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Explaining Technological Change: A Survey

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Abstract

In this survey we present and critically discuss different theoretical approaches (e.g. Neo-classical, Marxist, Schumpeterian, Evolutionary) to the explanation of technological change. We argue that all the approaches taken separately show major limitations. In particular, it seems to be necessary to take into account and explore the existing *nexus* between technological and institutional change. While the relationship between technology and institutions is a non-issue in neo-classical theory, other approaches fruitfully consider the influence institutions exert on the rate and direction of technological change. The concept of *organisational equilibria*, accounting for the existing feedback between technological and institutional change, may contribute to the construction of a more general theory of the sources of technological change as solicited, among others, by Dosi (1997) and Ruttan (2001).

Keywords: technological change, institutional change, induced technical change, Marx, Schumpeter, evolutionary theory, organisational equilibria

JEL Classification: B14, B21, B25, O30

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1 - Introduction

Technological change is widely recognised as a major source of economic change and development. Nonetheless, mainstream economics, while nominally accepting the importance of technical change, have in practise divorced from these important issue and still treat it only as residual factor that need not to be explained (Freeman, 1988). Moreover, even though technical change has been extensively studied – mainly by heterodox economists – during the last 40 years, there is still no agreement on what should be considered the building blocks of a general theory of innovation and technological change. Thus, before trying, as suggested among other by Dosi (1997) and Ruttan (2001), to pursue this ambitious but no more postponeable task, it seems necessary to re-consider and assess the contribution offered by the already available theories.

The question we pose is: what does *explain* the rate and the direction of technical change?[1]

As it is evident, the breadth of our survey is extremely limited. Indeed, we avoid going into any other, though relevant, aspect concerning innovation and technological change. Nonetheless, even so, we do not aim at being exhaustive. We have deliberately selected the approaches[2] and within the approaches the authors who seemed to us more representative and stimulating.

The paper is structured as follows. In section 2, we shall start from the neo-classic treatment of innovation. Even though, as recognised by many scholars, the orthodox approach of innovation is highly unsatisfactory, it will allow us to introduce several issues that will be discussed in the following sections and provide us a useful term of comparison for the other theories. In sections 3 – 5 we describe the Schumepterian, the Marxian and the evolutionary theories of technological change. In section 6 we offer an assessment of the different theories emphasising their strength and weakness in explaining technical change. In particular, we will briefly discuss their capacity to account for technological and institutional co-evolution and change.

2 - Neo-classical theories

The basic neo-classical tool for the study of technology and technological change is the notion of production function. The production function specifies a quantitative relation between inputs and

[1] In this work we heavily draw upon the excellent book by Jon Elster (1982) *Explaining Technical Change. A Case Study in the Philosophy of Science*. In a way, this survey can be considered an attempt to extent his analysis taking into account the contributions to the debate concerning the explanation of technical change published during this twenty years.

[2] In particular, this preliminary version of the paper does not consider the Règulation Theory, the New Institutional approach, the path-dependent version of the evolutionary theory and the managerial theories of the firms.

outputs. The standard approach assumes that there are just two inputs (aggregate capital and labour) producing one homogeneous output. Moreover, it is usually assumed that the production function is continuos and continuously differentiable in both the variables, that there are decreasing marginal products and constant return to scale. This last assumption has two important consequences. The first is that under this assumption the product is exhausted. The second is that it permits a convenient representation of the production function by means of unit isoquant.

Neo-classical economics is committed to the explanation of all social economic and political phenomena in terms of rational choice under constraints. Thus, technical change is only another instance of maximisation under constraints. Neo-classical theory assumes that which of the virtually infinite factor combinations will be realised - all the points of the isoquant being assumed equally accessible to the firm - is decided by a rational choice of the entrepreneur that selects the factor combination that maximises his profit. Thus, the rate and the direction of technical change are assumed to result from a deliberate and rational choice of the representative agent.

The direction of technical change

The classical statement of the orthodox position on the issue of factor-biased technical change is found in this passage form *The Theory of Wages* (1934) of Hicks:

> "The real reason for the predominance of labour-saving inventions is surely that which was hinted at in our discussion of substitution. A change in the relative prices of the factors of production is itself a spur to invention, and to invention of a particular kind – directing to economising the use of a factor which has become relatively more expensive."[3]

In other words, a relative higher price of labour (capital) is thought to lead to labour-saving (capital–saving) innovations. This substitution mechanism is the core of the induced technical change theory explanation of factor-biased innovations[4].

According to Elster (1982), the Hicksian view, although intuitive, is victim of a logical fallacy. Labour-saving innovations seems to be the rational response of all the firms *collectively* reacting to rising wage. But, in a perfectly competitive environment, the wage rate is a parameter and the representative firm assumed to act individually can not change it. Indeed, external economies cannot motivate behaviour under perfect competition (Elster, 1982)[5].

[3] Hicks, 1932, p.125

[4] As pointed out by Ruttan, departures from neo-classical theory, when successful, are eventually seen as extensions and become incorporate into the orthodox theory. This is what happened to induced technical change theory that is now considered as an extension rather than a departure from neo-classical theory (Ruttan, 2001. P.21).

[5] In addition, Elster suggests that if there is in fact a tendency to labour-saving innovation the reduction in wages has to be regarded only ad a by-product of innovation and not as the reason for it. (Elster, 1982, p. 103)

Fellner (1961) argues that firm with some degree of monopsony power have an incentive to make innovation aiming at saving on the increasingly dearer factor even if each firm act individually. The reason is that in this way they would be able to internalise some of the external economies its innovation produces. In addition, he suggests that expectations about the future dynamic of relative factor prices would be sufficient to induce even firms operating in a purely competitive environment to innovate in order to save on the increasingly expensive factor (Ruttan, 2001). As noted by Elster in the first case (monospony power) Fellner restricts the possibility of application of induced technical change theory to a very specific case. In second case, (competitive environment) the defence is not logically consistent. The situation described is one in which each firm has an incentive to innovate if no other do so and a disincentive to innovate if all other do. Thus, it is not possible to give a rational-choice explication of the theory of innovation along Fellner lines.

An explicit and very influential criticism of the induced technical change hypothesis is the one expressed by Salter (1960). He contests the Hicksian argument pointing out that:

> "The entrepreneur is interested in reducing cost in total, not particular cost such as labour or capital costs. When labour costs rise any advance that reduces total cost is welcome, and whether it is achieved by saving labour or capital is irrelevant".[6]

Thus, there is no reason to expect that dearer labour should stimulate the search for a labour-saving innovation. According to Elster (1982), the argument put forward by Salter is logically correct. The firm, following a change in factor prices, will *substitute* one factor for the other until a new equilibrium is reached. Thus, there is no more need to economise on the factor introducing an innovation that will even more save on it. Indeed, in equilibrium all factors are equally scarce and equally expensive. In other words, the functioning of the market mechanism eliminates the (*hypothesised*) inducement to innovation.

According to Ruttan (2001) the Salter's argument would have been refuted by a series of theoretical and empirical papers published starting from the 1960s. Among the theoretical ones, the most important is Ahmad (1966). In this article it is developed a micro-founded approach to induced innovation introducing the concept of *innovation possibility curve* (IPC). It is assumed that at each given time, there is a set of potential production processes, determined by the basis state of knowledge, available to be developed. The IPC is the envelope of all unit isoquant of the subset of all these potential processes, which the entrepreneur might develop given the available amount of

[6] Salter (1960), p.44

R&D expenditure (Ruttan 2001, p. 7). Similar to this formalisation is the one proposed by Kennedy (1964)[7].

Both approaches have been deeply criticised. As pointed out by Mansfield (1968), the existence and the realism of the IPC function are questionable. Elster (1982) observes that no one of the two theories gave any reason for believing that the innovative possibility frontier has any psychological reality for the entrepreneur. Rational-choice explanation has to be based on an actor choosing the action that makes most sense to him, not the action that is optimal in some absolute sense. Consequently, if the feasible set does not manifest himself to the agent it can not influence the choice if this has to be rational. In addition, Elster laments the fact that both Ahmad and Kennedy do not tell us how the entrepreneur is supposed to find the frontier and move along it until he finds the maximum. In other words, these theories of induce technical change lack micro-foundations.

Ruttan (2001) disregards all this critics concerning the theoretical foundation of the induced innovation argument. On the contrary, Ruttan emphasises that the Ahmad version of the factor induced technical change model stimulated a big deal of applied research and empirical test of the theory. The results of these studies support the view that in agriculture, in United States and abroad, the changes (and sometimes) the differences in relative factor endowments and prices exert a substantial impact on the direction of technical change. Conversely, within the industrial sectors the effects are weaker and it seems to be relevant only for the natural resources and raw material using industries.

The rate of technical change

According to Elster (1982) the orthodox literature assumes the stock and the increase of the scientific basic knowledge as exogenously determined with respect to the economic domain. Thus, given the rate of production of scientific knowledge, the standard neo-classical approach explains the decision to innovate and the rate of technical change in terms of two different mechanisms: appropriability and market structure.

In a capitalist economy a crucial determinant of the rate of technical change is the way private returns to innovation are enhanced and protected. There are different possible means to enhance innovative efforts by firms. According to the neo-classical approach the most relevant are: 1) private secret; 2) State intervention trough incentives; 3) the patent systems; 4) the emergence of monopolies (Elster, 1982).

[7] The main difference with the Ahmad model concerns the fact that in Kennedy's model the focus is on the effect of

Traditionally the market structure was considered exogenous to, and provided a causal explanation for, the rate of innovative activity[8]. But it is now widely recognised that industrial concentration and research intensity are simultaneously determined (see Dasgupta and Stigliz, 1980).

According to Mansfield (1968) the rate of technical change in an industry largely depends on the amount of resources devoted by firm and by the Government to the innovative activity[9]. As Mansfield put it:

> "The amount of resources devote by the Government depend on "how closely the industry is relate to defence, public health and other social needs [..]; on the extent of external economies [..] and on more political factors"[10]

The amount of resources devoted by firms depends, on the contrary, on the expected profits. Thus, the rate of technical change is influenced, as any other output of the firm, by the interaction between demand and supply factors. On one hand, if a given technological change is likely to reduce production costs, the following increase in demand for that particular product will increase the expected return from innovating. On the other hand, in the industries in which the dominant source of technological advance is basic science, improvement in scientific knowledge will lower the cost of innovation and will stimulate it. In the industries in which technological advance is only loosely connected with scientific research and the most important source of innovation is "learning by doing", the rate of technological change will depend on the number of people working in the industry (Mansfield, 1968).

Indeed, for a long time, a controversy among economist and historians of technology concerned the relative significance of "demand pull" versus "science and technology push" in determining the rate of innovations. (Freeman, 1994). The classical study by Schoomler (1966) provides a justification for the demand-pull approach. He does not deny the role of basic scientific research but he tries to demonstrate, in a massive study of patent statistics for invention in four industries,[11]that usually the peaks and trough of inventive activity lagged behind the peaks and trough of investment activity (Freeman, 1994,p. 479). He concludes that changes in the pattern of demand, measured as investments in new capital goods, are more important in stimulating innovation than advances in the state of knowledge. The demand induced model received during the 1960s support both from academics and policy-makers. Among the first group, the most influential were Lucas (1967) and

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changes in relative factor shares- rather than in relative factor prices- on the direction of innovation.

[8] For a throughout discussion of the Schumpeterian hypothesis see section 4 and Cantwell (2001)

[9] Mansfield (1968) adds to the factors explaining the rate of technological change also the market structure, the attitude towards technological change of the management, the organisational form of innovation research, the research effort of other firms, government agencies, universities and other countries (Mansfield, 1968, p.19)

[10] Mansfield (1968), p.17

[11] The four industries are railroads, agriculatural machinery, paper, petroleum

Vernon (1966). Note that the support of the latter group, it is hardly surprising given the theoretical coherence between the predominant (at that time) Keynesian national economic policies and the demand pull version of the induced innovation theory. In their review of the "demand-pull controversy" Mowery and Rosemberg (1979) argue that much of the empirical research supporting the view that technical change is mainly demand induced was seriously flawed (Freeman, 1994). In particular, they point out that the concept of demand employed in many of the studies has been so broad as to embrace virtually all possible determinant (Ruttan, 2001). During the 1980s and 1990s other studies tested the Schmooler hypothesis either using the same data used in the pioneer study (Verspagen and Kleinknecht (1990) either using a more comprehensive data set Scherer (1982) and Walsh (1984). In all of them the founding is still a synchronicity between demand and innovation but it is a much weaker relationship than the one suggested by the study by Schoomler. In addition it emerged that both the demand and the supply factors play an important role in innovation and that this relationship vary with time, the maturity of the industrial sector and the richness of the industry's knowledge base. Moreover, the results of empirical research point to the abandonment of the liner model of innovation, whether supply or demand driven, in favour of more sophisticated and realistic models which innovation is the result of a complex interaction, characterised by numerous feedback loops, between users and new development in science and technology (Freeman, 1994).

Some critics of the neo-classical approach

According to Dosi (1997), the classic induced technical change story had the pioneering merit of trying to provide some analytical link between today's economic conditions (relative prices or demand patterns), allocative decisions, and tomorrow's technological possibilities[12] (Dosi, 1997, 1533-1534).

Nonetheless, Elster (1982) is very sceptical regarding the explanatory power of neo-classical models of technological change. Two are the main sources of uncertainty characterising the innovation decisions. The first one concerns the innovation possibilities. The second and more fundamental regards the strategic nature of the situation. According to Elster there is too much uncertainty for rational choice to be a useful tool to deal with such a complex situation. Thus, it seems that neo-classical theory is not well suited for the study of the rate and direction of technical change. It is supremely efficient tool for equilibrium analysis but it is conceptually ill at ease when dealing with genuinely dynamic problems. (Elster, 1982, p 111).

It is evident how the neo-classical theory is unable to deal with such a complex issue. Drawing on the fundamental contributions of Herbert Simon, Winter (1964) gives a demonstration that neo-classical notion of maximisation involves an infinite regress and should be replaced by that of satisfying.

As pointed out by Elster (1982), David (1975) critics the concept of production function arguing that the production function has no explanatory status being only a merely transient fiction. There are three arguments supporting his view. First, Davis shows how substitution may involve an element of innovation. This implies that factor substitution not simply involves a movement along the function but a shift of the function itself. Second, if economies of scale are assumed, it is introduced an element of irreversibility which is completely at odds with the idea of a given set of isoquants between which the firm can move freely. In addition, the adoption of the concept of learning by doing would imply that the only fact of being on a point on an isoquant would make the isoquant moving making impossible for the agent to know in each moment the position of the production function itself.

Finally, the so-called Cambridge Controversy and the re-switching of technique argument have shown than in heterogeneous capital goods models the traditional marginalist concept of substitution breaks down. Indeed, the direction of change of the input proportion cannot be related unambiguously to the changes of factor prices (Kalmbach and Kurz, 1986). Thus, it can not be assumed that a change in input proportion is *necessarily* associated with a change in the opposite direction of the corresponding relative factor prices.

3 - Marxist Theories

The rate of technical change

Marx held that technical change was the prime mover of history. The Marxist classical explanation of the rate of innovation is very simple: capitalist innovate because they are forced to do so by competition, and they are able to innovate because they can drawn upon a stock of inventions (Elster, 1982).

In the capitalistic system the firm reinvests part of its profits in new production[13]. It is forced in doing so because of the saturation in the product market and pressure in the labour market[14]. If there

[12] In addition, Dosi (1997) notes that the New Growth Theory (one-dimensional) account of technical progress cannot address the question of the direction of change version

[13] On the contrary, in early stage of capitalism reinvestment (and thus reproduction of the capitalistic system) could take place without technical change, as long as there exist pre-capitalistic sector in which to invest.

is little innovation, demand saturation and rising wage will reduce profit rate below the minimum that the capitalist is willing to accept. Thus, one will observe product innovation as well as process innovation, since the saturation can be overcome both by producing new types of commodities and by producing old one more cheaply.(Elster, 1982)[15]. For the individual capitalist to invest and to innovate it is rational for profit maximisation and necessary for survival. In some sense it seems that the individual capitalist is condemned to innovate. But then, according to Marx, a contradiction emerges between the individual and the collective behaviour. If capitalists - as a class - do not innovate, the profit rate will fall because of saturation of demand and rising wages. But if, on the contrary, they will innovate the rate of profit will fall anyway[16]. Thus, capitalism is condemned to extinction.

Elster (1982) expounds a very interesting argument concerning the effects produced by innovations that bring about changes in the wage rate. He argues that innovations, being embodied in machines and tools, may shape and influence working class consciousness and combactivity. If a given innovation is cost-reducing at the pre-innovation wage rate, but not at the wage that will prevail as a consequence of the introduction of the innovation, the capitalist will not adopt it. On the contrary, a technique which is ex ante not cost reducing but that once introduced will fetter the wage struggle of the workers, will be adopted. These propositions are the core of the labour process approach to technical change. As it is clear, this is a very peculiar perspective. The labour force is not more regarded as a factor of production whose change in price induces innovations, but a self-conscious class, an actor who opposes the extraction of the surplus value. Similarly, the capitalist is not more the rational calculating profit-maximiser machine of neo-classical economics nor the Schumpeterian unbound Promehetus. (Elster, 1982, p. 171)[17]. Indeed, in the labour process approach the capitalist confronts not only the forces of nature and of the market but also the opposition of the working class fighting against him. Thus, the rate of innovation is explained by the strength of the opposition of the working class against capital accumulation and extraction of surplus value.

[14] Note that, according to Elster, there is little in Marx about innovation induced by demand saturation but "it fits well the kind of story he is telling. On the contrary, it is possible that Marx did see rising wages as an inducement to innovate" (Elster, 1982, p.167).

[15] Note that Marx was convinced of the superiority of communism both with respect to the search for new technique (i.e. rate of technical change) and with respect to the selection of socially useful innovations (i.e direction of technical change).

[16] For a discussion of the theory of the falling rate of profit, see Kurz (1998) and Elster (1982, 178-181)

[17] Nonetheless, it is possible to argue that, in describing the entrepreneur using innovation as a weapon in the class struggle, Marx is proposing a rational-actor approach (Elster, 1982, p.10).

The classical Marxist explanation of the direction of technical change

Marx was an attentive student of Ricardo's principles[18]. Like Ricardo, Marx distinguishes between different possible forms of technical progress. But, unlike Ricardo, he is convinced that the forms that would prevail in developed capitalism would be the one increasing the "organic composition of capital"[19]. According to Kurz (1998), Marx argues that the "organic composition of capital" would indeed arise because this would be the effect of the existing antagonism between wage labour and capital. There is said to be a structural conflict that the capitalist try to solve in their favour by replacing workers by machine, being the second much more controllable and disciplined. As Marx (1867) argues:

> "In England, strikes have regularly given rise to the invention and application of new machines. Machines were, it may be said, the weapon employed by the capitalist to quell the revolt of specialised labour. [..] But machinery acts not only as a competitor who gets the better of the workman, and is constantly on the point of making him superfluous [..]. It is the most powerful weapon for repressing strikes [..]. It would be possible to write quite a history of the inventions made since 1830s, for the sole purpose of supplying capital with weapons against revolts of the working class"[20].

According to Elster (1982) labour-saving innovations may go together with fewer but highly skilled workers who are more intractable and ungovernable. Thus, he suggests that the mechanism postulated by the labour process approach (i.e. a strict connection between working class combactivity, high wages and labour-saving innovations) may be not the general case. He suggests also that reading into Marx a Hicksian argument for the predominance of labour saving innovations could be misleading. In fact, even though in *Capital I* Marx explains mechanisation as induced by rising wages, in the crucial chapter on the falling rate of profit there is no mention of such a mechanism.

On the contrary, it seems that according to Marx technical change simply *must* be labour saving. Elster argues that Marx is wrong in assuming it. That view is due to a narrow vision of technical change and Marx has no valid arguments for the exclusion of the possibility of capital saving innovations.[21].

[18] Indeed, according to Kurz (1998), the form of technical progress contemplate in the form of a "rising composition of capital" reflects Ricardo's case of the introduction of a machine that reduces gross produce.
[19] This aspect of the Marx's theory is crucial to his view of the long term development of the capitalistic system. Indeed, the rising of "organic composition of capital" is thought to bound the general rate of profit to be downwards. This, in turn, is considered as an expression of the transient nature of the capitalistic mode of production. (Kurz, 1998).
[20] Marx (1867), pp. 435-6
[21] For a deeper discussion see Elster p.178

Technological and institutional change in the Marxian framework

Even though the Marxian theory of innovation seems seriously flawed, his description of the relationship between technology and institutions may turn out to be fertile and stimulating even though it is not exempt from critics.

Marx was committed to two theses concerning the relation between the productive forces (i.e. technology) and the relations of production (i.e. institutions). On the one hand he believed that the productive forces determine or condition the relation of production. On the other hand, he argues that the relations of production influence strongly the development of the forces.

Cohen (1978) suggests a solution to this apparent paradox arguing that the relations of production at any given time are what they are because of their ability to promote the development of the productive forces, and, most importantly to our argument, they change when they have no longer this ability. Thus, at any time, institutional set have a *causal* primacy over the technology, and the latter an *explanatory* primacy over the former. (Elster, 1982, p. 182)[22]. In this case, the institutional framework is thought to be explained in terms of its effects on technology. But it is not possible to point out a specific mechanism trough which the ruling technology selects the institutional set most able to further its development. For instance, there is no way to explain the emergence of capitalistic relations in England trough the need of the productive force to be developed. But, it is well possible, that once these relations had emerged, their superiority in supporting the new capitalistic economy made them become dominant. In fact, it may be possible to explain functionally the diffusion of a new institutional framework, set but not its emergence (Elster, 1982, 183).

4 - Schumpeter's Theory

Innovation and the historical form of the entrepreneur

According to Elster (1982, p.112), Schumpeter is the most influential single writer on technical change. He sees innovation - of which technological change is the main but not the only variety - as the main source of economic development[23]. Moreover, he suggests that innovations are also the

[22] Van Parijs (1981), argues, on the contrary, that the forces of production are doubly involved in the *explanation* of the relation of production. On e interpretation is that the relation of production are what they are because they are optimal for the repression of people (and not for the development of the productive forces in itself), but that the level of the productive forces is what determines which relations are optimal for the purpose of oppressing people. The second that the relations of production are what they are because they are optimal for the development of the forces of production, but it is the location along the centre-periphery dimension that determines which relations are optimal to this purpose.

[23]Thus, Schumpeter theory of development is largely independent of the so-called "natural endowments". Being based on technical change, development is only limited by the ability of the people, and in particular of the economic leaders. Ahmad (1994)

main cause of cyclical fluctuation of the capitalist economy. Indeed, in the capitalistic mode of production, growth and cycles are indissociable. (Elster, 1982) and without entrepreneurial innovation capitalism would stagnate (Frank, 1998). Schumpeter envisions development by discontinuous, spontaneous changes brought about by entrepreneurs doing things in a new way (i.e. innovating). Indeed, the entrepreneur is the subject of the disruption of the static (circular) flow of the (walrasian) economy.

In *The Theory of Capitalist Development* (1911) Schumpeter defines innovation as the carrying out of new combinations of the means of production and includes the following five cases: the introduction of a new good, the introduction of anew method of production, the opening of a new market, the conquest of a new source of supply of raw materials and the carrying out of a new organisation of any industry. Schumpeter distinguishes between two forms of innovation. The basic form of innovation is qualitative and discontinuous:

> "It is that kind of change arising from within the system which so displaces its equilibrium point that the new one cannot be reached from the old one by infinitesimal steps. Add successively as many mail coaches as you pleas, you will never get a railway thereby".[24]

The second form of innovation occurs through infinitesimally small steps and adaptive improvements in technique. What is important to emphasise is that Schumpeter insists on the great time span required for such adaptation to work itself out.

> "[The assumption that conduct is prompt and rational] holds good only when precedents without number have formed thought decades and, in fundamentals, through hundreds and thousands of years, and have eliminated unadapted behaviours."[25]

Thus, in a rapid changing environment there will be no enough time for rational conduct to be fixed. Most importantly, incremental adaptations can at most achieve local maxima, and even this would be inattainable in a rapidly changing environment (Elster ,1982, p. 115). On the contrary, as Schumpeter observes:

> "There may be rational conduct even in the absence of rational motive"[26]

According to Schumpeter, the course of history is not shaped by the aggregate mass of innovations, but by outstanding individual innovation. Schumpeter is clear to emphasise that entrepreneurs are not inventors, capitalist or a social class. Entrepreneurs are in essence only those individuals who carry out the new combinations, and they remain entrepreneurs only for that short period of time. According to Schumpeter they are neither profits nor necessity to induce innovations. Indeed, the

[24] Schumpeter (1934), p.64, note 1, cited also in Elster (1982)
[25] Schumpeter (1934), p.80
[26] Schumpeter (1934), p.91

entrepreneurial motives to innovate are three: "the will to conquer, "the dream and the will to found a private kingdom", "the joy of creating, of getting things done".[27]

Thus, the entrepreneur is a kind of romantic figure, exceptionally gifted individual, highly motivated and of superior will, who must endure social resistance and opposition, but if successful benefit all society through greater economic growth. Thus, capitalist societies do not have the property of homeorhesis. This implies that we can not predict macro variables using only macro variables because there is no stability of the system with respect to changes induced by individuals[28].

In this way the creative and unpredictable aspects of the innovative process are fully acknowledged as essential to its explanation. Thus, if adaptive response is understandable both *ex ante* and *ex post*, Schumpeter argues that creative response by the entrepreneur (being essentially unpredictable) can be only understood *ex post*[29]. This element of indefiniteness is crucial to Schumpeter's theory of innovation. According to it what the creative response of the entrepreneur will be is not knowable before the fact (Frank, 1998).

Schumpeter (1928) introduces the distinction between "competitive capitalism and "trustified capitalism". The distinction arises considering the characteristic of the innovation process. In the first case is "typically embodied in the foundation of new firms" and it is individualistic. In the second, innovation is embodied both in new firms and in existing firms and it is bureaucratic.

In his early writings, drawing upon the history of the nineteenth-century, Schumpeter identifies the typical entrepreneur with the owner of a small firm who implements his own innovations through new firms. In his American period, clearly impressed by the features of the twentieth century American capitalist economy, he attributed the entrepreneurial role to the large established corporations and to even the government agencies (Frank, 1998).

Indeed, as Schumpeter argues:

> "Every social environment has its own ways of filling the entrepreneur function"[30]

It is interesting to note that, when in *Capitalism, Socialism and Democracy* (1942) Schumpeter says that the state is likely to take over the innovative activities in the future, he is simply predicting - in fact with some regret - and not prescribing (Ahmad, 1994). Thus, who will fulfil the entrepreneurial function is historically determined. What is clear is that without the *entrepreneur* capitalism would

[27] The Theory of Capitalist Development, Schumpeter (1934), p.91
[28] Frank (1998) argues that Schumpeter's analysis of entrepreneurial innovation is a micro-behavioural approach, and that the macro-behavioural results of innovations are business cycles. Indeed, Schumpeter was strongly adverse to the aggregate method used by Keynes.
[29] Note that much of the difficulties in formalising Schumpeterian ideas derives from this critical theoretical assumption.
[30] "Economic Theory and Entrepreneurial History", Schumpeter (1949) p.260, cited in Frank (1998)

die out. Indeed, Schumpeter is arguing that capitalism will be destroyed by its own success[31]. The reason for that is the routinization of the process of technological change. Elster challenges this view arguing that even if the creation of new method of production is turned into an industry, the other innovation tasks mentioned by Schumpeter, such as the opening up of new market or the conquest of new sources of supply, will not be subject to routinization in the same sense as technological innovation can be. (Elster ,1982, p. 126)

The rate of innovation

According to Schumpeter, innovations are not responses to pre-existing needs, since they very often create the very need they satisfy. Since the subject of the innovation is the entrepreneur old industries fail to innovate not because of diminishing opportunities of innovation, but because of weakening of the motivation to innovate. Indeed, what spur innovations is not the *size* of potential profits, but the presence of an entrepreneur capable of "doing the thing".(Elster, 1982)

To the development of our discussion it is important to emphasise Schumpeter's view on long run:

> "A system - any system, economic or other - that at every given point fully utilises its possibilities to the best advantage may yet in the long rum be inferior to a system that does so at no given point in time, because the latter 's failure to do so may be a condition for the level or speed of long-run performance".[32]

As it is well-known, the so-called *Schumpeterian hypothesis* states that innovations are favoured by oligopoly[33]. Indeed:

> "It is true that there is or may be an element of genuine monopoly gain in those entrepreneurial profits which are the prizes offered by capitalist society to the successful innovator".

But, as Schumpeter suggests:

> "The main value to a concern of a single seller position that is secured by patent or monopolistic strategy does not consist so much in the opportunity to behave temporarily according to the monopolistic schema, as in the protection it affords against temporary

[31] This view is clearly inspire by similar though in Marx. The first statement of it by Schumpeter is found in "The instability of Capitalism" (1928), in which Schumpeter argues that capitalism is in a process of transformation into socialism, principally because of the smoothing and automation of the process of innovation.

[32] Schumpeter (1942), p.83

[33] Schumpeter did not insist on the idea that oligopolistic practises had negative consequences for the static allocation of resources. Indeed:

> "A system in which perfect competition prevails will, contrary to established opinions, produce in very many, perhaps in most cases, results similar to those which cold be expected from perfect competition and […] even if a system consistently turn out less than

> disorganisation of the market and the space it secures for long-range planning." (Schumpeter, 1943, pp. 102-103.)

In other words, Schumpeter is arguing that the large firm is more an innovator and an organisational device for learning than merely being a price and quantity decision taker. According to Cantwell (2001), this is a quotation challenge the classic interpretation of the *Schumpeterian hypothesis* and the very notion of analysing innovation as the outcome of the degree of market power or expected profit associated with one particular kind of market structure as opposed to another. The classical approach to Schumpeter's theory renders it understandable within the conventional framework of market-based analysis, in which institutions are discussed only with regard to their role in the process of economic exchange, primarily through markets. In this way, the distinctiveness of Schumpeter's notion of adding value through genuine innovation to the existing circular flow of income is lost.

The direction of technical change

Schumperter is not very much concerned with the issue of explaining the direction of technical change. Nonetheless, it is possible to have some insights about his view concerning this question drawing on his critics of the famous chapter *On Machine*, that Ricardo added in the third edition of his *Principle*. In arguing in support of the "compensation argument" concerning the effect of the introduction of a new machine; Schumpeter refers to the *Theory of Wage* by Hicks as

> "A better [in comparison with Classical political economy] technique [..] which left nothing to disagree about"[34]

Some critics and extensions

Even though Schumpeter's theory of innovation is a fundamental cornerstone of the economic theory of technical change, the empirical results of several studies published during the last forty years demonstrate the limitations of his theory of innovation and of entrepreneurship (Freeman, 1994). In particular, he had very little to say about the diffusion of innovation, the relationship between science and innovation, and between government agencies, universities and firms (Freeman, 1988).

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its optimum quantity, this would not in itself constitute disproof of optimal performance over time", Schumpeter (1939), p.288

[34] Schumpeter (1954), p.684

According to Cantwell (2001), Schumpeterian theory of innovation needs to be revisited. The original formulation of the theory stresses the need to identify the original sources of innovation as opposed to subsequent imitation in order to determine the distribution of innovative profits, with the initial innovator earning the higher share. This emphasis on the role of the first innovator and the belittlement of the following adopters as mere imitators tend to obscure many important aspects of innovation and diffusion (Freeman, 1994, p.468). Indeed, in modern institutional contest it is not necessarily technological leaders that become the best innovators, let alone the only innovators, but rather the firms that succeed in making the most effective combinations between new and old technologies and uncovering the most conducive new fields of application. Cantwell suggests extending Schumpeterian ideas into two directions. The first one would entail the consideration of inter-company technological co-operation as well as competition into the Schumpeterian framework. The second, the abandonment of the blurring distinction between innovation and imitation since, with greater technological complexity, imitation requires the related absorptive capacity that comes from innovation, and innovation always incorporates some elements of imitation[35].

Another deficiency of the Schumpeterian theory is that, disregarding the importance of externalities of technical change, it does not envisage any role for the government in bringing about innovation. The temporary monopoly power deriving from being the innovator compensates the entrepreneur for the cost incurred in. According to Ahmad (1994), a possible critic of this approach is that because of externalities, many worthwhile projects would not be undertaken.

Elster (1982) argues that the Schumpeterian description of the entrepreneur motives appears elusive or contradictory. The *will to conquer* seems to be an indefinite quest for accumulation. In this case, the Schumpeter description of the entrepreneur would closely resemble the Marx's one. On the other hand, he continues, Schumpeter (1942) stressed the "rational and antiheroic character of the bourgeois". According to Elster (1982) the difficulties to reconcile these two different interpretations arise in similar way when dealing with the theory of the formation of entrepreneurial expectations[36]. Elster argues that it is hard to decide whether Schumpeter conceives the motives and the expectation behind innovation as rational or irrational. At any rate, given the previous discussion, it seems that it would not make sense to describe his behaviour as the choice between

[35] Cantwell (2001) argues that, the widely used distinction between 'Schumpeter Mark I' and 'Schumpeter Mark II' technological regimes, according to whether innovations are introduced mainly by new entrants or by established firms (Malerba and Orsenigo, 1995), inherits the weakness of the Schumpeter's theory in which the first mover in a successful innovation is assumed to always perform best.

[36] For a discussion of the differences between the treatment of expectations in the Schumpeterian framework and in neo-classical theory see Elster 1982 p.118 .

the best alternative of a known feasible set. His gift is in expanding the feasible set, not choosing rationally within it. (Elster, 1982, p.120).

5 - Evolutionary Theories

Evolutionary economics have become increasingly fashionable during the last twenty years. According to Nelson (2001), there exist a vast and slightly dis-homogeneous body of thought ad writings associated with the term[37]. According to Dosi (1997), seven are the building blocks that characterise the evolutionary approach to economics. 1) the concern to explaining the *dynamics* of the processes and 2) to micro-found the theories 3) the assumption of bounded rationality and 4) heterogeneity among the agents 5) the systems are characterised by continuous emergence of varieties and in which 6) collective interactions perform as selection mechanism yielding differences among the agents 7) the explanation of aggregate phenomena has to be given in terms of emergent properties the system itself.

Central to this approach is the fundamental postulate of Marx and Schumpeter that economic growth and the evolutionary dynamics of the capitalist society is propelled by technical and institutional change. Indeed, evolutionary theory assigns a central role in economic theory to innovation and technological change. In particular, the nature, the characteristics and the properties of the innovative process have always been a major concern of the evolutionary approach.

As argued by Elster (1982), one of the main difference that distinguish evolutionary theory with respect to neo-classical, Marxist an even Schumpeterian theory of innovation is that, in explaining why firm are currently using a given technology, the emphasis is no more on the future goal but on the past history

Evolutionary theories emphasise the cumulative aspects of technology, the great importance of incremental as well as radical innovations, the multiple inputs to innovation from diverse sources within and outside the firm and the changes made to innovations by numerous adopter during diffusion, both within and between countries. (Freeman, 1994, p.468).

In addition, an increasingly widening empirical literature, at a firm, sectoral and country level, permits to define some of the fundamental feature of innovative activities. According to Dosi (1988, p.222) these are: a) the fundamental uncertainty features of the innovative activities; b) the

[37] In particular Nelson identifies three different strands of evolutionary analysis: 1) the one which has developed along the lines suggested in the book *An Evolutionary Theory of Economic Change* (Nelson and Winter, 1982); 2) the one which has its roots in biology and sociobiology ; 3) evolutionary game theory. For a discussion see, Nelson 2001, p.199-201

increasing importance of scientific knowledge for innovation; c) the increasing complexity of innovation and consequent the necessity of more formal organisation; d) the importance of learning by doing and learning by using.

It indisputable how paltry, in comparison to such a rich description, is the neo-classic conceptualisation of innovation and technical change. As is pointed out by Dosi (1997), evolutionary view of innovation and technological change is very different form the view of technology as information, and from the idea that firms can use and reproduce it drawing from a given set of stock of technological knowledge that characterises the orthodox approach.

The direction of technical change

Dosi (1997) offers an evolutionary version of the inducement theory. Indeed, Dosi argues that the changes in relative prices and in demand and supply conditions are likely to be fundamentals one in shaping the rate and the direction of technical change but only within given technological boundaries. His point of departure is the abandonment of the idea of a IFP in favour of the concept of technological paradigm (Dosi, 1982). Each technological paradigm is a body of knowledge specific of particular technologies and determines the opportunities of future technical advance. In addition they also channel the efforts along a specific technological trajectory. It fact it is assumed that the activity of technological progress develop along the economic and technological trade-off defined by the given paradigm (Dosi, 1988, p.224). One of the implications of this framework is that each technological paradigm "bind the scope for dynamic inter-factoral substitution". (Dosi, 1997, p.1534).

According to Dosi (1997) the most relevant feature of the patterns of technological change is that they can not be describe as simple and instantaneous reactions to changes in market conditions. In particular, the direction of technical change is often determined by the state-of-the-art of the technology already in use. In addition, it is the nature of the specific technology that determines the range within each technology can adjust to change in the economic environment (Dosi, 1988, p. 223). In particular, during the period of *normal* development technical change follows technological trajectories related to the ruling technological paradigm. The direction of technical change is constrained to zones technologically closely related to existing activities (Dosi, 1988, p.225). Indeed, the major discontinuities in the pattern of technical change arise form changes in the technological paradigm.

The evolutionary view of inducement theory is that relative price changes and demand or supply condition may change: a) the microeconomic rules of search, affecting the direction of exploration

in the opportunity space; b) the allocation of resources to search effort affecting the rate of innovation for a given direction; c) the market-criteria mechanism of selection by which different alternatives technologies are compared (Dosi, 1997).

Thus, differently from the neo-classic one, the evolutionary version of the induced technical change clearly distinguishes between the behavioural effects and system level effect – i.e. the selection mechanism of the changes in the economic environment. (Dosi, 1997, p. 1538)

The focus of orthodox economic research on the explanation of the direction of technical change has been on how market structure and demand influence innovation. In this way neo-classical economics disregards the fundamental fact that the process of technological change has a strong internal logic, which influences what demands can and cannot be met. Similarly, different technologies offer different possibilities of appropriation of returns. The understanding of the rate and direction of technical change has been enriched and at the same time complicated by these findings. Thus as pointed out by Nelson (1988) there is two way causal relationship between innovation on one side, and industry structure and firm behaviour on the other one.

The rate of technical change

The evolutionary literature attributes the observed inter-sectoral and inter-temporal differences in the rate of technical change due to the different a) opportunities of innovation of each paradigm b) strength of the link between the rate of scientific advance and the emergence of new paradigms c) degree of appropriability of different innovation d) sectoral technological base levels e) the pattern of demand f) environmental conditions

According to Dosi (1988, p.229), paradigm specific opportunities are the first determinant of the observed inter-sectoral rates of innovation. In addition, the probability of making technological advances – and, indeed, the rate of technological change - in firm, organisation and often countries is, among other things, a function of the technological level already achieved by them. Thus, technological change is a cumulative activity[38] (Dosi, 1988, p.223). In evolutionary theories there is no room for the concept of production function involving a large number of techniques to which firms have immediate and free access Elster, 1982, p.151).

Moreover, starting from the Industrial Revolution, the innovative process has been increasingly dependent from advances in scientific knowledge. This is particularly true for entirely new paradigms. The pace of emergence of new paradigms is a fundamental determinant of the rate of

innovation. As the rate of innovation within the existing paradigm decreases because of the increasing cost and difficulties in producing innovations, a new paradigms is likely to emerge. This is only a necessary condition. Indeed, for a new paradigm to be adopted it is often also necessary new scientific advance on which develop it. According to Dosi (1988), it is the continuous emergence of new paradigms and the spreading of their effects to the overall economy which prevented the decreasing return to dominate the process of economic growth in the long run.

According to Dosi (1988) there are several appropriability devices: a) patents b) secrecy c) lead effect d) cost and time for duplication e) learning curve f) superior sale and service effort g) economies of scale. The relative importance of the different ways of protecting innovations and the different level of appropriability varies across industries and technologies. In this contest a trade off emerges. As pointed out by Dosi (1997), with low appropriability (and thus low incentive to innovate) we would have prefect and immediate diffusion of the innovation yielding efficiency improvements and learning trough imitation. On the other hand, with high appropriabilty (and thus, probably, a high rate of innovation) very little of the benefits produced by the innovation will spread throughout the economy. The resulting effect of this trade off contributes to determine of the rate of innovation.

The conceptualisation of technology based on paradigms highlights the fact that changes in environment – related factors (demand, supply, factor prices) are important in *influencing* the rate of technological progress but they can not - as assumed by the neo-classical theory - *determine* it. Again, it is the paradigm what bound the extent of the influences that such factor can exert on the rate of the innovation process.

6 - An assessment and a proposal for further research

In reviewing different theories of the sources of technological change, Ruttan (1997, 2001) points out that all the three approaches he considers - i.e. induced technical change, evolutionary theory, path dependence- suffer major limitation if taken separately. For this reason he suggests integration of the three theories - in which the induced one plays the fundamental role - in order to construct a more general theory of technical change. Dosi (1997) proposes, challenging Ruttan's view, an evolutionary version of the induced theory and argue that the path-dependent account of innovation and technological change has to be integrated into the evolutionary theory, being the latter much richer the description and in the micro-foundation of the agent behaviour.

[38] It is evident that such an approach entails a theory of international trade which departs in a relevant way from the orthodox Hekscher-Ohlin model

In this work we have tried to figure out how different theories explain the rate and the direction of technological change. All of them, in dealing with such a complex issue, show some limitations and flaws that have been discussed in this work. For this reason, in way of conclusion and in order to suggest some line of further research, we propose to adopt another point of view to evaluate and judge the different approaches: the fact that they do or do not consider both technological and institutional changes and the possibility of their reciprocal influence. Indeed, we argue that the major challenge ahead in the construction of a more general theory of technological change is to attempt to disentangle the way in which one may influence the other and vice-versa.

As argued by Pagano (1999), the relationship between the characteristic of technology and of the institutional contest (in particular of the property rights) is a non-issue in neo-classical economics. Workers' or capitalist' ownership would have no effect on the characteristic of the technology employed by the firm. At the same time, the characteristic of the technology employed had no implication whatever on the ownership structure. All the decisions concerning technological change take place in an institutional vacuum.

In Schumpeter's theory technology change determines institutional change. The entrepreneur's behaviour challenges the society' structure and nothing can oppose his will. The deep and detailed Schumpetr's historical account lacks attention towards the evolution of institutions. In particular, the government is absent. Indeed, we can say that the entrepreneur seems to fluctuate in an institutional static setting.

In the Marxian framework two apparently contradicting theory of technological institutional change seems to co-exist. Indeed, Marx considers a two-way relationship between technology and institutions (e.g. property rights). The first one stresses the influence that the ruling (optimal) technology has on the institutional contest. The second emphasises the influence that the institutional contest has on the characteristics of the resources and technology which are employed and developed (Pagano, 1999)[39]. What is missing in the Marxian theory is a consideration of the possible integration of these two causal explications.

The evolutionary approach is the one that is better equipped to account for and incorporate both technical and institutional change. As pointed out by Freeman (1988), one of the main features of the approach is the assumption that the socio-insitutional framework always influences the pace of the technical and structural change (Freeman, 1988, p.2)[40]. Nonetheless, it seems that a satisfactory

[39] Pagano (1999) calls the two versions of the Marxian theory of history respectively "the technological deterministic view" and "the romantic view"

[40] In addition, Freeman (1988) suggests that this assumption is an inheritance of the Classical political economy.

account for the reciprocal influence of technological and institutional change has not been yet developed.

Pagano (1999) suggests that the concept of *organisational equilibria* could be a useful one to pursue this task. In particular, he argues that the nature of technology and of the institutional contest - e.g. property rights – may reinforce each other creating situation of institution stability, in the sense of being resistant to "weak" technology and property rights shocks (Pagano, 1999, p.10). The organisational equilibria may explain some puzzling feature of the dynamic of capitalism: the co-existence of different national forms that occur in spite of common technological innovation and the fact that different phases of capitalism are characterised by different leading countries and by the emergence of new technological paradigms and organisational species[41]. In this sense, the concept of organisational equilibria seem to be a possible enrichment of the evolutionary theory of technical change along the lines suggest by Dosi (1997).

[41] On the origin of new organisational species, see Pagano (2001).

7 - References

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