Eastern Economic Journal, Volume X, April-June, 1984

TOWARDS A DYNAMIC ANALYSIS OF THE "TRAVERSE"

Mario Amendola*

1. The "Traverse" and Analysis of the Innovation Process

Adolph Lowe's extensive study of the "traverse", has remained rather isolated from the mainstream of economic literature (1976). Much the same fate has befallen John Hicks's highly controversial "Neo-Austrian theory" which purports to be a helpful new way of dealing with fixed capital in the analysis of the transition from one steady-growth path to another. (1970, 1973)

The analysis of the "traverse", even in the sketchy and limited way pursued up to now, is one of the most genuine pieces of dynamic analysis produced so far; in particular, it has provided the most adequate theoretical framework for treating the process of innovation, which is the process through which technical progress reveals its truly dynamic nature. Modern growth theory and the comparative dynamic analysis derived from it, has not proved capable of dealing properly with the phenomenon of changing technology (conceived of as the shift of a given production function) as a basis for comparing alternative equilibrium positions. That is why Hicks and Lowe, each in his own way and quite independently from the other, have followed alternative routes in their respective analysis of the "traverse", with the objective of shedding light on the way in which technical progress actually works its way through the economy[1].

Similarity of interests and perspective, and dissimilarity of basic assumptions and proposed models, are an instructive framework in which problems and solutions can be compared and contrasted. A comparison between the two contributions, certainly the most important in the field, will single out the relevant issues (ie. what is really meant by technical progress; how should fixed capital be dealt with in a dynamic context; how should the process of production be represented) while also focusing methodological and analytical problems. From this perspective, the two models appear as logically successive steps along the path to a better understanding of the process of change of the economy.

Moving from an orthodox sectoral framework, Lowe fixes attention on time sequence rather than on the horizontal structure of production. Not yet freed from the traditional approach, his representation of technical progress and the underlying process of production does not permit analysis of the transition process which takes place in time.

Hicks achieves a complete break with the traditional theoretical apparatus, thus going the whole way in the direction anticipated by Lowe. Sequential analysis of a process of change requires a process of production conceived as a sequence in real time; this is exactly what Neo-Austrian theory does. In this new approach, the relevant

*University of Rome

moments of a transition phase are not obscured by circular relations in production, so that the way is open for an analysis of the process of innovation.

The impossibility of carrying out a genuinely dynamic analysis within the analytical framework represented by the traditional theory of production, and the need for a radical change of perspective which extends to the very definition of the process of production, emerges from the comparison between Lowe and Hicks which is developed in the following pages.

The "traverse" in sectoral models

A necessarily brief overview of the way technical progress and the process of innovation have been treated within the context of the analysis of the "traverse" will help us to get to the point. The "traverse" is the problem of the change from a particular configuration of the productive capacity of the economy to another. In some models, it is a change in the growth rate which requires a readjustment of existing capacity; in others it is technical progress which brings out, and at the same time is prompted by, a transformation of productive capacity to reflect a newly dominant technology. Productive capacity is the expression of a given technology which is identified with a given stock of fixed and/or circulating-capital goods which is combined with labour in certain proportions (technical coefficients).

Readjustment or transformation[2] of existing capacity is most easily carried out in models in which goods can be used either as consumption or as capital goods, so that a fall in consumption automatically means an increase in whatever capital goods are required to assure the transition[3].

Hicks introduces heterogeneity between consumption goods and capital goods in his two-sector (corn, tractors) model of "traverse" in "Capital and Growth". (1965, Chapter XVI) For example, tractors and labour produce tractors and, when used in different proportions, also corn, and can move freely from one sector to the other. However, owing to the hypothesis of heterogeneity, changes in consumption no longer mean immediate opposite changes in the number of tractors, and hence are no longer able to automatically assure the "traverse". Transition from one steady-growth rate to a higher (or a lower) one can be realized only through transfers of labour and tractors between the corn sector and the tractor sector, so as to modify their relative weight in accordance with the new growth rate[4]. Readjustment of productive capacity through horizontal transfers between sectors, on the other hand, is treated as a stability problem, and the focus is on the condition required (a higher capital intensity in the consumption-good sector, in the case considered) to assure the convergence to the new steady-growth path, maintaining full employment of both capital and labour.

Technical change within a similiar two-sector model is introduced by Spaventa in the form of a simple reduction of the technical coefficients: both the consumption and the (circulating) capital good do not change their physical identity in the passage from one technique to the other (1973). Formulated in this way technical progress comes to the same thing as a change in the growth rate, and the "traverse" reduces to a readjustment of the relative size of the two sectors to be realized through horizontal transfers under the same convergence condition underlined by Hicks.

To sum up: heterogeneity between consumption and capital goods implies that if the quantity of a capital good is insufficient for the requirements of a new situation, that it cannot be increased by simply "squeezing" consumption; this gives rise to a process of transition which requires transfers between the different sectors. The assumption that

the inputs remain physically unchanged allows treatment of the transition as a stability problem, even in the presence of technical progress. Thus the differentiation between goods points to the process which productive capacity must undergo in order to change its configuration, but the representation of technical progress as a mere reduction of inputs cancels the need for the analysis of such a process and reduces everything to a problem of convergence conditions.

The change in perspective in Lowe's model

Lowe takes a further step by differentiating not only between consumption and capital goods but also between capital goods themselves. This step permits him to shift the focus of analysis to the process through which the productive capacity of the economy is actually adjusted[5]. His investigation centers on the "formation, application and liquidation of real capital", that real capital which locks the economy into a particular technique, because "if we want to change the employment capacity of the existing stock of fixed capital, we have to change its physical form" (Lowe, 1976, p. 10). By shifting focus from the new equilibrium of productive capacity to what happens on the way to it requires a sequential analysis, not in the sense of "depicting successive but separate levels of capital formed and labour trained", but in the sense of "offering an insight into the intervening processes during which new capital is being formed and labour is being trained" (p. 10). This is compatible involving the process of transformation of productive capacity in real time.

For this purpose Lowe assumes an economy divided into three aggregate sectors, a consumer-good sector, say II, and two capital-good sectors: Ib, which produces the capital goods used as inputs in sector II, and Ia, which produces the capital goods used as inputs both in sector Ib and in sector Ia itself. There are therefore two different kinds of capital goods (machines): those required to reproduce themselves and to produce the machines that will be used in sector II, and the latter, required to produce the consumption goods. It follows that only machines of the first kind can be transferred, between the two capital-good sectors Ia and Ib, but not between the capital and consumption-good sectors, as in traditional two-sector models.

The implications of this analytical framework go beyond the simple addition of a further sector to the model. Differentiation between the capital goods, in fact, introduces a new dimension into the process of production, establishing a sequence (Ia Ib II) according to which fixed capital in sector Ia must be increased before any increase can be obtained in the production of consumption goods. Thus the transition, that is, the reshaping of productive capacity, can no longer be accomplished by simply readjusting the relative weight of the different sectors through mere horizontal transfers between them. Thus the sectors lose their character of simple compartments in the economy and become instead diffrent phases in a sequential process of production articulated, what emerges is a vertical transfer of resources between different phases, to be carried out in time. The stability approach is no longer able to encompass the full sequence of adjustment of the various sectors one at a time; the timing of the events matters, and intertemporal complementarity calls for a sequential analysis of the process. Thus the model brings to light the strict relationship between the sectoral representation of the economy and the hypothesis of transferability, and the loss of analytical relevance of such a representation as the capital goods become more and more specialized and hence not transferable.

While Lowe's model implies a sequence, it also retains circularity within the capital-good sectors, where the equipment considered is technically suited to reproduce itself as well as to produce the equipment required as inputs to the consumption good

sector. The capacity of physical self-reproduction, according to Lowe is, in fact, the only way to stop the infinite technical regress with which we would otherwise get involved. Another sector is needed to produce the machines used as inputs in sector Ia, and then another one, and so on... (pp. 29-30). Circularity, however, makes the differentiation between the capital goods vanish; so we are back to the orthodox sectoral representation in which the adjustment can be realized through horizontal transfers, namely between sectors Ib and Ia.

Both sequentiality (unilateral dependence over time) and circularity (mutual interdependence) are thus present side by side in the model; and it is just this hybrid character, we shall see, that while disclosing the real dynamic problems involved in a process of transition between techniques, will not permit their proper treatment.

The Neo-Austrian approach

In Hicks' Neo-Austrian model, capital goods become internal to each process of production and labour is envisioned as a stream of freely transferable inputs which become converted into a stream of final outputs (consumption goods). Production is fully integrated vertically: the capital good used in each process is produced within it, and the process must be taken as a whole over time. The sectors disappear and real, irreversible time emerges as the fundamental dimension of the process of production. Thus, the time articulation of the different phases (the "time profile") becomes the distinctive feature.

With the help of this analytical framework Hicks turns to the same problem considered by Lowe; the analysis of the path along which an economy adjusts itself to an external disturbance, specifically a change in the technique[6]. Given the strong intertemporal complementarity which characterizes the process of production, this sort of study clearly lends itself to sequential analysis. It is, in fact, with the help of sequential analysis that Hicks seeks to build a bridge between equilibrium economics and an economics which must be securely in time, like the analysis of the "traverse".

Hicks envisions the process of production as extending over a sequence of periods (weeks) integrating different successive phases lasting one or more years[7]: "The one week relations...determine the course of the model in week T, when everything that has happened before week T is taken as given. Having determined the course in week T, we can then proceed to week T+1, applying similar relations, but with the performance of week T now forming part of the past. And so on, and so on. The path of the economy, over any number of successive weeks, can thus be determined" (1973, p. 63). In particular, the output and the employment, at week T, depend entirely on the processes that have been started in the past, and on the techniques that are used in those processes.

The basic element of the sequence is the rate of new process starts, which is endogenized and made dependent on the rate of starts in the past. This is obtained assuming that all output which is not consumed is invested (ie. under the "Full Performance" hypothesis activity is limited only by savings) and that consumption out of profits (ie. the take-out which cannot be used to start new processes) is constant in absolute terms (Q-hypothesis). (1973, Chapter V) Since the rate of starts is made endogenous, the model is sequential and can be used to describe the "traverse" from one steady-growth path to another in the case of a technological innovation and under the alternative constraints of a fixed wage rate and of full employment. (1973, Chapter VIII, (X) In brief: technical progress brings about an increase in profits, all surplus profits - given the Full Performance and the Q hypotheses - are saved and invested, hence there is an increase in the rate of starts and, in a first moment, increased activity in the

construction phase. Thus the path of output and employment is determined and the "traverse" is traced out.[8]

Circular relations in production and the process of acquisition of a new technology

It has been seen that, in models with a horizontal sectoral structure of production, the "traverse" is accomplished through a reallocation of capital goods and labour between different sectors. Innovation uses the same inputs as the old technique although in different proportions. Technical progress, therefore, does not imply the appearance of new (different) capital goods or require a transformation of productive capacity but takes the form of a reduction of technical coefficients. Issues of capital formation and capital liquidation - to recall Lowe's words - are not in the foreground.

If technical progress consists of a simple reduction of technical coefficients, it can be analysed by comparing equilibria; each exhibits a productive structure already completely adjusted to the newly dominating technology. The process of transition, in the sense of "what happens on the way", fades away, and the "traverse" can be treated as a stability problem, identifying the conditions for convergence to a new equilibrium.

The traditional representation of technical progress, and the analysis of the "traverse" which is based on it, portrays a sequence of technological states which differ from one another with respect to the quantity of capital and labour and their combination, but, to use again Lowe's words, "is not able to offer an insight into the intervening processes during which new capital is being formed and labour is being trained". This has been clearly recognised by Spaventa, who treats technical progress as a simple reduction in inputs in his standard two-sector model, but cautions that "the real problems, however, still lie ahead. What happens if the two techniques employ fixed capital and if the machines appropriate to each of them are physically different? If this is the case, the stocks left over from technique 2 are not only quantitatively, but also qualitatively, inappropriate to the technique 1. These, and not the ones we have so far considered, are the true problems of transition" (Spaventa, p. 183).

Thus everything comes down to what is meant by technical progress. If the relevant aspect of this phenomenon is the process in which the productive capacity of the economy is transformed so as to acquire a different specification, and 2) the transformation of productive capacity requires the liquidation of old equipment and the building of new and different capital goods, then the problem cannot properly be dealt with in models having a horizontal sectoral structure; ie. "if the Method of Sectoral Disintegration is adopted...the time taken to make the machine is liable to be forgotten" (Hicks, 1973, p. 5).

But the time taken to make the machine - machines being the concrete expression of productive capacity - is the relevant moment of the process of acquisition of innovation; it is exactly the analysis of this moment which is lost in Lowe's model, in consequence of the hypothesis of circularity between sectors Ia and Ib. Sequential analysis is thus excluded at the most needed point. Circularity, in fact, implies that Lowe's "liberation of existing capacity, is in the first phase of the "traverse" merely involves "a shift in the physical aggregate that the two equipment-good sectors produce, in the direction of less secundary and more primary equipment". Thus, "the capacity that is located in sector Ib is freed in part from its original task of replacing and expanding capacity in sector II. This liberated capacity is now to be used to expand sector Ia" (Lowe, p. 110-111).

When a change in the technique is considered, however, the capacity liberated is to

be used to produce not only more but different capital equipment, which not only expands sector Ia but changes the way it works. As in the case of a change in the growth rate - where the stock of capital is quantitatively inappropriate to the new situation, but no problem of change in its physical identity is involved - there is again a simple transfer of machines from one sector to the other which starts the transition in Lowe's model. There is reliance on the assumption, common to all standard sectoral models, that old machines can be used to produce the new ones. "Any improved equipment must be initially produced with the help of preexisting, that is unimproved, equipment goods...Only when, in this manner, old ways have succeded in making improved primary or secondary equipment, will the application of such novel equipment reduce average unit costs of output" (p. 238). Circularity can thus be retained in presence of technical progress, and the reshaping of productive capacity realized through transfers of machines between sectors Ib and Ia.

Old ways of producing new equipment, however, clearly means that no change in the process of production takes place in the relevant moment of the embodiment of the new technology; that is, in the machine-making phase. This is why simple expansion of sector Ia can be identified as technical progress. Yet, the assumption that old machines, and old ways, can be used to produce the new equipment conceives of the process through which productive capacity acquires a different specification in the easiest way: it cancels it.

Capital in a dynamic context

Although useful for the understanding of the working of the economy, circular relations in production are an obstacle in the analysis of the process of innovation. A model which hypothesizes a horizontal sectoral structure implies that capital goods exist in their own right and can take part in different processes of production. In Hick's view, when innovation is considered, "it is undesirable that these goods should be physically specified, since there is no way of establishing a physical relation between the capital goods that are required in the one technique and those that are required in the other (Hicks, 1970, p. 193). If we want to maintain this relation, if we want the capital goods to go on serving as a link between two different technological states assuming that old machines can produce the new ones, the process of acquiring the new technology to the simple and istantaneous shifting of existing equipment to a different task and/or to a different compaartment of the economy.

In Hicks' view "The only relation that can be established (between the old and the new technique) runs in terms of costs and of capacity to produce final output; and this is precisely what is preserved in an Austrian theory" (ibid). In other words, capital goods must be dealt with in a different way, and this, in turn, requires a different way of conceiving the process of production. In the Neo-Austrian full vertical integration model, fixed capital goods are implied, but they are regarded as intermediate products; they become the particular expression of each given kind of process, and cannot exist outside it. Only labour, uncommitted unspecified labour, will be present at the moment one technique gives way to another: this conception requires a completely new start of the process of production for each innovation, and analysis of the phase during which the process itself acquires its new profile, building its own specific equipment in its own original way.

While this is as far as Hicks goes, it is possible to envision farther reaching developments. In a thoroughly dynamic context "technique" cannot be reduced to a mere combination of physical inputs petrified in a given piece of equipment, but must be seen as a time articulated sequence of phases in which the machine, in the traditional sense, is

only one aspect (and in some cases not even a significant aspect). This calls for a reconstruction from a much wider perspective. Further, the question of how to deal in this new framework, with the concept of capital and the respective roles of capital and labour in the process of innovation, opens a whole new field of analysis. All that is still virgin land which has become opened to exploration by the breakthrough which Adolph Lowe and John Hicks have made in the traditional body of theory.

References

Mario Amendola, "Modelle neo-austriaco e transizlone fra equilibri dinamice." Note Economiche, November, 1972.

J. R. Hicks, Capital and Time, Clarendon Press, Oxford 1973. "A Neo-Austrian Growth Theory", Economic Journal, June 1970.

J. R. Hicks, Economic Perspectives, Clarendon Press, Oxford.

A. Lowe, The Path of Economic Growth, Cambridge University Press, Cambridge 1976.

R. Solow, "The Interest Rate and Transition Between Techniques", Socialism, Capitalism and Economic Growth: Essays Presented to Maurice Dobb, ed. C. H. Feinstein, Cambridge 1967.

L. Spaventa, "Notes on Problems of Transition Between Techniques", Models of Economic Growth, eds. J. Mirrlees, N. H. Stern, MacMillan, London, 1973.

Footnotes

1. Lowe's book, "The Path of Economic Growth," in effect, takes up the problem of the "traverse" in general, and not only the case of a transition between techniques to which on the contrary Hicks devotes the whole of his analysis. It is just this case, however, which appears to be the most interesting for its implications in terms of dynamic analyis.

2. The two terms can be used indifferently in most of the models where, as we shall see, changes in the growth rate and technological innovations are treated in the same way.

3. This is the case in Solow's circulating-capital-goods model proposed for the analysis of transition between two equally profitable techniques at the switch-point of a wage-interest frontier, in "The Interest Rate and Transition Between Techniques", Socialism, Capitalism and Economic Growth: Essays Presented to Maurice Dobb, ed. C.H. Feinstein, Cambridge 1967.

4. A higher (lower) steady-growth rate requires in fact a greater (smaller) relative size of the capital-good sector.

5. This is in fact quite different from a stability analysis. As Hicks points out, "even if we were assured (as we may not be) that the model has a tendency to coverge to a new equilibrium, it remains a matter of importance what happens on the way", Capital and Time, p. 11.

6. "The problem with which we shall be concerned...is the determination of the path of our economy when it is not in a steady-state. Such a path must have a definite time-reference, for out of steady-state one point is not like any other. In particular it must have a beginning...One would like to assume that this initial state (taken as given) is itself...the result of a transition which is still incomplete; but a state of that sort we do not yet understand. So it seems inevitable that we would begin from what we do understand, that we should begin with an economy which is in a steady-state is subjected to some kind of disturbance", "1973", p. 81. Lowe, on the other hand, writes "Our task consists in examining the initial impact of the technological change on a preexisting, dynamic equilibrium, and in elaborating the structural and motorial conditions for the establishment of a new dynamic equilibrium after the innovation has been absorbed", (1976, p. 249).

7. Hicks considers in particular the simple case of two phases: a construction phase, during which the machine embodying a given technique is built, and an utilization phase, during which the machine is used for the production of the consumption good.

8. The relation between the construction phase and the utilization phase, which determines the time-profile of the process of production in the simple case proposed by Hicks is of paramount importance, in this context. It is, in fact, what happens during the construction phase, and the time required by the latter before the utilization of the new machines can begin, which makes it possible to sort out the relevant phenomena of a process of transition. In particular, the highly controversial issue of technological unemployment is dealt with in a systematic way, and a proof of Ricardo's "machinery effect" (the introduction of machinery has an adverse effect on employment in the short run) is the outcome of a particular kind of innovation. For an extension of the "machinery effect" to all cases of technical progress in processes of production with a more general time-profile, see M. Amendola, (1972).