Università Cattolica del Sacro Cuore

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E SVILUPPO ECONOMICO INTERNAZIONALE

Resources and Economic Dynamics, Technology and Rents

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Abstract

The essay investigates non producible (natural) resources and rent from three points of views: stylized facts, quantitative economics and economic theory.

Taking the first point of view, the author discusses how economic growth can be represented in terms of never-ending tension between scarcity and technical progress. At least since the onset of modern economic growth, whenever scarcity produced a slowdown of growth, technical progress followed and scarcity was thereby removed. Scarcity, in a long-run perspective, has always been of the «relative» type, while absolute scarcity never set in. This essay consider this problem from many points of view.

First of all it considers the point of view of quantitative economics like those of Simon Kuznets and Wassily Leontief who emphasized the relative character of scarcity and the importance of keeping the relationship between scarcity and innovation into account (this is especially true of Kuznets).

Secondly the essay considers the contribution of economic theory. In this connection, the author points out that both the macroeconomic and multi-sectoral models developed since the 1930s overlooked the investigation of scarce natural resources and rent, as well as their relationship with technical progress. Only Piero Sraffa examined non producible resources and rent but he has done it in a single-period model.

The author of this essay investigated the same issues in a more general analytical set-up starting with a contribution published in 1967 followed by many others. Later on, Quadrio Curzio and Pellizzari, especially in the 1996 volume, analyzed the general

relationships among production, prices, income distribution, technical progress and growth when scarce resources play a significant role. Those contributions also investigated the nature of technological rents, which are an important feature of modern economic growth in the presence of technical progress.

At the same time Quadrio Curzio, in collaboration with Marco Fortis and Roberto Zoboli, analysed historical, quantitative and qualitative aspects of economic dynamics, and the way in which natural resources and raw materials exert an influence on economic growth and more generally economic dynamics. Those aspects are not fully considered in the present essay, but they represent its fundamental background.

Finally in 2008 Quadrio Curzio, Pellizzari and Zoboli outlined in a valuable encyclopaedic dictionary a compact synthesis of the above approach to the economic analysis of raw materials and primary commodities.

The essay takes a point of view which is not typical of the «post-Keynesian» approach, yet it belongs to a post-classical perspective that is closely connected to the Italian-Cambridge tradition of political economy as a social discipline. Tradition on which Alberto Quadrio Curzio, especially researching with Roberto Scazzieri, focused his attention in many essays from a methodological point of view.

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1. Introduction[1]

Within the so-called post-Keynesian framework little attention has been paid to the role of natural resources and raw materials in dynamic processes and to the consequences for the technology choices and income distribution along the patterns of economic growth. These aspects, which are becoming more and more important also in relations to environmental problems, are instead investigated within theories stemming from classical economic thought. There are similarities between the post-Keynesian approach and the post-classical approach especially because they converge in combining theory with reality and history (of facts and ideas) with a particular focus on development and its governance. For this reason, I think that the so called Italian-Cambridge school (that sometimes is called post-Keynesian school) is a combination of post-Keynesian and post classical political economy which also includes the contribution of many other non-mainstream economists. In fact we are convinced that the discipline of economics has become a science whose advancement is based on the contributions of many scholars rather than individual geniuses. Accordingly, we can find similarities with a number of economists who were neither direct nor indirect adherents of Keynes, but rather belonged to post-classical economists who aimed to combine theory and facts.

I am convinced that all these contributions are useful and should be evaluated in the context of the entire range of economic thought.

This essay concerns the topic of "resources, technology and rents" from the perspective of historical-economic and economic

[1] This essay is the English version of the article *Risorse e dinamica economica, tecnologia e rendite*, published in *Gli economisti postkeynesiani di Cambridge e l'Italia*, Atti dei Convegni Lincei, n. 261, Accademia Nazionale dei Lincei, Scienze e Lettere Editore Commerciale, Roma, 2011, pp. 409-432.

theory stylizations that has been often neglected by so-called pure theory but fortunately addressed by "applied theory".

Initially, I have developed a theoretical approach on this issue (Quadrio Curzio, 1967, 1975). Subsequently, it has been generalized – from the theoretical point of view – in cooperation with Fausta Pellizzari (Quadrio Curzio and Pellizzari 1996) and – in terms of application – with Marco Fortis and Roberto Zoboli (Quadrio Curzio and Fortis 1986, Quadrio Curzio, Fortis and Zoboli 1991, 1994).

After near lifetime dedicated to this research on a topic that has taken a back seat in the Italian debate (and having oriented many economists at this topics), I feel that I am justified in self-quoting, even if it may be considered not pretty elegant.

One objective of this essay is to clarify how the study of economic theory (if not a formal exercise) is based on stylized economics history and economic analysis history, which identify the stage in the development of science and reality in which the theory fits or is reputed to fit. I know that every work in the field of economics entails a dilemma over analytical rigor versus interpretative relevance; this dilemma is less antagonistic in economic theory, which is composed of at least three parts: a formal analytical component; a historical-quantitative component; and a quantitative component. All three approaches use different methods but can all be considered "theories" in that they lead to generalizable interpretative propositions. If this were not the case, the first would be an exercise in tautology, the second a description without interpretation, and the third would be an exercise of calculus but without a convincing explanation. In the following reflections I refer to the contributions of formal-analytical economic theory, but only after an introduction of stylized economic history, historical-quantitative economic theory and quantitative economic theory.

This work should also be seen in the context more specifically of the history of economic though on resources-technologies-

dynamics. It would be interesting to examine the stances taken in classical and marginalist theory in this regard but this would be too much of a diversion (for a survey of these theories see Quadrio Curzio 1997). Therefore, I start from the 1930s and show how some canonic post-Keynesian theories totally disregard this thinking, while other post-classical theories deal with it. Some specific directions of theoretical analysis that persist include: growth without scarcity (begun by Harrod and von Neumann); complex development and relative scarcity (initiated by Kuznets) and the analysis (begun in the 1970s by Leontief) of the dynamics in natural resources and relative scarcity.

Yet none of these lines of economic thought appear sufficiently general to be projected into the current resources, technology or rents arguments whose principal historical-theoretical roots can be found in Ricardo (and to an extent in Marshall). In the early 1960s Sraffa pursued this course but his contribution referred to a single period and a multi-sector context.

For these reasons I feel that the model I proposed provides a contribution to the study of natural resources, complex and dynamic scarcity, and rents.

2. Definitions and stylizations: scarcity is relative and technological

First, it is useful to outline the basis of my reasoning:

- *resources*: mainly natural resources but also those from the broadest categories of relative and absolute scarcity, static and dynamic scarcity, innovative scarcity and technological scarcity;

- *technology*: as an expression of the antagonism-synergy between scarcity and innovation, technical choices, technical progress, and the relations between scarcity and producibility;

- *rents* in the categories of extensive and intensive rents, surplus rents, differential rents, marginal rents, quasi-rents, structural rents and technological rents. I trace all income distribution back to these levels.

It is also useful to recall economic history and some stylized current events, in order to make explicit the complexity (and our awareness of it) of this topic in the economic past and present.

a) Resources are scarce

The main focus is on natural resources, the raw materials derived from them and their scarcity, topics in which stylized economic history has taken a great interest. This interest focuses mainly on quantitative scarcity and often has oscillated between the conceptions of absolute scarcity and relative scarcity, the first being unchangeable and the second disputable and in many cases possible to eliminate with technical progress and technological substitution. The concept of no scarcity has also been considered.

Natural resources can be renewable, for example, agricultural and forestry resources, or non-renewable, for example minerals. But all may be exhausted if consumed to excess. Renewable resources, such as agro-forestry products, may be reconstitutable but sometimes only in the very long term. Amounts of non-renewable resources may be boosted through artificial, recycling processes or extensive (new mines) or substitution processes.

Until recent decades, with some exceptions, many natural resources were not considered to be in danger of being exhausted. No consideration was given to the use of natural resources not seen as posing direct threats to production and/or consumption processes, or those needed to generate other potentially scarce raw materials. Natural resources were considered to be free goods and resources, such as air and in some cases water, and were undervalued.

Today we know that all environmental resources are scarce and are becoming more so due to their heavy exploitation in manufacturing processes and their excessive consumption; the rate at which they are being consumed, in many cases, appears to be much faster than in the past. Furthermore, the chain of raw material-natural resource-environment is more complex than the partial raw materials-natural resources chain. An example here is wood which is a raw material derived from forests and is renewable although often only very slowly. Deforestation, in its turn, affects the atmosphere and the climate, thereby affecting other natural-environmental resources, whose recovery is extremely uncertain. Even the phenomenon of pollution of natural and environmental resources, such as water and air, translate into indirect consumption for the purposes of production (industrial pollution) and consumption (civil pollution).

It is useful, therefore, to remember that in the identification of two types of natural resources there are overlaps. These two types are directly productive and environmental natural resources and correspondingly, raw materials for direct production and environmental raw materials which, indirectly and aside from market relations, are a part of production and consumption.

Our analysis deals primarily with (but does not stop at) directly productive natural resources and raw materials and the related means of production, both renewable and non-renewable but scarce in terms of demand for raw materials.

b) In the past scarcity was relative

If we glance at economic history and current trends, we find continual references to the scarcity (quantitative and/or qualitative) of natural resources and the concomitant slowing of economic growth but also consequent and independent innovation [Antonelli and Quadrio Curzio (editors) 1988; Quadrio Curzio, Fortis and Zoboli 1994; 1996].

There is no doubt that, throughout the centuries, situations of acute scarcity of natural resources and raw materials have oc-

curred but then the choice of techniques and technological innovation have removed or extended the boundary of scarcity. It is clear also that at least some innovation was generated by a scarcity of natural resources. Thus the long-term dynamics and growth of today's industrialized economies can be interpreted, at least in part, as their multiple and sometimes unexplainable causes, and in the light of the principle of antagonism-coexistence-synergy between the scarcity of natural resources and raw materials on the one hand, and the producibility of goods on the other.

The scarcity of natural resources has helped to generate technical and economic progress which has modified the antagonism between resource scarcity and the producibility of goods, transforming it into synergy. This transformation emerges in many ways: through the transfer of natural resources from unusable to usable areas thus increasing the endowment of natural resources of a given quality; through the substitution of scarce resources with other abundant and previously unusable resources made possible by new technological knowledge, and/or through substitution with means of production and produced goods; by reducing the demand for natural resources and raw materials per unit of production or by increasing the productivity of natural resources and raw materials.

From another perspective, we could say that, historically, technical and economic progress has increased the "distance" between natural resources and raw materials on the one hand and the demand for finished goods and the means of production on the other. A similar difference between industrialized economies and developing economies can be expressed in similar terms: in today's industrialized economies technical progress has tended, albeit not continuously, to distance (original) natural resources from demand for goods and raw materials, reducing direct pressure from the latter on the former; in developing countries, however, the pressure on natural resources has increased due to a combination of more and faster growth and relative technological backwardness.

The above arguments can be applied to many historical, global and specific contexts. For example, we could analyze the three economic revolutions that have occurred since the 17th century: the geographical-mercantilist revolution, the industrial-technological revolution and the scientific-technological revolution [Quadrio Curzio 1993a]. The first exploited new natural resources but did not generate technological distance between natural resources and final demand; the second, based on energy produced by machines, introduced a new "force" different from that produced by human beings and natural agents (wind and water), and involved "contradictions" between natural resources, from which very high yields were extracted, and the use of "new" raw materials and significant substitutions, alongside increased demand for raw materials in order for production to grow; the third technological revolution was motivated by the industrial revolution which produced a new abundance of processes and products on the one hand, but also at least two types of scarcity of environmental and natural resources. These scarce environmental and natural resources were addressed by biology and genetics studies, innovations in new materials, atomic energy, telecommunications (and many others) in a continual process of invention-discovery-innovation.

An impressive amount of important analysis has been done on these topics (among the most recent, see Mokyr, 1990) leading to the conclusion that economic history is a component of "innovative scarcity", that is scarcity, which generates innovation but which also creates new and different forms of scarcity, which, until now, have been relative. However, this cannot be guaranteed in the future.

All this legitimizes the continued study of scarce resources because although scientific and technological innovation seems to be able to solve many problems, it may not do so in a sufficiently short time to prevent the emergence of new scarcities. In addition, the translation and application of the innovation may be neither institutionally nor economically feasible or desirable.

For example, although the age old fear of agro-food scarcity in relation to population numbers would appear to have been overcome, we are being faced by another scarcity, that is, environmental scarcity. Although the problems related to the environment have been known for some time, they have never caused such generalized anxiety as concern over agro-food scarcity. However, it is now being realized that environmental scarcity, in some cases, could be extremely dangerous due to its changeable, transnational and often less identifiable character, and it could emerge in particularly threatening ways or with uncertain reversibility [Quadrio Curzio, Fortis and Zoboli 1994].

Since environmental resources are consumed in many ways (including direct consumption in the form of exploitation of land, forests, water, air, etc. and indirect consumption through waste dumping, industrial pollution and pollution stemming from urbanization and consumption) the problem and its spread are such that it is difficult to say whether we are faced with absolute scarcity, which then must lead to an overall slowdown in economic growth, or relative scarcity which can be overcome by scientific-technical progress and education. Much will depend on the dimensions of the cumulative planetary effects of resource use and pollution, demographic dynamics and their geographical distribution-concentration, the degree of political, institutional-legal, economic and civil awareness of the problem, and ongoing scientific and technological research [Quadrio Curzio, Fortis and Zoboli 1994; Quadrio Curzio and Zoboli 1995].

It must be accepted that a world without natural scarcity constraints does not exist and cannot be enabled by a post-Keynesian interpretation.

c) Technology has solved scarcity problem till now

If it is true that stylized economic history demonstrates how scarcity of natural resources so far (and thanks to scientific and

technological innovation) has turned out to be "relative scarcity", it is also true that there are "technological scarcities".

Relative scarcities have always at times been extremely binding and they have often extended over long periods. Qualitative scarcities are becoming increasingly important and a relative scarcity for an individual economic system might be an absolute scarcity for the planet in its historical process. The decline of some scarcities is always associated with the increase in other scarcities.

Technological scarcities coexist with relative scarcities in the same way that technical progress can remove them. The attenuation of scarcity thus depends on science and technology, just as the management of scarcity depends on legal norms and national and supra-national institutions.

The "translation" of these scientific and institutional factors of progress and civilization into economic terms of production and markets that are non-corrosive of the stock of natural and environmental resources, is what will make the difference in this historical period compared to previous ones. The needs of the market sometimes lead to solutions that are damaging to scarce resources and the environment; appropriate investment in research and technology could avoid this. Solutions that are damaging in the longer term need to controlled by laws and institutions, which must impose constraints precisely to prevent the emergence of additional irreversible scarcities.

The analytical-formal treatment adopted here does not address laws or institutions, which is not to say that their importance for economic and civil development, in the past, the present and the future is and will be very great. Here I focus on technology, choice of techniques and technical progress. Thus, the concepts of technological scarcity and natural scarcity and technological innovation described above constitute the starting point for a theoretical analysis of past and present reality.

Most of us are aware that mankind, for many years, has had to deal with problems related to of natural resources and raw materials [Quadrio Curzio 1993a; Antonelli and Quadrio Curzio 1988; Quadrio Curzio and Fortis 1986; Quadrio Curzio, Fortis and Zoboli 1991; 1993; 1996], and the historical and current aspects are numerous to address in this essay. They also cannot be reduced to the summary criteria proposed here. However, I believe that the analysis provided here brings economic theory a little closer to stylized economic history, and also to the applied economics pursued and promoted by publications such as *Materie Prime* (Raw Materials) and *Innovation and Raw Materials* (Innovation and Raw Materials) journals[2] , within a significant context that is highly significant given the contributions of highly qualified analysts and scholars.

It is also clear that the enormous complexity of economic development cannot be reduced only to the role of technological factors and substitution of scarce natural resources. Thus the concept of technological scarcity encompasses both optimism and pessimism: on the one hand, the possibility of overcoming scarcity with innovation; on the other hand, the scarcity of innovation; and finally the economic-civil applicability of innovation. This points to the need for prudence in considering economic dynamics without constraints and legitimizes the study of scarce natural resources.

3. Economic theories with a historical and analytical-quantitative imprint

The first line of research in this context is the historical-quantitative theory of growth and development which began, or

[2] Both *Raw Materials* and *Innovation and Raw Materials* were quarterly journals; the former published by Nomisma from 1982 to 1990, and the latter published by Montedison from 1992 to 1993.

rather was taken up again in the 1930s with the fundamental contributions of Simon Kuznets [for an excellent collection of essays see Kuznets 1990 and Castellino's introduction].

Kuznets felt that attention should be focused on long term dynamics, as in classical economics, and on secular dynamics which involve shorter cycles. He analyzed around a hundred statistical data series of quantities and prices, for the United States and four other countries, which led to the identification of secular trends with the joint presence of short term cycles, longer cycles, and "secondary secular movements", now known as "Kuznets cycles".

Kuznets also examined the importance, in various historical phases, of the nations and the economic sectors that had led development. He extended this historical-quantitative approach in many subsequent works devoted to the main themes in development, such as relations between demographic trends and economic development, the influence of technological innovation, structural transformation, historical income inequality trends, capital accumulation, and the limited international diffusion of development.

The complexity of development emerges from this historical-quantitative theory, and what interests us here are the references to natural resources and the environment. In particular there are four points in Kuznets' theory that intersect with these problems:

- his examination of the structural transformation of the economy and agriculture;
- his examination of capital accumulation;
- his analysis of technological innovation and its significance in terms of energy and industrial materials;
- his analysis of the impact of innovation on the environment.

I do not examine these aspects in detail here, but would suggest that ultimately Kuznets is optimistic about the ability of technology to respond, through the mechanisms of adaptation, to the negative effects on the environment that it initially may induce. His reflections in this context are summarized as follows:

"In the first place [...] resources are a function of technology [...]. Secondly, the long time span associated with the major technological innovations and their features of newness make it nearly impossible to foresee the final effects, both positive and negative, and thus to prepare for them. [...] Thirdly, in the past economic growth and technological innovations implied serious processes of general environmental deterioration, which in the end were overcome albeit with difficulty. [...] Fourthly, based on experience we can hypothesize that now, thanks to the available knowledge and technology, processes of adaptation to the negative effects of technological innovation will take place in terms of the exhaustion of resources and environmental deterioration. [...] Social and political obstacles are probably greater than the limits posed by our technological abilities" [Kuznets 1990, pp. 162 ff.].

The other analytical-quantitative theoretical research direction of interest here is the work of Leontief [Leontief *et al.* 1977] on natural resources.

It is important to remember that this contribution from Leontief is included by some in the elaboration of "global models" that began in the 1970s. I am less convinced about this classification for two reasons. First, Leontief relies on economic theory while the "global models" are forecasts without theory. Second, Leontief to some extent reacted to these "global models" which provided very pessimistic forecasts about the exhaustion of natural resources and the risk of a collapse of the global economy, thus sustaining more or less explicitly a conception of the absolute scarcity of natural resources from which descended proposals for achieving a generic condition of ecological and economic stabili-

ty, a sort of stationary state [Meadows *et al.* 1972]. Leontief's work, in contrast, is a model of the global economy based on a solid conception of economic input-output theory which reaches conclusions about the relative scarcity of natural resources-raw materials. It is composed of various input-output sub-models connected and related to the same number of regions in the world for which the interrelations between the production and the consumption of goods, services and natural resources are analyzed. In my view, Leontief's approach, which is very similar to that of Kuznets, can be summarized as follows:

"the main limits to sustained economic growth and accelerated development are political social and institutional rather than material. In the 20th century there is no insurmountable material barrier that can inhibit the accelerated development of developing regions..." [Leontief *et al.* 1977].

A renewed interest in "global models" has developed alongside with the anxiety about the climate change in recent years since the latter has been perceived to be systemic in nature. The growing production of "global ecological models", and especially "climate models", and multidisciplinary models of the large scale interactions between ecological and social systems, has been accompanied by a resurgence in the design of global models in the tradition of the 1970s, or along similar lines. However, these models has been critically revised since they were considered as generic, partial and fallacious by their authors (Meadows *et alt.* 1992).

The contrasting approaches of Meadows [1972] and Leontief [Duchin and Lange 1994], that is, of absolute scarcity and relative scarcity, have been re-addressed in writings that draw directly on both schools of analysis, now directed towards "extended" resource-environmental scarcity.

The different evaluation of the possible impacts of innovation and the mechanisms it generates, appears still to be the main fac-

tor dividing these two approaches, and also in the most recent version oriented towards the environment.

4. Formal-analytical economic theories - with growth and without natural scarcity

I now move on to formal-analytical economic theories.

Ideally, this would require an introduction starting with the classical economists (Quadrio Curzio, Pellizzari, 1996; 1999 chapter 1). Yet, here this is not possible. Notwithstanding, it should be remembered that the classical economists, in particular Ricardo, tried to take account of the phenomena that we have stylized, but ended up overestimating the scarcity of natural resources.

Marginalists had a different conception of scarcity in which the concept of natural resources was less important (with the exception of Marshall's analysis) than a generalized system of allocation of scarce resources.

From the 1930s the role of scarcity and natural resources was underestimated. It is difficult to put these theories into a single category although many were of the post-classical type in terms of their attention to the phenomena of global dynamics, production and accumulation.

The reasons for this interest, which began in the 1930s and 1940s, are many but there are two principal schools of thought which took up the analysis of dynamics in the 1930s. The first is Roy Harrod's macroeconomic theory [1939, 1948] which reconnects with the Keynesian approach and which examines capital accumulation, the dynamics of the labor force and technical progress. The other is John von Neumann's multisectoral theory [1937] which deals with the problem of maximum growth and which, albeit with many significant differences, in its multisec-

toral approach reconnects to Leontief's framework of industrial interdependencies [1941] and his dynamic version [1953].

The aim is not to reexamine the various lines of study of the dynamics in these contributions but to point out their similar approach to natural resources, raw materials and rents in these dynamic processes: all neglect, exclude or underestimate them.

A few quotes from Harrod's macro-dynamic approach and von Neumann-Leontief's multisectoral approach are illustrative.

a) Aggregate models

Let us consider here the various models, which in themselves are rather heterogeneous.

Roy Harrod, after summarizing Ricardo, wrote the following:

"The [Classical, author's note] dynamic theory was crude, in part untenable as universal law, and in part untenable altogether. [It, author's note] had two aspects.

There was 1) the theory of motive power, and 2) the theory of progressive redistribution ... accumulation was the motive power...In this approach there are two propositions in the classical system which can be tentatively discarded. One is the population doctrine ...changes in it may be regarded as exogenous changes. Secondly, I propose to discard the law of diminishing returns from the land as one of the primary determinants in a progressive economy. I discard it only because in our particular context it appears that its influence may be quantitatively unimportant" [Harrod 1948, pp. 18 and ff.].

Essentially, Harrod, hypothetically and albeit with a degree of caution, excludes scarce natural resources, on the rather questionable basis that they have a negligible quantitative impact. But his underestimation of natural resources and rents, or more generally scarce resources and rents, is rather generalized, as shown

by an important review of the theory of growth by Hahn and Matthews [1965].

The contributions to the theory of growth can be classified as being within the two camps of Neo-Keynesian and Neoclassical theory. Among the "prototypes" of the Neo-Keynesian camp we see that Kaldor [1955-1956] says nothing about scarce resources-rent, but that Robinson [1956] addresses them rather extensively. Although Robinson's approach contains many original points, it is still limited by a historical conception of land and rents in agriculture. Among the Neoclassical theorists, Solow [1956] assumes that there are no scarce resources that cannot be increased, arguing that the introduction of a scarce "land" factor would lead to Ricardian diminishing returns. In contrast to the Neoclassical approach, Meade (1961) considers land and rent in an original fashion but in our opinion still with a rather weighty historical legacy.

In other words, in my view, on the topic of land and rent, Robinson and Meade look backwards instead of forwards. However, their views remain exceptional because the general approach to these themes is one of indifference.

b) Multi-sectoral models

Von Neumann, who proposed the multi-sectoral model, wrote that:

"... goods are produced not only from 'natural factors of production', but in the first place from each other (von Neumann, 1937, p. 1); "... natural factors of production, including labour, can be expanded in unlimited quantities" (*ibid*, p. 3)

thus excluding the existence of scale constraints on natural factors of production, although he does recognize that they play an important role in the production process.

Leontief [1941; 1953] is more cautious. While his theory takes account of all the sectors that transform primary commodities, he does not examine the scale constraints that natural resources impose upon the production system. Leontief's proposition, which seems incisive regarding natural resources, as follows:

"Invisible in all these tables but ever present as a third factor or rather as a whole additional set of factors determining [US] productive capacity and, in particular, its comparative advantage vis-à-vis the rest of the world, are natural resources: agricultural land, forests, rivers, and our rich mineral deposits. Absence of systematic quantitative information, similar to that which has been collected, […] with respect to capital and labor, prevents us as yet from introducing this important element explicitly into this preliminary analysis." (Leontief, 1953, p. 96).

Although other economists in later works deal with scarce resources and rents we do not include them in this review but immediately refer to a scholar of the theory of growth, Pasinetti, out of appreciation for his multi-sectoral analysis of the theory of production, distribution and growth. Pasinetti constructed:

"... a theoretical model for an industrial economic system … of pure production [in which, author's note] all considered commodities are produced, and can be made in practically whatever quantity may be wanted, provided that they are devoted that amount of effort they technically require.

To avoid unnecessary complications, scarce resources will not be considered. This does not imply any disregard of the problems of rationality. [...][furthermore, editor's note] the procedure does not mean that natural resources are assumed to be homogeneous and non-scarce [...][but only that, editor's note] the basic theory will be developed *independently* of the optimum allocation of scarce resources." (Pasinetti, 1981, pp. 23-24)

Two remarks can be added to Pasinetti's propositions, deriving from the theory we have been developing over many years. The first is that including scarce resources in a production model turns out to be a very complex operation whose results profoundly change a pure theory of production and growth, based on formulations developed over many years. The second observation is that the problem of scarce resources, when natural resources are also included, in our opinion does not depend on rational choice and optimum resource allocation. Even Pasinetti [1981, Ch. IX), referring to his model, differentiates between choice of technique and change in technique, topics that he wrote on extensively. However, the problem is even more complicated by scarce resources resulting from the existence of multiple possible orders of succession of techniques and their composition in technologies.

These macroeconomic and multi-sectoral theories remain extremely significant contributions in terms of understanding the dynamics, technology, technical progress, accumulation and dynamics of quantities, prices and distribution, and explain most but not all of the economic dynamics from a theoretical point of view.

It would seems, however, that these scholars position economic analysis at the extreme opposite to the Marginalist approach, passing from general static scarcity to absolute dynamic producibility and forgetting that there can also be relative dynamic scarcity, of which natural resources are an important expression. The choice of these analytical-formal theories is understandable from the point of view of "theoretical specialization"; however, they are unacceptable for interpreting all of reality, even in a stylized manner.

5. Scarce resources and uni-period structural rents

None of the theoretical-analytical treatments presented above include specific analysis of production [for a review of the theory of production see Kurz and Salvador, 1995] or distribution [for a review of the theory of distribution see Quadrio Curzio 1993b], which, with sufficient degree of generality, includes scarce resources and rents.

Sraffa, in *Produzione di merci a mezzo di merci. Premesse a una critica della teoria economica* [1960], developed a multi-sectoral model of production, distribution and prices, which partially foregrounds a Ricardian approach to "land", "natural resources" and "rent", but unfortunately did not extend this theory to dynamics.

The literature on this author is extensive. Yet, the aspects of Sraffa's theory that interest us here are:

a) Natural resources and non-basic goods. The first aspect is the combination of *scarcity* of natural resources and the *circularity* of production processes. "Land", synonymous with a particular type of natural resource, is included in a multi-sectoral and circular representation of production. This inclusion might appear incompatible with the principle of circularity and was implicitly or explicitly evaluated as being so by various economists who thus considered Sraffa's Chapter XI entitled *Land*, secondary to if not incoherent in terms of the central topic, the production of goods.

On this basis, we can argue that, in spite of his originality, Sraffa attributes to "land" a rather limited role. Furthermore, his approach in explaining the interruption of the circularity of production of commodities by means of commodities due to the presence of a non-produced means of production, leads also to this conclusion based on his comparing two formally symmetrical magnitudes in his model, e.g. non-basic natural resources and commodities.

b) Structural rents. This is the second aspect of Sraffa's contribution although he does describe it as such. Note that for Sraffa scarcity is important not because it is a condition of growth, but because it influences prices and distribution and because it explains rents. In our definition, rent is structural insofar as an economy's structure and level of production entail at least two processes that use land and produce the raw material itself. This leads to differential rents for more productive land, and zero rents for non-productive land, which with other processes that do not use land, determines the prices of commodities, the profit rate or the unit wage. According to Sraffa:

"if different qualities *n* of land are used, they will give rise to an equal number of different methods of grain production ... there will thus be *n* equations of production to which the condition shall be added that one of the types of land will not give any rent" [Sraffa 1960, pp. 94 ff.].

For intensive rent:

"if the quality of the land is uniform and its availability is limited, this in itself makes compatible the use of two different production processes on similar types of land ... one next to the other thus determining a uniform rent per hectare" [*ibid*., p. 96].

In other words, if the profit rate or unit wage are given exogenously, and assuming that the level of production requires the activation of two or more processes with land, the rent for each of these processes is determined by the relative structure and efficiency of the production process.

c) The order of fertility: an open question. The third aspect regards the problem of the order of fertility of various types of land. Sraffa points out that a natural order of the fertility of land does not exist. Let us consider a case of extensive cultivation which involves various processes, some of which use different pieces of land, and others that do not use land, but all of which

produce the same commodity. The fertility of each piece of land could be unambiguously identified in physical terms only if the production processes for each piece of land could be ordered in physical terms of input and output, which is absolutely unrealistic:

"The order of fertility ... is not defined independently of rents [and therefore of prices, author's note]; this order can vary with the variation in profit rates and unit wages" [*ibid.*, p. 95]

With these propositions Sraffa opens up the problem of the inexistence of an "order of fertility" and the problem of changes in the order of processes that use "land", which however he does not solve.

And this is where the problems with Sraffa's theory begin.

While on the one hand his approach to resources-scarcity-rents is highly original and a starting point for the modern theory of rent, which also motivated this contribution, on the other hand in many ways it is only an outline. For example, because Sraffa's model deals with fixed quantities, it overlooks relations between variations in the price-distribution-rents system and those in the "land"-production-"wheat" system.

d) Quasi-rents. The final aspect of interest in Sraffa's theory is the concept of quasi-rents which opens up the possibility of applying the theory of structural rent to all non-reproduced means of production, regardless of their origin, scarce compared to the scale of production and operating alongside other means of production included in processes with different efficiencies.

6. Resources, dynamic scarcity, and technology rents

Thus, if we exclude Sraffa's contribution, treatment of natural resources, connected scarcity, rents, non-reproduced and scarce

means of production, and quasi-rents is largely neglected in the theoretical models proposed at the beginning of the 1960s.

This was the motivation for my multi-sectoral model which, builds on the theories of Sraffa, von Neumann and Leontief, and both centrally and organically takes account of "natural" or more generally "scarce resources" or non-produced or non-reproduced means of production and the commodities-raw materials generated by them, and "rent".

I developed two complementary and consecutive models, in 1967 and 1975, which subsequently were generalized. Here I provide a summary of these in order to linking the present to previous analyses.

a) Technological rent, order of efficiency and rentability. The first framework [Quadrio Curzio 1967] models uni-period situations and comparisons.

It was taken up and generalized in various subsequent works [Quadrio Curzio 1977, 1996; Quadrio Curzio, Manara and Faliva 1987].

These analyses can be summarized in two main points:

i) identifying the orders of efficiency and rentability of processes that use various scarce resources, and the effects of autonomous variations in income distribution and those induced by changes in levels of activity on these orders. The role of rent in distribution becomes central and significant, and changes the well known relations between wages and profits;

ii) identifying global technologies that include many processes to produce the same commodity, as well as processes that produce distinct commodities. This enables examination of variations in a technology's efficiency, structure

and scale, based on constraints stemming from the gradual exhaustion of scarce resources to increase production levels.

So, whereas surplus rent stems from differing land fertility, and structural rent derives from two processes, activated simultaneously to produce the same commodity, it is now "technological rent" that accounts for the broader aspects of a technology and its changes based on the effects of scarcity factors on the growth of production or changes in the income distribution and in the orders of efficiency among processes using scarce resources.

b) Relative scarcity and non-equiproportional dynamics. The second model [Quadrio Curzio 1975] developed by the author deals with dynamics and growth in a context of scarce resources. This model was broadened and generalized in various other works [Quadrio Curzio 1986; Quadrio Curzio and Pellizzari 1991].

The basis of it is "compound technologies" which include fixed coefficient production techniques, characterized by scarce resources and temporally connected to other techniques in the process of accumulation. The dynamics emerges at variable rates, depending on the various commodities and their complex problems of structural compatibility between techniques, from which we derive the residuals of accumulation, that is, of non-cumulative net products.

Thus, the significance of "technological scarcity" emerges, that is, there is scarcity not only of resources but also of techniques, constrained in scale and structure by the scarce resources.

On this basis, in *Rent, Resources, Technologies* [Quadrio Curzio and Pellizzari 1996] the authors carry out an analysis that on the one hand reproduces and generalizes the previous results, and on the other hand develops more general categories linked to technology, that depict situations of technological scarcity and technological rent.

In this book some principal lines of thought are identified, obviously with no pretence to provide a simplified re-explanation of the treatment which, among other things, involved a complex analytical apparatus enriched by a series of numerical simulations. Those interested in pursuing this further will find all Quadrio Curzio's previous analyses generalized and also other results.

b1) The multiplicity of orders of efficiency. A first line of thought generalizes the analysis of order of efficiency among processes with non-produced means of production that produce the same commodity-raw material. The following orders of efficiency are identified: physical; uniperiodical price-distribution; physical dynamics; value dynamics; and dynamic price-distribution. Each of these orders of efficiency becomes important under different conditions of the growth or accumulation of production for the decision about the sequencing of the processes with non-produced means of production.

b2) Compound technologies and orders of efficiency. A second line of thought relates to the changes imposed on technology by the presence of natural resources and non-produced means of production. If we recall the compound technologies scheme in which there are many techniques each characterized by a natural resource or a non-produced means of production, the "composition" becomes generalized. These techniques differ from each other but are then combined in the processes of accumulation and growth. This entails a complex analysis of orders of efficiency (physical-dynamic; value-dynamic; price-distribution dynamic) of the techniques and therefore the order of their activation in the accumulation and dynamics. It means also that there are various non-proportional dynamics according to the different structures of the technical matrices and different significance of the residuals of production which cannot be accumulated.

b3) Alternative dynamic paths. A third line is related to the modalities of the dynamics. As mentioned above, the maximum

modality model proposed by von Neumann, which is at a constant rate equal to the uniform rate of net product which is also the rate of accumulation, is no longer possible with non-produced means of production. The various alternative dynamic paths depend on time horizons, residuals of non-cumulative net product, whether or not they can be ordered, and gaps in each technique's internal growth rates. The multiplicity of cases makes it impossible analytically to identify them all. Analysis of the various cases points to two orders of dynamic efficiency: physical-dynamic and value-dynamic.

The problem of determining whether the dynamic orders of efficiency that ensure maximum growth are compatible with the price-distribution dynamic can be dealt with similarly. This is an important issue because the profit-operator, that is, the operator that guides accumulation and chooses technologies, adopts a behavior of following the price-distribution order of efficiency. This leads to the conclusion that a dynamic price-distribution order of efficiency can be found that will determine the choice of technologies that produces maximum growth.

b4) Dynamic income distribution. The fourth line of thought is the effects of accumulation and dynamics on income distribution between wages, profits and rents in terms of unit magnitudes, total magnitudes and shares.

Some interesting novelties emerge here in terms of depicting various coincidences or conflicts of interest between the respective operators that "control" a production factor and those that receive wages, profits and rents. In particular this analysis, which is limited to the case of maximum accumulation, enables us to assess the effects of growth on various categories of income recipients.

Here again the analysis shows that the features peculiar to the physical-technological system deriving from scarcity are decisive for income distribution. But, again, the most innovative aspect is

rent, which profoundly changes the distribution, throwing light on the complex interests of the operators in the process of accumulation.

b5) Technical progress and technological progress. A fifth line of thought is related to the identification of a complex series of types of technical progress (structural, natural, linear, absolute, and relative): in the compound technology model such progress can be classified only in terms of numerous variables. The distinction between progress inherent in a technique and progress inherent in a technology enables us to evaluate the interrelationships between technical and technological progress, and to determine their consequences in terms of the economic system's capacity for accumulation and growth and the lessening of the constraints imposed by non-produced means of production.

Changes in prices and income distribution owing to technical and technological progress allow us to identify additional categories of rent connected to various types of progress and therefore to evaluate the interests of the various operators promoting their introduction.

7. Conclusions

This essay focused on a theoretical model initially proposed by the author and then generalized with co-authors, is founded on historical-stylized "premises". After the model was generalized in the 1996 book written with Fausta Pellizzari, it began to be used in an environmental context [Quadrio Curzio and Pellizzari 2004], where the model has undiscovered potential. Other presentations of the theory have been made [Quadrio Curzio 1998 and 2003] and it is important to stress their inclusion [Quadrio Curzio, Pellizzari, Zoboli 2008] in an encyclopedic work devoted to the theory in its widest context, as well as to reality, politics,

and history. Because our formulation fits with these contexts, it is also useful for analyzing reality and informing policy making[3].

We believe that this model shows that scarce resources, natural resources and raw materials on the one hand, and technological scarcity and the technological rents associated with it on the other hand, play very important roles in the phenomena of production, distribution, accumulation, growth, choice of techniques, and technological progress. The findings are significant and challenging for the conclusions deriving from multi-sectoral models in the absence of scarce natural resources, raw materials and non-produced means of production.

At the same time, I am aware of the partial character of this analysis, which would be difficult to classify as a post-Keynesian theory according to a purist definition. However, it can certainly be considered a post-Classical theory, combining theoretical analysis and economic history with an important focus on the unification of these two components enabled by the history of economic thought. This is the methodical approach that Roberto Scazzieri and I cultivated over many years, developing it in various studies [Quadrio Curzio and Scazzieri 1983; 1986; 1989], in which we also proposed a differentiation between structural and transformational apparatus in the analysis of economic reality which, in terms of the role of scarce resources, tend to converge.

[3] I sincerely thank Alberto Clò, editor (with Piero Bernardinin) of Volume IV of the *Enciclopedia degli idrocarburi* (Encyclopedia of Hydrocarbons) (ENI-Treccani, Roma 2008) dedicated to *Economia, politica, diritto degli idrocarburi* (Economics, politics and hydrocarbon laws). His invitation to me (and also Fausta Pellizzar and Roberto Zoboli) to write essays to introduce this volume of the Encyclopedia on the topics of natural resources and raw materials is important to me because the Encyclopedia is a valuable example of the ties between economics, science and technology on the one hand, and institutions, politics and law on the other.

I would conclude by saying we are somewhat skeptical about rigid classification of "economist schools" when they include purists. We find it more useful to categorize according to methods and study topics, underlining the importance of dialogue with each other in mutual respect. There is perhaps one distinction that would not support this categorization: that between supporters of absolutist models and realist economists. The first group is dedicated to depicting a virtual reality which will never be realized, circumstances that its members perceive to be and indicate as "errors of facts" and not as "theoretical irrealism". Adherents to the second group also use theories but seek to make them compatible with historical and current reality, well aware that their theories are not perfect but hopefully (and probably) useful. Yet even here some convergence is necessary and possible: on the one hand, economists who deal with models become more realistic and realists become more generalist, and on the other hand, that realist economists do not limit themselves to describing facts without adequately interpreting them. I am aware that specialization is indispensable but am convinced also that economists are social scientists who – at least prospectively – must also take into account relations between economics, institutions, and society [Quadrio Curzio 2002; 2007].

References

Antonelli G. e Quadrio Curzio A. (a cura di) (1988), *The Agro-Technological System towards 2000*, North Holland, Amsterdam.

Duchin F. e Lange G.-M. (1994), *The Future of the Environment. Ecological Economics and Technological Change*, Oxford University Press, Oxford.

Hahn F.H. e Matthews R.C.O. (1965), *The Theory of Economic Growth: a Survey*, in *Surveys of Economic Theory*, American Eonomic Association-Royal Economic Society, 3 voll., Macmillan, London, vol. II, trad. it. *Teoria dello sviluppo economico*, in *Il pensiero economico contemporaneo*, 3 voll., Franco Angeli, Milano, vol. II, 1968.

Harrod R. (1939), *An Essay in Dynamic Theory,* in «The Economic Journal», vol. XLIX, pp. 14-33.

Harrod R. (1948), *Toward a Dynamic Economics*, Macmillan, London, trad. it. *Dinamica economica*, Il Mulino, Bologna, 1990.

Kaldor N. (1955-56), *Alternative Theories of Distribution*, in «The Review of Economic Studies», n. 2, pp. 83-100, trad. it. della sezione IV *Teorie alternative della distribuzione: la teoria keynesiana*, in Lombardini S. e Quadrio Curzio A. (a cura di) (1972), *La distribuzione del reddito nella teoria economica*, Franco Angeli, Milano, pp. 234-245.

Kurz D.H. e Salvadori N. (1995), *Theory of Production*, Cambridge University Press, Cambridge.

Kuznets S. (1990), *Popolazione, tecnologia, sviluppo*, a cura di Castellino O., Il Mulino, Bologna.

Leontief W. (1941), *The Structure of American Economy*, *1919-1929*, Harvard University Press, Cambridge Mass.

Leontief W. et al. (1953), *Studies in the Structure of the American Economy,* Oxford University Press, New York.

Leontief W. et al. (1977), *The Future of the World Economy*, Oxford University Press, Oxford, trad. it. *Il futuro dell'economia mondiale*, Mondadori, Milano, 1977.

Meade J. (1961), *A Neoclassical Theory of Economic Growth,* Unwin University Books, London, II ed. 1964.

Meadows D. et al. (1972), *The Limits to Growth. The First Report to the Club of Rome*, Universe Book, New York, trad. it. *I limiti dello sviluppo*, Mondadori, Milano, 1974.

Meadows D. et al. (1992), *Beyond the Limits*, Chelsea Green Publishing Company, Post Mills Vt.

Mokyr J. (1990), *The Lever of Riches. Technological Creativity and Economic Progress*, Oxford University Press, Oxford.

Pasinetti L. (1981), *Structural Change and Economic Growth: A Theoretical Essay on the Dynamics of the Wealth of Nations,* Cambridge University Press, Cambridge, trad. it. *Dinamica strutturale e sviluppo economico: un'indagine teorica sui mutamenti nella ricchezza delle nazioni,* UTET, Torino, 1984.

Quadrio Curzio A. (1967), *Rendita e distribuzione in un modello economico plurisettoriale*, Giuffrè, Milano.

Quadrio Curzio A. (1975), *Accumulazione del capitale e rendita*, Il Mulino, Bologna.

Quadrio Curzio A. (1977), *Rendita, distribuzione del reddito, ordine di efficienza e di redditività*, in Pasinetti L. (a cura di), *Contributi alla teoria della produzione congiunta*, Il Mulino, Bologna, pp. 301-327, trad. ingl. *Rent, Income Distribution and Orders of Efficiency and Rentability*, in Pasinetti L. (a cura di) (1980), *Essay on the Theory of Joint Production*, Macmillan, London, pp. 219-240.

Quadrio Curzio A. (1986), *Technological Scarcity: an Essay on Production and Structural Change*, in Baranzini M. e Scazzieri R. (a cura di), *Foundations of Economics - Structure of Inquiry and Economic Theory*, Basil Blackwell, Oxford, pp. 311-338.

Quadrio Curzio A. (1987), *Land Rent*, in *The New Palgrave Dictionary of Economics*, Macmillan, London.

Quadrio Curzio A. (1993a), *Innovation, Resources and World Economy: a Survey on Twelve Years of Contributions through two Journals*, in «Innovazione e materie prime», vol. II, n. 2-3, pp. 5-20.

Quadrio Curzio A. (1993b), *Distribuzione della Ricchezza e del Reddito*, in «Enciclopedia delle Scienze Sociali», Istituto della Enciclopedia Italiana Treccani, Roma, pp. 136-142.

Quadrio Curzio A. (1996), *Production and Efficiency with Global Technologies*, (ed. inglese ampliata di Quadrio Curzio, Manara e Faliva 1987) in Landesmann M. e Scazzieri R. (a cura di), *Production and Economic Dynamics*, con un'appendice di Manara C.F. e Faliva M., Cambridge University Press, Cambridge.

Quadrio Curzio A. (1997), *Rendita*, in «Enciclopedia delle Scienze Sociali», Istituto della Enciclopedia Italiana Treccani, vol. VII, Roma, pp. 395-407.

Quadrio Curzio A. (1998), *Risorse e rendita: un contributo teorico con premesse storiche*, in «Il Risparmio», n. 3, pp. 417-441.

Quadrio Curzio A. (1998), *Rent*, in Kurz H.D. e Salvadori N. (a cura di), *Elgar Companion to Classical Economics (ECCE)*, Edward Elgar, Cheltenham, pp. 289-293.

Quadrio Curzio A. (2002), *Sussidiarietà e sviluppo. Paradigmi per l'Europa e per l'Italia*, Vita e Pensiero, Milano.

Quadrio Curzio A. (2003), *Technological Scarcity: an Essay on Production and Structural Change*, in Hagemann H., Landesmann M. e Scazzieri R. (a cura di), *The Economics of Structural Change*, Edward Elgar Publishing, vol. II, pp. 138-165.

Quadrio Curzio A. (2007), *Economisti ed Economia. Per un'Italia europea: paradigmi tra il XVIII e il XX secolo*, Il Mulino, Bologna.

Quadrio Curzio A. e Fortis M. (1986), *Industrial Raw Materials: a Multy-country, Multy-commodity analysis, 1971-1983*, in «Studies in Banking and Finance», North Holland, Amsterdam, n. 4, pp. 99-107.

Quadrio Curzio A., Fortis M. e Zoboli R. (1991), *Technology and Natural Resources in the Growth of the Economies*, in «Innovazione e materie prime», n. 1, pp. 1-16.

Quadrio Curzio A., Fortis M. e Zoboli R. (1996), *Materie Prime*, in «Enciclopedia delle Scienze Sociali», Istituto della Enciclopedia Italiana Treccani, Roma, pp. 559-575.

Quadrio Curzio A., Fortis M. e Zoboli R. (a cura di) (1994), *Innovation, Resources and Economic Growth*, Springer-Verlag, Berlin-Heidelberg.

Quadrio Curzio A., Manara C.F. e Faliva M. (1987), *Produzione ed Efficienza con tecnologie globali*, in «Economia Politica», Il Mulino, anno IV, n. 1, pp. 11-47.

Quadrio Curzio A. e Pellizzari F. (1991), *Structural Rigidities and Dynamic Choice of Technologies*, in «Rivista internazionale di scienze economiche e commerciali», Milano, anno XXXVIII, n. 6-7, pp. 482-517.

Quadrio Curzio A. e Pellizzari F. (1996), *Risorse, Tecnologie, Rendita*, Il Mulino, Bologna.

Quadrio Curzio A. e Pellizzari F. (1999), *Rent, Resources, Technologies*, Springer-Verlag, Berlin-Heidelberg.

Quadrio Curzio A. e Pellizzari F. (2004), *Rent, Technology, and the Environment*, in Arena R. e Salvadori N. (a cura di), *Money, Credit and the Role of the State*, *Essay in Honour of Augusto Graziani*, Ashgate, Burlington, USA, pp. 335-348.

Quadrio Curzio A., Pellizzari F. e Zoboli R. (2008), *La teoria economica delle risorse naturali esauribili*, in «Enciclopedia degli Idrocarburi», vol. IV, *Economia, politica, diritto degli idrocarburi*, Istituto della Enciclopedia Treccani, Roma, pp. 3-10.

Quadrio Curzio A., Pellizzari F. e Zoboli R. (2008), *Innovazione tecnologica, scarsità relativa, investimenti,* in «Enciclopedia degli Idrocarburi», vol. IV, *Economia, politica, diritto degli idrocarburi*, Istituto della Enciclopedia Treccani, Roma, pp. 11-22.

Quadrio Curzio A. e Scazzieri R. (1983), *Sui momenti costitutivi dell'economia politica*, Il Mulino, Bologna.

Quadrio Curzio A. e Scazzieri R. (1986), *The exchange production duality and the dynamics of economic knowledge*, in Baranzini M. e Scazzieri R. (a cura di), *Foundations of Econom-*

ics - Structures of inquiry and economic theory, Basil Blackwell, pp. 377-407.

Quadrio Curzio A. e Scazzieri R. (1989), *La scienza economica e gli strumenti di analisi con applicazione alla dinamica economica strutturale,* in «Dynamis. Quaderni IDSE», n. 1, CNR, Milano.

Quadrio Curzio A. e Scazzieri R. (2008), *Historical stylizations and monetary theory*, in Scazzieri R., Sen A. e Zamagni S. (a cura di), *Markets, Money and Capital. Hicksian Economics for the Twenty-First Century*, Cambridge University Press, Cambridge, pp. 185-203.

Quadrio Curzio A. e Zoboli R. (a cura di) (1995), *Scienza, economia e tecnologia per l'ambiente*, in «Quaderni della Fondazione Cariplo per la Ricerca Scientifica» Milano.
Robinson J.V. (1956), *The Accumulation of Capital,* London., trad. it. *L'accumulazione del Capitale,* Milano, Edizioni di Comunità, 1961.

Solow R.M. (1956), *A Contribution to the Theory of Economic Growth*, in «Quarterly Journal of Economics», vol. 70, pp. 65-94.

Sraffa P. (1960), *Produzione di merci a mezzo di merci - Premessa a una critica della teoria economica*, Einaudi, Torino.

von Neumann J. (1937), *Uber ein okonomisches Gleichungssystem und eine Verallgemeinerung der Brouwerschen Fixpunktsatzews,* in *Ergebnisse eines mathematischen Kolloquiums*, vol. VIII, Vienna, pp. 73-83, ed. inglese *A Model of General Economic Equilibrium*, in «The Review of Economic Studies», vol. XIII, 1945-46, trad. it. in «L'industria», 1952, n. 1, pp. 1-13.

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