05	3.10	0.98
Hours of work	1.74	-0.60	1.39	1.61
Capital:labor ratio	1.60	1.61	0.68	1.85
Railroad freight	5.53	-1.76	2.99	1.47
Copyrights	3.61	0.01	0.13	2.32
Patent applications (inventions)	4.98	-3.68	0.60	3.31
Gross public investment	4.20	1.02	4.10	0.02
Business failure rate	-2.33	-0.06	-0.45	2.93
Contribution of each variable to the average rate of growth of labor productivity				
Model I	1890-1920	1921-1933	1934-1964	1965-1987
Labor productivity (predicted)	1.46	0.08	3.10	0.90
Hours of work	1.11	-0.39	2.67	0.45
Capital:labor ratio	0.35	0.46	0.43	0.45
Model II	1890-1920	1921-1933	1934-1964	1965-1987
Labor productivity (predicted)	1.62	-0.03	3.28	1.07
Hours of work	—	—	1.46	0.40
Capital:labor ratio	—	0.29	0.49	0.53
Railroad freight	1.25	-0.33	0.57	—
Copyrights	0.28	0.01	0.18	0.24
Patent applications (inventions)	—	—	0.06	—
Gross public investment	—	—	0.50	0.00
Business failure rate	0.08	0.00	0.02	-0.10

Table 3: Rate of growth of the variables and their contribution to labor productivity growth

CONTRIBUTION TO PRODUCTIVITY SLOWDOWN OF EACH EXPLANATORY VARIABLE		
	Change in the average rate of growth between 1934-1964 and 1965-1987	
Labor productivity (actual)	-2.12	
Labor productivity (predicted)	-2.21	
	$b_{65-87}(x_{65-87} - x_{34-64})$	$(b_{65-87} - b_{34-64})x_{34-64}$
Hours of work	0.23	-1.29
Capital:labor ratio	0.84	-0.80
Railroad freight	-0.29	-0.28
Copyrights	0.06	0.00
Patent applications (inventions)	0.28	-0.34
Gross public investment	-0.50	0.00
Business failure rate	-0.12	0.00
Total	0.50	-2.71

Table 4: Contribution of variables and change in coefficients to the slowdown in labor productivity after 1965

of the variables changes also quite a bit. The capital:labor ratio becomes the major factor, in front of employment. Copyrights recover some of their importance. The increase of business failures of this last period plays against productivity growth and the influence of government investment becomes nihil.

5.3 The SOLOW paradox: from an intensive to a quasi-extensive productivity regime

This framework delivers a genuine interpretation about the SOLOW paradox, at odds with the majority of existing literature. In fact, conventional wisdom points out that the American economy has invested too little, due to a low household saving rate, has incurred increasing difficulties in passing from breakthrough innovations to profitable mass production and finally that too many regulations and restrictions to competition have inhibited product and process innovations (E.F. DENISON, 1979). A final argument stresses that the catching up of the American productivity levels by foreign competitors would now imply a more sluggish technical change, in the United States and other OECD countries. According to other macroeconomists, all this structural problems would be minor in comparison with an unadequate policy mix, specially concerning interest rates, exchange rate and public spending (R.Z. LAWRENCE, 1984)

5.3.1 The fallacies of conventional wisdom

No doubt that by comparison with Japan, Germany or even Italy and France, the saving rate is very low in North America in such a manner that in spite of significant foreign direct investment, the rate of investment in total GDP is far lower, with far reaching consequences upon the relative competitiveness of the U.S. (W.J. BAUMOL et alii, 1991, chapter 5). If the firms invest less than their competitors they get lower productivity increases, launch less new products and benefit from reduced learning by doing effects in such a manner that the American trajectory might differ more and more from those of Japan, Germany or other European countries. The argument captures a large part of truth ... but falls into a logical fallacy: the progressive reduction of the productivity gap between the American manufacturers and the rest of the world would explain a slow deceleration of productivity trends abroad ... but not at all the severe slowdown experienced in the U.S. at the end of the 1960's.

On the other side, the literature about the U.S. productivity puzzle suffers from an excessive number of partial explanations, among which it is hard to select the more relevant ones. Under this respect, the accounting methodology coined by E.F. DENISON is disappointing indeed: adding dozens of scattered factors does not explain more than half of the residual. By contrast, other scholars privilege a limited range of explaining factors (the influence of oil shocks, uncertainty, foreign competition, the inadequacy of the education system, ...) and do not contemplate how these various factors combine themselves into a coherent explanation. It is the very interest of the notion of productivity regime to provide such a synthetic approach: seven factors capturing macroeconomic variables, technological innovations and the forms of competition explain nearly 96% of actual productivity from 1934 to 1987 (Tables 3 and 4). The present paper first proposes a hierarchization of these scattered explanations and, second and more importanly, outlines an alternative explanation: the idea of the exhaustion of the previous Fordist productivity regime delivers a synthetic and rather coherent interpretation which fits with many stylized facts pointed out by the specialists of technical change. Let us briefly develop these two arguments.

A first result totally challenges the conventional view about the American productivity puzzle and provides a clear example of the originality of a productivity regime approach (Table 4). Had the Fordist regime observed from 1934 to 1964 still been binding until 1987, an acceleration of the capital:labor ratio from 0.68% per year to 1.85% should have implied a productivity increase of 0.84%. Consequently, our econometric results, however tentative, would suggest that the American industry does not suffer so much from an absolute scarcity of capital but from an unadequate allocation which does not provide anymore the same returns as in the 1960's. From strictly quantitative, the puzzle turns qualitative i.e. concerns the quality of the management and the directions of the technical paradigm in North-America.

5.3.2 The legacy of deregulation and public infrastructure neglect: Poor productivity

Similarly, the initial vision "à la Paul ROMER" (1986) is severely challenged by the analysis of the fate of the increasing returns to scale associated to labor, and by derivation to the size of the American domestic market. Benefiting from a large pool of well educated workers, a large number of engineers and scientists, the growth of the working population observed after 1964 (the hours worked grew by 1.61% compared to 1.39% before 1964) should have triggered a larger division of labor and consequently delivered more product and process innovations. Had the previous increasing returns to scale been kept constant, the trend of the hours would have implied an acceleration of labor productivity around 0.23%. Again, the issue is no more purely quantitative (the larger the population, the more numerous the innovations and the faster the productivity trends) but qualitative indeed: how is technical and social division of labor structured ? If the number of controllers and the surveillance costs are increasing, then aggregate productivity might be hurt by this very specific capitalist form of labor division (D.M. GORDON, 1991).

A third conventional wisdom, made popular by conservative economists and politicians, is seemingly severely challenged by our econometric estimates: a stiffening of domestic and foreign competition, for instance stimulated by deregulation and massive direct foreign investment would enhance productivity. Quite on the contrary, the cointegrated relation attributes a negative impact to business failure, with a constant impact all over the period 1890–1987. Of course, one might suspect a spurious correlation: during recessions, the relative inertia of employment decisions generate a productivity cycle, i.e. a deceleration along with an increase in bankrupcies. In any case, whatever the causal mechanisms, the statistical tests show that more competition is finally detrimental to productivity. Consequently, when the failure rate which used to decline by -0.45% from 1934 to 1964, is climbing up by 2.93% afterwards, this implies a (modest) reduction in productivity rates around -0.12% (4).

Similarly, the supply side economists have convinced a large fraction of politicians ... and sometimes public opinion that public spending, specially investment, was fundamentally inefficient of at least less efficient than the same spending undertaken by the private sector. Consequently, all over the O.E.C.D. countries and specially in the United States, the public investment has been curbed down after 1964: it used to grow at 4.10% per year, but since then has been stagnating until the very recent period (Table 3). Given the related impact of gross public investment upon productivity, this reversal explains a quite significant reduction in the efficiency of the American economy, around 0.50%. The true supply side economics has to take into account the positive impact of some public investment in infrastructures, transportation, telecommunication and of course education. Our very crude estimates seemingly confirm the results previously obtained by D.A. ASCHAUER (1989) and R. FORD and P. PORET (1991): public expenditures can be productive and consequently any myopic cut might finally hinder the performance of the private sector itself. Of course, much more detailed investigations would be needed to support such a key hint.

5.3.3 The irresistible erosion of the American Fordism hegemony

A fourth conventional view is calibrated by the present econometric study. Usually, most of the difficulties of the American manufacturing industries are related to a slackening of the innovative effort during the 1970's. The problem would concern insufficient R.&D. expenditures and/or federal programmes for high tech industries. Again, this is not totally confirmed by our estimates. Clearly, the number of patent applications and copyrights have speeded up during the 1970's and the 1980's (Table 3), in accordance with the general perception that a lot of innovations are coming to the market and shaping manufacturing management. Had the impact of innovation kept the same value as during the Fordist era, such a technological dynamism would have implied a surge in productivity around 0.34% (4). In fact, the contribution of innovation has become negative during the period 1965–1987, due to a total vanishing of the impact of patents upon productivity: the loss of expertise in managing the synchronization of innovation, production and marketing is finally responsible of a productivity decline around -0.34%. These results, even if rather shaky, support the view that the American gap is not in the domain of research (M.L. DERTOUZOS and alii, 1989) but in the relation between the advance of knowledge and the organization of the firm, more or less victim of Fordist nostalgia (R. BOYER, 1991).

But the two more important sources of productivity slowdown are still to be presented: basically, the exhaustion of the previous principles of labor division and increasing returns to scale as well as the inadequacy of a Fordist conception of mechanization explain more than -2.09% decline in apparent labor productivity. Both, the external and internal sources of efficiency are considerably reduced as soon as 1964, i.e. well before the productivity slowdown and still more the two oil shocks which exacerbated the issue but did not create it. On the horizontal side of the division of labor, the major finding is the strong decline of the increasing returns to scale from 1.05 during the years 1934 to 1964 to 0.246 afterwards (Table 2). This factor contributes to the more important productivity decline among the seven factors under review: -1.29% for an actual productivity slowdown of -2.12%. On the vertical side of the division of labor, i.e. the mechanization process, a similar evolution takes place. The return of the capital:labor ratio drops from 0.719 to 0.285, which strongly confirms the regulationnist hunch that after some threshold the investment in Fordist methods does not deliver any more the expected results. Either social struggles or absenteeism do affect productivity and quality, or an excessive dedication of specialized equipments induces a low capacity utilization and possibly a rapid obsolescence in the context of rapid innovation and dynamic foreign competition. Still more, the built-in rigidity of the Fordist way of handling innovation, design and production is specially detrimental to the American firms, when Japanese and European competitors finally implement variants of flexible mass production. Consequenlty, the demise of the Fordist hegemony at the world level exacerbates the domestic crisis and the challenge of the post-World War II capital-labor compromise.

5.4 From the American system to the crisis in the flexibilization of Fordist mass production

The periodization delivered by the complete model has to be related with a series of direct or indirect evidences about the transformations of industrial organization. Only the most

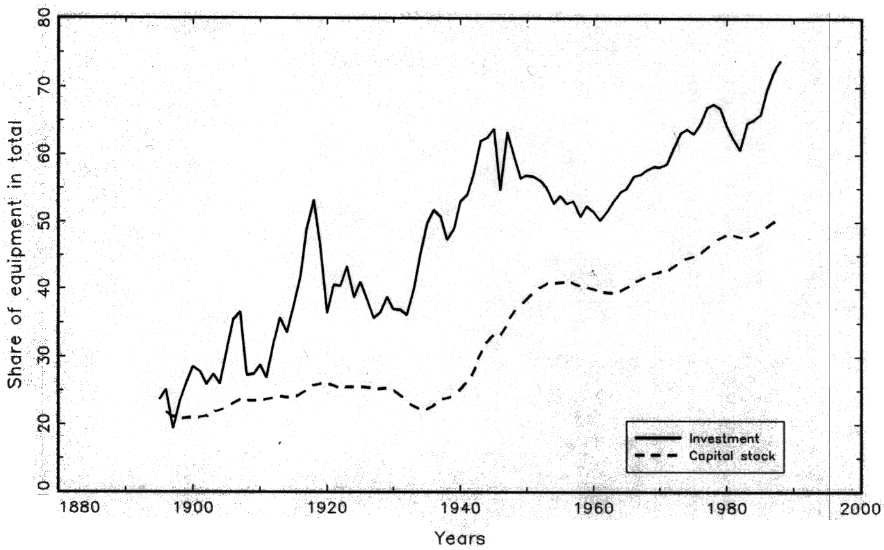

Figure 13: Share of equipment in gross fixed private capital formation and in gross fixed capital stock (1982$)

significant information will be given briefly by the present section. Broadly speaking, the major rupture takes place between 1933 and the second World War, whereas the loss of momentum of the Fordist productivity regime is widely recognized by statistical indexes as well as rather detailed engineering and historical studies.

5.4.1 From the American System to Fordism: 1869–1932

According to D.A. HOUNSHELL (1984), the American system of production emerges quite early in the antebellum period by opposition to the English manufacture: via standardization of components and replacement of manual labor by machinery wherever it can be introduced, mass production is initiated in the context of few skilled workers. By lack of satisfactory data the productivity regime has not been sorted out. G. DUMENIL and D. LEVY (1991b) tell that the productivity has first speeded and then stagnated after 1882 (Figure 7). These emerging problems might be at the origin of the Scientific Management movement, even if D.A. HOUNSHELL tends to downplay the role of one of his leading engineer F.W. TAYLOR (p. 204): improving the machines and rationalizing work organization and pay systems were the key components of a new strategy for productivity. This shows up in the first regime via significant increasing returns to scale and a modest impact of the capital:labor ratio, whereas the development of the railroad traffic helps in reducing transportation costs and therefore reaping the benefits of the joint extension of markets and division of labor. The large firm is contemporary with this turning point (A. CHANDLER, 1990).

The second productivity regime takes place during the 1920s's and shows rather large continuities with respect to the prewar one. Nevertheless, the organization of production experiences a significant deepening of the previous Scientific Management principles:

"Mass production is the focussing upon a manufacturing project of the principles of power, accuracy, economy, system, continuity, and speed" Henry FORD quoted by David HOUNSHELL (1984, p. 217). This author emphasizes that the famous car maker did not invente mass production but only perfected it to unprecedented level of efficiency. The econometric estimates confirm the rather large continuity with respect to 1890–1920 and consequently down play the initial emphasize put by regulation researches upon the radical novelty of Fordism. Nevertheless quite surprisingly D. HOUNSHELL considers that 1932 is a turning point since it manifest the limits of Fordism and the coming of flexible mass production. The econometric methods for detecting breaks precisely deliver the same turning point.

5.4.2 The surge of mechanization after 1933

In fact, it is well recognized that within the total capital stock, one has to make a clear distinction between equipments and structures: the first are modernizing and rationalizing work organization, the second simply extending a known set of technology. Consequently, the ratio of equipments in total capital stock is a very good index for the more or less intensive character of accumulation (Figure 13). The more drastic change takes place around 1933: previously the share of equipment was quasi-constant, whereas afterwards it is steadily increasing with a significant slowing down at the end of the 1950's. A closer look delivers two sub-periods within each broad epoch: from 1880–1920 the mechanization is slightly increasing but stagnate or even decline until 1932. The efficiency of the capital:labor ratio is limited and does not vary so much across these two periods. The Fordist period from 1934–1964 is unique indeed since the mechanization has an unprecedented speed, correlated with large increasing returns to scale and a high impact of the capital:labor ratio. But after 1964, the mechanization continues at a slower rate and is associated with a strong loss of efficiency. This has to be explained by a more qualitative analysis of the principles of each sociotechnical system.

5.4.3 Rise and demise of Fordism: 1934–1991

R. AYRES (1991) has proposed a general periodization of the various stages of production organization and process control (Figure 14). Initially the English system was characterized by a low degree of mechanization and the quasi absence of indirect labor, but a significant product variety. Then comes the American system with standardization and mechanization. The third period begins around 1918 with the diffusion of Taylorism and scientific management. The fourth epoch is associated with transfer lines and statistical quality control. Finally, the emergence of numerically controlled equipments takes place around 1975, whereas flexible manufacturing systems originate from the synchronization, optimization and deepening of the previous technological and organizational advances. Basically, line workers share drop drastically from 2/3 in 1950 to 1/3 in 1985, for the FMS at the technological frontiers.

But precisely, the American manufacturing system which invented a superior organization with respect the English manufacture has been continuously refining this breakthrough, at least until the mid-1960's. Since the 1970's, the American firms have encountered more and more difficulties in implementing and diffusing the innovations they nevertheless had invented (R. LESTER, 1991; M.L. DERTOUZOS et alii, 1989). Therefore, the work organization actually implemented in the U.S. progressively diverges from the best practice: at the frontiers during the Taylorist and Fordist epochs, the American manufacturers are now falling behind (M. ABRAMOVITZ, 1991). The chronology of actually implemented technological regimes consequently shows a genuine pattern (Figure 14).

The first epoch corresponds to the American system, within which the standardization of product, division of labor and the invention of specialized equipments are the main sources for productivity increase. The absence of data does not permit a direct test of these factors. The second epoch is closely related to Taylorism here associated to scientific management and rationalization of work by time and motion. Both model I and model II confirm these hypotheses: basically, the size of the employment allows increasing returns to scale, which seems closely related to the impact of railroads upon the constitution of the American domestic market (not impassing that the railroad freight variable capture most of the effect of the two others variables, the hours of work and the capital:labor ratio). The incorporation into equipments plays a significant role in the simpler model, but seems partially correlated with the variables measuring the extent of the market and the dynamism of innovation. In fact a regime is precisely such a synchronisation of machinery, skills, innovation and markets.

According to R. AYRES (1990), the next stage of production organisation experiences its climax around 1950 with the diffusion of transfer line and statistical quality control (Figure 14), i.e. a vision which is coherent with the analyses by B. CORIAT (1982). But the regulation approach adds that the impact of such an organizational innovation has generated significant productivity increases only when associated with the diffusion of mass consumption to the wage earners themselves due to a quite specific capital-labor compromise (M. AGLIETTA, 1982; R. BOYER, 1985; M. JUILLARD, 1988). The econometric estimates do not contradict this interpretation. First, the high elasticity of productivity with respect to the capital:labor ratio around 0.6 and 0.7 suggests that a significant part of technical change is embodied into equipment or at least that the rise of the machines which is faster than the growth of infrastructures has a larger impact than previously upon the average productivity of total capital. Second, quite impressively and surprisingly, increasing returns to scale are obtained, 1.9 and 1.05 for model I and II, respectively. This means that the size of the labor force has been a stimulus for labor division inside and outside the firm and that the evolution of population might have been a limiting factor in the American Fordist growth: this is common to both the old cumulative causation theories by N. KALDOR and G. MYRDAL (1972) and the renewal of Adam SMITH ideas by P. ROMER (1986). In this last case the investment in skills, R.&D. and education is increasing with the size of the population. But the returns on employment are so high that they deserve some qualification and interpretation. They might be attributed to the upgrading of skills after the New Deal or World War II and the hypothesis could be tested by adding a quality index to the volume of total hours worked. But the elasticity is so huge that it might capture the impact of some unobserved variables: the fact that the elasticity drops from 1.9 to 1.05 when copyrights, public investment and business failures are added clearly suggests that the volume of employment captures a lot of related variables. Still more, the idea that the Fordist compromise upon wage formation played a role in sustaining buoyant markets after 1934 should be tested again with the same econometric techniques: may be the elasticities capture the related stabilization and dynamism of aggregate demand.

5.4.4 The decline of U.S. technological hegemony

The last period, 1964–1987 shows a striking discordance between the potential productivity and quality improvement associated with flexible manufacturing system and computer integrated manufacturing (Figure 14) with the difficulties of American firms to cope with the new organizational and social challenge (Table 5). Whereas the enhancement of skills and the better integration of R.&D., production and marketing are at the core of the new principles, the U.S. manufacturing sectors are still using new information techniques as a tool for controling workers, therefore loosing most of the potential gains open by FMS and related modern organizations (W. LAZONICK, 1991). This has been a recurrent theme among radical scholars (S. MARGLIN, 1972; D.M. GORDON, R. EDWARDS and M. REICH, 1982) but it takes a special importance in the new productive models (M. AOKI, 1988, 1990). Unfortunately, it has not been possible to collect or build social variables over one century in order to test the importance of social division of labor which has been shown very significant in explaining the American productivity slowdown (T. WEISSKOPF, S. BOWLES, and D.M. GORDON, 1988).

Nevertheless, the two models broadly confirm a regulationnist interpretation: for technological or social reasons the impact of the capital-labor relation declines strongly from 0.72 to 0.28 after 1964 and simultaneously the increasing returns to scale linked to the volume of hours is reduce from 1.05 to 0.25. The apparent influence of copyright and gross public investment are not changing, which could suggest that the productivity problem is not related to high-tech and innovation as such, but to the orientation and content of investment and the social relation of production. Paradoxically, the last period, 1964–1987, looks more like the first one, 1890–1920, than any of the intermediate one: again this is a reason for thinking that accumulation has become mainly extensive since the mid-1960's. In passing this contradicts the view of R. BRENNER and M. GLICK (1991) who infer from the very nature of capitalist social production relationships and casual observations of mechanization that accumulation is always intensive, without any variation through time. The split between extensive and intensive accumulation is not only a matter of qualitative analysis but also of quantitative assessement.

Roughly speaking, a comparison of the productivity regimes with the socio-technical systems show a good compatibility, quite surprising indeed given the inner fragility of any time serie analysis upon aggregate variables. An ultimate check of these results is now proposed.

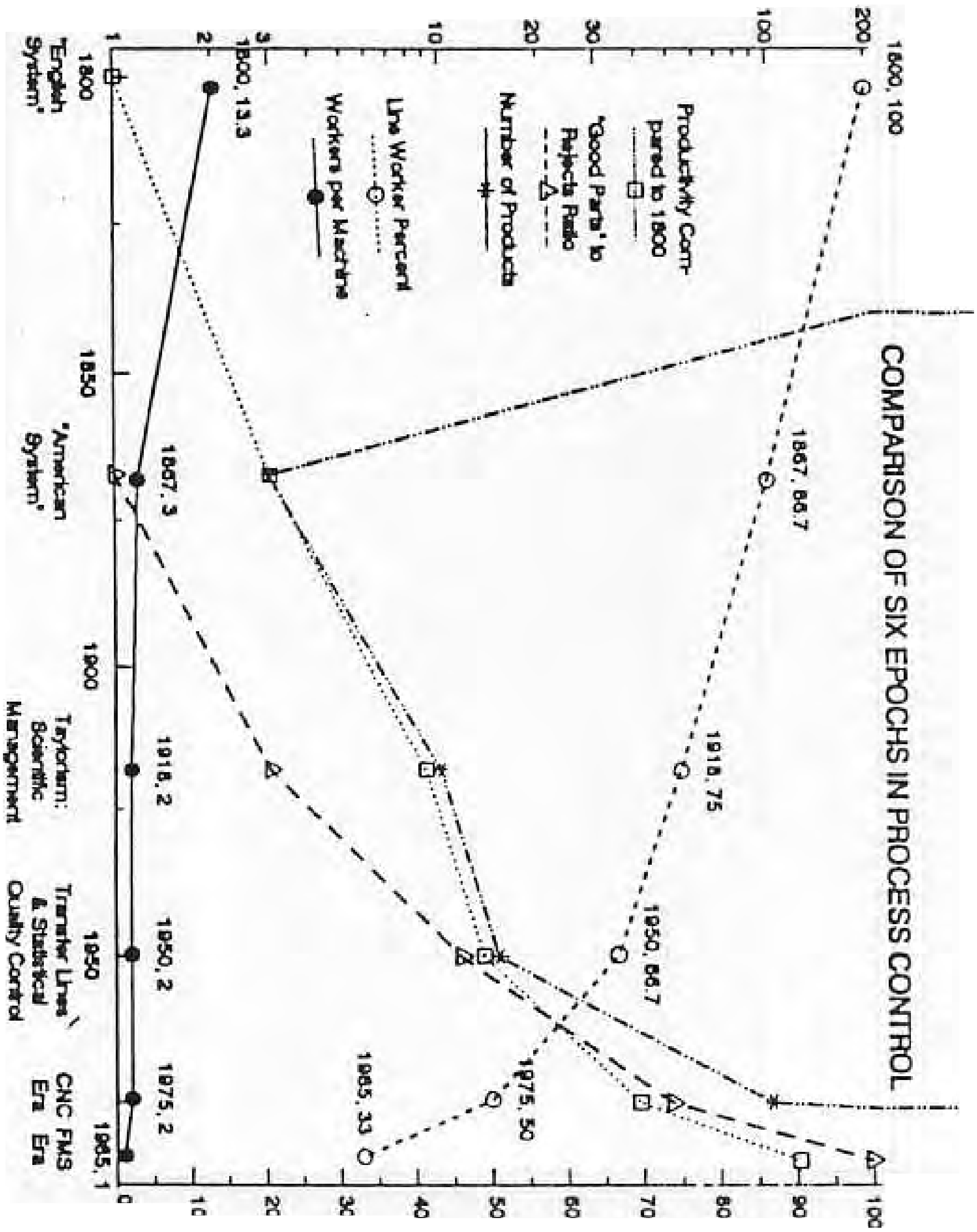

Figure 14: Comparison of six epochs in process control

PRODUCTIVE SYSTEMS / FEATURES	AMERICAN SYSTEM	TAYLORISM	FORDISM	EXTENSIVE PRODUCTIVE REGIME IN US
1.Division of Labor	1. Between low and high skills	1. Separation conception / execution	1. Deepening of taylorism	1. Still OST, but growth of services
2. Mechanization	2. Specialized equipment	2. Rationalisation in the use of equipment	2. Assembly line	2. In order to keep workers control
3.Technical Change	3. Engineering	3. Time and motion	3. Via mechanization	3. Limits of high tech
4.Products	4. Standardized products	4. Mainly standardized products	4. Minor diversification of products (from Ford T to annual model change)	4. Few successful, new products
INNOVATIONS				
	5. Incorporation of low skilled workers	5. Destruction of previous crafmanship knowledge	5. Direct control of working time by the assembly line	5. Neo-Fordism
	6. Standardization of components	6. Rationalisation of equipments	6. Genuine compromise with wage-earners	6. More competitve labor market
CONTINUITIES / DISCONTIBUITIES				
7.Reduction of costs	7. Large	7. Large	7. Very large	7. Productivity slow-down
8. Differentiation of product	8. Still lower for components	8. No clear change	8. Initially reduced and then minor enlargement	8. Low differentiation
9.Geographical extension	9. Limited and then growing	9. Growing but some obstacles	9. Rather large after WWII	9. Quite general

Table 5: The sociotechnical systems as matrix for productivity regimes

6 PRODUCTIVITY REGIMES: INTEREST, CONVERGENCES AND DIVERGENCES AMONG ALTERNATIVE STUDIES

The concern for technological epochs is not totally new, therefore a brief review of the literature can enlighten the present results. Basically, it seems that every time that the stability of aggregate production function for the U.S. economy has been tested, the hypothesis has been rejected and the idea of regime or shift proposed by the authors. Only a drastic use of dummy variables can restore an apparent stability to a productivity equation.

The existence of technological epochs: a neglected conclusion from previous econometric studies

Quite surprisingly, M. BROWN and J. POPKIN (1962) and M. BROWN and J. De CANI (1963) reject the stability of a Cobb-Douglas function, as well as of a CES. They find out three epochs: from 1890 to 1918, high increasing returns to scale prevail around 1.47 (Table 6), with a special influence of the returns associated to the hours worked; in the intermediate period, 1919–1937, the impact of the capital:labor ratio increases but that of the hours decline, in such a manner that the returns to scale are near unity; finally, from 1937 to 1958, the basic change is associated with an increase of exogeneous technical change, with little variation in the elasticities. One notes that the periodization is finally close to that exhibited by our own estimates (Table 2) and that the interwar period has a very poor fit, which suggests that it cannot be interpreted within the framework of production function which supposes a full utilization of available factors and the absence of any problem of realization.

Another difference between Tables 2 and 6 relates to the presence or the absence of any time trend: if included, the factor elasticities are apparently lower than in our method which prefers to constrain the evolution of capital and hours to explain the evolution of GDP and consequenlty delivers higher estimates. After all, it is more satisfactory to conceive technical change as related to learning by doing effects, embodied into equipments, workers and organization, rather than mechanistically linked to the simple lapse of time.

6.2 Is regime change smooth or does it exhibit significant discontinuities?

Larger divergences are observed with respect to the numerous investigations of productivity, investment and profit by G. DUMENIL and D. LEVY (1991a, 1991b). Since the present study uses the same data, the discrepancies can only be attributed to methodological differences. A synthetic table has been built in order to diagnose the roots of diverging interpretations (Table 7).

Firstly, these authors want to disentangle between the substitution along a given isoquant and the shift of the production function over time. According to our analysis, such a distinction always presents some degree of arbitrariness, whereas only the aggregate effects matter for a productivity regime (see section 2.4). Secondly, in the initial G. DUMENIL and D. LEVY research (1989), the time trend therefore captured the variations in factor

Table 6: Stability tests for Cobb-Douglas and CES production functions

	Fonction de Cobb-Douglas $Q_t = A \cdot K^a_t \cdot N^b_t \cdot e^{ct}$					Fonction C E S $\text{Log } N/K = ß \log (C/W) + \mu \text{ Log } (N/K)_{-1}$			
ESTIMATIONS / PERIODS	a	b	c	a+b	R^2	ß	μ	$ß/1-\mu$	R^2
1890-1918	0,49 (5.3)	0,97 (11,6)	- 0,48 (1,0)	1,47	0,9974	0,34 (2,8)	0,37 (2,2)	0,55	0,847
1919-1937	0,61 (3,3)	0,44 (2,4)	0,079 (4,3)	1,04	0,9687	0,078 (0,8)	0,75 (3,4)	0,31	0,73
1937-1958	0,53 (8,5)	0,51 (3,9)	0,127 (5,4)	0,99	0,9930	0,11 (2,9)	0,76 (4,8)	0,47	0,86

Sources : M. BROWN, J. POPKIN "A measure of technological change and returns to scale",*Review of Economics and Statitics*, Vol. XLIV, n° 4, November 1962, p. 402-411.
M. BROWN, J. de CANI "A measure of technological employment", *Review of Economics and Statistics*, Vol. XLV, n° 4, Novembre 1963, p. 386-394.

AUTHORS	EQUATION TESTED	METHOD	PERIOD OF ANALYSIS	NUMBER OF REGIMES AND BREAK-POINTS	MAIN DIFFERENCES AMONG REGIMES	FACTORS AND/OR VARIABLES
BROWN M. J. POPKIN (1962)	COBB-DOUGLAS	Chow test	1890 - 1958	3 epochs 1919 and 1937	Decline of increasing returns to scale, rise in exogeneous technical change	Capital-Labor
BROWN M. J. De CANI (1963)	CES	Chow test	1890 - 1958	3 epochs 1919 and 1937	Decrease in elasticity of substitution poor fit for 1919-1937	Capital-Labor
DUMENIL G. D. LEVY (1990)	COBB-DOUGLAS CES	Variable elasticities and logistic for the shift factors	1869 - 1985	3 periods 1929 and 1945	. Shift from structures to equipment . Two regimes separated by a logistic diffusion process centered in 1944	Structures, Equipment, Labor
DUMENIL G. D. LEVY (1991)	Vintage model		1850-1989	3 periods . for productivity of capital 1899 and 1949 . for labor productivity logistic centered on 1937	. The intermediate period begin 12 years earlier than in (1990) paper	Capital and Labor
GORDON D. R. EDWARDS M. REICH (1982)	Institutional analysis	Set of structural data	1820-1970	3 periods : 1870 and 1930 subperiods 1900 and 1950	. Form of workers control and mechanization . Labor organization	Capital Surveillance
GORDON D.M. (1991)	Productivity regime	Quality of R^2 intensity	1902 - 1979	2 regimes + transition 1905 - 1927 1940 - 1979	. The drive system, based on labor . Postwar social model based upon Capital and technical change	Capital, Labor, Intensity, Technical change, Competitive pressure
BOYER R. M. JUILLARD (1991)	Productivity regime	Maximum likehood search for break-points	1890 - 1987	4 regimes 1920, 1933, 1964	. Varying returns to scale and impact of mechanization . The last regime is quasi extensive	Capital, Labor and Technical variable

Table 7: A summary of the various chronologies for productivity regimes

elasticities and probably underestimates their embodiment into equipments or labor. Simultaneously, the increase in real wages which was supposed to govern technical change in their early papers, are endogenous in the long run in such a manner that it is hard to believe that the labor saving bias of technical change can be totally attributed to autonomous real-wages demand.

The two most recent papers (1991a) and (1991b) correct these deficiencies and prefer to test the presence of time trend in the factor elasticities along with a shift factor describing technical change as solely linked to time: in the present paper the absence of such a trend may explain why the various elasticities are higher, which raises a rather important methodological issue to be investigated by anothe paper (R. BOYER and M. JUILLARD, 1992). A third difference concern the periodization: it is difficult to admit that the bumpy interwar period is only the unfolding of a smooth logistic curve, whereas it very likely corresponds to a drastic and dramatic change from one productivity regime to another.

Finally, the present analysis suggests that the productivity slowdown observed since the mid-1960's is not the mechanical consequence of the unfolding of a diffusion process: of course, the productivity potential of Fordism progressively levels off, but it is apparently replaced by a mainly extensive accumulation regime with its own properties. Nevertheless, both researches share that no steady state long run trends are observed in the U.S. economy since the Civil War and that the World War II has been a turning point in the implementation of a new productive organization with a permanent jump in the productivity of capital. For both approaches, this is still a mystery to be enlightened.

6.3 The embeddedness of productivity regimes into capitalist social relation

A third series of investigations originates from the Marxian and radical american traditions (S. MARGLIN, 1978; D.M. GORDON, R. EDWARDS and M. REICH, 1982). Basically the evolution of productivity is seen as the outcome of the precise configuration of the social relations of production, which themselves are structured by the pattern of accumulation, the nature of past crises and possible capital-labor accords derived from epochal changes. From 1820 to 1970, three labor epochs are proposed: initial proletarisation until 1870, then homogenization until the 1930's and finally segmentation as the leading configuration after World War II, each period experiencing three phases (exploration, consolidation and ultimately decay). As far as productivity is concerned, the evolution of the capital:labor ratio, the share of non-production workers in total manufacturing employment and total factor productivity suggest that possible breaking points are around 1900, 1930, 1950. Since the analysis is mainly historical and institutional no econometric test is provided by D.M. GORDON et alii (1982).

A more recent paper by D.M. GORDON (1991) precisely extends to the period 1890–1987 the test of social models of productivity which had been elaborated in order to explain both the contemporary productivity puzzle (T. WEISSKOPF, S. BOWLES and D.M. GORDON, 1983) and the absence of any long run recovry of profit and accumulation under the REAGAN administration (S. BOWLES, D. GORDON and T. WEISSKOPF, 1989). This study shares many common features with the present paper: the idea that a productivity regime has to be preferred to the conventional production function approach, the search for a large variety of explaining variables including the neoclassical ones, the aim to relate regimes to institutions and the pattern of accumulation and finally the conclusion that the 1940–1979 period is different from the interwar as well as the pre-World War I epoch. Therefore the productivity regimes exhibit a strong historical flavor, at odds this the old as well as the new theories about endogenous technical change and growth.

Firstly, the same variable may have an opposite impact upon productivity according to the regime and consequently the régulation mode this variable is embedded into and generated by. For instance, accident rate used to be positively correlated to productivity within the drive system from 1905 to 1927, but negatively within the social model of U.S. post-World War II growth. Secondly, the quality of the fit for each regime first improves drastically, then remains good and quasi-constant and finally after two or three decades sharply decays: this a confirmation of the vision of a regime with its three phases: exploration, consolidation and finally decay or crisis.

Thirdly, these sequences correspond to rather clear chronology of social and institutional transformations which genrally are the outcome of conflicts and struggles at the firms and society level. A lot of realism is therefore gained by comparing with the alternative vision of a smooth evolution of factor substitution and technical change, only temporarily affected by stochastic perturbations. Again the drastic surge in equipment apparent productivity during World War II is more than a noise or disturbance but very likely an epochal and strucural change with long lasting influence upon all the components of the accumulation regime.

6.4 Simplicity and parcimony versus exhaustivity and complexity

On top of these converging broad conceptions, some diverging choices have to be pointed out. D.M. GORDON (1991) has enlarged the conventional variables explaining productivity toward measures of work control, labor relations and the strength of competition abroad and at home, all these variables being delivered by contemporary statistical data. The present paper has focused upon the possible sources of increasing returns and priviledged more technical variables. Being quite preliminary, it has not already gathered all the relevant social variables, which is quite difficult over a century long priod.

Consequently, we get a standard equation with only a minimal number of parameter changes, whereas he obtains two totally customized regimes with many explanatory variables including several dummies. Another econometric difference may provide a rationale for the different periodisations. In our study only a long run relation is looked for, without estimating the dynamic process of adjustment to this relation. On the contrary, D.M. GORDON estimates directly the productivity growth rate and consequently the two sets of estimated are not directly comparable.

Most of the divergence in the resulting periodisations (Table 7) may be traced back to these contrasted techniques: the only agreement bears upon the regime shift after the 1930's. This hypothesis is to be checked by subsequent and more detailled comparisons of the econometrics. Similarly, remains to be investigated how the explaining contributions vary accross the two types of models, in particular, what is the relative importance of social, technological and economic factors, and if they differ from one regime to another.

Both these diverging results and a lot of common objectives call for a new research agenda, after a brief summary of the major findings of this paper.

7 CONCLUSION

It is time to sum up what are the main conclusions of this econometric exercice. For simplicity sake, six tentative results are to be discussed.

7.1 Each productivity regime is the outcome of a socio-technological system

From a theoretical standpoint, the approach which tries to disentangle a short run production function with a long run technical progress function runs into severe problems, not to speak of the identification problems associated with econometric estimates. Basically any econometric or acounting analysis of productivity is mixing the two series of factors, which in fact are to be tested jointly. In a sense, the notion of a productivity regime takes into account this strong interdependency between substitution effects and shift factors. A second strength of a productivity regime is to combine a whole spectrum of roots for technical change, not only R.&D. expenditures but learning by doing, learning by using and finally the embodiment into workers, capital or organization. A priori, these factors do not define any single endogenous growth model.

Finally, this notion helps in fighting against the implicit technological determinism which permeates most of the econometric analysis of production function and does not postulate any full-employment equilibrium. Quite on the contrary, a lot of economic and social determinants can be brought into the analysis: the nature of the skills and labor division within and between firms, the quality of industrial relations and internal organization of the firms, the importance of welfare institutions, without forgetting the nature of basic political compromises. Consequently, each mix of these variables defines a socio-technical system, just to generalize a concept proposed by the specialists of technical change (G. DOSI et alii, 1988). In turn, every socio-technical system is potentially characterized by definite mechanism promoting ... or impeding productivity increases. Social relations, institutions and conventions play a prominent role in the genesis and functioning of a productivity regime, which ends up being quite different from the conventional production function approach, not by mere cosmetic or semantic difference but from a theoretical perspective.

7.2 One century of American growth: Four productivity periods

A brief survey of the characteristics of technical change in the U.S., associated with the analysis of a set of structural variables, finally deliver a converging diagnosis about the changing pattern of productivity increases. A systematic search for breaking points over the period 1890–1989 finally deliver three turning points: 1920, 1933, 1964. From an empirical point of view, changing productivity regimes clearly emerge from these econometric exercices. Untill 1920, the process of mechanization did deliver significant productivity increases thanks to a moderate impact of the capital:labor ratio as well as the increasing returns to scale associated to labor. The second periods corresponds to a deepening of the previous trends, but not a complete structural change of these factors. This period may be better considered as a transition period rather than a regime in its own right which would ever get stabilized. Quite on the contrary, from 1933 to 1964, two sources of productivity increases are exacerbated: the mechanization provides a new vintage for productive advances, whereas the extension of the market allows a larger division of labor and possibly dynamic increasing returns to scale. All these mechanisms decay and quasi vanish after 1964, in such manner that the accumulation appears to be more extensive than intensive and looks like more like the first regime (1889–1920) than a minor transformation of the Fordist productivity regime (1933–1964).

Consequently, productivity regimes matter for American long term growth. Contrary to the widely held view that the U.S. economy has not experienced any structural transformations over one century, some social analysis of labor relations (D. GORDON et alii, 1982) suggest that a series of regimes follow one another, according to three sequences: first new principles and organizations emerge, they then diffuse if they fit to the existing social relations and macroeconomic trends but they finally mature and ultimately decay and are decomposed. During the same intermediate period, a productivity regime is declining, whereas a new one is looked for according to a rather myopic trial and error process. This stimulating and realistic hypothesis has not be tested here, but it could be done by a further investigation, since it introduces a sharp contrast with conventional theory, be new or old.

7.3 The impossible task of endogenous growth theory: In the long run, productivity regimes change

Basically, the so-called new endogenous theory has revived some past growth analyses which had been trying to explain why growth could be cumulative and without limit even with limited resources (K. ARROW, 1962; H. UZAWA, 1971). Its merits are to deliver an elegant framework in which every economic agent optimize his or her decisions over an intertemporal horizon, supposing rational expectations: it is sufficient to suppose that the dynamic increasing returns to scale associated to R.&D., education, infrastructures or investment are external to the firms and/or individuals (P. ROMER, 1986). Since this rediscovery, the number of papers, books and articles proposing sophisticated macro models with micro foundations has exploded, and given birth to a new industry about endogenous growth.

The present analysis challenges the relevance of such an optimism about the complete renewal of our understanding of the growth process. First of all, the theme is not new for heterodox economists: N. KALDOR, G. MYRDAL and many others have investigated cumulative causation models which precisely deal with these mechanisms ... but without providing nice, elegant but farfetched micro foundation. Second, the hypothesis of full optimization with rational expectations is rather non-sensical for innovation analysis: by definition, it is impossible to forecast basically new knowledges, according to the very argument that K. POPPER used to address to the Marxian view about historical laws.

Could the firms manufacturing horse carriage expect the invention of the motor engine and the car industry? Or alternatively, could some of the micro-electronics innovators in Silicon Valley, expect that they will be bankrupted less than two decades after the inventions of the micro chips?

Furthermore, the American historical record totally challenges the view inherent to this theory that the very same mechanisms have been operating since the first industrial revolution. One gets the impression that for Paul ROMER the spillover effects associated with basic knowledge have been at the core of any stage of growth, whereas for E. HELPMAN and G.M. GROSSMANN (1991) product differentiation is crucial for the capitalist process, not to speak of R. LUCAS who is now privileging the impact of education and learning by doing. But the list is not exhaustive: for D.A. ASCHAUER (1989), public investment, whether in education, transportation or telecommunication might explain a large part of the productivity puzzle at least in the United States. These are too many contradictory explanations for a single phenomenon! In fact, the esthetics and the logic of each brand of model are outruning the empirical relevance of each one: it is an empirical matter to check which are the leading mechanisms for a given period and a given economy. The merit of productivity regimes is precisely to combine actually existing mechanisms and get a simplified but if possible realistic representation of the on going accumulation regimes and "régulation" modes.

Our econometric results, even if quite tentative, confirm this strong historicity of technical change, productivity and growth. During the second half of the XIXth century, the railroad construction has played a determinant role in market growth and technical change. Afterwards, the mechanization of firms and the cumulative knowledge embodied within equipments, as well as the extension of the market in response to the New Deal and the post-World War II capital-labor accord have been the major sources for technological improvement. Finally,the exhaustion of this Fordist regime confirms that any configuration, however initially dynamic and powerful, enters into a period of decay, demise and possibly of structural crisis. This is a second form of historicity within a productivity regime, to be added to the transformation for one to another regime. None of these stylized facts can be reconcilied within the framework of neo-classical conventional hypothesis about full-employment, complete rationality and perfect expectations. At least one of these hypotheses has to be discarded in order to get destructive creation, both growth and depression (P. AGHION and P. HOWITT, 1991). Still more, any rigourous methodology in economics has to combine inductive (the stylized facts) and deductive approaches (be rationality and/or equilibrium).

7.4 From extensive to intensive accumulation and back

We have now some stuff to reply to the severe criticisms by R. BRENNER and M. GLICK (1991). The regulationnists would totally misinterpret the Marxian message according to which the capitalist relations of production imply a constant search for labor saving technical change. This theoretical error would be associated with a basic ignorance of the major stylized facts for the American economy: "long before the era of Taylorist-Fordist transformations, new machines, representing new advances in productive efficiency, had been more or less regulary—though certainly not continually—coming into use." (p. 59). In other words, with minor variations through time, the accumulation would be mainly intensive since near a century. Consequently, this "leads (the regulationnists) to propose an untenable theorization of the history of the capitalism per se of the mid-Nineteenth century to the late 1960s" (p. 108). R. BRENNER and M. GLICK seem to say that one century of American capitalism is simply "business as usual": productivity constantly increases, so does workers alienation and if crises happen, they do resemble to any previous accumulation crises.

Clearly, RA suffers from a lot of deficiencies but can withstand against such broad considerations, both theoretically and empirically. Of course, since the seminal thesis and then book by M. AGLIETTA (1982), the regulationnists have given revised definitions of the intensivity of an accumulation regime: the prevalence of relative surplus value over absolute surplus, the rise of apparent labor productivity above some threshold (around 2 %), the role of mechanization in such increases or more recently the existence of a strong and significant relation between growth and productivity. In each case, theoretically at least, one may get different characterization about the extensiveness or intensiveness of accumulation, which is a matter of degree and never an absolute feature.

The American system, by opposition to the English manufacture, did initially provide a strong speeding up of productivity, with an impressive catching up of the United States with respect to England (D.M. GORDON, 1991). But after a successful period, the genuine American system run into trouble and levelled off into a crisis period characterized by very slow productivity gains, even if the mechanization was booming along with a series of potentially radical innovations such as the electrical engine (P.A. DAVID, 1991). Under these circumtances, is it not legitimate to speak of a mainly extensive accumulation regime, given the poor productivity performances? Similarly, our two models show that not only the pattern of productivity growth is not the same since the Civil War, but that the mechanisms at the origin of the increase in efficiency are clearly different from epoque to epoque. Furthermore, it gives a stricking image about the collapse of the Fordist regime and its implicit replacement by a very labor intensive—i.e. extensive—growth regime? Should one continue to argue that the regime is still intensive, under the fallacious argument that it is in the "genes of capitalism" to improve productivity ... even if during two decades the joint efforts of managers, conservative politicians and scientists making new discoveries have been unable to fulfill such an objective? In other terms, is inner essence of capitalism more important that its factual existence?

7.5 The productivity slowdown: from the demise of Fordism to a quasi-extensive accumulation regime

It is clear enough that the various regimes provide to each historical epoch its flavor, or more precisely a definite set of mechanisms for productivity increases, whereas the regulation mode contributes to set the trends in capital deepening, employment and all other relevant variables. Consequently, the long run evolutions derive from two distinct mechanisms: first the impact of macroeconomic variables assuming a regime stability, second the impact associated with the structural shift from one regime to another. The exercise is specially interesting for the last period (Table 4).

Whereas labor productivity per hour was growing by 3.1% from 1934–1964, it slows down to 0.98% from 1965 to 1987. If the Fordist productivity regime had remained unchanged, the simulations show that productivity would have speeded up: the capital per hour is growing faster, so does the total number of hours worked and the applications for design which would have implied an acceleration of productivity around 1.35%. Of course, simultaneously, the reduction in public investment partially compensate these positive factors. On the whole, within the previous regime, the macroeconomic evolutions observed after 1965 would have triggered an higher productivity growth around 0.5%.

But this does not take into account the very large reduction in the efficiency of the capital-labor evolution: given the drastic deterioration observed, the productivity is 0.8% lower than previously; similarly, the increasing returns to scale associate to labor are quite vanishing, which trigger a deceleration around 1.29%. This decline is accompanied by a parallel decrease in the efficiency of design, which deliver a further 0.34% deceleration in productivity. Adding up all this factors, the shift from the Fordist to the extensive regime explains a slowing down of about 2.71%. Combining the impact of the change in macroeconomic and socio-technical variables with this regime shift, one explains a reduction in labor productivity trends by 2.21%, to be compared with the observed slowdown around 2.12%.

One might challenge as mere tautology such an explanation: productivity decelerate because production becomes less efficient! A first response emphasizes that this interpretation its at odd with conventional wisdom according which the American economy has not sufficiently invested in comparison with foreign competitors. This might be true, specially with respect to Japan and its impressive investment rate, but this vision hides a major internal weakness in the process of deciding and allocating capital, R.&D. expenditures and more generally in the process for passing from an innovation to mass production of quality goods at competitive prices (DERTOUZOS, LESTER and SOLOW, 1989). This focuses upon the inner characteristics of this American socio-technical system: excessive impact of R.&D. expenditures devoted to defense with few spill over toward the competitiveness of the private sector, insufficient integration of research, production and marketing, poor industrial relation and lack of adequate training institutions, negative impact of a sophisticated financial system preoccupied with returns in the short run (R. BOYER, 1991). A lot of other institutional and economic features confirm this diagnosis: basically American Fordism has progressively exhausted its dynamic and competitive age (Figures 11 and 12) and has shifted from an intensive accumulation regime centered upon mass consumption to a mainly extensive regime in which a quasi stagnation of hourly real wage after taxes is compensated by a multiplication of wage earners per family and an impressive increase in consumer credit (M. JUILLARD, 1988; R. BOYER, 1989) and inceased income and wealth unequalities (L. MISHEL and D.M. FRANKEL, 1991). Many statistical investigations confirm that income inequalities have widen, the poorer experiencing a significant decline in their living standards, whereas a small number of privileged has extended its luxury and conspicuous consumption (M. REICH, 1991). The demand side of the Fordist accumulation regime is challenged since near two decades. The supply side too, since the productivity slowdown, the inability of the majority of American manufacturers to cope with foreign competition about quality and services, clearly manifests the social institutional and technological limits of the genuine Fordism built in United States.

Consequently, the hypothesis of a productivity regime change is highly corroborated by most of on going researchers on technological change, income distribution and the transformation of contemporary American institutions. The loss of efficacy of the investment and the strong decline in the increasing returns to scale associated to labor which are exhibited by the econometric estimates (Table 2) follow a pattern very similar to that of industrial organization, and the growing difficulty to pass from inventions and innovations to profitable production. This synchronism between econometric estimates and the major stylized facts about the history of American business is confirmed by a wider outlook of technology over one century.

7.6 The mystery is half solved: an agenda for further investigations

To sum up, the productivity puzzle is half solved: it has to be attributed to the progressive decline of the Fordist productive regime and the absence of any clear substitute, as efficient in promoting productivity growth; quite on the contrary, the American economy has finally converged toward a quasi-extensive accumulation regime, which is much more similar to the regimes observed before the 1920's than the one characterizing the Golden Age. A. MADDISON (1991) is right in pointing out that the 1970's and 1980's are not exceptional in American history. Alas, firms, workers and politicians had found buoyant expectations about the Fordist virtuous circle in which everybody finally benefited from technical change. Nevertheless the mystery is only half solved: the econometric estimates do deliver an interesting and we hope convincing story about the American productivity demise, which is furthermore congruent with a lot of institutional and technological studies. It remains to be carefully demonstrated that the evolution of the productivity regime is to be related to the suggested evolution of social relations of production and the socio-technical system.

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