Innovation, competition, and growth: Schumpeterian ideas within a Hicksian framework

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Abstract Schumpeter's ideas, which should be the basis of any evolutionary approach to the relations between innovation, competition and growth, are revisited and interpreted within the analytical framework proposed by Hicks in *Capital and Time*. Two main results emerge. First, the introduction of any new technology may lead to higher unemployment and reduced productivity; only an active monetary (and banking policy) will allow the economy to capture productivity gains. Second, within an industry confronted by recurrent technological changes, certain monopoly practices may be needed for this industry to converge towards an efficient market structure determined by the content of technology and the profile of demand. These results suggest some reconsideration of the macroeconomic and industrial or competition policies designed, in Europe, to cope with both technical change and globalization in modern economies.

Keywords Competition · Creative destruction · Growth · Innovation · Market structure · Stabilisation · Volatility

JEL Classification L1 · 03 · 04

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1 Introduction

Any growth process implies qualitative change, at both the micro and macro levels. It is a process of creative destruction, which cannot be reduced to an equilibrium path. Therefore, analysis of such a process must include study of the sources and consequences of the distortions that are inevitable in qualitative change. This is at the heart of Schumpeter's ideas about the nature of economic development. However, making these ideas analytically manageable requires the application of a dynamic method, which was not developed by Schumpeter: he only pointed to the need to consider a model that would take account of the characteristics of a process involving the breaking down of the circular flow, that is, of a general equilibrium model à la Walras. Hicks, who developed this type of modelling which focuses on the temporal or sequential dimensions of the economic process, is frequently regarded as a neo-classical or a standard Keynesian economist. He does not refer to Schumpeter's approach to change as contributing to his dynamic analytical approach, while Schumpeter does refer to the type of dynamic modelling introduced by Hicks. However, Hicks maintains the idea that innovation and growth result from the breaking-up of a previously established general economic equilibrium—a Walrasian equilibrium. In his book *Capital and Time* (Hicks 1973), he shows why and how this disruption puts the economy out of equilibrium and opens up a transition phase, which is characterized by a temporary diminution of both growth rate and employment level.

In this paper, we revisit Schumpeter's ideas but within an analytical framework that is an extension of Hicks's model. This allows us to deal with two important issues: on the one hand, the relation between volatility and growth and, on the other hand, the relation between competition and innovation. This leads to policy conclusions that are in line with most of Schumpeter's proposals and focuses on the role of gradualism as a means of making an innovative process viable.

2 Schumpeter's basic ideas

Rather than distinguishing between the successive contributions of Schumpeter to the economic analysis of evolution and identifying to what extent they are different or opposite, we focus on ideas he developed in *Theory of Economic Development* (Schumpeter 1934) and *Capitalism, Socialism and Democracy* (Schumpeter 1950), which provide some of the basic elements of an evolutionary theory. These concern the nature of change, the role of credit, the impact of monopolist practices, the function of prices and the source of viability of any process of change.

First, Schumpeter insisted repeatedly on the idea that any economic change involves two entirely distinct phenomena—growth and development. While growth is a purely quantitative phenomenon, development consists of

qualitative change, a 'spontaneous and discontinuous' change that arises from within the economic process. This distinction has strong implications. As Schumpeter pointed out, "add successively as many mail coaches as you please, you will never get a railway thereby" (Schumpeter 1934, p. 64). Therefore, from an analytical viewpoint, development, which is a condition of growth, is a "disturbance of equilibrium, which forever alters and displaces the equilibrium state previously existing" (ibid.).

It is the role of the entrepreneur to disturb the existing equilibrium. However, the introduction of a new technology is only possible if entrepreneurs have access to, can borrow, additional funds, that is, if an active banking policy is in place. "The essential function of credit consists in enabling the entrepreneur to withdraw the producers' goods which he needs from their previous employment, by exercising a demand for them, and thereby to force the economic system into new channels" (Schumpeter 1934, p. 106).

In this context, competition cannot be reduced to a perfect state of affairs: it is a process that takes place in an imperfect world. Therefore, monopolistic practices become normal and rational behavior for firms that have to be efficient and viable. "In the process of creative destruction, restrictive practices may do much to steady the ship and to alleviate temporary difficulties" (Schumpeter 1950, p. 87). "Restrictions of this type, in the conditions of perennial gale, are incidents of a long-run process which they protect rather than impede" (Schumpeter 1950, p. 88)

Of course, monopolistic practices include price behaviors. While in standard analysis, prices must respond to changes in costs and shifts in supply and demand, in Schumpeter's perspective, they must, to some extent, be sticky. "What the business strategy really aims at is to avoid seasonal, random, and cyclical fluctuations in prices and to move only in response to the more fundamental changes in the conditions that underlie these fluctuations. Since these more fundamental changes take time in declaring themselves, this involves moving slowly by discrete steps" (Schumpeter 1950, p. 93).

Finally, Schumpeter addresses the question of the intensity and the speed of structural changes and pleads for gradualism. "There is certainly no point in trying to conserve obsolescent industries indefinitely; but there is a point in trying to avoid their coming down with a crash and in attempting to turn a rout, which may become a center of cumulative depressive effects, into orderly retreat" (Schumpeter 1950, p. 90).

3 Which analytical framework?

Schumpeter's ideas can be revisited within an analytical framework that Schumpeter himself, quoting Hicks among other scholars, defined as "the analysis of sequences in time" (Schumpeter 1950, p. 103). Hicks elaborated such an analysis. Schumpeter (ibid.) evoked *Value and Capital* (1939). We shall make use of *Capital and Time* (1973).

3.1 Hicks's framework

It is, as underlined by Schumpeter, impossible in fact to produce new products with old productive capacity (or old competencies). Any innovative choice requires the construction of new production processes and the destruction of the old. This process of creative destruction takes time. The neo-Austrian framework, which Hicks developed in *Capital and Time*, has the essential characteristic to put into light this fact.

Hicks's model focuses on a process of production described as a scheme for converting a stream of (primary) labor inputs into a stream of final output. This process is fully integrated vertically, that is, it must be taken as a whole over time. It extends over a sequence of periods, which integrate two successive phases, interpreted as the phase of the construction and the phase of the utilization of productive capacity. This makes it possible to explicitly consider the phase of the construction of productive capacity, from which we necessarily abstract in the standard equilibrium approach, to be the physical expression of technology. But it also shows that the effective definition of technology (the viability of the process of innovation) depends on the possibility of assuring a regular functioning of the productive capacity; that is, on the possibility of re-establishing the interaction between the phases of construction and utilization as sketched out by their intertemporal complementarity, disturbed by the attempt to introduce a new technology or a new product.

Then, the productive capacity of an economy can be represented as a population of production processes. Each process has a life cycle. Each given behavior of the economy is sustained by a productive capacity characterized by a given age structure of the production processes. An equilibrium state or path, here defined as a steady state, is sustained by a particular age structure, meaning a *constant age distribution* of production processes. This means that the 'horizontal dimension' of productive capacity—namely, the array of production processes at different moments of their lifetime, coexisting at a given moment—must be consistent with its 'vertical dimension'—that is, the time pattern of production associated with this age structure. When this is so, that is, when the phases of the construction and utilization of productive capacity are harmonized at each given moment, in time and over time, no market disequilibria arise. Investment and consumption and the supply and demand of final output are also harmonized. Productivity is actually a measure of the technical performance of the economy.

A qualitative change—as opposed to merely quantitative growth that is perfectly compatible with the equilibrium state just defined—implies a change in the way in which the economy functions, that is, a structural modification which, according to the above definition, is characterized in the first place by a change in the age structure of productive capacity with respect to its previous equilibrium configuration. Therefore, investment and consumption and supply and demand are no longer harmonized over time. A qualitative change necessarily creates a *distortion* in the age distribution of production processes, which *propagates itself* and generates an out-of-equilibrium path.

This distortion and its propagation are one of the main aspects of the *perennial gale of creative destruction*.

In this framework, the productivity of the economy depends on the successive investment decisions that determine the age structure of productive capacity at each moment of the ongoing process of innovation, rather than reflecting the nature of technology or delays in the adjustment of production or employment. In other words, it reflects the way in which the economy functions. While the rate of accumulation determines the growth rate of productivity, it, in turn, depends on the latter, and this interaction may result in a complex dynamics defining the evolution of the economy.

In this framework, as in the Schumpeter's analysis, capital is no longer a production factor; it is a *fund* of resources that allows the firms to carry out production processes and to finance the wage fund. Therefore, finance cannot be neutral with respect to real investment and labor productivity.

The main result of Hicks's analysis is to provide a robust explanation of the so-called Ricardo Machinery Effect. Hicks considers a technical progress forward biased: an increase in the labor required in the construction phase is more than compensated for by the decrease in the labor required in the utilization phase. *Full performance* is assumed, which, in a real economy, implies that the entire product is consumed or invested (there are no co-ordination failures that would result in market imbalances). As a consequence of the increase in the quantity of labor dedicated to the construction of new processes, the intensity of construction is reduced and, later, also the gross product of the economy. With fixed wages, unemployment appears as a consequence of the *temporary* distortion in the age distribution of production processes, not of the characteristics of the new technique. With flexible wages allowing for full employment, the same distortion results in a fall in the level of productivity, which also is unrelated to the characteristics of the new technique.

3.2 An extension of the Hicks framework

The assumption of full performance can and must be removed, and a sequential process of decision introduced. Supply and demand for the final output are no longer necessarily equal. Market functioning obeys stock-flow mechanisms (periodic price adjustments).

The above assumptions allow us to analyze the process of restructuring of the productive capacity through which innovation occurs. Now, the distortions in the structure of productive capacity are not only mechanistic, but reveal the conditions that characterize the decision process.

In fact, co-ordination problems emerge as a consequence of the imperfection of knowledge coupled with the irreversibility of the production and investment decisions. Co-ordination mechanisms determine the constraints and information that are relevant to the decision-making processes and, hence, affect the properties of the path of evolution of the economy. In particular, co-ordination is the process that works to make the actions of agents consistent. This process, when well managed, leads to an order. As Metcalfe (2001, p. 572)

points out, "order implies regularity and regularity arises from the co-ordination of diverse behaviours". Full employment is one of the main characteristics of this order. As we shall see, it is only when co-ordination mechanisms allow the economy, although disturbed by a qualitative change, to follow a quasi regular path, that full employment can be re-established and productivity gains captured.

However, co-ordination problems that occur out of equilibrium are different from co-ordination problems in equilibrium. In the latter case, co-ordination is *ex ante*: there are multiple suboptimal equilibria, Pareto ranked, and co-ordination failures occur when agents are coordinated on a bad equilibrium. Out of equilibrium, we have to deal instead with a process occurring step by step in sequentially interacting disequilibria rather than with a series of snapshots each reflecting a different equilibrium state of the economy. The backbone of an out-of-equilibrium process is the accumulation through which adjustments—which necessarily imply a restructuring of productive capacity—take place in time. Co-ordination problems arise in the production side of the economy, namely, from the dissociation in time of inputs from outputs, and of revenues from costs, due to the distortion in productive capacity resulting from a shock, which throws the economy out of equilibrium. The imperfection of knowledge is also essential for defining these problems. In the perspective considered, in fact, we can no longer deal with given information contexts, but only with the acquisition of information itself, which is linked to the development *in time* of the production process, and hence is sequential. Thus, market disequilibria, which are the expression of the co-ordination problems arising during adjustment processes, reflect what happens, sequentially in time, to productive capacity.

3.3 The role of competition

Competition is an essential element of the co-ordination mechanism required for economic changes to be successfully brought about. When seen as an interaction process, taking place within an environment characterized by incomplete information and irreversibility, competition, by definition, is imperfect in the usual sense; but it also has a different nature. It is a process that generates the required information along the way. It appears, as Hayek (1948) defines it, as a process of discovery of relevant information. This information emerges from the interaction in time among economic agents—firms and customers, but also public authorities, banks and other financial intermediaries. In a dynamic context, that is, in a context characterized by successive innovations carried out by the firms, this interaction is very complex, because it involves not only a great number of economic agents, but also several markets that are more or less vertically interrelated.

Analysis, therefore, must focus on how and in what conditions this interaction works. This cannot be strategic interaction as in game theory, which is an interaction reflecting choices the results of which are known in advance. It is an interaction i*n real time*, a step by step interaction, consisting of *trial*

and error. In other words, it is a process of disequilibrium, the results of which depend on how the economic agents *react along the way* to current market disequilibria. This process can be erratic or even cumulative, or may converge towards a dynamic equilibrium. More precisely, it means that transactions take place at different prices, which are not equilibrium prices. Only rational use of decentralized information can keep these prices near to equilibrium. Thus, convergence towards a dynamic equilibrium depends on the reactions to these imbalances along the way. This convergence is nothing but a disequilibrium process. Reactions (adjustments) are necessarily in time and exploit all the available (incomplete) information.

While instantaneous adjustment (a tautological perfect flexibility that empties the concept of adjustment of its essential time dimension) is the proper of market procedure when we look at competition as a state, and the problem is that of the 'right' choice of the optimal state, this may not be the case when we are looking at competition as a disequilibrium process. The problem when the agents sequentially react to oncoming disequilibria is to prevent too strong disturbances. Behaviors, rules and institutions must focus on this. As we shall see, their objective needs to be the prevention of excessive market imbalances and the inappropriate destruction of production processes.

4 Productivity, volatility and growth

The first problem we address relates to the sources of output volatility and its effects on the performance of the global economy. Our analysis will also provide an explanation for the so-called productivity paradox.

Fluctuations are often attributed to changes in technologies or preferences. Within the modern macroeconomic framework, they are an expression of equilibrium, as in the Real Business Cycle analysis, where fluctuations are explained as the result of the reactions of intertemporally optimizing agents, to random technological shocks. These fluctuations are supposed to be natural and correspond to the better performance that the economy is able to reach. In our perspective, fluctuations remain deviations from a previously existing equilibrium, and are a demonstration of co-ordination failures. As a consequence, good performance will result from strategies and policies that smooth these fluctuations.

Productivity is the crucial variable here in the sense that what is at stake is the way in which the productivity gains associated with the introduction of a superior technology are really obtained. Within an equilibrium framework, productivity growth, exogenously given or resulting from appropriate incentives, determines output growth. Moreover, along a steady state, the productivity of the economy depends on exogenously given technical coefficients and growth rates. Out of equilibrium, it also depends on the age distribution of the production processes, that is, on the way co-ordination problems are dealt with. Then, all depends on the main determinants of the co-ordination mechanisms, the fiscal and monetary policies as well as price and

wage adjustments (labor and product market policies). It is their interaction that determines the performance of the economy and, hence, productivity and employment.

4.1 A Solow type scenario

Making use of the evolutionary model developed by Amendola and Gaffard (1998, 2003, 2006) and Amendola et al. (2004a, b, 2005),[1] let us deal first with a case where co-ordination problems do not arise, notwithstanding the distortion of productive capacity resulting from a shock, represented by the introduction of a superior technology, and characterized by an increase in construction costs that is more than compensated for by the reduction in costs in the following phase of utilization of the new productive capacity, that is, by strong 'forward biased' technical progress. This case, fairly common in standard models, requires extreme assumptions: in particular, firms have perfect knowledge of the model of the economy, and hence try to maintain the coherence of production processes over time so as to prevent distortions in productive capacity. This means, as regards investment decisions, tuning the dynamics of the rate of start of production processes to the equilibrium growth rate of the economy and, as regards current production decisions, never scrapping production processes in the utilization phase for a lack of demand.

In other words, firms do not react to current market disequilibria, which are seen as purely random phenomena, and do not revise their plans in response to these disequilibria. Moreover we assume that external finance is endogenously determined on the basis of the financial needs of firms, which means that the monetary authorities (or banks) have perfect knowledge of these needs and determine the amount of credit needed to satisfy them.

As shown with the model used by means of numerical simulations, the introduction of the new technology generates an initial fluctuation, which brings about temporary unemployment as well as a temporary fall in productivity. However, this fluctuation very soon damps down and the economy converges to a new steady-state corresponding to the superior technology, with a higher level of productivity—which allows lower prices and higher real wages—and full employment. The full intertemporal co-ordination of the decision process, maintained notwithstanding the shock experienced owing to the assumed firm behavior, assures the re-absorption of the initial negative effects on employment and productivity, without any scrapping of the production processes. Then, *technical progress is likely to result in productivity gains that reveal the superiority of the new technique*.

The case described is the only example of a process of change that converges to a new equilibrium state completely determined by one of the 'fundamentals' of the economy: the properties of the new technology. As in the Hicks's (1973, pp. 89–99) analysis of the Traverse, unemployment emerges as a transitory

[1] Model and simulations are described in the books and papers here quoted and can be provided upon request.

phenomenon during the period of adjustment to the new steady state. The results are the same as those that would be obtained if we considered a once-for-all technological shock in the Solow's model, with the exception of the temporary negative effect on employment and productivity. The reason for this is that the hypothesis of expectations based on perfect knowledge of the model of the economy does not allow current disequilibria to affect the plans of the agents, which cancels out the sequential dimension of the decision process.

4.2 An active monetary policy for innovation and growth

Using the above scenario as a benchmark, we can no longer make assumptions aimed at avoiding the emergence of co-ordination problems, and instead should put these problems at the center of the stage. This can first be achieved by assuming that current production decisions take into account changes in final demand based on adaptive expectations (that is, take account of current disequilibria). On the other hand, although we maintain the hypothesis of 'rational' investment behavior aimed at preventing distortions of productive capacity, and therefore abstract from the consideration of current disequilibria, the fact that these disequilibria actually arise as the result of the appearance of co-ordination problems may set a constraint on the investment itself, through the availability of financial and/or human resources.

Co-ordination concerns productive resources, that is, financial and human resources, which must be kept in a certain relation of complementarity. This requires taking account of the source and allocation of these resources. In particular, as regards the source of financial resources, it means dealing with monetary and banking policy, represented in our model by the supply of external finance, and with social consumption, represented by changes in the 'take-out' (defined as the fraction of available financial resources not spent on production processes). On the other hand, co-ordination also concerns the adjustment mechanisms, represented by price and wage changes, which determine the allocation of productive resources; namely, to what extent these resources are devoted either to the construction or to the utilization of productive capacity.

Thus, the first scenario privileges a passive monetary policy, which leaves the growth rate of the money supply unaffected by current shocks and, instead, allows it to be determined by the original steady-state growth rate of the economy (i.e. by a Friedman rule). With proportional savings (rendered in the model by a growth rate in the 'take out', which follows the current growth rate of the economy) and sufficiently flexible prices and wages, co-ordination problems, resulting in distortions of productive capacity, bring about increasing levels of unemployment, and decreasing levels of productivity and real wages. It is only with sticky prices and wages that we obtain persistent, but more or less stable unemployment, and a slower reduction in productivity and real wages, a sort of Keynesian equilibrium.

The above scenario illustrates the so-called productivity paradox, that is, the fall in productivity notwithstanding the introduction of a superior technique

in terms of the production coefficients. There is a divorce between the productivity of the technique, which can only be verified in an economy in the steady state associated with this technique, and the effective productivity of the economy resulting from an out-of-equilibrium process of transition. This divorce has nothing to do with the character of the specific technique; it depends on the co-ordination problems that arise in the context of a break in the intertemporal complementarity of production. This scenario also shows that the persistence of unemployment depends on the problems of co-ordination out of equilibrium rather than on the rigidities of the labor market. Although both nominal and real wages keep going down, not only unemployment is not re-absorbed, but it might be continually increasing. The standard solution to unemployment, a reduction in real wages, may result in a sequential process of further distortions to productive capacity rather than in re-establishing co-ordination and hence re-absorbing unemployment.

When monetary policy is aimed at maintaining stable prices, even with sticky prices and wages, we have a reduction in the rate of growth of output, a scrapping of production processes (reflecting strong fluctuations in final demand) and an asymptotic increase in unemployment notwithstanding the fall in real wages.

Only an expansive monetary (and banking) policy aimed at sustaining a transitory increase in the growth rate, accompanied by a certain rigidity in prices and wages, would make it possible to re-absorb unemployment, to increase productivity and real wages, and to avoid the scrapping of production processes, at the cost of limited inflation. In other words, it would do exactly what monetary and banking policy should do: it cannot be expected to lift the long-term sustainable growth rate, but it should ensure that any productivity gains that occur spontaneously or as a result of supply-side policies are realized in jobs and output and are not going to waste through recession and unemployment. Thanks to accommodating monetary and banking policies, there are no really strong distortions in the structure of productive capacity. A weaker rigidity does not essentially change these results. This proves that when there is a good co-ordination between financial and human resources, as in the cases just examined, commodity and labor market rigidities do not really matter. If price and wage flexibility does not matter, this is simply because the financial constraints are removed and, hence, coherent investment decisions can be carried out, which will prevent the emergence over time of overly strong market disequilibria.

To sum up. Active monetary and banking policies allow productivity gains associated with the introduction of a new and superior technology to be captured. As Schumpeter pointed out, money forces the economic system into new channels and allows a quasi-steady state to be re-established.

4.3 More on the nature and role of fluctuations

Within our model, innovation generates a break down in the circular flow, and the gains captured from innovation require the circular flow to be

re-established. In other words, innovation generates fluctuations, but for this innovation to be a success, these fluctuations must be dampened. This does not accord with the more standard view, which insists on the good, in fact the cleansing effects of bad times. Indeed, a recent analysis (Aghion and Banerjee 2005) concludes that volatility may result in lower mean growth, due to the existence of a credit constraint that hampers long-term investment. But these constraints are presumed to be institutional in type. With optimal institutions, that is, with a developed financial system, volatility would boost growth rates, due to a cleansing effect, while within a less developed financial system, volatility would result in lower mean growth.

Our model stresses another aspect. Volatility results from distortions in the structure of productive capacity, which prevent the economy from capturing productivity gains. Thus re-establishing a structure of productive capacity that supports a steady state requires relaxation of the credit constraint, that is, an accommodating monetary and banking policy. The institutional architecture should then be designed so as to allow the monetary authority to manage the trade-off between inflationary pressures and growth, rather than focusing only on the rate of inflation.

5 Competition and innovation

The second problem we address is the relation between competition and growth. Competition is usually considered as a factor of efficiency, and hence a growth factor. But, as is well known, perfect competition is not compatible with increasing returns, which are at the heart of the growth process, and monopoly rents are the real incentives to innovate and, hence, to create new methods and new products. So, following Schumpeter's intuition, we expect some reconciliation between competition and growth, precisely in considering competition as a process that helps co-ordination and thus allows productivity gains to be captured.

5.1 Stabilizing the market structure in order to capture the gains from innovation

The idea is that the prevailing market structure depends on how co-ordination issues are dealt with. Thus, increasing returns can be compatible with any market structure. However, in order to achieve these increasing returns, it is necessary to employ monopolistic practices.

Within Industrial Organization analysis, based on intertemporal optimization and rational expectations, technology, preferences, and incentives explain both firm performance and market structure. However, our focus is on the co-ordination issues that emerge as a consequence of the breaking up of the industrial structures induced by innovative choices. In our model (Amendola and Gaffard 2006; Amendola et al. 2000, 2003, 2006), technology, instead of being a precondition for the diffusion process, becomes the outcome of an innovation process. Innovation is a process of creative destruction: it implies

the building up of new productive capacity and the destruction of the old one. Gains are not instantly realized: during the early phase of innovation, there is a divorce between costs and proceeds that results in co-ordination problems.

In this framework, agents do not pick optimal points *ex ante* from given opportunity sets. Instead, they obey simple, feedback-based decision rules. Rational behavior does not prevent agents from making wrong expectations that result in market imbalances. Convergence towards a dynamic equilibrium depends on the reactions to the imbalances that arise along the way.

Therefore, competition is supposed to help to re-establish co-ordination, thereby making the innovation process viable. This means that the relevant information has to be created and communicated through the kind of interaction that prevails in the market. As we shall see, co-ordination through market transactions is only possible if the appropriate bounds to competitive behaviors are in place.

Different scenarios are achieved by computing a sequential model analyzing what happens in a market in which two or more firms are competing by innovating, simultaneously or sequentially (Amendola and Gaffard 2006; Amendola et al. 2000, 2003, 2006).[2] Technological change is 'forward biased' in the sense that increasing construction (labor) costs are more than compensated for by increasing output rates. At the beginning of the experiment, the firms have an equal share of the market and face an aggregate final demand, which is growing at a given rate. There are no biases in the functioning of the product and labor markets. Prices are based on the structure of productive capacity (embodying the most recent technology) capable of sustaining a steady state: in other words, they are fixed at a level that corresponds to the average long-term unit cost associated with the prevailing technology. Cost changes, not automatically transferred to prices during the early phase, have a negative effect on unit margins. Finally, entry and exit conditions are free.

At the beginning of the simulations, the industry is in equilibrium. The investment carried out by each firm is designed both to maintain consistency during the construction and utilization of productive capacity phases, and to keep pace with the investments being made by the other firms with the objective of achieving a stable market structure. A technological shock breaks down both the internal consistency of the capital structure of the firms involved and the existing market structure. Investments will become either insufficient or excessive with respect to the level required to maintain the internal and external equilibrium in the productive capacity of the firms. This reflects the existence (or not) of a resource constraint: a financial constraint and/or a human resource constraint in our model, which in combination with the prevailing price and wage change regimes and the specific features of the environment (in particular, the original number of firms in the market) will determine the viability or not of the adjustment process that follows the initial shock.

[2]Model and simulations are described in the books and papers here quoted and can be provided upon request.

With prices that cover 'long term' costs and reveal a kind of stickiness, a strong resource constraint (whether a financial or a human one) prevents an excessive capacity competition between the incumbents from becoming too strong, and hence favors the profitable entry of new firms that are supposed to have the required funds, given the exogenously determined targeted market share. An entry–exit process characterized by a concentration index that decreases or increases before it is stabilized occurs. Costs are diminishing, although through fluctuations, which means that the productivity gains associated with the new technologies are actually obtained. Unit margins, which are necessarily negative at the beginning of any innovation process characterized by higher construction costs, converge towards a more or less normal level.

This holds only when the human resource constraint prevails over the financial one, and the wage reaction coefficient is sufficiently low, that is, when the scarcity of the labor resource does not produce wide variations in wages. If the wage reaction coefficient is too high, and this is accompanied by a too high wage elasticity of labor supply, a very unstable market structure will obstruct the viability of the innovation process.

This applies also when increasing returns to adoption prevail with the difference that with the same given properties of demand and successive techniques, the number of firms characterising the dynamic equilibrium will be smaller.

It is worth mentioning that, under specific co-ordination conditions, whatever the initial number of firms, the industry converges towards a dynamic equilibrium—towards a sort of natural market structure determined by the properties of the demand and the profile of the new technologies. Of course, what matters is less the characteristics of this market structure than the conditions for this structure actually to emerge.

On the other hand, weak resource constraints, which favor investment by the incumbents, make it difficult for new firms to enter and results in a relatively high instability of market shares, which is associated with an increase in the concentration index. With a large number of initial incumbents, there are huge fluctuations in the number of firms over time, their size being all the more important as the initial number of firms is higher. A selection process takes place, which is cumulative in character. Any exit results in a reduction in the average market price (the exiting firms being the less competitive ones, that is, those charging higher prices), which renders marginal firms more fragile and may even push them out of the market. The strength of this effect increase, the higher is the initial number of firms and the more contiguous their positioning. The concentration index increases. Costs and unit margins exhibit strong fluctuations, but without a decreasing or an increasing trend, which means that the gains from innovations are not actually obtained. The instability of the market structure appears to be an obstacle to the viability of the innovation process.

When prices evolve in line with current costs and thus can be said to be volatile despite the existence of resources constraints, strong turbulence occurs, which prevents the economy from becoming viable. There is a shake-out

process that does not necessarily result in the stabilized market structure that is associated with the ability of firms to capture possible productivity gains. Nevertheless, under this price regime and in conditions of monopolistic competition, when the global market is segmented by customers that do not react to changes in the prices charged by different firms, the market structure stabilizes and productivity gains are realized. This is because market shares are much less sensitive to price gaps. Price fluctuations do not perturb the demand profile or the temporal structure of productive capacity.

To sum up, as Schumpeter pointed out, monopoly practices, which limit competitive investments, and price rigidities, far from being the cause of a misallocation of resources, appear to be the means of capturing productivity gains.

5.2 More on the role of competition

In a Schumpeterian view (Aghion and Griffith 2005), the heightened threat of entry by firms making use of advanced technology should encourage innovation by incumbents close to the technology frontier. Those farther away from the frontier have no hope of winning against a potential entrant. Therefore, the heightened threat of entry acts to reduce the incumbents' expected payoff from investing in R&D, that is, their incentives to innovate. In other words, competition encourages neck-and-neck firms to innovate, but discourages laggard firms from doing so. Moreover, neck-and-neck firms are assumed to be close to the technology frontier. Thus, when an economy is close to the technology frontier, competition, defined in respect of the level of the barriers to entry, will be required. Some empirical analyses confirm this result.

Our modelling highlights an alternative interpretation of the evidence. When the market structure has stabilized, the surviving firms (two or more) are neck-to-neck and productivity gains are captured. The firms in the industry are close to the frontier and achieve normal profit margins. A high level of competition prevails whatever the number of firms in the market (i.e. whatever the market structure). In this context, the technology frontier is determined endogenously. It is the result of a process of change that has been made viable. For firms to be close to the frontier and to be neck-and-neck depends on the co-ordination conditions, on market imperfections or market connections, which are not barriers to entry, but favor investment in a context of incomplete information. As Schumpeter pointed out, competition is compatible with price rigidities and monopoly practices, which do not result in Pareto inferior outcomes.

6 Policy issues

The results of our model have certain policy implications. It would be a mistake to base macroeconomic policies on rigid rules that would impose neutrality of money and budget. It would also be "a mistake to base the theory of government regulation of industry on the principle that big business should be

made to work as the respective industry would work in perfect competition" (Schumpeter 1950, p. 106). In our perspective, which could be described as 'Schumpeter after Hicks', active macroeconomic policies and market connections or monopolist practices appear to be necessary ingredients for boosting innovation and growth. This is the reverse of the current consensus in Europe.

At given moments in time and over time, trade offs between objectives are inevitable. These trade offs are the expression of policies that cannot be neutral, even when based on the same sets of rules. Thus, inflation may be the result of real shocks, implying imbalances in the final commodities markets rather than being pure nominal shocks. In this case, the expansionary monetary policy responsible for this inflation is an expression of the intent to pursue the objectives of growth and employment rather than price stability. It is aimed at reducing the disequilibrium between savings and investment (investment reckoned to be insufficient) so as to reduce the gap between the supply and demand of final commodities. The observed inflation then does not reflect the time inconsistency of economic policy, which should be taken account of by private agents; it is rather a temporally coherent choice, since the acceptance of a certain level of inflation today makes it possible to re-absorb it fully tomorrow, while at the same time reducing unemployment.

Similarly, a systematic (with a fixed rule) constraint on budgetary deficits is based on the idea that deficits are the result of (discretionary) policy mistakes. It is supposed to have no influence on the evolution of the economy. We have seen that lack of investment is the main obstacle to the process of restructuring productive capacity, which, in turn, makes innovation viable. This necessarily increases the deficit in the first phase of the process, but is the only way to re-absorb it once (and if) the process itself is successfully carried out and the innovation gains are obtained. The US's enormous budgetary deficit in the 1980s was fully re-absorbed and transformed into a surplus as the result of a successful growth process in the 1990s.

On the other hand, industrial policy must create incentives for firms to engage in co-operation, which is the key to the viability of such a complex process as innovation, which is characterized by interaction among multiple actors. This is not meant to eliminate the competitive character of the market, but to strengthen the co-ordinating role of competition. This requires creating the conditions in which competition causes "the rate of investment in product development to rise or fall towards the level at which this investment yields only a normal return" (Richardson 1998, p. 172). These conditions mainly take the form of market connections or restraints that limit competitive investments (Richardson 1960).

Such considerations indicate that timely as well as intertemporal trade offs call for complementarity in the action of the various institutions, a complementarity that cannot be assured if the institutions themselves are constrained by rigid rules obliging each of them at any moment to pursue a unique objective.

This particularly applies to the European Union (EU). The main problem facing the EU is slow growth: the poor performance witnessed so far must be attributable to the failure of economic policy to generate a successful process

of innovation rather than to the existence of irrelevant institutions. What we have said calls for the establishment of an authority in Europe capable of sending the strong signals required to actually push Europe's economic actors to engage in a growth process, and help to co-ordinate their actions.

Within this perspective, the policies that the European Union is able to implement within the constraints imposed by the existing institutions do not appear to be adequate. Monetary policy alone cannot pursue price stability, something that the European Central Bank, abstracting from the lip service paid to the problems of growth and employment, is obliged to do. It should instead be aimed at relaxing the financial constraints to growth. The Stability Pact, a sort of defence against the dangers of single countries transferring the effects of their excessive budget deficits to others, is based on a fixed rule that does not put a brake on expansionary phases, and aggravates recessionary ones. As such, it is not sustainable, and this represents the strongest brake on any take off by the European economies. Its negative impact would be reduced if harmonization of fiscal policies was not based on rules, but on discretionary interventions involving political choices at European level. In this case, management of any deficits could become the tool of economic policy, a fiscal policy to complement monetary policy in order to promote innovation and growth. Finally, competition policy focuses mainly on market structure and its associated market power, at the risk of penalizing certain market connections that create appropriate conditions for innovation and growth.

To sum up, macroeconomic policy should be more cyclical and should obey the rules *with* discretion. Monopolistic practices should be considered in relation to dynamic efficiency. More generally, economic policy cannot be reduced to rigid rules derived from abstract theory: it must rather consist of continuous trade-offs between economic targets that translate social choices. These policies derived from the extension of Hick's model of change would be in line with the Schumpeter's analysis of the innovation process as a perennial gale of destructive creation.

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