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Mario Amendola

University of Roma La Sapienza

Jean-Luc Gaffard

*University of Nice Sophia Antipolis,
OFCE Centre of Economic Research of Sciences-Po
and Institut Universitaire de France*

Observatoire Français des Conjonctures Économiques

69, Quai d'Orsay 75340 Paris Cedex 07

Tel : 01 44 18 54 00 Fax : 01 45 56 06 15

E-mail: ofce@ofce.sciences-po.fr Web: <http://www.ofce.sciences-po.fr>

Revisiting the ‘machinery effect’: from Ricardo to Hicks and ahead[★]

Mario Amendola

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Jean-Luc Gaffard

*University of Nice Sophia Antipolis,
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Abstract

Ricardo had the intuition that unemployment is the result of a problem of (lack of) co-ordination in the process of introduction of a new technology. The controversy between optimists and pessimists that followed and keeps dividing the economists is the result of the absence of an analytical framework able to deal properly with out-of-equilibrium processes as is the one through which a technological restructuring of production takes place. Taking advantage of the analytical advance by Hicks, this paper confirms Ricardo’s intuition, and shows that the technological unemployment instead of being a mechanical problem due to the characteristics of technology results from co-ordination failures.

Key words: capital, co-ordination, invention, machinery effect

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1. Introduction

The relation between technology and employment has been at the heart of economic theory since when put to the fore by Ricardo in his famous chapter ‘On machinery’ appended to the third edition of his *Principles*, where he rejected his previous optimistic view on the subject. As a matter of fact what looks through the famous example contained in this chapter is that what actually creates unemployment is not technology in itself as the process through which technology is introduced into the economy. Ricardo had the intuition that unemployment is the result of a problem of (lack of) coordination in this process.

The controversy between optimists and pessimists that followed and keeps dividing the economists is the result of the absence in the dominating economic theory of an analytical framework able to deal properly with out-of-equilibrium processes as is the one through which a technological restructuring of production takes place. This theory looks in fact at capital as a stock of physical goods into which free capital has been already embodied, and which is divided into fixed capital goods (structures and machinery) and working capital (which includes wage goods).

The Neo-Austrian representation of the process of production introduced by Hicks puts into the shade the argument of fixed vs. circulating capital that has characterized the controversy, to shift the focus on the real issue at stake in the technological restructuring process, that is, ‘that investment at cost is not the same as investment of output capacity’ thus dissociating in time inputs from output and costs from proceeds when we are out of equilibrium. And, we shall see, allowing re-establishing the classic analysis of the wage fund as the economic beginning of a production process.

This paper puts explicitly into light the fact that the so-called technological unemployment is not a temporary mechanical problem due to the characteristics of technology but a more general problem due to market behaviours and policies. Already in Ricardo’s analysis, the focus is on the transition path. Unemployment, far from being a characteristic of the economy in a long-term equilibrium associated with a given (and new) technology - that is, a property of this technology - appears a temporary effect of a change in technology (section 2). Samuelson has maintained that Ricardo’s intuition was typically a fallacy. His argument does not consider the appropriate concept of capital, though (section 3). Hicks has been the first to give a robust analytical content to Ricardo’s intuition, focusing on the temporal distortion of the structure of productive capacity that follows an initial impulse (sections 4 and 5). Thus he opens the way to an analysis that attributes the machinery effect to market mechanisms and hence to co-ordination failures. Following along this line it can be shown that changes in the level of the interest rate may exert a strong influence on the value of capital and hence on the

time profile of production processes and the rate of unemployment, whatever the nature of the new technology (section 6). Finally, the change of analytical perspective implied by the focus on co-ordination allows to throw light on some puzzles like the productivity paradox and to stress policy requirements of the viability of processes of structural change (section 7).

2. Ricardo on machinery and employment: from long-run to a transition model

As is well known Ricardo changed his mind about the influence of machinery on employment. In his *Essay on the Influence of a Low price of Corn on the Profits of Stock* (1815), he wrote:

The effect (of a lower price of corn) on the interests of ... (the labouring) class would be nearly the same as the effects of improved machinery, which, it is no longer questioned, has a decided tendency to raise the real wage of labour (*Works* vol IV p. 35)

And in a letter to Mc Culloch of 29 March 1820

The employment of machinery I think never diminishes the demand for labour – it is never a cause of a fall in the price of labour (*Works*, vol VIII p. 171)

But in the third edition of his *Principles*, he added a new chapter ‘On Machinery’, in which he remind us his previous opinion that he acknowledged as a mistake.

Ever since I first turned my attention to questions. I have been of opinion, that such an application of machinery to any branch of production, as should have the effect of saving labour was a general god, accompanied only with that portion of inconvenience which in most cases attends the removal of capital and labour from one employment to another. It appeared to me, that provided the landlords had the same money rents, they should be benefited by the reduction in the prices of some of the commodities on which those rents were expended, and which reduction of price could not fail to be the consequence of the employment of machinery. The capitalist, I thought, was eventually benefited precisely in the same manner. He, indeed, who made the discovery of the machine, or who first usefully applied it, would enjoy an additional advantage, by making great profits for a time; but, in proportion as the machine came into general use, the price of the commodity produced, would, from the effect of competition, sink to its cost of production, when the capitalist would get the same money profits as before, and he would only participate in the general advantage, as a consumer, by being enabled, with the same money revenue, to command an additional quantity of comforts and enjoyments. The class of labourers also, I thought, was equally benefited by the use of machinery, as they would have the means of buying more commodities with the same money wages, and I thought that no reduction of wages would take place, because the capitalist would have the power of demanding and employing the same quantity of labour as before, although he might be under the necessity of employing it in the production of a new, or at any rate of a different commodity.

This is so because Ricardo believed that the overall demand of labour and money wages would not be reduced as the result of the use of new machines in the production of goods, and this would benefit all three social classes (landlords, capitalists and workers) due to the decrease in the monetary prices of goods as the result of the greater production efficiency of the new machines. However, he goes on:

These were my opinions, and they continue unaltered, as far as regards the landlord and the capitalist; but I am convinced, that the substitution of machinery for human labour, is often very injurious to the interests of the class of labourers. My mistake arose from the supposition, that whenever the net income of a society increased, its gross income would also increase; I now, however, see the reason to be satisfied that the one fund, from which landlords and capitalists derive their revenue, may increase, while the other, that upon which the labouring class mainly depend, may diminish. (*Works*, vol I, pp. 386-88)

That is, the overall demand of labour and/or money wages may indeed diminish as the result of the introduction of new machines. This conclusion is sustained by the famous numerical example whose main argument is worth recalling here.

In this example each year a capitalist, with a fixed capital (a machine) worth 7000£ and a circulating capital worth 13000£ obtains a gross annual product worth 15000£, with a net product equal to 2000 £, that is a 10% rate of profit. At the end of the year, after consuming this profit or disposing of it in any other way, the capitalist still has a fixed capital of 7000£ and a circulating capital of 13000£. Let us assume that, next year, he decides to employ half of the workers (whose wages are paid from the 13000£ of circulating capital) to produce an additional machine worth 7500£ and commodities worth 7500£. What would be the case the following year?

While the machine was being made, only one-half of the usual quantity of food and necessaries would be obtained, and they would be only one-half the value of the quantity, which was produced before. The machine would be worth 7500£, and the food and necessaries 7500£, and, therefore, the capital of the capitalist would be as great as before; for he would have besides these two values, his fixed capital worth 7000£, making in the whole 20000£ capital and 2000 profit. After deducting this latter sum for his own expenses, he would have a no greater circulating capital than 5500£ with which to carry on his subsequent operations; and, therefore, his means of employing labour, would be reduced in the proportion of 13000£ to 5500£, and, consequently, all the labour which was before employed by 7500£, would become redundant (...). In this case, then, although the net produce will not diminish in value, although its power of purchasing commodities may be greatly increased, the gross produce will have fallen from the value of 15000£ to the a value of 7500£, and as the power of supporting a population, and employing labour, depends always on the gross produce of a nation, and not on its net produce, there will be necessarily a diminution in the demand for labour, population will become redundant, and the situation of the labouring classes will be that of distress and poverty. (*Works* vol I pp 389-90)

Thus, Ricardo shows a case in which an unchanged net income is actually associated with a falling gross income (the means of employing labour). This is the result of a change in the structure of the capital, the total worth of which remains unchanged: what changes is what in modern parlance we would define (not properly, as we shall see) the ratio of fixed capital (which includes the machines, that are increased in the example) to circulating capital (representing the wages fund) which is decreased correspondingly, bringing about a reduction in the demand for labour. It is shown that fixed capital is produced at the expense of circulating capital, with the result that the wage fund is reduced while the machine is being made, until the greater productivity of the newer type of machines will build it again and hence unemployment will be reabsorbed.

Of course, given the higher productivity of the new production processes, unemployment will be reabsorbed.

As, however, the power of saving from revenue to add to capital, must depend on the efficiency of the net revenue, to satisfy the wants of the capitalist, it could not fail to follow from the reduction in the price of commodities consequent on the introduction of machinery, that with the same wants he would have increased means of saving, - increased facility of transferring revenue into capital. But with every increase of capital he would employ more labourers; and, therefore, a portion of people thrown out of work in the first instance, would be subsequently employed; and if the increased production, in consequence of the employment of the machine was so great as to afford, in the shape of net produce, as great a quantity of food and necessaries as existed before in the form of gross produce, there would be the same ability to employ the whole population, and, therefore, there would not necessarily be any redundancy of people. (*Works* vol I p. 390)

With this example, Ricardo described what happens step by step. He proposed what might be considered as a sequential analysis. Thus, he has shown that fixed capital would be produced at the expense of circulating capital, in which case the wage fund would be reduced until the greater productivity of the newer type of machinery would built it again. The process of change, which has been so described, is characterised by a temporary unemployment.

3. Is the Ricardo Machinery Effect a fallacy or a splendid intuition?

In a critical paper Samuelson (1994) maintains that the statement according to which the introduction of machinery, by diminishing the wage fund, identified with circulating capital, results necessarily in a reduction in employment and/or a decrease in the real wage, is a 'fallacy', based on the wrong idea that the demand for labour derives from circulating capital alone. It is then easy for Samuelson to show that, in a context where a horizontal integration of the process of production is stressed so that fixed capital is combined with working capital for the production of final goods, there is no simple and one-way relation between the composition of capital and employment or the real wage rate.

In any minimal production period, the outlay advanced on direct wages will be only a fraction of the total outlay that entrepreneurs must advance on all inputs. The wage fund that they advance, and on which they earn interest, is thus much less than the total Kuznets-measured capital in the economy. It is one part of all capitals and is no more like circulating capitals than it is like a dollar advanced to buy or rent a durable input. Why confuse the numerical 'wage fund' with one kind of capital rather than another? Modern economists in the age after Sraffa should be particularly understanding of the truth that the wage fund is not to be confused with the totality of 'circulating capital' and that is the malleable *result* of the equilibrium process and not a causal determinant of the level of the real wage in any meaningful long run, intermediate run, or short run.

In order to reinforce his point, Samuelson evokes both the contribution of James Stuart and Hollander' view as to what would have been Ricardo's step ahead in the understanding of the effects of technical change

Sir James Stuart in his (1767) *Inquiry* made a most significant contribution to the understanding of technological change. He distinguished between fixed capital (structures and machinery) and circulating or working capital (the latter including wage goods), the demand for labour deriving from circulating capital alone. Technical change, provided it did not reduce aggregate circulating capital, would not entail labour displacements (1767 1966, I, pp. 121-25).

The next step along the road was by Ricardo in 1821, when he demonstrated that it was possible for there to occur a 'conversion' of circulating into fixed capital – technical progress taking the form of a reduction of circulating in favour of fixed capital – the end result being a reduction in the aggregate demand for labour (Hollander 1987 pp 32-33)

However, Samuelson's criticism (as well as the Hollander diagnosis) depends on the confusion that he makes between what the classics, by referring to a vertically integrated view of production, actually intended by wage fund – the whole capital of the economy seen as a fund, as free capital which will circulate through the reproduction process – and what he seems to believe the classics had in mind but actually they did not: the wage fund as the working part of the existing physical capital, on which alone the demand for labour would be made to depend.

Samuelson sticks to a 'modern' interpretation of the notion of capital, characterised by a horizontal division between fixed and circulating capital, derived from the vision of a horizontal structure of production, typical of an equilibrium approach. The classics instead looked at the wage fund as at the economic beginning of a production process

considered ... in the context of the reproduction of final goods (national revenue) and, therefore, in the context of a one-way (but circular) avenue going from the consumption goods exchanged for labour at the beginning ... to the final ... goods returned by labour at the end (Meacci 1994).

Within this vertically integrated view of production the wage fund appears exactly as a fund, a ‘sum of values’ (Hicks 1974) which makes it possible to start off and to carry out the production process by being invested in a type of capital which presents itself as circulating capital (fixed capital being nothing else, in this perspective, than capital whose circulation requires a span of time longer than the single period).

The notion of the classics is best rendered by Jevons’ observation that one should not say ‘a railway is fixed capital, but that capital is fixed in the railway’ (1871 p. 264): a remark which invariably points out to the wage fund as the typical form of capital at the beginning of its transformation (free capital) (ibid.).

The question to be asked, then, is not “why confuse the numerical ‘wage fund’ with one kind of capital rather than another”, but what kind of concept of capital is appropriate to consider.

Now, while in the previous editions of the *Principles* Ricardo compared what we nowadays would call different equilibrium paths characterised by different already established technologies, in the chapter ‘On Machinery’ he actually focused on what happens to an economy during the out-of-equilibrium process through which a new technology is introduced, that is, ‘while the machine was being made’ (ibid.): a problem that the synchronic ex-post representation of the process of production typical of the equilibrium analytical framework, which is behind the horizontal division between fixed and circulating capital, is not suited to deal properly.

What Ricardo lacked, and what makes his numerical example a splendid intuition but not an explicit analysis of the technological transition, is a representation of the process of production compatible with the vision of capital, and of the wage fund, as the ‘free capital’ that he had in mind.

4. The revival of Ricardo’s Machinery Effect: Hicks’ Traverse Model

This representation of the process of production is exactly what is provided by the Neo-Austrian model first developed by Hicks (1970, 1973). By stressing the time structure of production, its vertical integration, and its intertemporal complementarity, this makes it possible to consider a thoroughly sequential analytical context within which to analyse transition processes between different technological equilibria.

As in the original Austrian version, fixed capital is not explicitly shown in the model: which allows a return to the idea of capital as a fund, as free capital. The difference is similar to that between the old Walrasian theory and the Activity Analysis.

While the old Austrian theory was ‘point-output’ (its elementary process having a single dated output), we shall use an elementary process that converts a sequence (or stream) of

inputs into a sequence of outputs. Our conception of capital-using production is thereby made much more general. The former difficulty of dealing with fixed capital is wholly overcome. (p. 8)

Thus, the process, whose coefficients are conveniently grouped into two phases – with the focus on the phase of construction of a ‘new’ productive capacity, during which costs must be beard but no final output accrues, and on its coming necessarily before the phase of its utilization – must be taken as a whole. Its full vertical integration stresses the intertemporal complementarity of the different phases, each of which does not exist without the other. Indeed, in this perspective,

the steady state (...) will be no more than a means to an end – to the study of an economy which is not expanding uniformly, an economy in which things actually happen. Now for the study of a non-steady path more assumptions are needed than for the study of a steady state path; more assumptions, and more distinctions. It will be useful, before we pass to the formal theory of steady state, to examine these distinctions. For when we have them, we shall find ourselves able to take the steady state theory itself in a more fruitful way. (p. 47)

Lowered into a sequential context the Neo-Austrian representation of the process of production becomes the backbone of an evolution path of the economy as a step-by-step process sketched out by a sequence constraints-decisions- constraints. This is the result of a blend of Austrian and classic analytical ingredients, as it also restores the concept of the wage fund - interpreted as circular reproduction in the perspective stressed by the classics - as a constraint emerging from and impinging on a transition process characterised by a sequential determination of prices and quantities. In the analytical context just mentioned, in fact – unlike in the standard neoclassical analysis where the ‘short’ and the ‘long’ periods, distinguished solely in terms of the constraints under which producers are supposed to operate, are treated separately – a sequential relation between them is established in the sense that, as pointed out by Abba Lerner, “in the long run we just arrive at another short run”, and, “as an element in the determination of the sequence, the Wage Fund comes back into its own” (Hicks 1973 p. 62).

In the specific sequential process analysed by Hicks - the Traverse of a barter economy (where productive resources, besides labour, are physical output) from a state adjusted to a given productive technique to the state adjusted to a superior one - the wage fund, in each given period, is determined by current final output. This, once ‘taken out’ the parts of it devoted to finance labour employed on ongoing production processes (whether still in the construction or already in the utilisation phase), or consumption of other kinds, is fully used to start new production processes embodying the new technology (the so called Full Performance assumption).

The rate of starts of these processes, thus made endogenous, sketches out the path followed by the economy, a fully predetermined path once the value of the parameters of the model are given. Full Performance, on the other hand, also implies flow equilibrium in each period, both in the sense that final output is totally absorbed by existing demand and in the sense that investment is equal to ex ante saving. But, we shall see, there is nothing of the sort in the labour market.

What makes this analysis an essential step forward in economic dynamics is to put production back to the centre of the stage. Adjustments, changes, in a simple word ‘dynamics’, are a matter of production. Production in the sense of productive capacity, how it comes about, not simply how it is used. As a matter of fact any attempt to bring about a real change, that is, a different way of functioning of the economy, implies bringing back into light the time articulation of the production process – its having to go first through a phase of construction of a different productive capacity in order to be able to use it later for current production – obscured by the synchronisation of production in equilibrium.

When construction and utilisation are seen as the two essential moments of the process of production, intertemporal complementarity appears as its main aspect. The main implication of the breaking of this intertemporal complementarity out of equilibrium, as is the case with any radical change, is the distinction “between investment at cost and investment of output capacity” (Hicks 1973, p. 98). This distinction, fully reabsorbed in any established state of the economy, stands out during adjustment processes. It stresses the dissociation in time of inputs from output, and of costs from proceeds, that characterises these processes and determines important transition problems: like, in the first place, a temporary fall in final output, and hence in the resources available to sustain employment. This is the reason of Ricardo’s ‘machinery effect’ as shown in his famous example, whose analytical proof is certainly a paramount result obtained by Hicks in his study of the Traverse.

5. Improved machinery vs the introduction of machinery

One may argue that Hicks’ demonstration of the machinery effect is only robust when he considers a Traverse concerning the introduction of a given technique under a fix wage assumption. As a matter of fact, if full employment is instead the binding constraint, changes in technique as a consequence of changes in real wage would take place during the adjustment process. Then the problem of expectations would become relevant, because it is the expected value of the real wage that determines the choice of technique. Hicks makes the assumption of static expectations according to which “when the decision to adopt a particular technique for new processes is taken, the current wage is expected to remain unchanged” (Hicks 1973 p. 56). He justifies the generality of his approach, although based on a specific assumption, by

considering any technical change as being, primarily, the effect of a technological impulse or an autonomous invention. Induced inventions that are the result of the current movement of wages, are only secondary inventions. And the unemployment issue he intends to address is that entailed by primary inventions.

When (...) we come to history, (...) the technology, and the technological frontier, themselves become suspect... The notion of technology, as a collection of techniques, laid up in a library to be taken down from their shelves as required, (...) is a caricature of the inventive process... Why should we not say that every change in technique is an invention, which may be large or small? It certainly partakes, to some degree, of the character of an invention; for it requires, for its application, some new knowledge, or some new expertise. There is no firm line, on the score of novelty, between shifts that change the technology and shifts that do not” (Hicks 1973 p. 120)

In *Capital and Time*, as he himself acknowledges, he began “to understand why there had been so much trouble with that old distinction between autonomous and induced invention (which) is a static distinction, quite out of time, though it concerns a matter where some time-reference is essential. When one puts it back *into time*, it looks quite different” (Hicks 1976 p. 295).

This discussion is a reminiscence of some controversies about the nature, and to some extent the ambiguity, of the argument developed by Ricardo. Following Hollander (1971, 1979), Eltis (1985) remarks that Ricardo has two distinct arguments

There is a first argument in which increasing mechanisation is endogenously associated with the rising wage which is a central element of Ricardo’s account of what occurs as economies develop. That process can never produce a declining trend in employment. Second, there is the case where ‘improved machinery is suddenly discovered’ (Ricardo vol I p. 395). These exogenous discoveries of machinery can obviously take any form and have any kind of effect on employment” (p. 268).

Here, Eltis refers to this sentence in the *Principles*, in which Ricardo is supposed to speak about the particular conditions that would explain the fall in employment. Then, he is able to separate two different situations: the first one is when invention is endogenously determined, that is, when a rise in the wage rate induces the capitalist to adopt a more mechanised production process, and the second one when the invention is exogenous and suddenly introduced. And considering a numerical example used by Ricardo in a letter to Mc Culloch, he adds: “it has been shown that spontaneous inventions are the only one that can be associated with a falling demand for labour in the economy as a whole: but if an invention is an exogenous event there is no reason why because it would be profitable to exploit it”. Clearly, he maintains that the first situation is more general than the second one, which to some extent could be ignored.

Ricardo's logic is therefore tight only where he speaks of endogenous technical change associated with the rising wage (in relation to the costs of machinery) that is central to his whole argument. It is the influence of this on his total argument that therefore merits attention, and given the textual evidence and his statement that he assumes the sudden discovery of machinery only for expositional reasons – 'to elucidate the principle' – it is probably endogenous invention associated with a rising wage that he principally had in mind when he analysed the causes and effects of mechanisation. (p. 270)

This comment privileges a neo-classical lecture of Ricardo's arguments and, above all, introduces a confusion consisting in assimilating endogenous technical progress with a regular growth process, mixing the long run with the short run and ignoring the specificity of a transition path. It should be clear that he was mainly interested in the adverse effect on employment of an impulse. "What he surely have had in mind is not 'improved machinery' (though he says 'improved machinery') but the introduction of machinery: the introduction of a strongly fixed-capital using technique in place of one which, as an approximation, could be regarded as circulating-capital-using only" (Hicks 1973 p. 99).

6. The crucial role of market mechanisms

The proof of the 'machinery effect' provided by Hicks is limited to a specific time profile of the production process and to the case of a 'forward biased' technical change, that is, of a technological progress that requires a more indirect production technique as in the first industrial revolution. Furthermore, his analysis of the Traverse, reduced to a predetermined trajectory by the Full Performance assumption, justifies Solow's statement that it is "well adapted to the mechanical job of tracing out the route by which the new process replaces the old (...) But that accounting does not take us very far" (1974 p. 191).

The fact, however, is that Hicks' analysis, although itself actually figuring out a technological transition as a predetermined trajectory, is a first essential step for the analysis of technological transitions as thorough processes. The Neo-Austrian representation of the production process, we have just mentioned, with the intuition that 'investment at cost is not investment of output capacity' out of equilibrium, stresses the fundamental coordination problem that characterises transition processes and that is the thorough reason for all the phenomena (mainly technological unemployment and productivity slowdown) associated with the process itself.

A first step in this direction is Amendola (1972) who has shown that, with a more general type of production process, whatever the kind of technical progress, the introduction of a new and superior technology, by affecting the capital value of the production processes belonging to the old technique, may involve a variation in the optimal length of these processes, that is,

a sudden truncation of old production processes in their utilisation phase that inevitably causes a fall of final output, a resource constraint and hence a fall in the demand for labour.

Here the arbitrary saving function considered by Hicks is essential. An optimal saving behaviour, which took into account the intertemporal complementarity of production processes, could possibly serve the purpose of maintaining full employment over time. But this – in the same way as the hypothesis of flexible real wages would artificially conceal the problem of technological unemployment by instantaneously absorbing it – would only lead to the rejection of the idea that intertemporal complementarity of production processes matters. The theory that would emerge, then, would not be “a sequential theory of the kind we are endeavouring to construct” (Hicks 1973 p. 56).

Following on the hint provided by Amendola’s analysis, stressing market mechanisms rather than the character of technology, Patriarca (2009) shows that the truncation of some of the production processes embodying the old technique as a new one is introduced will take place even if there are not variations in the optimal life of these processes. The fall in output and its effect on employment is therefore a phenomenon that will always take place in the early phases of innovation processes. Each process of production represented as a sequence of inputs and outputs over time is characterized by a capital value profile over time. Due to the market mechanism based on changes in capital value of productive capacity as the result of changes in the interest rate, the appearing of a new technique, and the increase in the interest rate that it entails, will cancel the capital value of existing production processes in the early stages of the construction phase. This obsolescence process, differently from the case of a variation in the optimal life, will concern processes in the phase of construction and not in the phase of utilization. However, the time when the truncated processes would have reached their normal utilization phases will arrive, and then, lacking the output of these processes, the total output, and employment, will necessarily fall.

The analysis based on changes in the capital value of productive capacity as the result of changes in the interest rate provides interesting policy insights. Let us consider, in particular, the case of a stickiness of the capital market reaction, such as to slow down the adjustment of the market interest rate to the internal rate of return of a new superior technique (Patriarca 2009). While the old rate of interest prevails, investment in the new technique will give extra profits with respect to the processes embodying the old technique, which will be scrapped to provide funds to finance investment in the new technique notwithstanding their capital value remains positive (but lower than that of the new processes) at the still prevailing interest rate. This will be true both for old processes both in the early stages of the construction phase and in the last stages of the utilization phase, that is, the stages corresponding to the lower parts of the capital value profile of those processes. With respect to the case of an immediate

adjustment, where the fall in total output was delayed until the new processes arrived at the utilization phase, a slow adjustment would then anticipate the falling on total output due to the sudden truncation of effective productive capacity. The need to explore policy measures acting on the speed of adjustment acquires then relevance.

This last point allows putting the ‘machinery effect’ in a wider perspective. It has no longer a mechanical origin, as in the case of a resource constraint due to the nature of the technology, but is regarded instead as depending on the rise of the interest rate and hence on a market mechanism. It appears in other words as a co-ordination problem, the coordination that is the essence of the functioning of markets. In particular, it is shown that the breaking of coordination involved is the result of the optimizing decisions taken by the economic agents. A phenomenon that cannot take place in Hicks’ analysis, where no decision process is contemplated due to the Full Performance assumption, and hence a breaking of coordination can only be the result of a resource constraint due to the character of the technology.

7. Innovation as a co-ordination process: policy implications

Being able to throw light on what happens ‘on the way’ is a momentous achievement, and not so much for the specific analytical results obtained as for the change of analytical perspective that it implies. As a matter of fact although in his analysis ‘the way’ considered is still ‘the way to’ a predetermined point of arrival, Hicks himself makes it clear that the problem of convergence to this point (which is in the end why the equilibrium structure is called in) is not really the important thing, and that what happens on the way may matter in itself

Convergence to equilibrium has been shown to be dubious, but it has also been shown to be unimportant. Even at the best, it will take a long time... and before the time has elapsed something new will surely have occurred. It is therefore of the first importance that something can be said... about the short-run and medium-run effects of an exogenous disturbance (Hicks 1975 p. 366).

The shift of focus on co-ordination problems originating from market mechanisms widens the interpretative reach of the consideration of the distinction between ‘investment at cost’ and ‘investment of output capacity’ out of equilibrium. In particular it allows a convincing explanation of the so-called Productivity Paradox, that is, a general slowdown in productivity happening in spite of tremendous technical progress.

As a matter of fact the paradox is only apparently such, and it arises because of the way production and technology are defined in the standard theory. In the standard representation of technology the productivity gains are built within the production function: as soon as a superior

technique becomes available and is adopted the output associated with given inputs, and hence productivity, is actually realized. The existence of problems of coordination, which might hamper the effective appropriation of the potential returns of technology, is excluded by assumption.

In a Neo-Austrian analysis, instead, productivity appears as the uncertain result of an innovation process, which is essentially a coordination process. The introduction of a new technology pushes the economy out of equilibrium: investment and consumption are no longer harmonised. The subsequent adjustment process does not instantaneously result in higher performances. In other words, productivity is the outcome of the way in which the economy is able to deal with the coordination problems raised by the technological shock. The potential inability of the economy to successfully incorporate a new technique is all but paradoxical.

In a perspective in which rather than being explained by the nature of technology unemployment appears as the result of co-ordination failures, not only full employment can be associated with any technology, but also, full employment can be maintained when technology changes, provided appropriate behaviours and policy measures will take place, which favour a better co-ordination over time. This has been pointed out by Hicks himself (1969). Considering the price to be paid for an improvement in technique to convert a stationary into expanding economy, he adds in fact that this price could naturally be reduced by borrowing from abroad (if that were possible). It would also be reduced if it were possible to draw upon stocks of finished goods that had been previously accumulated. Temporary reductions in consumption from profits or from wages could also (in a sense) be an easement. These are reasons why credit inflation (in Keynes' manner) can be an easement; though the problem with which we are here concerned is not Keynes' problem. (p. 171)

In the same vein, he mentions the limits of an analysis that, actually, does not take into account the co-ordination issues that are at the heart of a more comprehensive explanation of unemployment

(The Austrian Method) shares with the Classics, with Ricardo and also with Smith, what appears from a Keynesian standpoint to be a major weakness. Though it can take into account of structural unemployment, it cannot allow for Keynesian unemployment – for the under-functioning, which Keynesian economics is about. It has, very obviously, nothing to say about money; but that is not all. Even a barter economy, if such a conceivable, could under-function, for there can be piling-up of unsold stocks of goods, as well as of idle balances. To all things as these it turns a blind eye. (Hicks 1985 p. 157)

We have seen that the analysis of the Traverse shares this weakness; but we have also seen that pushing along the way opened by this analysis this weakness can be overcome.

The Hicksian or Neo-Austrian view of production makes it possible to see how a shock of any kind brings about first and foremost a distortion of the existing productive capacity due to a breaking of the intertemporal complementarity of the production process. This implies the

appearance of disequilibria, and hence of problems of co-ordination that, although originating on the production side, extend to all aspects of economic activity (resulting, for example, in inflation unemployment and so on). Reactions to these disequilibria stimulate an out-of-equilibrium process of adjustment. This is sketched out by sequentially interacting disequilibria, which will amplify or dampen the original deformation of the structure of productive capacity – and hence create or eliminate viability problems – according to the working of the co-ordination mechanisms along the way. If co-ordination is not re-established, this will result in particular in increasing levels of unemployment, and decreasing levels of productivity and real wages (Amendola, Gaffard 1998, 2006; Amendola, Gaffard, Saraceno 2005).

Let us consider the case of the introduction of a new technology characterised by higher construction costs. The costs come earlier, and hence cannot be financed out of current production. This causes a distortion of productive capacity and the dissociation in time of inputs from output and of costs from receipts, which puts a financial constraint on investment in capacity. The availability of financial resources *at the right time* is then essential to build a bridge over time between costs and revenues, so as to render the required restructuring of productive capacity viable while it is still on the way and does not yet deliver output and revenues. If these resources are not available, the necessary investment cannot be realised, which will further reduce final output and postpone (or even cast doubts on the effective obtainment of) the expected increases in productivity. What we shall have in the meantime is less production and less labour demand. Unemployment, lower revenues and the subsequent fall in final demand will further reduce receipts and financial resources. Insufficient investments will paradoxically result in excess supply, excessive productive capacity and in the scrapping of production processes. And so on, in a process that is a threat to the viability of the change undertaken.

This process also occurs if the new technology requires a different gamut of skills. We shall immediately have the appearance of a human resource constraint, taking the form of a labour mismatch, which implies the co-existence of unemployment and unfilled vacancies (for lower and higher skills respectively). Once again this will result in lower investment and hence in a subsequent fall in revenues and final demand. Unemployment thus reveals the existence of co-ordination problems at the economy level. It cannot be reduced to a matching problem, to be solved thanks to appropriate changes in the regulations of the labour market or appropriate actions that would allow workers to learn new competencies. Policy interventions are required to allow actually reaping the economic gains of technology.

These modern developments stemming from Hicks' analysis confirm Ricardo's intuition according to which unemployment, far from being the expression of the intrinsic properties of a new technology, is the result of distortions in the structure of productive capacity that reveal

the existence of co-ordination failures and the possibility of correcting the latter by means of adapted policy measures.

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