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# SURVEYING STRUCTURAL CHANGE: SEMINAL CONTRIBUTIONS AND A BIBLIOMETRIC ACCOUNT

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# Surveying structural change: seminal contributions and a bibliometric account

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**Abstract**

The main aim of this paper is to provide a comprehensive survey of the economic literature on structural change. Along with an insightful literature review of the seminal contributions in the field, we perform a quantitative analysis that takes into account all the theoretical and empirical articles on the subject that were published from 1969 onwards. This effort to gather the relevant documentation is based on a review of 910 abstracts from articles published in all the economic journals found in the Econlit database over the past forty years.

According to our quantitative analysis, structural change analysis received a major boost in the 1990s, with a considerable increase in the number of articles published on the matter. The marked rise in interest seems to be primarily related to the growing concern to find explanations for the process of technological change and its effects on the economy. In the first half of the current decade technological change comprises a predominant area of research, accounting for about one quarter of the articles published. Despite the increased formalism observed in the 1990s, our results further highlight that the bulk of the research in this field remains empirically led. Furthermore, and quite surprisingly, discussions concerning ICTs do not seem to have been translated so far into a substantial increase in research on structural change-related issues.

*Keywords*: Structural Change; Bibliometrics; Econlit

JEL-Codes: O10; O30; C89

## 1. Introduction

Structural change analysis is differentiated from standard economic research in that it assumes that the infinite multiplicity of reality can be studied by focussing on a relatively small number of groups or activities that comprise the economic system, and thus form the economic structure.[1] In this sense, a structural representation provides a selective description of the economic system, which is obtained by substituting the observed heterogeneity with sets of classes of relatively homogeneous groups of agents or sectors of activity. In this framework, the definition of structure and of the unit of analysis is made to depend on the problem under investigation. This allows for a considerable degree of flexibility that is absent from standard micro and macroeconomic analyses, thus making it an appealing tool for the study of economic dynamics. The complexity of economic change is probably better understood within a framework which permits changing from one classification scheme to another, so as to obtain the structural representation that is most suited to analyzing the impact of a particular force of change, or to describing the economic system at a particular moment in time. Moreover, the division of the economic system into different subsystems means that differentiated patterns of change in those subsystems can be taken into account (the different elements of a productive structure are transformed at different speeds), which is entirely at odds with stationary state dynamics.[2]

Despite the fact that structural change analysis has an important tradition in economic theory, to the best of our knowledge, there has been no attempt to provide an overall survey on the matter. Several factors may account for this. Firstly, even though the phenomenon of structural change is as old as the very problems of economic development, the term 'economics of structural change' was until recently practically unknown. The enormous heterogeneity of studies in this area, inherently related with the complexity of the matter, does not lend itself easily to a unified approach and only recently there have been some attempts (Baranzini and Scazzieri, 1990; Landesmann and Scazzieri, 1996) to organize the theoretical approach in a systematic manner. Secondly, the terms 'structure' and 'structural change' are widely used in economic research under very different meanings and, in many cases, those meanings have no connection with 'structural change analysis' (see our discussion in Section

[1] See also Hagemann *et al.* (2003) for a discussion of the purpose and scope of the economics of structural change.

[2] See the discussion in Landesmann and Scazzieri (1990) on this feature of structural change and on the notion of 'relative structural invariance'.

3 below). This presents several difficulties when trying to identify and organize the existing theoretical and empirical work in the field.

This paper attempts to fill this gap, providing a comprehensive survey of the economic literature on structural change. Apart from an insightful literature review of the seminal contributions in the field, a quantitative analysis is also performed that takes into account all the theoretical and empirical articles on the subject that were published from 1969 onwards. This effort to summarize the relevant documentation is based on a review of the abstracts from articles published in all the economic journals found in the Econlit database over the past forty years.

## 2. Methodological considerations on the analysis of structural change research

An important aspect to be taken into account when analyzing the literature on the economics of structural change is that the terms 'structure' and 'structural change' are used in economic research under very different meanings, and some of those meanings have no direct bearing on 'structural change analysis'. Moreover, in many cases, there is considerable vagueness in the ways in which the terms are used, which hampers a precise interpretation of what is meant.[3]

In his semantic study of 'structure' and 'structural change', Machlup (1991) provides an extensive list of the various (economic) uses of the terms, distinguishing them according to their relative degree of clearness. Taking into account only the clearer definitions, there are at least nine different meanings with which structure and structural change can be related. Along with the notion of economic structure as 'different arrangements of productive activity in the economy especially to different *distributions* of productive factors among various sectors of the economy, various occupations, geographic regions, types of product, etc.' (Machlup, 1991: 76, original emphasis), which seems to be the most common use of the term in development economics and in economic history, there are several other meanings, expressing the appeal of this term in an extensive array of theoretical and applied research. For example, structure is also used to denote the fundamental conditions that are assumed as invariant for purposes of analysis and modelling, regardless of the nature of the model and, simultaneously, it is taken as synonymous of a 'composition that does not change easily' (Machlup, 1991: 78), referring mostly to the composition of basic macro-economic

[3] According to Machlup, structure (and thus structural change) 'is often a weaselword used to avoid commitment to a definite and clear thought' (Machlup, 1991: 75).

magnitudes, such as national product, investment, employment, exports or imports. This latter feature of structure as composition is also apparent in Ishikawa's (1987: 523) definition of structural change, in which it is seen as 'a change in the relative weight of significant components of the aggregative indicators of the economy, such as national product and expenditure, exports and imports, and the population and labour force'.[4]

For the purposes of this study, only theoretical and empirical papers developed according to the framework of structural change analysis described above were considered, disregarding all other possible uses of the terms. More precisely, the studies selected were those that divide the economic system into a limited number of subsystems, in order to analyze the dynamic properties of the economy as a whole. Studies focussing on the econometrical meaning of structural change were also disregarded, especially those that are mostly concerned with the development of testing procedures to cope with the phenomenon of time series structural change.

Together with a survey of the seminal contributions in this field, both in the form of monographs and papers, a quantitative analysis is performed based exclusively on the articles published on structural change analysis from January 1969 up to August 2005. This effort to gather the relevant documentation is based on a review of the abstracts from articles published in all the economic journals found in the Econlit database over the past forty years (1969-2005). The database was constructed by using the term 'structural change' as the search keyword. The total number of analyzed records was 2329, where texts corresponding to comments, rejoinders, *corrigendas* or addressing different meanings of structural change were eliminated from the categorization. Also, some records did not have an abstract and were also excluded (but included in the temporal analysis). In the end, 910 records remained (from a total of 1247 with and without abstracts). Publications on the economics of structural change were analyzed in terms of eleven main themes, which were selected on the basis of the literature review undertaken. Those themes are: 1) Development; 2) Technical change and innovation; 3) Convergence and growth; 4) Economic fluctuations; 5) International trade; 6) Employment and migrations; 7) Industrial dynamics; 8) Institutions and policies; 9) Regional and urban economics; 10) Measurement and methods; 11) Environment and sustainability. Apart from the main theme of research, the articles were also classified according to the main

[4] The New Palgrave. A Dictionary of Economics, 1987.

method of research used, by considering six major classes: 1) formal; 2) appreciative; 3) formal and empirical; 4) appreciative and empirical; 5) empirical; and 6) surveys.[5]

In the following sections, a comprehensive overview of the literature is provided, which is complemented, whenever possible, with the results obtained from the quantitative analysis performed. It is our hope furthermore that this effort to review all the relevant documentation may comprise a relevant step toward a more rigorous account of the paths taken by structural change research in the past forty years.

## 3. On structural change: a comprehensive literature survey

### 3.1. The fundaments of structural change: Classical economists (1700s-1870)

The idea that the dynamics of economic systems is inherently associated with changes in their structure had already been explored by classical economists. Although they did not actually use the term 'structure' in any significant way, many authors (e.g. Steuart, 1767; Turgot, 1766; Smith, 1776) contended that the progress of wealth was intimately related to changes in the pattern of interaction among a few critical variables, which can be seen as distinct representations of the economic structure. For example, in Smith's *An Inquiry into the Nature and Causes of the Wealth of Nations* (1776), there is an explicit reference to the relationship between the sectoral composition of the economy and the stage of development reached. In fact, each stage is characterized by a particular composition of product, and a change in this composition is seen as a major requirement to reach higher stages of development.

Furthermore, in classical essays, there is an explicit attempt to identify the major forces that allow the economy to switch from one structure to another. In Smith's (1763; 1776) work, the main dynamic impulse to change comes from the division of labour. The productivity gains associated with labour specialization, related to the greater dexterity of the workforce, to the rationalization of resources and to higher incentives to innovate, induced changes in the identity and composition of economic activities, thus giving rise to a new structure of the economy. Another contribution in this period, from Rae (1834), points to invention, rather than the division of labour, as the major force driving structural change. From his perspective, the invention of new tools and machines brings on the division of labour (and not the other way around), which is then reflected in the changing structure of the economy. Rae also points out that the advantages arising from the division of labour, contrarily to Smith's point

[5] The distinction between formal and appreciative theorizing follows Nelson and Winter's (1982) original proposal and intends to separate the theoretical explanations that are expressed in mathematical terms (through modellization), from the theoretical work in which this kind of construction is absent.

of view, come mostly from a more efficient use of the stock of instruments in the society, rather than from the increased efficiency of the workforce. Ricardo (1817), in his turn, emphasized the role of non-producible resources in the progress of wealth. Output growth requires growth of factor inputs but land is 'not unlimited in quantity and uniform in quality' (Ricardo, 1817: 70). This means that as growth proceeds, more land must be taken into cultivation, but land cannot be created. The growth of overall production requires then a continuous substitution of produced for non-produced inputs, which implies the changing composition of the productive system, together with significant changes in income distribution.

For the most part, classical economics was carried out in a rather descriptive fashion, without an explicit analytical account of the economic structure. Some exceptions to this general pattern can nevertheless be found in the works of Quesnay (1758) and Marx (1885). The first author, in his *Tableau Économique* (1758), provided a simple description of the analytical structure of the economy, exploring the general interdependence between economic sectors. Crucial to Quesnay's analysis is the notion that 'natural proportions' between sectors can be identified and that it is possible to examine whether or not a given pattern of social expenditure is a sustainable one. The same idea is also present in Marx's schemes of accumulation and reproduction of capital (Marx, 1885), perhaps the most rigorous formulation to date of a growth model. Distinguishing between 'constant' and 'variable' capital, the former representing circulating capital such as raw materials and the latter meaning advances to labour (i.e., wage payments), Marx (1885) argued that the tendency for increases over time in the ratio of constant to variable capital (the 'organic composition of capital') implied a re-proportioning of the various commodities produced. He also stressed that this transformation had to follow a particular pattern, so as to achieve a viable expansion of the economic system. In both cases, the analytical representation of the economic structure is based on a circular view of the productive process.[6] Goods are produced not only from natural factors of production, but also from each other, and a particular good *x* entering the production of a good *y* can also use the latter in its production. The interdependence of the economic system is captured by considering the flows of commodities among different

[6] In contrast with this view, the Austrian theory of the formation of capital (Böhm-Bawerk, 1891) considers the productive process from a linear perspective. Defining capital (whether fixed or circulating) as an aggregate of intermediate products, Böhm-Bawerk formulates the concept of "period of production", which corresponds to the time lag between the investment of "original factors" (land and labour) and the acquisition of consumable commodities. From this analysis, all goods are grouped according to their distance in time from the consumer, which provides an overall linear picture of the productive process.

sectors and income groups within a particular period (one year, for example). The two schemes are therefore characterized by a static representation of the production relationships. Nothing is said about the specification of the time structure of interrelationships between sectors, or about the way in which the economic system is supposed to evolve over time. Nevertheless, both approaches were used to examine certain aspects of structural dynamics, through the addition of specific dynamic behavioural principles. These principles meant extending the view from a single accounting period to a whole sequence of periods in the productive process, thus introducing a dynamic character to both analyses.[7]

### 3.2. The marginalist revolution and the relative neglect of structural change analysis (1870s-1940s)

The emergence of the marginalist revolution by the end of the 19th century, with its emphasis on the problems of optimal resource allocation, shifted the focus away from long-term dynamics and their association with structural change. Nevertheless, in the inter-war period, some progress was made in the analytical representation of economic structure and there were also some interesting developments in the business cycle literature that focussed on the relationship between structural changes at the industrial level and macroeconomic fluctuations.

In the first domain, there is the seminal contribution from Leontief's (1928, 1941) input-output model, in which the perspective of the economy as a circular flow is once again brought to the fore. The production process is illustrated by means of multiple causal relationships, where certain commodities are generated by other commodities that are themselves used and consumed in further production. Leontief explores this idea of general interdependence, providing a detailed quantitative description of the structural properties of the components of a given economic system, and considering simultaneously the relationship between vertical product flows and the horizontal arrangement of production activities. In a standard input-output table, each row and corresponding column represents one particular sector, and each individual entry expresses the amount of the commodity or service produced by the sector (identified in the row) that has been delivered at the sector represented in the corresponding column**.** This structural representation of the economy provides the basis for determining the total sectoral output as well as the magnitude of the inter-sectoral transactions required to satisfy consumers' final demands. In particular, it is possible to derive a matrix

[7] See in this respect the discussion on productive interrelationships and economic dynamics in Landesmann and Scazzieri (1990).

describing the material input requirements of all producing sectors (matrix of technical input coefficients), which is also used to determine the relationship between the prices of goods produced by the different sectors and the value added payments (expressed in monetary units) made by each industry per unit of its output. In static input-output models, additions to the productive stocks of the economy are treated as a component part of the final demand vector. In the dynamic formulations of the Leontief system, the horizontal-flow description is supplemented by the specification of construction and delivery lags. These formulations permit the simulation of structural changes (such as changes in the composition of investment and consumption and changes in the technology), assessing their implications in terms of the overall workings of the economic system.

The idea of circularity in production is also present in another important contribution to the analytical representation of the economic system: that from von Neumann's general equilibrium model (von Neumann, 1937). Von Neumann studies the dynamic properties of a multi-sectoral economic system, identifying the 'intensities' of the various productive processes (i.e., the dimension of the different productive sectors) that maximize the overall expansion of the economy. However, since it is assumed that the ratios of the intensities are constant over time, the system undergoes an equi-proportional expansion in the production of all sectors, and thus structural change is completely neglected.[8]

In the business cycle literature, there were some attempts (e.g., Robertson, 1915; Aftalion, 1927; Frisch, 1933; Schumpeter, 1939) to explain macroeconomic fluctuations on the basis of industrial structural change. In the works of Robertson (1915) and Aftalion (1927), the major causes determining the occurrence and intensity of fluctuation in individual industries are related to the replacement and change of the industries' fixed capital stock, and special attention is given to the way in which producers form their forecasts of future prices and make the corresponding investment decisions. More specifically, the occurrence of a time lag between the moment at which producers place their orders for industrial equipment and the moment at which that equipment is put into use implies that a relatively small change in the demand for consumption goods translates into major changes in the production of capital goods. The longer the time lag, the higher the industry over-investment will be and, consequently, the more severe the subsequent depression. Both approaches highlight therefore the capitalistic nature of the business cycle that is associated to the 'capitalistic' techniques of production. Although other factors can influence the duration and intensity of business cycles,

[8] See Pasinetti (1993) for a discussion on the shortcomings of 'proportional dynamics'.

such as income and credit variations, they are seen mainly as a consequence rather than a cause of cyclical instability (Aftalion, 1927).

The argument according to which the length of the period required to construct and prepare for the use of fixed capital as a major factor in the explanation of business cycles can be found in Ragnar Frisch's analysis of the 'propagation problem' (Frisch, 1933). In this seminal work, Frisch points out that in order to get a satisfactory explanation of the cyclical fluctuations of the economy, one has to look at the 'impulse problem' and at the 'propagation problem' simultaneously, that is, at the exogenous factors that disturb the economy and the way in which those shocks are propagated and transformed into a cyclical pattern. Representing the economy by means of a determinate system of equations expressing the production of capital goods and the behaviour of consumers, Frisch provides a macro-dynamic explanation for the observed oscillations of the economy.[9] In Frisch's model, though, once the economy has been hit by a shock, the oscillations will progressively dampen until they disappear. In order to maintain the economy continuously swinging, the dynamic system has to be exposed to a continuous stream of erratic shocks, and the consequent irregular fluctuations must be transformed into cycles. Frisch looks at this 'impulse problem', providing a mathematical examination of the mechanism by which the accumulation of erratic influences may create the swings observed in statistical data.[10] Apart from the erratic shocks, the effects of innovation are also taken into account by Frisch as an additional source of energy, building upon another important contribution in the domain of the structural theory of the business cycle: Schumpeter's theory of innovations and their effect on the overall movement of the economy (Schumpeter, 1939).

According to Schumpeter, innovation, the major driving force behind economic progress in capitalist economies, arises from technological competition among firms. Schumpeter defines innovation in a broad sense as 'new combinations of existing factors of production' (Schumpeter, 1928: 377), exemplifying with the emergence of new products and new

[9] Frisch demonstrates that the system is satisfied if each of the variables is assumed to be made up of trend and cyclical components. Assuming a set of numerical values for the structural coefficients of the model, the author identifies, apart from the secular trend, a primary cycle with a period of 8.57 years, a secondary cycle with a period of 3.5 years, and a tertiary cycle with a period of a little more than two years. The remarkable correspondence between the lengths of the first two cycles and the empirical long and short-run business cycles, respectively, give credibility to the theory formulated. Moreover, since the length of the cycles obtained depends almost exclusively on the value attributed to the parameter representing the length of time needed for the completion of fixed capital, Aftalion and Robertson's argument obtains some validation**.**

[10] This theme was also approached by Slutsky (1937), in his classic article 'The summation of random causes as the source of cyclical processes'. However, according to Frisch (1933), Slutsky does not provide an 'exact and general law telling what *sort* of cycles a given accumulation will create' (Frisch, 1933: 199, original emphasis).

methods of production, the creation or exploitation of new markets and new ways to organize business. In his view, once an (important) innovation is introduced, it is followed by a complex process of dissemination by imitation and further improvement by other firms in the market, along with the appearance of other innovations in related fields of activity. There is thus a tendency for innovations to cluster, not only in certain activities, but also in particular time periods. For a while, the 'cluster' of activities in which innovation appeared will grow at a higher rate than the overall growth rate of the economy, but sooner or later, the potential for further growth becomes exhausted, and growth slows down. According to Schumpeter (1939), this cyclical development of clusters can be transmitted to the overall economy, contributing in this way to the observed discontinuity of the growth process and to the formation of business cycles of several lengths.[11]

### 3.3. Development economics and the revival of structural change analysis (1950s-1960s)

The sporadic incursions into the business cycle theory, together with the above-mentioned developments in the analytical representation of economic structure reflected a limited concern for the issue of structural change in the period between the two wars. In the post-war period, however, the interest in structural change analysis gained a new momentum, with the appearance and consolidation of development economics as an autonomous field of research, and a vast number of studies analyzing the processes of historical growth were produced, where emphasis was placed on the decomposition of the economic system.

At the time, development economics was largely concerned with the ways in which the different sectors of the economy adapted over time to overall changes in the economy, making extensive use of the concepts and methodologies of structural change analysis. Rostow's 'stage approach' to development (Rostow, 1960) reported the existence of structural discontinuities in the process of development, which were related to the concept of necessary pre-requisites for the transition to higher stages of development. One of the pre-requisites taking centre stage – the take-off – was the emergence of a leading sector that would induce the transformation of the productive structure in order to achieve higher rates of growth. Although this theory was later heavily criticized, in particular by Gershenkron (1962), who argued against the notion of a unique path of development, it had a tremendous impact on the

[11] Schumpeter's ideas on the relationship between innovation and business cycles were not well received by the economic community at the time of their publication, and were severely criticized by Kuznets (1940), who questioned their logical coherence and adherence to reality. In the 1970s, however, those ideas were once again brought to the fore, and became the centre of an intense debate among the supporters of Schumpeter's thesis on 'long waves' and its detractors, a debate that still remains today. See Fagerberg (2003) for a discussion on the matter.

contemporary theories of development. At about this time, the dual-economy models (Lewis, 1954) and 'big-push' theories were also very popular. They all stressed the importance of taking into account sectoral differences in order to explain the overall progress of the economy. In Lewis's model those differences were addressed through the distinction between the traditional and the modern sectors of the economy. In the face of a stagnant traditional sector with a high elastic supply of labour, the shift of labour towards modern industry would be beneficial at the aggregate level, as workers with low productivity would be put to more productive uses, and growth would continue until the modern sector had exhausted all reserves of labour in the subsistence sector. The works of Rosenstein-Rodan (1943, 1961) and Nurkse (1953), in their turn, emphasized sectoral differences as a requirement for balanced growth. In the former, the complementarities among different industries, such as those between production and consumption structures, were the main argument in favour of large-scale planned industrialization (the 'big-push'). Only through a planned industrialization effort would it be possible to distribute investment in the 'right' proportions, matching the structure of output to the structure of domestic demand. Nurkse, for his part, argued in favour of the promotion of a diversified increase in output that took into account domestic elasticities of demand in order to create mutually supporting demand (Nurkse, 1953). Although stressing the incapacity of less developed economies to promote a strategy of balanced growth, Hirschman (1958) also highlighted the close link between structural change and growth, by analyzing the linkages among sectors and the propagation of growth from leading sectors to other segments of the economy.

On the empirical side, there were also several studies published at this time that focussed on the changes in the composition of demand, production, and factor use. A main reference is Chenery's work in the search for uniform patterns of change in the structure of production across countries and over time (e.g., Chenery and Watanabe, 1958; Chenery, 1960; Chenery and Taylor, 1968). By means of a rigorous statistical framework, Chenery – on his own and in collaboration with other authors – performed a vast number of tests on the evolution of the economic structure, and from those tests he endogenously determined structural classification schemes and derived general patterns of economic development. In Chenery and Taylor (1968), for example, post-war changes in the composition of the national product of several countries were compared by means of an extensive amount of econometrical tests. Those tests resulted in the clustering of countries into three distinct groups – large, small primary-oriented and small industry-oriented – which showed different growth patterns, revealing distinct

interactions of scale and resource endowments in each group. At the same time as Chenery's work, there were also other studies that examined the changes in the structure of production and consumption by performing econometric analyses, such as Houthakker's analysis of the Engel's law of demand (Houthakker, 1957) and Temin's search for similar patterns of industrial growth (Temin, 1967).

In parallel with econometric studies, a large amount of work was devoted to the analysis of growth processes from an historical perspective that assumed the decomposition of the economy into a relatively small number of sectors. In many cases, the decomposition of the economic system was defined aprioristically and structural dynamics were mainly identified with the process of sectoral re-proportioning of the economy. Hoffman (1931, 1958), for example, examined the pattern of industrial growth of several countries by dividing the economic system into two major groups, one including the consumer goods industries, and the other the capital goods industries. From his viewpoint all industrialization processes exhibit the same general pattern of development, which can be described by the evolution in the relationship between the net outputs of the two groups of industries. In the first stage, consumer goods industries have a clear predominance over capital goods industries; in the second, capital goods industries grow at a relatively higher growth rate than consumer goods industries, which then leads to the third stage, in which the total output of both industries is divided into roughly equal proportions.[12]

Fisher (1939) adopted a different schematic decomposition of the economy, distinguishing between primary, secondary and tertiary production. This conceptual framework had already been used by Clark (1938), who in broad terms identified primary production with agriculture and related industries (like fishery, forestry, and hunting), secondary production with manufacturing, and tertiary production with all economic activities not included under the first two categories. Despite using the same nomenclature, Fisher (1939) proposes a different interpretation of the 'primary, secondary, tertiary' scheme that is based on the structure of consumer demand. Under the proposed framework, primary production is related to the economic activities that satisfy basic primary needs, secondary production includes 'all manufacturing activities designed to produce things for which there is a more or less standardized or conventional demand, but which could not be described as essentials' (Fisher, 1939: 31), and finally, tertiary production includes 'every new or relatively new type of

[12] According to Hoffman (1958), it may even be a fourth phase of industrialization in which the capital-goods industries would be more important than the consumer-goods industries.

consumers' demand, the production and distribution of which is made possible by improvements in technical efficiency, which release resources hitherto required for primary or secondary production' (Fisher, 1939: 32). As can be seen from these definitions, the 'primary, secondary, tertiary' scheme acquires under Fisher's classification a more precise connection with the relationship between growth and structural change, which, according to the author, means that attention can be focussed on the 'growing points' of the economy.

A tri-partite decomposition of the economic system is also considered by Kuznets (1961, 1971) in his outstanding analysis of the relationship between long-run economic growth and structural change. The three major sectors, which can in broad terms be classified as 'agriculture', 'industry' and 'services', reflect to some extent the basic criterion of Fisher's (1939) decomposition, expressing the position occupied by the products on the scale of the immediacy and priority of demand. But unlike Fisher, Kuznets does not infer from that particular decomposition of the economic system the growth potential of the economy. In fact, he points out several flaws in the sectoral structure considered, which arise mainly from its incapacity to reveal the impact of technological progress on growth, the basic source of 'modern economic growth' (Kuznets, 1971). The evidence presented by Kuznets for the group of countries that initiated modern economic growth between the late eighteenth century and the 1880s reveals an historical association between high rates of growth of per capita product and productivity and the high rate of shifts in production structure. Kuznets explains this strong association as the result of the combined action of three major influences arising from changes in the structure of consumer demand, changes in comparative advantage and changes in the technology. From this conjunction of factors, technological change is seen as the decisive influence, since it represents the root cause behind the high rates of growth in aggregate product and productivity that characterize modern economic growth. Technological innovation is not, however, evenly distributed among all existing branches of production. At any given point in time, its influence is concentrated on a particular group of 'growth' industries that, as the name indicates, grow much more rapidly than the rest of the economy and therefore induce changes in the structure of production. These changes are then necessarily followed by changes in other aspects of the economic structure, such as changes in demographic patterns, in legal and political institutions, and in some elements of the 'social

ideology', which in turn may induce further changes in technology and in the structure of production.[13]

Other historical approaches to the growth process, instead of relying on an aprioristic decomposition of economic activity, derive decomposition from the analysis undertaken, clustering the different sectors of the economy according to the similarity of their dynamics. An important contribution to this approach can be found in the work of Svennilson (1954), who studies the process of economic growth in Europe over the 1913-50 period. Svennilson sees long-term economic growth as being intimately related to structural transformation, a phenomenon that he associates with a wide range of changes, including mechanization, changes in input-output relations, shifts in the distribution of consumption, changes in exports and imports and the re-distribution of labour between industries (Svennilson, 1954). Thus to substantiate this view, Svennilson examines the transformation of the economy in great detail in his analysis of European economic growth in the first half of the 20$^{th}$ century, building on a long series of information on markets and industries, along with data on the evolution of national aggregates. Long-term economic growth, Svennilson argues, influences the process of transformation in manifold ways, which in turn affects growth. One of the links between long-run growth and structural transformation, also mentioned by Kuznets (1961, 1971), is based on the well-known empirical regularity expressed by Engel's law. Rising per capita income originates shifts in the structure of consumer demand, which in turn, through input-output relations, give rise to changes in the distribution of labour among industries, and even to changes in the pattern of spatial distribution of population and urbanization. These changes may then affect growth, by revealing new needs and inducing further innovation.

An important aspect stressed by Svennilson has to do with the role of investment in the overall process of growth and structural transformation. Since all the different types of transformation involve the creation of new capital equipment, investment arises as an aspect of overwhelming relevance in the transformation process. For instance, structural transformation can be retarded by an incipient level of investment that does not permit the substitution of old (obsolete) capital with new and more efficient types of capital equipment. According to Svennilson (1954), inertia in the renewal of capital equipment was precisely one

[13] The sequences of change in the economic and social structure as described by Kuznets (1971) can follow a number of different paths. The path described above is only one of the possibilities.

of the most important factors determining the low rate of growth in Europe between the two wars.[14]

The role of investment in the development process is also emphasized by Rosenberg (1963), although different reasons are called upon. According to Rosenberg, a high rate of investment may be of crucial importance since it leads to the establishment of a capital goods sector with a sufficiently high dimension, one that allows the economy to innovate and stimulate technological change. Analyzing the history of today's developed countries, Rosenberg highlights the crucial role that the capital goods sector has had in the process of technological innovation. Not only was it in this sector that most of the major innovations arose, but most importantly, it was the emergence of a progressively more highly specialized capital goods sector that opened the way to the formation of a technological background that has provided the necessary skills and attitudes conducive to technical progress.[15] In this respect, the size of the capital goods sector takes on critical importance. In line with Smith (1776), Rosenberg argues that the efficiency of capital-goods industries, more than consumer-goods industries, depends to a considerable degree on the extent of the division of labour, which in turn depends on the size of the market. In his view, capital-goods industries usually enjoy economies of specialization, benefiting from increasing efficiency levels when they concentrate on a relatively narrow range of products, which necessarily implies a large demand for their products. Applying this argument to the particular situation of underdeveloped economies, Rosenberg (1963) argues that they suffer from considerable handicaps. The absence of an organized domestic capital goods sector inhibits the development of the technological base on which further technical progress depends. This explains why they were unable to develop, as would be expected, capital-saving techniques in a symmetrical way to that which occurred in today's developed economies (where the relative scarcity of labour gave rise to the development of labour-saving technology). Indeed, the

[14] This link between investment and technical progress is formally explored by Salter (1960). In Salter's model, any single industry is seen as comprising a number of different plants built at different times, which embody in their capital equipment the best-practice technique available at the date of their construction. At any given point in time there is thus the coexistence of different plants with different 'vintages of capital goods', where only the recently constructed plants have employed techniques that meet current best-practice standards. A prominent feature of the model is that investment is seen as the vehicle of technical change, where the rate of diffusion of new techniques and the subsequent rise in productivity depend on the rate at which investment is made.

[15] According to Rosenberg, 'there is an important learning process involved in machine production, and a high degree of specialization is conducive not only to an effective learning process but to an effective application of that which is learnt' (Rosenberg, 1963: 220).

capacity to develop capital-saving technologies necessarily implies the development of a capital goods sector first.[16]

### 3.4. From development economics towards a technology focus (1970s-1980s)

#### 3.4.1. The growing importance of technological issues

The vast number of contributions from the fields of development economics and economic history to structural change analysis, from which only a few examples have been extracted, were mainly developed along empirical or appreciative strands, without recourse to any formal reasoning. In fact, despite their greater adherence to reality, most of the theoretical analyses on development economics over this period were developed in non-formalized terms, which may explain the poor standing that development economics had among theoretical economists.[17]

This situation was about to change, however, in the 1970s, when development economics experienced a profound transformation in its core methodologies and major themes of debate (Backhouse, 1990). The interest in the formulation of (ambitious) macro theories of development strongly declined, with the shift of development economics towards a micro approach that made intensive use of the neoclassical toolbox. In contrast with earlier models that stressed 'structural rigidities', this new (neoclassical) approach assumed the existence of a reasonable degree of flexibility in the economy (e.g., Little, 1982). The answers to be given to the problems of underdeveloped economies, according to this new approach, ought to be based on the definition of the right incentives to get markets working (Easterley, 2002), rather than on substituting the market through (structuralist) planned intervention. The resurgence of neoclassical development economics and its reliance on the price mechanism led inevitably to decreasing interest in structural change analysis, although the latter on its own does not necessarily translate into state intervention. As Chenery (1988) puts it, 'recognizing the interrelations among the principal elements of the structural transformation does not in itself

[16] In a different paper, Ames and Rosenberg (1964) address the related issue of the relationship between technical progress and specialization. In particular, it is argued that 'technological change, on average, increases the (vertical) specialization of labour and decreases the (vertical) specialization of machinery' (Ames and Rosenberg, 1964: 371). In what concerns the latter, Ames and Rosenberg mention a tendency towards a higher level of diversification (decreased specialization) of firms in later stages of industrialization. In their opinion, this happens because firms will tend to protect themselves from technological and consumer demand changes, by producing a mixture of intermediate and finished goods (instead of producing exclusively finished goods). The fact that industrial economies have a much higher proportion of the production of intermediate goods is seen in this context as a possible explanation for their greater capacity to react to changes in demand in comparison with less developed economies.

[17] For the more orthodox strand in economics, all reasoning must be expressed in mathematical terms, in order to establish the logical coherence of theoretical arguments (Backhouse, 2000).

constitute an argument for more government intervention or overall planning' (Chenery, 1988: 201). Even though there were still some studies on development economics following the 1970s that pursued a long-run approach, emphasizing the role of structural change on development (e.g., Chenery, 1975; Chakravarty, 1980; Urata, 1986, Murphy *et al.*, 1989), their relative importance in the overall production in this field was severely reduced.

In this same period, however, most particularly from the 1980s, a number of interesting studies focussing on technical change from historical and evolutionary perspectives came to the fore. These studies drew attention to the disequilibrium processes by which new technologies were generated, and explicitly addressed the links between changes at the level of microstructures and higher-level changes.

Within the historical approach to structural dynamics, some studies analyzed the process of growth by focussing on changes occurring in the industrial structure as technological leadership changed across countries. Original work in this area was at first mostly concerned with the effects of the technological spread induced by the industrial revolution (e.g., Lewis, 1978), but later, several studies focussed on more contemporary periods, exploring the role of international knowledge spillovers as a source of growth and 'catch-up' in the post-war period, building on the influential work of Abramovitz (1979, 1986). In his 1986 paper, Abramovitz analyzes the theoretical and empirical appeal of the 'catch-up hypothesis', which in its simplest form states an inverse relationship between the initial productivity levels of countries and their productivity growth rates in the long run. The tendency of countries to converge is based on the existence of a technological gap (Nelson and Phelps, 1969) between advanced and less developed countries. According to this hypothesis, the technological gap carries a potential for generating growth more rapidly in the technologically backward countries, since they can borrow technologies that have already been employed by the technological leaders, and therefore make a larger productivity leap. Abramovitz (1986) draws attention to the need to extend and qualify this simple catch-up hypothesis, taking into account the specific societal characteristics of the countries. In his view, only the countries that possess adequate 'social capabilities', that is, those with sufficient educational achievements and adequately qualified and organized institutions, can exploit the available technological opportunities, and are thus able to catch up with the more advanced countries. Furthermore, Abramovitz argues that the pace at which the potential for catch-up is realized depends on a number of factors, related with the ways in which the diffusion of knowledge is

made, the pace of structural change and the rates of investment and of the expansion of demand.[18]

At the same time as Abramovitz's work, an important strand in the literature focussed on the phenomenon of path dependence, exploring the idea that past events influence the overall process of technological change, and emphasized the general indeterminacy of economic outcomes. Although the idea of path dependence had already been explored by Salter (1960), it received a major boost in the works of David (1985) and Arthur (1988, 1989). According to the first author, technological change is essentially seen as a path-dependent process, in which random events or 'historical accidents', particularly in the early phases of the introduction of a technology, can have a decisive influence on the long-run outcomes of the economy. Under specific circumstances, that is, in the presence of technical interrelatedness, scale economies and irreversibilities due to learning, the occurrence of minor events can even 'lock-in' the economy to an inferior technology, as the example of the QWERTY typewriter keyboard illustrates (David, 1985). In a similar line of reasoning but pursuing a more formal approach, Arthur (1988, 1999) highlights the role of increasing returns in the path-dependency of technology adoption and the possible lock-in of the economy by historical events. In the presence of increasing returns, whether derived from network externalities, learning effects or investment indivisibilities, a technology that was by chance adopted early on can increase its dominance and eventually drive 'superior' concurrent technologies off the market. This is in sharp contrast with the alternative situations of constant and diminishing returns to scale, in which, as Arthur (1989) acknowledges, the adoption process is both ergodic (small events cannot influence the outcome) and path-efficient. However, technologies that display increasing returns with adoption are probably the majority (Arthur, 1989).

Underlying both David's (1985) and Arthur's (1988, 1989) analyses of technological adoption and change is the idea that manifold uncertain outcomes may exist, and that the 'selection' of

[18] An interesting aspect that is highlighted by Abramovitz (1986) has to do with the observed changes in leadership and, more generally, the changes occurring in the ranking of countries according to their relative productivity levels. The simple catch-up hypothesis reflects only the reduction of productivity differentials between countries, and not these types of changes. In this respect, Abramovitz mentions that the idea that a follower's potential for rapid growth weakens as its technological level converges on the leader's may not necessarily materialize if social capability is itself endogenous. In this case, a possible endogenous enlargement of social capabilities by followers can make those countries leapfrog the initial leaders (for example, followers can successfully exploit the possibilities of advanced technologies, and thus be able to compete in markets that they could not contest previously). At the same time, there may be exogenous factors in the convergence process that influence the ranking of countries. The specific social capabilities of a country and its endowment of resources may fulfil the requirements necessary for the full exploitation of an existing technology, but may be less capable of adapting to new technologies.

the outcome that ultimately prevails is dependent on a number of specific circumstances. This 'evolutionary' line of reasoning is also present in Dosi's (1982) analysis of the determinants and directions of technological change. Like David and Arthur, Dosi (1982) attempts to look inside the 'black box', providing an explanation for the emergence and development of technologies. To this end, he develops a theoretical model of technical change which is based on the similarities between scientific discovery and technological progress. More precisely, Dosi (1982) uses the Kuhnian concept of 'scientific paradigm' to derive the analogous concept of 'technological paradigm', which in his model ultimately determines the cluster of possible technological directions to pursue ('technological trajectories'). This framework allows him to distinguish between continuous changes and discontinuities in technological innovation by considering, respectively, changes along a technological paradigm and changes in the paradigm itself. At the same time, it sheds some light on the procedures by which new technological paradigms emerge and are selected among a set of possible options. In this respect, Dosi (1982) explicitly considers the interplay between scientific advances, economic factors and institutional variables, providing a more comprehensive account of the factors behind technological change than do the pure 'demand-pull' or 'technology-push' theories. He also highlights the relationship between technological change and industrial structure, underlining the connection between the 'technological' phases involved in the selection of new technological paradigms and of technical progress along established technological paths, and the phases of emergence and maturity of an industry, respectively. While the first phase will in general be accompanied by the appearance of new 'Schumpeterian' companies, the establishment of a defined technological paradigm will typically be followed by the consolidation of an oligopolistic market structure.

The related notion of 'techno-economic paradigm' is put forward in Perez's evolutionary interpretation of Kondratiev long waves (Perez, 1985). According to this view, it is possible to identify the Kondratiev waves with the rise and fall of successive technological revolutions, which introduce new ways of managing and organizing the economy that are so pervasive that they affect almost all industries and economic activities. In Perez's work, the change from one paradigm to another not only lies in the opportunity to economically explore a cluster of radical innovations, as in Dosi's work, but it is crucially dependent on the emergence of a 'key factor' whose abundant supply, rapidly falling costs and multiple applications, facilitate the spread of innovation throughout the economy. At the turn of the 20th century, for example, the role of key-factor was played by low-cost steel, whereas in our days, according

to Perez, it falls upon cheap microelectronics. An important point stressed by Perez (1985) has to do with the fact that the managerial and organizational styles that accompany the cluster of radical innovations may conflict with previous forms of organization and management of the economic activity, which were more adapted to the earlier techno-economic paradigm. The full exploitation of the growth potential associated with the new technological paradigm can only be accomplished, therefore, after the restructuring of the socio-institutional framework, which inevitably requires a considerable amount of time. In this period of time, a crisis will emerge, corresponding to the recession and depression phases of Schumpeter's long waves of economic development, with recovery depending crucially on society's ability to adapt to new social and institutional requirements.

The growing emphasis on technological issues in structural change analysis seems to be confirmed in our bibliometric analysis. As shown in Figure 1, the share of papers concerned with Technological Change and Innovation is continuously rising in the period under study,[19] and is particularly relevant in more recent years.

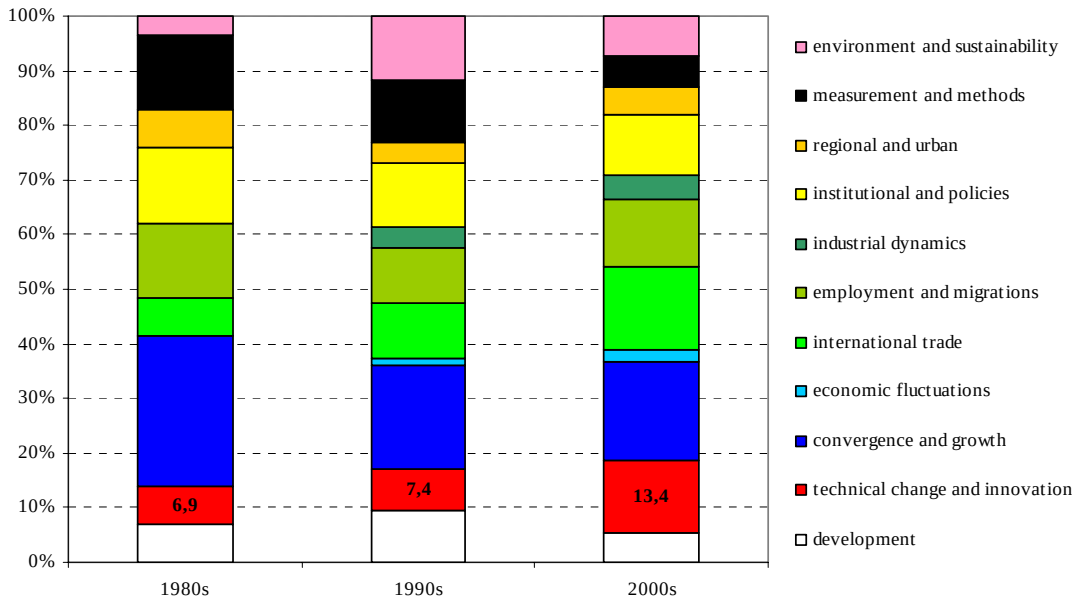


**Figure 1: The distribution (%) of papers on Structural Change by main theme of analysis**

*Source*: Authors' own computations based on articles in journals collected from the Econlit database, 1969-2005 (n=910).

[19] The classification of papers according to the main theme of analysis could only be done from the 1980s onwards, because in the earlier period the selected papers did not have an abstract.

### 3.4.2. The relative disregard of formalism

Most of the above-mentioned works on structural change analysis over this period, in a similar way to the previous one, were developed in a piecemeal, empirical fashion with little attempt to organize thoughts into a formal framework. In fact, one of the main drawbacks of structural change analysis seems to derive precisely from the difficulties experienced in formalizing its main ideas. As can be seen in the figure below, the approach in most of the work produced in this area during the 1980s is largely empirical (summing all the works with an empirical and an empirical plus appreciative strand, they amount to almost 60%), with formal studies representing only a small fraction of the total production – purely formal works only represents 10% of papers published on structural change in the reference period.

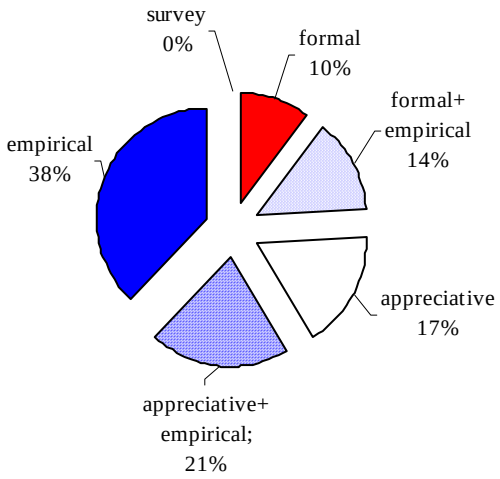


**Figure 2: The distribution (%) of papers on Structural Change by Type in the 1980s**

*Source*: Authors' own computations based on articles in journals collected from the Econlit database, 1980-1989 (n=29).

*Note*: Although in the 1980s we have 168 structural change articles, 139 do not have an abstract which prevented their classification by type.

In the post-war period, despite the vast amount of work on structural change mentioned above, there was an almost total neglect of the more strictly theoretical terms of the matter. A notable exception can be found in the work of Lowe (1955, 1976), one of the pioneers of 'traverse analysis', which examined the transition between the steady-states of an economy which were disturbed by a change in the exogenous determinants of growth (such as the supply of labour or technical progress). Lowe (1955, 1976) studied the change in economic processes, elaborating on a modified version of the Marxian schema of reproduction. One important modification introduced by Lowe concerned the division of the capital goods-producing sector into two sub-sectors: one that produced the equipment for the consumer

goods sector, and the other that produced the equipment for both subgroups of the capital goods sector. The decomposition of the economy into three aggregate sectors, which were organized in a hierarchical order - sector 1 produced the capital goods used as inputs in sector 2 and sector 1 itself, and sector 2 produced the capital goods used as inputs in the consumer goods sector (sector 3) – meant that the intertemporal complementarities during the adjustment periods of the economy could be taken into account, with sector 1 assuming the key role in the process. Under the assumption of full utilization of the economy's capital stock, any process of expansion would imply a prior increase in fixed capital in sector 1 (and subsequently in sector 2), so as to obtain an increase in the production of consumption goods. The adjustment path of the economy is thus characterized by a *sequential* process of production and restructuring of the economy, in which the capital stock is rebuilt. The inherited stock of fixed capital is thus seen in this model as a major bottleneck that the economy has to overcome. The necessary adjustment path is made through processes of formation and change of real capital that comprise the link between sequential stages of growth.

Lowe used this model to analyze the dynamic consequences of once-over changes, exploring the conditions under which a new equilibrium could be restored. Assuming an increase in the labour supply, he examined the aggregate changes and the structural shifts among the three sectors which could restore stationary equilibrium in the most economical manner. His post-classical model (Lowe, 1976) also took into account the impact caused by non-neutral process innovations, identifying the conditions that had to be fulfilled in order to reabsorb displaced labour and reach the new steady-state equilibrium.

Another exception is Baumol's unbalanced growth model (Baumol, 1967), in which some negative aspects associated with technical progress – more precisely, with the unbalanced pace of technical progress between sectors - are stressed. In Baumol's view, the economy can be seen as comprising two major groups of activities: those that are technologically progressive, in which innovations, capital deepening and economies of scale boost a continuous rise in productivity; and those that can only enjoy sporadic increases in productivity. This basic distinction stems from the intrinsic nature of the activities, and particularly from the role played by labour in the corresponding production processes. While in some activities, such as manufacturing, labour is only a means to attain the product, in others, like most of the service activities, it constitutes an end in itself. This particular feature makes technological substitution of the workforce difficult to achieve, and thus productivity

increases are slower than in the rest of the economy. The basic distinction between sectors is put forward in a model, in which labour productivity rises cumulatively in one sector, while in the other it is held constant over time. Since wages increase in the same way in all sectors, this leads to the cumulative rise of relative costs in the non-progressive sector of the economy, which cannot compensate for the rise in wage levels. Consequently, the activities in this latter sector will tend to be driven off the market, unless their demand is relatively price inelastic.[20] In this case, their relative share in output can be maintained, and as a result, an increasing number of the total labour force must be transferred to this sector, with the consequent slowdown in the rate of growth of the economy. Considering that there is a low substitutability in demand structures, this result can explain the increase in the 'service share' in total employment in the economy.

When performing traverse analysis, Lowe (1955, 1976) always considers an inter-industry approach, and is extremely critical of the linear view of the production process associated with the Austrian perspective and of its neglect of the role played by fixed capital in the structure of production. In contrast, Hicks soon became disappointed with the inter-industry approach, which he used in *Capital and Growth* (1965), switching to a vertical integration approach in his *Capital and Time* (1973).[21] At the origin of this change was the need to focus on innovations that take the form of new methods for making the same final product, something that could not be achieved in a multi-sectoral model with a horizontal structure, since 'there is no way of establishing a physical relation between the capital goods that are required in the one technique and those that are required in the other' (Hicks, 1977: 193). In Hicks' approach, the stream of labour inputs and the stream of final product outputs define the process of production. All intermediate products used in the production of final goods are ultimately reduced to the amount of labour that was used in their production, as in the Böhm-Bawerkian theory of capital. Hicks defines the conditions that characterize a steady-state equilibrium, and then examines what happens when that equilibrium is disturbed, upon the introduction of a new production technique. He shows that when a new, more profitable technique becomes available, there will be a period of time (the 'Early Phase of the Traverse') during which processes using old and new techniques will coexist. He then examines

[20] At this point, Baumol (1967) argues that some activities that face relatively inelastic demands may continue in the market, either by receiving public support (like theatres, for example), or by becoming market niches, directed towards luxury trade (such as high quality food or clothing services).

[21] Hicks, however, did not exclude entirely the horizontal approach, which is explored, in parallel with the vertical integration approach, in a later work (Hicks, 1985).

alternative scenarios that lead to different adjustment paths of the economy, contrasting with the path that would have been followed if the invention had not occurred.[22]

The main contribution within the structural theories of economic growth came, however, from Pasinetti's work on economic dynamics (Pasinetti, 1981, 1993). Like Lowe (1976), Pasinetti identifies technical progress as the major engine of economic change and devotes a great deal of attention to the problems associated with technological unemployment. His analysis is however rooted in entirely different grounds. In contrast with Lowe and Hicks, Pasinetti does not perform traverse analysis, since he is primarily interested in the conditions that must be fulfilled for an economy to achieve and maintain a 'satisfactory state of economic growth'.[23] To this end, a vertically integrated approach is adopted, and the economic system is described as a set of vertically integrated sectors, in which each sector produces a single final consumption good using labour as the unique factor of production. In this framework, technical progress influences the dynamics of the economic system through two major channels. The first one, defined as 'strictly technological' (Pasinetti, 1993: 36), refers to changes in technological coefficients (productivity increases) as well as to the introduction of new techniques and new goods and services in the economy. The second channel is related with the rise in per capita income and its influence on consumer demand, as described by Engel's Law. According to this empirical regularity, the increase in per capita income is reflected in differentiated increases in the demand for various goods and services and, consequently, the composition of the total production of the economy will also be different.

At any given moment in time, the theoretical framework is expressed by two systems of equations, in physical quantities and in prices. The price system is determined by the structural evolution of technology, whereas the physical quantity system is determined by the structural evolution of consumption demand.[24] In each sector, the physical output will grow in each period at a percentage rate that represents the sum of the rate of population growth and the rate of increase in per capita demand for the good or service from the sector. Since this

[22] Although this latter approach can lead to an easier treatment of the introduction of new capital goods in the economy, it still suffers from the main drawbacks associated with a pure vertically integrated model, namely the disregard for the 'machine-tool' sector and for the circular flow of the economy. See Hagemann (1990) for a comparative analysis on the potentialities and drawbacks of the inter-industry and vertically-integrated approaches.

[23] Described as a state in which there is approximately full employment of the labour force and full utilization of productive resources. (Pasinetti and Scazzieri, 1987: 527).

[24] In this sense, the evolution of prices is based on the classical labour theory of value, reflecting the physical quantity of labour embodied by the corresponding commodities, whereas the evolution of quantities is more in line with the Keynesian framework, in which the dynamics of production reflects the evolution of the corresponding effective demand.

latter component is variable across sectors, a *structural dynamics of production* emerges. At the same time, the differentiated rate of change in the technical coefficients across sectors generates an impact on the corresponding equilibrium prices of the commodities at a given wage rate, thus determining the *structural dynamics of the system of prices*. In particular, by assuming that the wage rate behaves as a 'natural' wage rate, the growth of wages will be roughly uniform across sectors. This means that, in order to preserve efficiency in sectors experiencing productivity growth at a higher rate than the average, the prices of goods (in relation to the prices of the other sectors) must decrease, whereas in the other sectors they must increase. As a result, all sectors of the economy are influenced by technical progress, either by increasing their productivity or by raising their relative prices.

An important consequence of the dynamics of production and prices is associated with the dynamic behaviour of employment. As time goes by, the different productive sectors are undergoing structural dynamics in both their outputs and costs, which has direct repercussions on the quantity of labour required. Considering a constant total population, the change in the demand for labour in each sector will depend on the comparison between the rate of growth of per capita demand for the corresponding commodity and the rate of growth of the sector's labour productivity. More precisely, if the sector's growth in per capita demand exceeds the corresponding growth in labour productivity, the sector will expand its share of total employment (and vice-versa). As a result, there will be relative changes in employment in the various sectors, thus determining the *structural dynamics of employment*.

Taking into consideration simultaneously the structural dynamics of prices, production and employment, Pasinetti (1981, 1993) demonstrates that the achievement of the full employment condition raises a *permanent* problem of complex macroeconomic coordination. The emergence of technical progress, although extremely beneficial in terms of the new goods and services that it introduces, and the rise in productivity that it brings about, also bears complex problems of adjustment in the economy. In fact, an immediate consequence of technical progress is a decrease in technical coefficients, and thus a tendency to generate unemployment as time goes on. Although there are a number of ways to counter this tendency (see Pasinetti, 1993: 54), full employment can only be achieved if there is an adequate level of labour mobility between productive activities and/or a reduction in the available labour (through a decrease in the activity rate and/or an increase in leisure time). In any case, the necessary adjustment that is needed in each single period of time requires the coordination of individual and collective choices that is far from being automatic. This raises a number of

institutional and policy questions so as to adequately respond to the challenging task of pursuing full employment.

A different perspective on the relationship between structural change and growth is put forward by Quadrio-Curzio (1986). In contrast with the studies mentioned above, Quadrio-Curzio brings directly to the fore the role of non-produced means of production and raw materials in the analysis of the production processes. Although already considered in the writings of the early classical economists (most notably, Ricardo and Malthus), the idea that the scarcity of natural resources can act as a constraint to growth was for a long time neglected by economic theory, even in the context of multi-sectoral models (e.g., Leontief, 1941; von Neumann, 1945).

Inspired by the work of Ricardo and taking Sraffa's *Production of Commodities by Means of Commodities* (1960, Chapter XI) as the point of departure for his analysis, Quadrio-Curzio (1986) attempts to integrate natural resources and raw materials in a dynamic theory of production. To this end, he defines a linear model in which the economic system is seen as comprising two major parts: one includes the sectors which produce a single raw material using labour, produced and non-produced means of production; the other includes the sectors producing commodities using labour, raw materials and produced commodities as a means of production. In this framework, the production system is described either in terms of global technologies and jointed techniques, or of composite technologies and disjointed techniques. The first representation, used in the analysis of uni-periodical situations, offers a synthetic description of the physical system, allowing the author to examine how technology changes when non-produced means of production are included in the analysis. In particular, Quadrio-Curzio demonstrates that those changes can be of two types: those that affect only the relative weight of the processes where non-produced means of production are activated; and those that imply an increase in the number of such processes. The representation of composite technologies allows for a more general approach, and is used by the author to study the production interdependences in dynamic situations. The overall analysis yields a rather complex picture of the production system, in which the dynamics associated with the different techniques are not proportional among the various sectors, and do not imply a constant growth rate. Moreover, the presence of non-produced means of production complicates the relationships between efficiency, the choice of techniques and technical progress, making the evaluation of technical change a particularly difficult task. This occurs because technical change depends not only on the internal efficiency of each of the single techniques available,

but also on the compatibility among the structures of the various techniques that are successively emerging, as the constraints imposed on growth by non-produced means of production become evident. Given these compatibility problems, a residual is created in the switchover from one production structure to another, diminishing the overall benefits associated with technical progress.

### 3.5. The 1990s: the resurgence of structural change research and the broadening of its scope

The 1990s are characterized by a striking rise in the interest in structural change analysis, with a considerable increase in the number of articles published on the matter. As can be seen from Figure 1 below, there seems to be a clear rise in the number of publications on the subject, when compared with the previous decades.

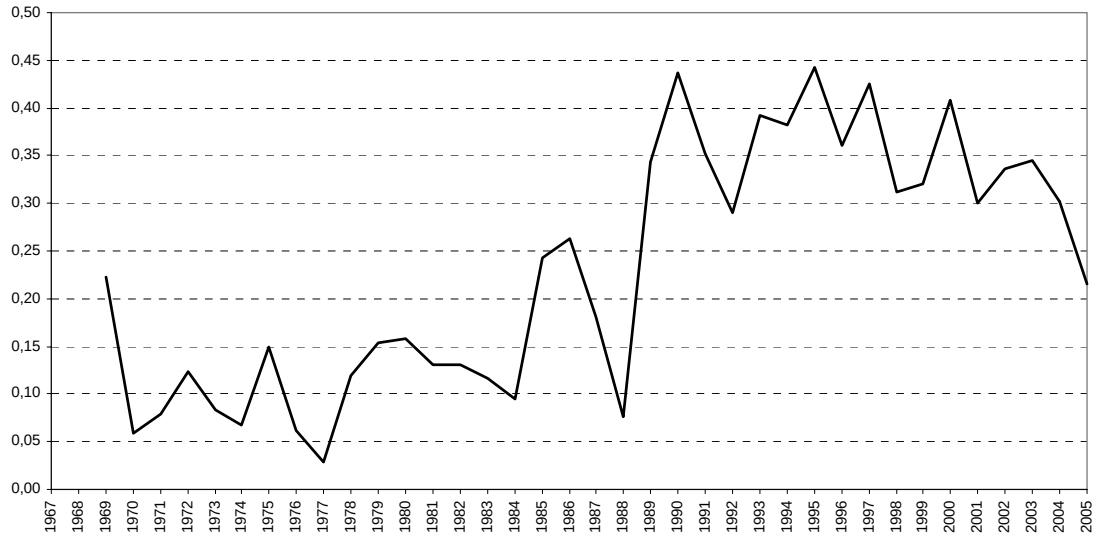


**Figure 3: Evolution of the relative weight of articles on Structural Change in the total articles published in Econlit, 1969-2005**

*Note*: The line results from dividing the number of papers on structural change by the total number of papers published in each year in journals indexed in Econlit. Just as a reference, the number of papers published under the heading of 'structural change' totalled 1247 between 1969-2005, whereas the corresponding number for all areas is 453457.

The rising importance of this approach, which is also apparent from the establishment in 1990 of a new journal entirely dedicated to the subject - *Structural Change and Economic Dynamics* -, seems to be primarily related with increasing interest in the explanation of the phenomena of technical change, which, as we have seen before, had been gathering force in the previous decades.[25]

[25] It is interesting to note that from the 1247 articles published within the area of structural change from 1969 up to 2005, 262 (21% of total) were published in *Structural Change and Economic Dynamics* – see Figure 7 in the final part of this section.

Indeed, the 1980s and 1990s witnessed 'a far greater readiness to look inside the 'black box' (...) and study the actual processes of invention, innovation and diffusion within and between firms, industries and countries' (Freeman, 1994: 464). The emergence of the *New Economy* and the controversy generated around the impact of information and communication technologies (ICTs) on aggregate productivity growth (the so-called 'productivity paradox') further stimulated the debate on technical change and its impact on growth.[26] Together with important developments occurring in mainstream economics (e.g., Romer, 1990; Grossman and Helpman, 1991), much of the work in this area has been developed under an alternative approach, known as 'neo-Schumpeterian' or 'evolutionary' economics. Proponents of this latter approach strongly criticize mainstream economics, arguing that a theory which is firmly grounded on purely rational behaviour and equilibrium assumptions cannot deal appropriately with the complex and uncertain nature of technology. In contrast, they stress the idea of disharmony and competition in the growth process, and place themselves at quite distant from aggregate production function models, by explicitly addressing the connection between processes of change at micro and industrial levels and overall macroeconomic dynamics.[27] From this perspective, processes of microevolutions of technique, organization and institution are significantly affected by higher-level changes and vice-versa, which means that causal connections between macroeconomic variables cannot be fully understood without considering the interdependence among the different levels of analysis. In this context, one possible explanation for the rising interest in structural change analysis can be found in its inherent ability to address the dynamic interaction between different levels of interdependence. Structural change analysis comes forward then as a powerful analytical tool that is capable of establishing the connection between turbulent microeconomic dynamics and relatively stable macroeconomic patterns in the process of technical change, as a substantial amount of work in this area indicates (e.g., Metcalfe, 1998; Montobbio, 2002; Saviotti and Pyka, 2004; Eliasson et al., 2004). At the same time, structural change analysis emphasizes the sequential nature of the processes of economic change, providing a more realistic view of the process of technology adoption and its effects on the economy. In particular, it provides a useful foundation for the study of the adjustment and intertemporal coordination problems brought on by technical progress, an issue that is totally neglected by the mainstream

[26] See, for example, Baily and Gordon (1988), David (1990) and more recently Freeman (2001) and Amendola *et al.* (2005).

[27] One of the main challenges pointed out by Nelson and Winter (1982) in the work that laid the foundations of evolutionary economics was precisely related with the need to establish the links between diversity and uncertainty at the micro level and relatively ordered growth and technological patterns at the macroeconomic level.

equilibrium approach, which takes intertemporal coordination for granted.[28] In summary, as Amendola and Gaffard (1998: 107) clearly put it, 'it is only through the consideration of relations which bring about different aggregations that we introduce real time, irreversibilities, and qualitative change', and are thus able to address the complexity and uncertainty of technical progress.

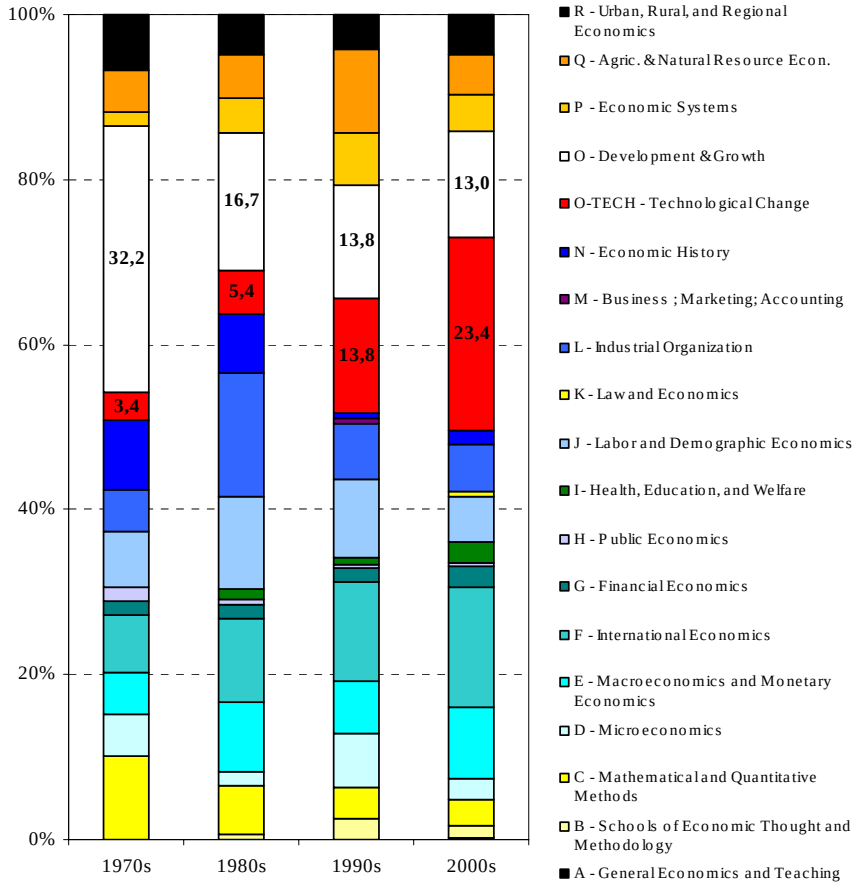


**Figure 4: The distribution (%) of papers on Structural Change by JEL Codes**

*Source*: Authors' own computations based on articles in journals collected from the Econlit database, 1969-2005 (n=910).

The rising importance of technical change at the level of structural change analysis is reflected in the proliferation of studies focussing on the impact of leading technological sectors in the economy, and in particular of ICT-related industries. As can be seen in Figure 4, the share of papers concerned with Technological Change (which is usually included under the heading JEL code O – Development, Technological, Change and Growth) almost trebled

[28] See in this respect Amendola and Gaffard (1998), and more recently Amendola *et al.* (2005).

from 5.4% in the 1980s to 13.8% in the 1990s. This trend remains in the 2000s reaching the status of dominant category in this last period.[29]

At the empirical level, several examples can be found. Quah (1997) examines the evolution of the structure of production in a sample of economies, showing that richer countries have higher contributions to economic growth from the IT sector. IT contributions to GDP growth are, however, relatively small, and therefore the empirical confirmation of IT as the main engine of growth in more recent years is not established.[30] More recently, Fagerberg (2000) finds changes in the employment share of the electronics industry to be positively related with the manufacturing sector's productivity growth, evidence that is corroborated by Carree (2003), although with a substantial reduction in the estimated spillover effects. Ten Raa and Wolff (2000), using a new method to decompose TFP growth, find that 'computers and office machinery' have given the highest contribution to the economy's productivity growth, and were in this sense the major engine of growth in the U.S. economy during the 1970s and 1980s. Amable (2000), in his turn, in a series of panel-data estimations which include developed countries along with NICs, finds that countries whose foreign trade structure has a comparative advantage in electronics enjoy faster productivity growth. Peneder (2003) also finds a positive relationship between the relative shares in the exports and imports of technology-driven and high-skilled industries and the growth of per capita GDP in his panel-data estimation for a sample of OECD countries. On the whole, these findings suggest the existence of substantial positive spillovers arising from leading technological industries, and in particular from electronic industries.

At an intermediate level between theory and empirics, some models have been developed in an attempt to explain the successful experiences of Ireland and the East Asian countries (Barry and Bradley, 1997; Nelson and Pack, 1999) on the basis of their greater ability to change structure towards increasingly more modern technology. In Nelson and Pack's two-sector model, for example, aggregate productivity is driven by the expansion of the modern sector, which uses more productive technologies and has higher profitability than the traditional crafts sector. The factors taken as crucial in explaining the rapid transformation from technological backwardness and poverty to relative modernity and affluence rely on the ability to absorb and assimilate modern technology and to shift industrial structure towards

[29] Note that the classification in Figure 4 differs (although it is related to) from Figure 1. In this latter, we classify papers by main theme, based on the analysis of their abstracts. Differently, classification underlying Figure 4 results from the papers' keywords according to JEL.

[30] This fact can, however, be due to the poorer accounting distinction between IT and non-IT activities, as acknowledged by the author.

more technologically progressive activities. In these works, structural change is once more considered as one of the key sources of growth and development, but in a different way than before, with emphasis being given to the transformation of the economy with respect to technologically progressive industries. Moreover, the concept seems to have lost its 'interventionist' character, where policy recommendations are generally defined in rather loose terms (Fagerberg, 2000).

In a more formalized approach, Saviotti and Pyka (2004), develop a model in which economic growth is created by the emergence of new sectors (such as ICT related industries). Exploring the employment implications of the model, the authors conclude that aggregate employment can grow, provided that the creation of new sectors compensate the tendency of falling employment in older sectors. The model explicitly addresses the links between micro and macro-variables of the economy, providing an example of the compatibility between turbulence at the micro level and relatively ordered patterns at higher levels of the economy. Eliasson *et al.* (2004), in their turn, study the interactions between the micro and macro levels in the economy, using the Swedish micro-to-macro model MOSES to perform simulations on the sustainability of the New Economy. Their main hypothesis is that the technological potential of the New Economy can only be fully explored when it is diffused in the 'older industries' through the Schumpeterian process of creative destruction, which requires a considerable amount of time. The modelling framework of the paper is not only able to capture the 'productivity paradox', but also provides an explanation for the non-emergence of the New Economy in several countries, based on their lack of institutional capabilities, in a line similar to Perez (1985) and Abramovitz (1989).

The growing concern with the effects of the ICT revolution is reflected in the rising share of papers addressing the issue, as can be seen in the figure below, although its relative importance within structural change research still remains relatively small.

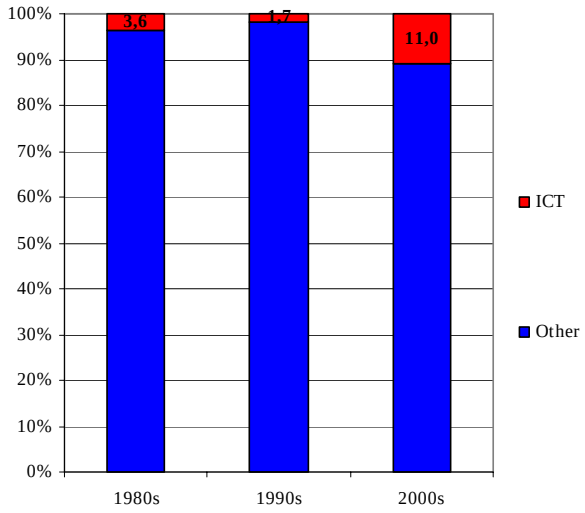


**Figure 5: The distribution (%) of papers on Structural Change by ICT focus**

*Source*: Authors' own computations based on articles in journals collected from the Econlit database, 1969-2005 (n=910).

As mentioned earlier, the bulk of the work on structural change relies mainly to empirical analysis. This is even more evident if we take into consideration the evolution of papers by type during the period in study (1969-2005). Figure 6 clearly shows that the empirically-led studies remain dominant over the entire period, although their relative importance declined in the 1990s, reflecting a trend towards increasing formalism in this period. It seems that this tendency did not endure in more recent years, but it is important to bear in mind that for this last period, the data available relates to only half the decade.

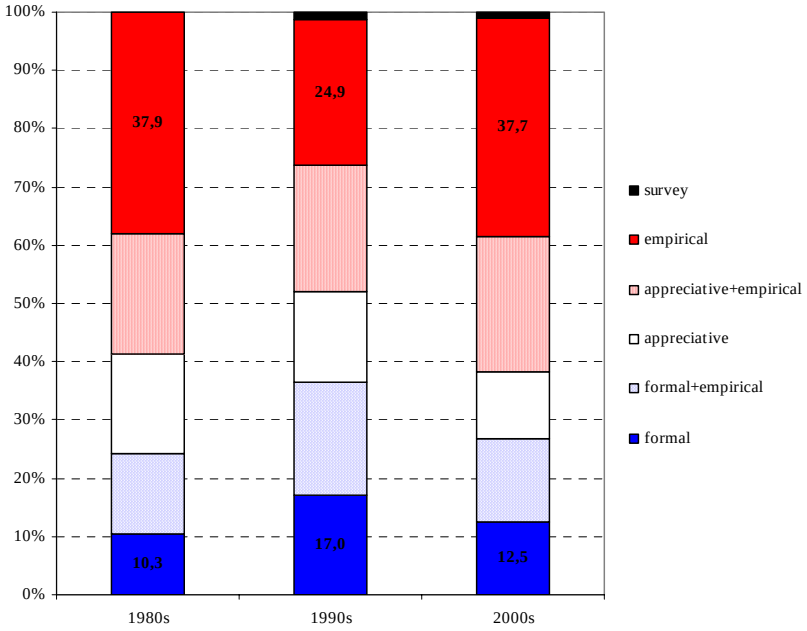


**Figure 6: The distribution (%) of papers on Structural Change by Type**

*Source*: Authors' own computations based on articles in journals collected from the Econlit database, 1969-2005 (n=910)

The increasing formalism in the 1990s cannot be dissociated from the appearance of the journal *Structural Change and Economic Dynamics*, which embraces a substantial percentage (21%) of the total papers analyzed (Figure 7). This journal is classified as a B journal (i.e., 'good journals for all research fields', cf. the Tinberg Institute grid) according to our purposed ranking of journals.[31]

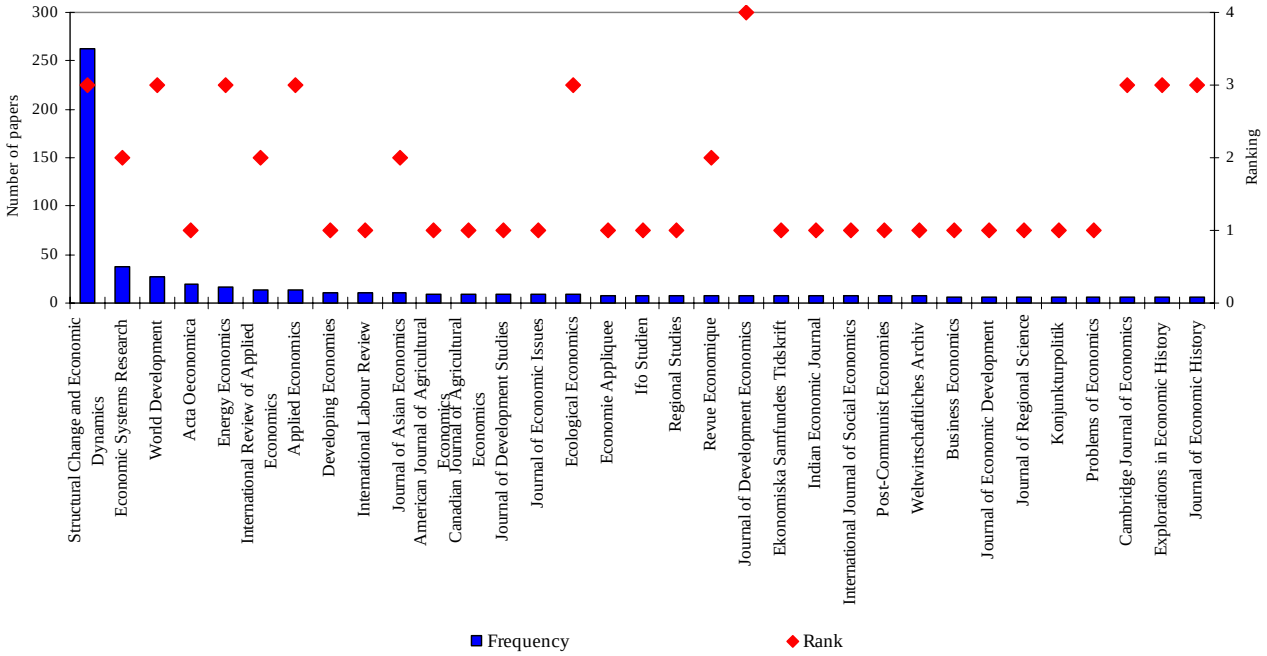


**Figure 7: Structural change papers by Top-30 Journals**
*Source*: Authors' own computations based on articles in journals collected from the Econlit database, 1969-2005 (n=1247).
*Note*: Top-30 Journals comprise 47.2% of total papers.

It is clear from Figure 7 that although there is a reasonable number of B journals in the top-10 ranking, NC (Non-classified) is the predominant classification for the entire top-30 group. This is representative of the overall sample (1247 papers) in which 48% of papers are NC while the highest ranking journals (AA; A, and B) represent approximately 41%.

An interesting aspect has to do with the relation between the journals' ranking and the articles' classification according to the main method of research – formal *versus* empirical. It is noticeable that formally-based papers tend to be published in higher ranking journals when compared to more empirically or appreciatively-based ones (cf. Figure 8). This does to some

[31] Based on the March 2006 RePEc journals list by impact factor and (partially) applying the Tinbergen Institute classification system, we computed a ranking of the academic journals indexed in Econlit. The Tinbergen Institute has drawn up a classification of journals in the field of economics. In this ranking, journals have been classified as: AA: generally accepted top-level journals; A: very good journals covering economics in general and the top journals in each field; B: good journals for all research fields. This classification is roughly based on the following cut offs (according to the impact factor), AA: > 3; A: > 1.5; B > 0.3. We added three other categories, C: >0.1, D: impact factor lower than 0.1, and NC: journals that are not ranked (in RePEc, the Tinbergen Institute ranking, or Kalaitzidakis *et al*., 2003).

extent reflect the overall tendency towards formalism in economic research (Mirowski, 2002; Weintraub, 2002).

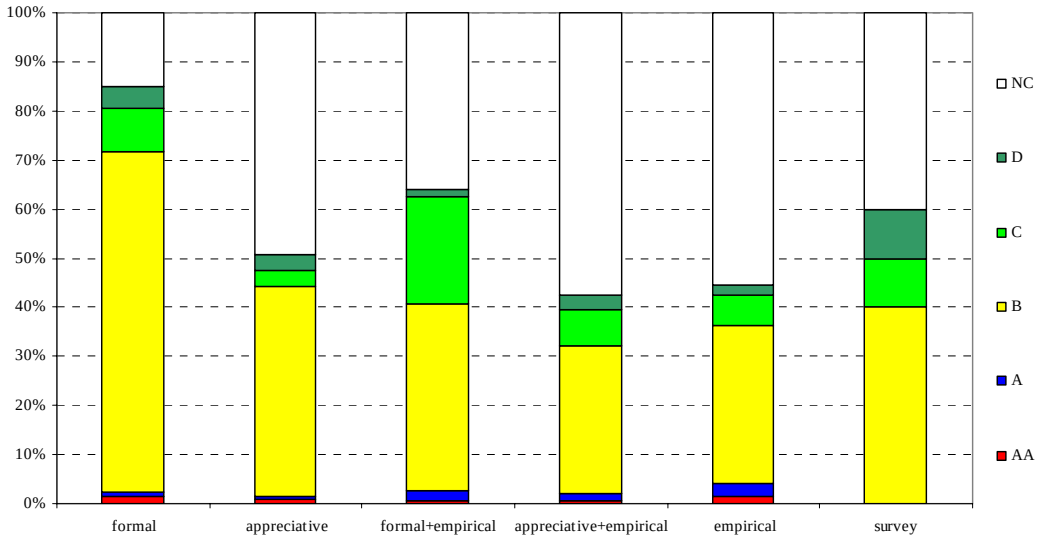


**Figure 8: The distribution (%) of papers on Structural Change by Type and Journal Ranking**

*Source*: Authors' own computations based on articles in journals collected from the Econlit database, 1969-2005 (n=910)

Taking into account the relevance of Technological Change and Innovation - surveyed in the present section -, it is worth noting that research on the matter tends to be published to a greater extent in top ranking journals, particularly in B journals (totalling almost 60% of the papers on this subject). In fact, together with 'Economic Fluctuations' and 'Environment and Sustainability', Technological Change and Innovation comprises one of the predominant issues in the highest ranking journals.

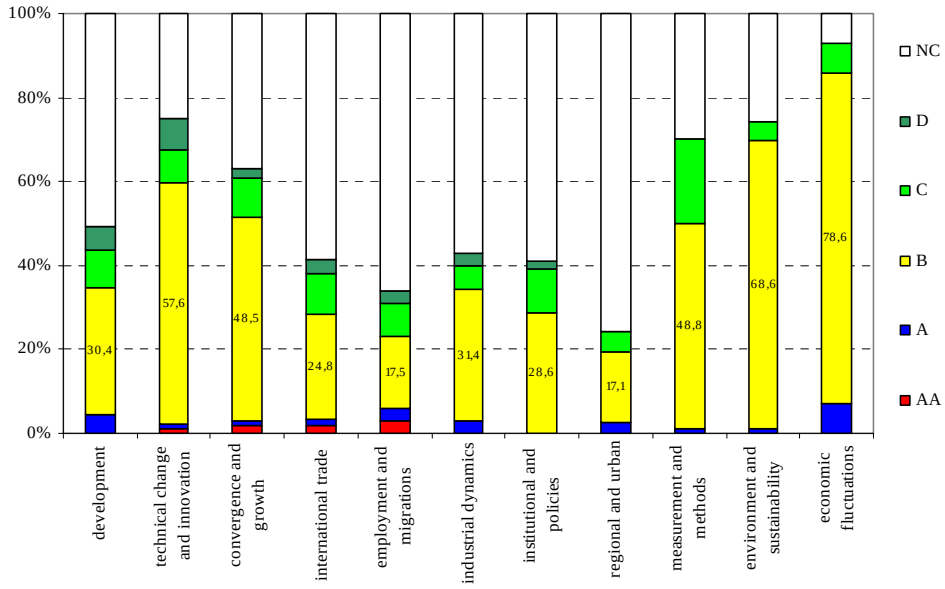


**Figure 9: The distribution (%) of papers on Structural Change by Theme and Journal Ranking**
*Source*: Authors' own computations based on articles in journals collected from the Econlit database, 1969-2005 (n=910)

## Conclusion

It is undeniable that structural change analysis has been an important area of research in economics. Nevertheless, to the best of our knowledge, no useful or comprehensive overview on the subject has been conducted to date. The aim of this paper was to fill this gap by providing a wide-ranging survey on structural change analysis using both conceptual analysis and bibliometric methods.

Five different periods were established, from a chronological perspective, according to the relative importance attributed to structural change, the main research method used, and the emphasis given to technological issues.

In the classical period, the analysis was mainly carried out at a broad economy level, mostly concerned with growth of income and wealth. An interesting aspect of this all-embracing approach was that it relied on the idea of decomposition into a restricted set of activities. In general, the analyses were conducted in a rather descriptive fashion, and lacked an explicit analytical account of the economic structure.

The appearance of the marginalist revolution at the end of the 19$^{th}$ century, with its emphasis on the problems of optimal resource allocation, shifted interest away from long-term dynamics and their association with structural change.

It was only in the post-war period that interest in structural change analysis gained a new boost, with the appearance and consolidation of development economics as an autonomous field of research, and with a vast number of studies focussed on the processes of historical growth where the decomposition of the economic system was the central feature.

By the 1970s a deep transformation was taking place in the development field of research with a shift towards a micro approach that made intensive use of the neoclassical framework, and induced a strong decline in structural change analysis. From this period onwards, there is a gradual and sustained move towards technological issues, firstly from a more empirical and historical approach and later associated to a higher level of formalism. This trend culminates with the establishment of the journal Structural Change and Economic Dynamics in the early 1990s.

More recently, studies on structural change analysis stress the importance of the leading technological sector as an engine of growth. However, the bulk of these studies are

empirically oriented with a weak connection to formal theorizing. This would probably comprise a very promising path for future research.

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