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Theories and Models of Structural Dynamics: An 'Ideal' General Framework ?

ABSTRACT.

This contribution concerns models and theories of structural economic dynamics. The theories and models analyzed in the paper follow two different approaches, circular and vertical, in the analysis of structural dynamics. The content of this contribution is essentially methodological. This work also aims at identifying a possible 'ideal' general framework for the analysis of structural economic dynamics, by singling out a core set of fundamental methodological and analytical principles that should constitute the basis of such a possible 'ideal' model.

Keywords: structural dynamics; methods of decomposition; multisectoral models, complexity.

JEL Classification: O41, D57, L16, B41.

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1. INTRODUCTION

Structural economic dynamics is the major theme of this paper and it is identified here as a method of investigation that is mainly related to the internal dynamics of the production processes characterised by a high rate of technical progress and marked organizational changes of production structures.

The analysis of theories and models of structural dynamics brings out a clear distinction between the description of the production system in terms of material flows reflecting inter-industry relationships and the description of the same system in terms of a set of vertically integrated sectors. In this paper I will limit my analysis to two typical models that emphasized the role of economic structure as the most essential factor in understanding the working and the process of development of economic systems. These two models are those designed by Wassily Leontief and Luigi Pasinetti. The choice of their models is important because it is possible to characterize many methodological and analytical features of a possible wider theory based on the different approaches to structural economic dynamics.

Moreover, the *methods of decomposition* of the system of production are examined. It is interesting from the analytical point of view that the dynamics of an economic system is related to the partition of the same economic system in subunits as processes of production, industries, vertically integrated sectors, to provide a disaggregated dynamic representation of structural change.

The analytical reconstruction of the circular and vertical theories of structural economic dynamics, carried out in this paper, aims at the identification of the core set of fundamental methodological and analytical principles (what I have called "ideal" theory of structural economic dynamics).

The essential features of a method of analysis consistent with this possible "ideal" model are the use of multi-sectoral models, the adoption of methods of decomposition, the relevance of technical progress, the central role of learning processes, the consideration of uneven growth, the study of normative conditions of equilibrium. The "ideal" model of structural economic dynamics is a general conceptual framework in which specific theories may be considered as *ad hoc* analytical structures providing a linkage between historical facts and theoretical analysis.

The concluding proposition of this paper is that the analysis of structural economic dynamics needs theoretical pluralism. This entails the acceptance of different analytical frameworks with respect to the problem at issue and suggests that theory selection presupposes both an adequate understanding of the economic structure and the description of relevant features of institutions and individual patterns of behaviour.

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2. TECHNOLOGY AND FLEXIBLE ECONOMIC BEHAVIOUR IN LEONTIEF'S CIRCULAR FLOW FRAMEWORK.

Wassily Leontief in his essay "The Economy as a Circular Flow"[1] introduces in an explicit way the concept and analytical framework of *circular flow*. This is essentially an analytical tool «which enables us to identify those causal relationships that are specific to the economic sphere»[2]. There he discusses the idea, already existing in the Quesnay's *tableau economique,* of the economic activity as a *circular process* that reproduces all the material goods used up in the process of production, so that this process can continue in the same way over the next period. The *circular flow* is considered as a process of rotation, which is indefinitely repeated.

So a model of a system of economic flows in a stationary state economy is represented. What is important in this model is that Leontief goes beyond the simple representation of economic process and identifies the objective technological framework as a first basic approach on which to construct, together with the relevant economic factors, a theory of the economic system. As a matter of fact, he maintains that the two aspects of analysis, the technological and the economic one, must not be separated.

Moreover in his analysis, Leontief considers technical change, due for instance to technological innovation, as the most relevant case among the possible changes, so he can examines a changing circular flow system. Hence he determines the production system in every details based on the laws of cost and, after that, he defines the system of exchange. It is interesting to note that the Leontief's system of exchange is underdetermined, that is 'open' to various possible solutions, since the number of unknowns is greater than the number of equations. In this framework it is possible to vary at will the exchange proportions. Consequently the distribution relationships of goods may also vary without affecting the circular flow of the economy[3].

From the analysis of Leontief's circular flow economy we can draw some observations. First, the theory of the circular flow system emphasizes the important role of technology in determining the structure of the economy, but it also introduces hypotheses of behaviour. This is especially clear in the analysis of exchange, in which Leontief sets the problem concerning the relation between income distribution and the determination of prices and shows that the solution of this problem may be found in the different possible institutional set-ups related to the social organization of ownership. In doing so Leontief introduces *degrees of freedom* in his analytical system, which thus becomes an 'open' one.

Second, the theory of *circular flow* is more flexible than the *input-output* analysis he subsequently developed, for in the latter case it is technology that thoroughly determines the structure of economic system.

Third, this theory of *circular flow*, despite all the attempts made by Leontief to consider the case in which technical coefficients may change unevenly, is associated with the absence of structural change in the stationary state.

Finally, it is worth stressing that the analytical framework of the *circular flow* introduces an horizontal pattern of interrelationship among production activities, and that these activities are, in a any case, limited in number.

The 'horizontal type' approach, which also entails the disaggregation of the productive system by industries, will be taken up later by Leontief in his *input-output* framework.

[1] This is Leontief's PhD thesis initially published in German "Die Wirtschaft als Kreislauf" in 1928 and later translated and published in English in the journal Structural Change and Economic Dynamics"(1991).
[2] Leontief, (1991, p.182).
[3] Leontief, (1991, p.194).

3. INPUT-OUTPUT METHOD OF ANALYSIS: COMPLEXITY, DECOMPOSABILITY AND THE ASSUMPTION OF LIMITED VARIETY.

The *input-output* method considers the quantitative interdependence among different productive activities of an economic system. The interdependence among single sectors or 'industries' of an economic system is described by a system of linear equations. The specific structural characteristics of this system are thus reflected in the coefficients of the equations and these coefficients are determined empirically.

In his *Structure of American Economy 1919-1939*[4], Leontief presents a framework of inter-industry relationships based on two systems of linear equations, one is referred to physical quantities, the other to prices. This framework is 'closed' with respect to final demand, since final demand is considered to be one among the industries of the system. Here, the system of physical quantities determines the *structure* of the economy but not its *scale* of operation, as the model is under the assumption of constant returns to scale in each industry.

In this model, productive relationships are of the horizontal or circular type. This is because the analytical representation of economic structure is based on a circular description of the flows of goods from one process to another, from one industry to another, along reciprocal relationships.This model does not entail a dynamic analysis, as the analysis carried out on its basis is limited to a virtual state of simple reproduction, in which there are no savings neither investment (the stationary state).

But Leontief goes further towards a dynamic analysis and introduces a new model[5], which he calls 'the open model with respect to final demand'. In this model, the matrix of technical coefficients does not include the consumption coefficients and the labour coefficients, whereas there is a separate vector of direct labour coefficients. This matrix and this vector together represent the technology of the system. There is also in this model a vector of final demand coefficients that are exogenously determined and known.

Leontief's models in the *Structure of American Economy* make the assumption of fixed technical coefficients, disregarding both returns to scale and technical progress. In these models, Leontief focuses upon the real economy, being aware that his static *input-output* analysis is constrained by the *relative invariance* of the structural characteristics of the *input-output* system, in which the strategic factor that fixes over time the structure is technology, whereas institutions and behavioural patterns (of firms and consumers) are not taken into account.

In his later work *Studies in the Structure of the American Economy*, Leontief undertakes the analysis of structural change[6]. One important difference with respect to the *Structure of the American Economy* is that in the previous *input-output* frameworks he had considered only *flows* of goods and services, whereas in the *Studies* he also considers commodity *stocks.* Hence he allows the empirical analysis of the investment process. With the introduction of stock-flow relationships Leontief overcomes the stationary state and moves towards a dynamic analysis, in which the assumption that a *constant proportion* of input flows is allocated to investment is dropped (as it is possible to analyse an economy whose sectors *do not* grow in a uniform way). It is important to stress that the dynamics of stock-flow relationships accounts for one aspect only of economic change: what can be explained in terms of invariant structural constants. The other, more deep-rooted causes of transformation are to be found in the variation of the basic structural relationships themselves, that is, in changes in consumers' tastes, and in the structure of productive processes.

Leontief also gives a definition of statics and dynamics in terms of his *input-output* frameworks and of the structural characteristics of the system[7]. In particular, his definition of statics is not associated with the concept of equilibrium, as in traditional analysis. This is because Leontief associates the

[4] Leontief (1951).
[5] Leontief (1951, pp.205-207); Leontief (1987, p.861).
[6] Leontief (1953, chp.2).
[7] Leontief (1953, p.53).

change in the variables of any given economic system with the observed variations in the basic structural relationships (such as changes in the structure of productive processes), As a result, Leontief's conception of statics highlights both the aspect of structure and that of variation. This means that in Leontief's static analysis the structural relationships show a relative invariance, making the change limited in extent. Also Leontief's definition of dynamics highlights both aspects of structure and change. In this case, the change in the value of variables over time is explained in terms of a fixed *empirical law of change.* Such a law is an invariant structural characteristic of the system.

The analysis of structural change embodies both aspects of structure and change. Such an analysis is developed by Leontief in a static context, by comparing the empirical relationships of the (American) economy observed at different points of time, and trying to identify possible substitutions of new combinations of inputs with respect to the old ones. Hence structural change in his *input-output* framework is defined as «a change in the structural matrix of the system»[8], where the investigation of the causes that have determined the change in the structural matrix (such as technical progress) is not carried out.

It is worth noting that *input-output* analysis is based on disaggregation and therefore on the *decomposability* of the productive system into a *limited number* of sub-units, such as the 'industries' or sectors, which identify the productive processes. This approach makes the analysis of structural change easier, because technical change is observed in each industry as the change of one or few coefficients, where the relative persistence of certain relationships and/or of certain elements is explicitly taken into account[9]. This shift in the focus of analysis from the *continuum* of heterogeneous activities to a relatively small number of sectors is typical of the economic analysis of structural change. Thus, a *finite variety* of features and activities is envisaged. Moreover, the notion of 'relative structural invariance', which may be implicitly derived from the analysis of technological change, becomes a distinctive feature in the analysis of structural change [10].

In Leontief's analysis economic change may alternatively be explained as structural change, or as a dynamic process. In the former case, the variation of dependent variables is related to changes in some of the basic data, in the latter case the law of change itself is considered to be given, that is, as 'built within' the structure of the explanatory framework [11].

The law of change too could change over time. This is the case of structural change in a dynamic system, or *structural dynamics*, which leads to a much more complex type of analysis. Hence in the *Studies,* Leontief makes an explicit distinction between three levels of analysis: structural change, dynamics and structural dynamics. Such a distinction lends itself to differences in theories, that is to different methods for describing and explaining the observed facts, rather than to some intrinsic property of the same observed world. This is why Leontief believes in a hierarchic relationship among these theories, which joins them together, rather than in a contrast that would make such theories alternative and therefore mutually exclusive. Leontief is also convinced that the generalization of any given theoretical approach (such as the one required if one wished to move from structural change analysis to dynamic analysis) presupposes the enlargement and deepening of its empirical basis.

A fundamental observation with respect to Leontief's analytical frameworks concerns the problem of *complexity.* As a matter of fact, one of the central question in Leontief's analysis concerns the complexity of the real productive system and the fact that this system is undergoing continuous processes of change. «In contrast to most physical science, we study a system that is not only exceedingly complex …but it is also in a state of constant flux»[12]. To face the complexity of interactions among economic units of the productive system and to identify both the direction and character of flows in the productive system, and the changes in the basic structural relationships,

[8] Leontief (1953, p.19).
[9] Leontief (1987, p.863).
[10] On the 'relative structural invariance' see Landesmann,Scazzieri (1996, pp.6-8), Schilirò (2003).
[11] Leontief examines the dynamic model in the *Studies* (1953), chp.3, and in the *Dynamic Inverse* (1972).
[12] Leontief (1971, p.1).

according to Leontief's strategy the following steps are necessary: (i) to extend and deepen the direct empirical knowledge of data and measurable parameters,(ii) to identify a *partition* of the set of productive activities into a *finite number* of industrial sectors.

The *decomposability* of the productive system into a finite number of separate but interdependent industries is a first step to reduce complexity. Decomposability is also a pre-condition for the analysis of dynamic properties.

The identification of invariant structural relationships is another essential analytical step to reduce complexity. This is because it takes explicitly into account the *relative persistence* of some elements or some relationships. Such *persistence* comes out in all its evidence when time is considered as a discrete variable. Moreover, the identification of invariant structural relationships depends on the type of empirical analysis to be carried out and on the problem context to be faced, as all that determines the structural specification of the model.

When a limited number of separate but horizontally interdependent industries are associated with a *finite variety* of activities, an *hypothesis of limited heterogeneity* is introduced. Such hypothesis has a strategic role in the analysis of structural change and allows a selective description of the productive system. This description is associated with a particular structural representation of the economy, which determines the set of relevant causal relationships.

There is a clear link between Leontief's frameworks of analysis and Quesnay's *tableau economique*. Both Quesnay and Leontief consider the economic activity as a circular process, yet in the *input-output* framework the structure is determined by the *state of technology* and not by the assumptions concerning economic agents' or social classes' behaviour, as it is the case with Quesnay[13]. However, it is worth noting that Leontief in his 1928 essay on "The Economy as a Circular Flow", considered the system to be an 'open' one. This means that individual economic behaviours and institutions have an important role in the exchange system. Another relevant difference between the two economists is that Quesnay proposes a 'benchmark' model that is not aimed to observe and measure the working of a real economy characterized by a circular or horizontal structure. The *tableau* has elements of a system focusing on behaviour and institutions, *and* on technologies in use, and it contains normative aspects[14]. On the contrary, Leontief develops a method for empirical analysis and proposes analytical instruments such as the inverse matrix in the static *input-output* model and the dynamic inverse for the dynamic analysis, which enables him to measure the direct and indirect effects of a change in the structure of a real system of production.

4. SYNTHETIC NOTIONS FOR STRUCTURAL ECONOMIC DYNAMICS: VERTICAL INTEGRATION AS A METHOD OF ANALYSIS.

Leontief's theory of production is based on the view of a 'perfect' circular economy, which presupposes that the production of goods is an essential prerequisite for the production of the same or other goods. In this model, all commodities depend on each other's production. This approach is associated with a view of the economic system that takes into account the whole network of relationships among the productive sectors (the 'industries'). It can therefore be maintained that a model of 'horizontal' integration has been introduced by Leontief.

In the horizontally integrated models, each commodity appears on both sides of the economic system: on the side of the factors of production and on the side of the outputs. No primary resource, nor any final consumption commodity has any logically pre-eminent role (the analytical constructions by Leontief (1951), Sraffa (1960), Hicks (1965), Quadrio Curzio (1986) belong to this class of models).

[13] Actually, Quesnay never used the term behavioural hypothesis rather he was writing about the 'natural order', but in any case the tableau was considering the possibility of flexible solutions.

[14] Steenge (2001).

But there is another approach that diverts attention from the issues concerning the reproduction of the economic system and focuses instead on the relationship between productive resources and their allocation. This is the approach based on the vertical integration of the productive processes. In this case, the productive system does not appear to be characterized any more by circular relationships. Rather, it is the consumption of goods that seems to be the final purpose of the process of production. Here we have a model of 'vertical' integration, in which the production of goods depends in terms of one-way causality on the availability of resources that are themselves independent of productive processes.

The models of general economic equilibrium in the modern formulation of the Lausanne School (Allais and Debreu), Hicks's analytical framework of temporary equilibrium, Pasinetti's notion of vertical integration (1973) and, finally, the vertical integration along the time dimension set forth by Hicks in *Capital and Time* (1973), although with different ends, all belong to the class of vertically integrated models.

In this paper, I shall concentrate on the theoretical lines followed by Pasinetti. His approach is based on two analytical strands: one is the vertical integration of productive processes, the other is the theory of structural economic dynamics.

The notion of a vertically integrated sector is set forth by Pasinetti in his contribution "The Notion of Vertical Integration in Economic Analysis" [15]. The author starts from the inter-industry analytical framework of the Leontief type, which confirms the continuity between Leontief's and Pasinetti's approaches to structural analysis. However, Pasinetti suggests some synthetic notions that he himself considers to be essential for dynamic analysis. In fact, he introduces the notion of *vertically integrated sector*.

First, Pasinetti decomposes his system not into a number of industries (as Leontief has done), but into *m sub-systems.* In this way, he stresses the reproducibility of means of production over time through a circular process. Such a notion of subsystem is also relevant to the analysis of uneven growth, since it avoids the "analytical unification" of the economic system through circular relationships [16]. Then, starting from the sub-systems, he defines the *vertically integrated sector* for the production of a physical unit of a commodity as a final good, which is composed by the *vertically integrated labour coefficient* and a unit of *vertically integrated productive capacity*. The logical operation of vertical integration is, according to Pasinetti, a device that allows structural analysis through a re-classification of commodity flows and stocks according to *logical units.* This is considered to be a necessary step to go into dynamic analysis. This approach is also especially useful to the identification of one-way causal links within the network of economic relationships. A relevant feature of the concept of vertically integrated sector is that it is not affected by technical progress. With regard to this, Pasinetti writes: "The vertically integrated sectors seem to belong to that category of synthetic notions that, once obtained, contribute to reduce in many directions the order of magnitude of the analytical difficulties"[17].

Pasinetti also calls attention to the *complexity* problems arising in the analysis of the structure of the productive system, especially when dynamic analysis has to be developed on the assumption of fixed capital and technical progress. Here, the logical process of vertical integration (with the related decomposition of the economic system into vertically integrated sectors, which allows for a *different unit of measurement* in each sector), becomes a way to reduce the *degree of complexity.*

Pasinetti (1988) proposes also a generalization of the notions of 'sub-system' and of 'vertically integrated sector' and offers new insights into dynamic analysis. The notion of *vertically hyper-integrated sector* entails that the relationship between any given unit of *vertically hyper-integrated productive capacity* and the corresponding physical units becomes irrelevant for the

[15] Pasinetti (1973).
[16] Scazzieri (1990, p.26).
[17] Pasinetti (1989, p.405).

analysis of the movements over time of the quantities of consumption goods and of the corresponding quantities of labour (even if it remains essential for the analysis of the interconnections of the expanding circular process at any point of time). This approach entails that the *degree of complexity* of the analysis is reduced, and lends itself to the consideration of multiple forms of technical progress.

Pasinetti explicitly acknowledges that there are two different approaches to the analysis of the structure of the economic system[18]. The first approach is the *circular* one and it is referred to the representation and decomposition of the productive system into *sub-systems.* In this case, it is possible to analyse the complex interrelationships among productive processes either in physical terms (when there is production with fixed capital, when there is joint production, when there are natural resources, etc.) or in terms of prices (when we examine the relationships of income distribution, the changes in relative prices, etc.). The second approach is that of *final demand,* relative to *vertically integrated sectors*, in which all complications associated with intermediate processes are left aside and the analysis concentrates on the relationships among final goods, on one side of the process, and their ultimate requirements (the quantities of labour) on the other end of the same process. It is noteworthy that, in Pasinetti's view, the two approaches are not alternative, but complementary ones. As a matter of fact, there is a one-to-one correspondence between an economic system expressed in terms of industries and the same economic system expressed in terms of vertically integrated sectors (either for the system of physical quantities or for the price system). But this correspondence is only true for a given technique and a given period of time. The one-to-one correspondence between the vertical and the horizontal system breaks down in the cases of structural change and structural dynamics.

5. CONTINUITY AND NON-PROPORTIONALITY OF GROWTH: THE STRUCTURAL ECONOMIC DYNAMICS IN A VERTICAL SETTING.

The vertical integration of productive processes allows Pasinetti to introduce synthetic notions for dynamic analysis that Leontief did not consider. Above all, vertical integration allows Pasinetti to conduct such analysis without assuming fixed coefficients, that forced all the inter-industry analysis in the limited dimension of statics and, at the same time, of taking into account the primary factor of change in the productive structure, that is the technical progress.

Pasinetti considers structural economic dynamics to be the *continuous* and *permanent* change in the composition of the basic macroeconomic magnitudes of the economic system over time. Hence, this is simply the *dynamics* of the overall *structure* of system under consideration.

The dynamic concepts of *industry* and *production* are at the centre of Pasinetti's theoretical analysis. According to him, production activity is not primarily an issue of rationality, since it requires *a process of learning.*

Pasinetti develops in *Structural Change and Economic Growth*[19] a multi-sectoral economic model characterized by uneven growth and associated with uneven productivity growth rates across the various sectors of the economy[20]. In this case, the production of any given good is a function of the various inputs such as labour, capital goods, and intermediate goods.

He formulates a *pure production* model. Such a model is represented by a system of physical quantities (of flows and stocks) and by a (dual) system of prices. In this model, all the productive processes, which are associated with final goods, are vertically integrated, in the sense that all the inputs are reduced to labour quantities and to services supplied by stocks of capital goods. In this case, Pasinetti outlines a *decomposition* of the economic system into *m vertically integrated sectors,*

[18] Pasinetti (1986).
[19] Pasinetti (1981).
[20] Pasinetti's idea of analysing the structural change of an economic system that grows unevenly is the same idea that already existed in Schumpeter, who singled out innovation as the distinguishing feature of capitalistic society, where such innovation determines the modifications in the quality and in the quantities of produced goods, and it becomes the primary cause of economic development.

and such a *decomposition* brings out a reduction in the *degree of complexity* of the economic system, since it also allows a definite causal chain from the exogenous variables (technology, population, consumers' preferences) to the determination of endogenous variables of the model: the prices and quantities of goods to be produced.

One of the characterizing features of Pasinetti's approach is that he develops his analysis at a 'natural' level of investigation. The latter is conceived as a level of analysis so fundamental that it is independent of the institutional set-up of society. The existence of *degrees of freedom* in the model is also important, as it gives a certain degree of flexibility to the model and makes it 'open'[21].

Structural dynamics with its features of continuity and non-proportionality of growth is also analysed in Pasinetti's later work *Structural Economic Dynamics. A Theory of the Economic Consequences of Human Learning*[22]. In this contribution, by conducting his analysis at ahigh level of abstraction, Pasinetti examines the learning-induced evolution through time of a *pure labour* economy, that is, of an economy in which the activity of production is carried out by labour alone, without the utilization of any intermediate input. Unlike von Neumann[23], who formalized in an elegant way a path of proportional dynamics, Pasinetti considers a path of structural economic dynamics, which is characterized by the permanent change through time of the composition of the basic macroeconomic magnitudes of an economic system. In this theory, technical progress exerts a pre-eminent role in the process of economic development relatively to capital accumulation.

The *pure labour* model of production represents a minimal basic multi-sectoral model, it makes use of a very limited number of assumptions and contains the essential characteristics of the production paradigm (the paradigm which Pasinetti associated both to Classical and Keynesian economics). Pasinetti identifies two different levels of analysis: the *natural* and the *institutional* one. He also emphasizes that the *natural* features of a given economic system should be examined before introducing institutional relationships. In the *pure labour* model, the economic system is decomposed into *vertically integrated sectors*. Another important characteristic of the model is the distinction between variables and constants. Such a distinction is considered to be different from the one between unknowns and data, since in dynamic analysis the magnitudes considered as constants are seldom the same we consider as data. For instance, the technology and the consumer's preferences, which in this model are exogenously given, actually change dramatically through time.

The *pure labour* model is referred to a perfectly developed and technologically advanced society, in which labour inputs only are used in production. Although labour is the only factor of production, Pasinetti assumes that the activity of production is carried out through an extensive division of labour, a marked specialization and a high level of productivity. This framework may represent some of the characterizing features of a *knowledge-based economy*[24]. The model contains a system of physical quantities and a system of prices. It is associated with Leontief's closed model which Pasinetti considers to be still useful for static analysis. The two systems of equations, of physical quantities and of prices, can be solved independently of each other. The model's solutions provide analytical foundations to the Smithian pure labour theory of value (solutions for the price system) and to the Keynesian principle of effective demand (solutions for the system of physical quantities). The model may be solved subject to a single coordination constraint (Pasinetti's fundamental macroeconomic condition). Such a condition may be expressed either in terms of the system of quantities or in terms of the system of prices.

Pasinetti's structural economic dynamics is based on the essential point that technical progress, defined as a complex phenomenon, is assumed to be a *process.* This means that technical progress is not a *datum*, but it is assumed to derive from processes of *continuous* changes in technical coefficients. According to Pasinetti, the main aspects of technical progress are two. The

[21] In the model there are degrees of freedom both in the system of physical quantities and in the system of prices. In each system the degree of freedom concerns the movement of one variable over time (for instance population in the case of the system of physical quantities).
[22] Pasinetti (1993).
[23] von Neumann (1937).
[24] David and Foray (2003).

first is of a strictly technological character and is related, for instance, to the specialization of workers. The second aspect concerns demand and, specifically, the dynamics of the structure of consumption goods on the basis of Engels' curves.

One important outcome of Pasinetti's analysis is that a path of structural economic dynamics consistent with full employment requires specific and deliberate interventions at any given period of time.This means that the problem of effective demand is, unlike what is suggested by Keynes, a permanent problem that must be solved continuously over time. Another feature of structural economic dynamics is economic coordination. Economic agents are many and different among them. Coordination is essential in order to implement policy actions that would permanently stimulate effective demand and allow the economic system to reach *full employment equilibrium.*

It is worth noting that Pasinetti's analysis calls attention to the existence of *degrees of freedom*, for instance in the way in which the macroeconomic equilibrium condition for full employment may be satisfied. On top of that, the learning processes associated with technical progress identify an *empirical law of change,* which leaves the system 'open', as it does not put any constraint on its assumptions.

The *pure labour* model is essentially a *normative model*. The absence of capital goods in this model simplifies the analysis of vertically integrated sectors, as it removes the problem of the substitution of capital goods for labour. In the *pure labour* model, vertical integration takes a stronger meaning, since in each *vertically integrated sector* a particular final good is associated with the corresponding quantities of direct and indirect labour without any other complication due to the process of reduction of intermediate goods. As a result, vertical integration reduces the *complexity* of the economic system, without loosing the capacity of showing those essential characteristics that are typical of structural economic dynamics. Another feature of the *pure labour* model is that the notion of 'relative structural invariance', that we have found in Leontief's circular analysis[25], is no longer necessary for the analysis of structural dynamics. This is because, with this model, the technical coefficients of production and the coefficients of demand change continuously as the exogenous variables. It is also important to emphasize that Pasinetti makes use of a vertically integrated model and hence of a particular *method of decomposition* of the productive system, which allows him to identify the causality direction of the dynamic processes of the change in the economic structure. Finally, the notion of 'relative structural invariance' looses its relevance since Pasinetti's analysis is developed at a *normative* level.

Pasinetti's approach and, in particular, his distinction between the *natural* and the *institutional* level of analysis[26] is a further step in the direction of a simplification and reduction of the *degree of complexity* of the economic system under consideration.

6. LEONTIEF'S AND PASINETTI'S FRAMEWORKS: METHODOLOGICAL AND ANALYTICAL ASPECTS.

The aim of this paper has been to compare and generalize Leontief's *input-output* frameworks and Pasinetti's models of structural change and structural dynamics. All these models indeed focus their attention on the analysis of economic structure, as the essential factor in understanding the working of the industrial economies and their process of development in the long run.

Emphasis on the economic structure is of critical relevance even today when the dynamics of modern industrial economies call attention to their character of *weightless* and *knowledge-based economies*. As a matter of fact, economic structure shows at the same time features of persistence and change.

[25] In Leontief the analysis of structural change is carried within an environment of comparative statics, where the notion of 'relative structural invariance' constitutes a typical characteristic. Schilirò (2006).

[26] The Pasinetti's natural economic system is that one which possesses some characteristics of analytical type and of logical cherence that makes it a pattern with strong normative properties.

The combination of the *input-output* (horizontally integrated) model with the structural dynamics vertically integrated model is appropriate both at the methodological level and at the analytical level. From the methodological point of view both types of models embody the idea of an economy based on production rather than on exchange. Moreover, the two types of model start their analysis from the description of 'stylized facts', relative to a modern industrial economy, and they integrate such 'stylized facts' with some analytical principles (such as the assumptions relative to production coefficents, or the equilibrium conditions of the system).

There are also differences from the methodological point of view. One of the most relevant ones, although not the only one, is the distinction between the *natural* level and the *institutional* level of analysis. This distinction, which was absent in Leontief's formulation, is important in Pasinetti, especially for the connection between analysis at the *natural* level and identification of normative criteria. In any case, we would suggest that in the approach based on the concept of *production* it is important both the relational side, that is the technological links of objective kind, and the contextual side, that is the institutional set-up.

Another distinction on the side of methodology concerns the scope of the two types of models. The *input-output* framework is useful to represent the growth (of scale)[27], whereas the model of structural dynamics is particularly suitable to represent the complex phenomenon of development and of non-proportional growth.

Beyond significant methodological differences there is one important point of agreement between Leontief and Pasinetti. This is their attempt to reduce the *degree of complexity* of the system. Both economists discuss methods of decomposition of the productive system, but at the same time each of them makes use of a different analytical device: the decomposition into sub-units (horizontally interrelated i*ndustries*) in Leontief's case, and the decomposition into *vertically integrated sectors* in Pasinetti's case.

As far the analytical questions are concerned, there is first of all the issue concerning the different methods of representing the process of reproduction of the economic system: circular versus vertical approaches. However, it is possible to identify analytical links between the two methods.

Another important issue is the existence of *degrees of freedom* in the analytical system. Pasinetti outlines a model that is 'open' and entails the existence of *degrees of freedom.* In Leontief's case his 1928 model is also a type of 'open' model, whereas the *input-output* framework of 1951 is no longer such[28]. Thirdly, an important feature common to both Leontief and Pasinetti is the multi-sectoral dimension. This allows the investigation of the dynamics of structural change through methods of decomposition. Finally, a common analytical feature is the consideration of two *distinct* systems of equations: one for the quantities and another for prices. As a consequence of that the quantities and the prices are logically determined separately not simultaneously. At the same time the two systems (quantities and prices), have the same matrix of coefficients (the matrix of technical coefficients).

7. TOWARDS AN "IDEAL" GENERAL FRAMEWORK?

The main theme of this paper has been to identify essential characteristics for the analysis of structural dynamics that can be distinguished in the circular and vertical approaches used in the analytical frameworks of Leontief and Pasinetti. This investigation was carried out also in view to suggest a possible "ideal" general framework of structural economic dynamics encompassing both approaches.

The first element of such an 'ideal' general framework is the integration of the 'stylized facts' of a modern industrial economy with analytical principles, allowing the system to maintain a certain

[27] Like the von Neumann's model.

[28] To better understand the contribution of Leontief to the analysis of structural change it is necessary to consider not only the input-output model, but also the other analytical frameworks proposed by Leontief [1928, 1951, 1972]).

degree of flexibility and, therefore, a certain degree of 'openness' relative to different institutional conditions and historical set-ups. A second feature of the 'ideal' framework is the complementarity between circular and vertical approaches. As a matter of fact, an "ideal" framework must encompass the analysis of the process of reintegration, which allows the system to reproduce itself overtime. This prerequisite can be met by adopting the circular approach, as it points out by the analysis of interdependencies among productive sectors. At the same time, it is also important to have some synthetic concepts. The reason is that such concepts (such as Pasinetti's *vertically integrated sectors*) facilitate the dynamic analysis, and in particular the analysis of technical progress. A third feature is reduction in the *degree of complexity.* The need to decompose the economic system into sub-units such as *industries* or single productive processes is certainly a need reflecting the *degree of complexity* of the analysis[29]. The *input-output* method is consistent with this goal, as it concentrates on a *finite variety* of characteristics and activities of the economic system (structural analysis implies that the degree of diversity of the economic environment is reduced by an *hypothesis of limited heterogeneity*)[30]. Moreover, the decomposition of the economic system into *vertically integrated sectors* allows synthetic notions to simplify dynamic analysis and permits to directly identify changes of the economic structure over time.

A peculiar feature of the 'ideal' framework is the notion of 'relative structural invariance'. This means that the economic structure is generally described in a way that some of its elements are considered to be fixed, while other elements may change over time. 'Relative structural invariance' is a distinctive feature of structural change, since it is always relative to a given structural description. This assumption is essential in order to determine the set of possible transformations that any given economic system may undergo. There is a clear relationship between the circular approach and the notion of 'relative structural invariance'. This is because relative structural invariance allows the study of structural change through a 'time differentiated' description of the interrelationships among elements of the economic system[31]. But this feature is not essential for the analysis of structural dynamics. Last but not least, the "ideal" model for the analysis of structural dynamics cannot represent 'stationary states', but must concern itself with the process of transformation of the productive structure over time. This excludes the possibility of dealing with structural change in terms of a comparison among equilibrium positions.

The essential features of the 'ideal' model are thus the use of a multi-sectoral representation of the economic system, the adoption of methods of decomposition, the central role of learning and technical progress, the consideration of non-proportional growth, the identification of normative conditions of equilibrium. These features, taken together, are the analytical core of a theory of structural economic dynamics, and they are compatible with the utilization of both horizontal and vertical frameworks.

To sum up, the "ideal" model of structural economic dynamics, that I tries to envisage in this contribution, is a general conceptual framework in which specific theories may be considered as *ad hoc* analytical constructions, providing a linkage between historical facts and theoretical analysis, with the aim of showing the diversity in the growth rates of different activities (industries, sectors, and so on) of the economy. Therefore, the analysis of structural economic dynamics concerns an economy in a perpetual state of qualitative and quantitative transformation. This kind of analysis needs theoretical pluralism, which entails the acceptance of *different* analytical frameworks with respect to the problem at issue, and suggests that theory selection presupposes both an adequate understanding of the economic structure and the description of relevant features of institutions and of individual patterns of behaviour.

[29] Schilirò (2004).
[30] Hagemann, Landesmann, Scazzieri (2003, pp.XI-XIII); Schilirò (2003); Schilirò (2006).
[31] Hagemann, Landesmann, Scazzieri (2003); Schilirò (2006).

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