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Does Technology Cause Business Cycles in the USA?

A Schumpeter-inspired Approach[1]

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Abstract: The purpose of this paper is to deal with questions of instability and economic crisis, deriving theoretical arguments from Schumpeter's works and presenting relevant empirical evidence for the case of the US manufacturing sector in the time period 1958-2006, just before the first signs of the global recession made their appearance. More precisely, we use a wide dataset that contains 473 manufacturing industries, that are clustered based on their annual change of hourly earnings per worker and we make an attempt to interpret the economic fluctuations in the clusters formed. Meanwhile, we study the causal relationships between the crucial variables dictated by Schumpeterian theory. In this context, a number of relevant techniques have been used, such as hierarchical clustering, canonical discriminant analysis, cointegration analysis, periodograms and Granger causality tests. Our findings seem to give credit to certain aspects of the Schumpeterian theory of business cycles. The results are discussed in a broader context, related to the US economy.

Keywords: Economic Crisis, US Manufacturing sector, Schumpeter, Business Cycles.

1. Introduction

The Western World is superior, in terms of economic growth, compared to the poverty in most parts of the world due to, among other things, its technological superiority. In the words of Mokyr (1990, preface): “The difference between rich nations and poor nations is not […] that the rich have more money than the poor, but that rich nations produce more goods and services. One reason they can do so is because their technology is better; that is, their ability to control and manipulate nature and people for productive ends is superior”.

In the meantime, it is also true that the history of technological change and innovation contains several uneven periods in the history of particular economies. For instance, several nations are quite rich in technological progress and innovation. However, several peaks are often followed by periods during which the rate of technological change falls. So far, no satisfactory explanation has been found. As Thomson (1984, p. 243) has argued: “[t]echnical change is like God. It is much discussed, worshipped by some, rejected by others, but little understood”. According to Mokyr (1990, p. 6), the reason is simple: “The diversity of technological history is such that almost any point can be contradicted with a counterexample.” However, “Technological change is never automatic. […] there usually must be a combination of considerations to…make it possible: (1) an opportunity for improvement…, or a need for improvement…and (2) a degree of superiority such that the new methods pay sufficiently to cover the costs of the change” (Landes 1969, p. 42).

In this paper, we are dealing with questions of instability and economic crises, deriving arguments from Schumpeterian theory and presenting relevant empirical evidence for the case of the US manufacturing sector using disaggregate industrial data for the time period 1957-2006, based on relevant quantitative techniques. In the Schumpeterian tradition, a crisis is the by-product of innovative activity which can create long waves that are caused by the clustering of innovations. Schumpeter conceptualized business cycles as disturbances in the equilibrium and a return to a new equilibrium point which gives the process a cyclical character. The paper investigates how technological change affects economic activity in the US manufacturing sector for the period 1957-2006.

This work contributes to the literature in the following ways: First, it provides an extensive review of the literature on the subject and introduces the relevant quantitative framework which combines, agglomerative clustering, discriminant analysis, spectral analysis, cointegration and Granger causality. Second, based on these quantitative approaches, the paper offers a complete investigation of a famous postulate of the core of the Schumpeterian theory for the US manufacturing sector, and it is the first, to the best of our knowledge, to do so by industry of economic activity, since it utilizes a large dataset containing 473 industries classified following the North American Industry Classification System (NAICS). Third, the paper uses a wide examines the US manufacturing sector for the period 1957-2006, just before the first signs of the US and global economic recession made their appearance, in order to avoid getting skewed and biased results.

The structure of the paper is as follows: section 2 presents a selective review of the literature on technology; section 3 presents the theoretical framework drawing on Schumpeter's original works; section 4 sets out the methodological framework; section 5 offers a brief discussion of the empirical findings; finally, section 6 concludes.

2. Technology in *Economics*

Technological change expresses various kinds of knowledge that can make it possible to produce (i) a qualitatively superior output (or even a completely new output) or (ii) a greater volume of output (Rosenberg 1982, p.3). The majority of studies and essays on technological change regard it only as a cost reducing-phenomenon, which introduces new processes that reduce the total cost while the product remains unchangeable. However, following the same author (Rosenberg 1982, p. 4), "to ignore product innovation and qualitative improvements in products is to ignore what may very well have been the most important long-term contribution of technical progress to human welfare".

Kuznets (1930) focused on the great importance of innovation to economic growth and provided econometric evidence on the existence of a business cycle with a length of approximately twenty (20) years for the US economy. According to his findings the existence of such a cycle could be attributed to investments in infrastructure. Also, for Schumpeter, the clustering of innovations is the driving force for business cycles creation and emphasized the importance of new products and the high degree of instability caused to capitalist economies by technological innovation (Schumpeter 1939, 1942). [2] Following Nunes (2016), for Schumpeter entrepreneurship is the expression of the human impulse to be creative and the role of the entrepreneur in a developing/growing economy is to destroy the *status quo* in order to create a new cycle and a new flow, in an inter-temporal context. For Schumpeter, economic growth is generated by new business ideas and persistent innovations (Landström, 2005). In fact, Schumpeter argued that entrepreneurial rewards are obtained from the temporary monopoly scenario that arises as the entrepreneur successfully develops his business through "new combinations" of ideas and resources (Schumpeter, 1934). Additionally, for Schumpeter, innovating, improving existing goods and services, creating or expanding markets, and improving production processes and organizational structures were some of the leading characteristics of the entrepreneur. Schumpeter's emphasis on innovation and its impact on capitalist economies was extended by Strassmann (1959) whose main objections to Schumpeter's theories was that 'they do not adequately explore the process of technological change as a series of complementary, mutually reinforcing developments' (Strassmann 1959 p. 218).

Another school of thought that emphasizes the role of technological progress is traced back to Marx who mostly emphasized on the importance of social forces leading to technological progress (Marx 1867). Usher (1954) has probably offered the "most carefully articulated expression, in the twentieth century, of the view of technological progress that emphasizes continuity" (e.g. Rosenberg 1982, p. 6). Usher (1954) was mainly concerned with the origins and the nature of the inventive process and not its consequences. More precisely, Usher (1954) identified three general approaches to the problem of explaining the emergence of invention, namely the trascentalist, the mechanistic process and the cumulative synthesis. Ruttan (1959) argued that Usher (1954) established the theoretical framework for a theory of innovation that Schumpeter was lacking. Furthermore, according to Ruttan (1959), Usher's (1954) cumulative synthesis theory provided a unified theory of social process by which 'new things' come into existence, and it was broad enough to encompass the notions of invention, innovation and

[2] As Freeman wrote: "Most economists when they do consider technical change and the long-term dynamics of the system, turn to Schumpeter, and it is true that almost alone among major twentieth-century economists Joseph Schumpeter *did* attempt to place technical change at the heart of his system and did also address problems of social and institutional change" (Dosi et al., 1988, p.5).

science. Also, Gilfillan (1935a,b) argued that technological change consists of numerous minor modifications, introducing the notion of 'Sociology of invention' in the literature of technology and innovation. Fishlow (1966) had a similar view of technological change, and provided a thorough investigation of US railroad sector incorporating Schumpeter's and Gilfillan’s ideas on the role of innovations in order to explain the fluctuations of the sector. In a similar vein to Gilfillan and Fishlow, Hollander (1965) and Enos (1962) provided evidence in favor of the fact that re-invention tends to contribute just as much to technological progress as the original technological breakthrough does.

Of course, the efforts of economists and economic historians to develop and present reliable quantitative or even qualitative explanations of the contribution of technology to economic growth were serious but have not always ended up in success. After World War II, the recognition of the crucial role of technological change in economic growth has its roots in the work of Abramovitz (1956) and Solow (1957), who were probably the first to quantify the contribution of technological progress in the growth of the US economy. The authors found that only a portion of the growth in the American output was the result of an increase in capital and labour, while a large part of it remained unexplained, the so-called, “residual”. In that context, Solow (1956, 1957) suggested using an exogenous factor, called “technological change”. The econometric studies by Denison (1962a, 1962b, 1967), and Denison and Chung (1976), estimated that the components of the residual were the advances in knowledge and the role of economies of scale. However, these studies did not manage to come to realistic conclusions, and after some other studies had been conducted by Griliches (1957), Parker and Klein (1966) and Parker (1967) leading to similar results, the assumption of the exogenous nature of technological change was serious questioned. In a seminal paper, Jorgenson et al. (1967) argued that the unrealistic results of previous studies in the Solow residual are due to inaccuracy measurement errors. In specific, he argued that TFP should be computed as the difference between the rate of growth of real product and the rate of growth of real factor input. More recent attempts to explain the size of TFP were made by, among others, Hart (1995) who argued that TFP is best explained by the dual increase in the average output-price/input-price differential resulting from the squeeze in the rate of profits. In an alternative approach, Cantner and Kruger (2007) suggested that the Solow residual should be determined using a frontier analysis in an attempt to get more accurate estimates.

A new series of articles by Johansen (1959), Solow (1960) and Nelson (1964), treated technological change as endogenous, embodied in new technological goods. Improvements to these articles came through the works of Kaldor and Mirlees (1962), and Arrow (1962) and were extended by Uzawa (1965), Phelps (1966), Shell (1967), and Gomulka (1970, 1971). As far the literature relating technological progress and innovation at the firm level is concerned, the seminal studies trying to test empirically this relation, were those of Horowitz (1963), Hamberg (1964), Mansfield (1964), Scherer (1965a,b), Comanor (1967), Philips (1971), Malecki (1980), Link (1980), Meisel and Lin (1983), Scherer (1984) and others.

Some new efforts by Romer (1986), Lucas (1988) and Scott (1989) who treat technology as “internal” to the firm, have taken place. Accordingly, the articles by Romer (1990), Grossman and Helpman (1991), argue that firms buy their innovations from the technological sector. In a breakthrough paper, Aghion and Howitt (1992) argued that the innovative activity should be categorized by the magnitude of the impact of each type of innovation on economic growth. On the other hand, a series of studies outside the neoclassical view made an effort to explain the differences in economic growth among nations. These approaches are in the spirit of Gerschenkron (1962), Ohkawa and Rosovsky (1973), and suggest that new institutions should be developed in order to enable nations to increase their growth potential and reduce the great inequality observed among nations (Abramovitz 1986, 1994, Nelson 1993 and Lundvall 1992). In an inspired approach, Galbraith and Calmon (1996) followed by Galbraith and Kim (1998) Galbraith (1998, 1999) and Calmon et al. (2000) developed a useful methodology for studying the unequality in earnings among various industries that could be attributed to a number of factors such technological change. Their methodology was based on agglomerative hierarchical clustering using the hourly earnings of workers as the key variable, and canonical discriminant analysis using relevant technological and aggregate latent variables to explain cluster formation.

Relatively recently, Aghion et al. (2005) managed to derive an inverted U-shape relationship between innovation and competition in a general equilibrium framework which shed new light on the innovation dynamics that drive productivity forward. Finally, under the prism of Schumpeterian theory, Smythe (2009) provided a thorough analysis of the Great Merger Movement that took place in American manufacturing in the period 1895-1904. According to this work, this movement can be attributed to competitive pressures that were associated to a significant number of technological innovations that occurred at the end of the 19th century, whose incorporation in the production process would yield uncertain benefits, in a competitive environment and, thus, competition had to be restrained. In fact, according to Cajaiba-Santana (2014), research on social innovation has been polarized between agentic and structuralist approaches.

In a similar vein, in this work, we deal with questions of causality in business cycle theory deriving theoretical arguments from Schumpeter's work.

3. Theoretical Framework

As we know, Schumpeter's work may be considered as the starting point for economics of technical change, while Schumpeter on the whole could be considered as pioneer of evolutionary economics (Alcouffe and Kuhn 2004, 226).

In the first Japanese edition of his *Theory of Economic Development,* Schumpeter noted that his purpose had been to create "a theoretic model of the process of economic change in time [. . .] to answer the question how the economic system generates the force which incessantly transforms it" (Clemence, 1951, 158–159). Schumpeter started this book with a treatise of circular flow which – excluding any innovative activities – leads to a stationary state. The stationary state is described by Walrasian equilibrium taking account of the interdependences of economic variables but applicable only to a stationary process, i.e. one which adapted itself to forces acting on it. Schumpeter described this equilibrium as "stationary flow" (Schumpeter 1912, ch. 1) characterized by the absence of any change. He made clear that this "stationary flow" is only a theoretical abstraction and serves as a reference point (Schumpeter 1928).

According to Schumpeter: "Development is the distinct phenomenon entirely foreign to what may be observed in the circular flow or in the tendency towards equilibrium". "It is spontaneous and discontinuous change in the channels of the flow, disturbance of equilibrium which forever alters and displaces the equilibrium previously existing" (Schumpeter 1983 [1934], 64). Development may be related etymologically to some kind of progress; a positive procedure; and in that sense it may be related to some kind of teleology.[3]The great Austrian theoretician defined economic development as "such changes in economic life as are not forced

[3]For Schumpeter, teleology is "the attempt to explain institutions and forms of behavior *causally* by the social need or purpose they are supposed to serve; which is not always erroneous" (Schumpeter 1954, 58).

upon it from without but arise by its own initiative, from within" (Schumpeter 1912, 63). It was a phenomenon foreign to what might be observed in the tendency towards equilibrium (*ibid*, 64). It involved discontinuous change in the channels of flow, disturbance of equilibrium, which forever altered the equilibrium state previously existing. He wrote that: "[W]hat we are about to consider is that kind of change arising from […] the system which so displaces its equilibrium point that the new one cannot be reached from the old one by infinitesimal steps. Add successively as many coaches as you please, you will never get a railway thereby" (Schumpeter 1912, 64). Economic development depends primarily upon productivity increases based on technology and innovation. More precisely, for Schumpeter this concept covered the following cases: "1. The introduction of a new good […] or a new quality of a good. 2. The introduction of a new method of production […]. 3. The opening of a new market […]. 4. The conquest of a new source of supply […]. 5. The carrying out of the new organisation of any industry" (Schumpeter 1912, 66).

In this spirit, Schumpeter used the term 'technological progress' to characterize these changes (Scherer 1992: 1417), which account for the greater part of economic development. He distinguished this process from growth due to the gradual increase in population and capital. He wrote: 'The slow and continuous increase in time of the national supply of productive means and of savings is obviously an important factor in explaining the course of economic history through centuries, but it is completely overshadowed by the fact that development consists primarily in employing existing resources in a different way, in doing new things with them, irrespective of whether those resources increase or not" (Schumpeter 1942, 65).

In the Schumpeterian system, technology is the cornerstone of economic evolution and appears as the making of new combinations. Fluctuations are related to three different sources, namely: external factors (i.e. changes in commercial policy, diseases, changes in gold production because of new discoveries, revolutions and disasters), growth (i.e. changes in economic data which occur continuously in the sense that the increment / decrement per unit of time can be currently absorbed by the system without perceptible disturbance) and innovation (i.e. the historic and irreversible change in the way of doing things and more specifically changes in production functions which cannot be decomposed into infinitesimal steps).

According to Los and Verspagen (2007) technology and innovation efforts can be classified in two large categories: "process- oriented" and "product oriented". "Process-oriented" technological and innovative efforts aim at lowering the unit cost of producing a given type of output maintaining a constant quality. On the other hand, the main purpose of "product oriented" technological and innovative efforts is to produce either completely new products or qualitative different varieties of existing products. Of course, innovation is a qualitatively different phenomenon from invention: "innovation is possible without anything we should indentify as invention, and invention does not necessarily induce innovation, but provides of itself [...] no economically relevant effect at all" (Schumpeter 1939, 84). Also, Schumpeter asserted that the social process which produces innovations is distinctly different "economically and sociologically" from the social process which produces inventions (e.g. Ruttan 1959, 597). Schumpeter distinguished innovation from invention by arguing that "innovation is endogenous to the system, but is finally determined by the entrepreneurial function, that unique capacity to make combinations" (Freeman and Louçã 2001, 59).

In the same spirit, the difference between innovation and invention has been extensively discussed in Van Duijn (1983) who argued that diffusion, i.e. the large-scale distribution of innovations, is the dominant force behind long waves. For Van Duijn (1983), invention was the creation of an idea while innovation was the implementation of this idea. Van Duijn's(1983) theorywas based on three basic principles, namely: (a) innovation; (b) innovation life cycles and (c) investments in infrastructure. He suggested that innovations and innovation life cycles were the boosters of the growth process, which were additionally strengthened by investments in infrastructure. He distinguished the following four distinct types of innovations: (a) important product innovations, which were able to create new industries; (b) important product innovations, in already established industries; (c) process innovations in existing industries and (d) process innovations in basic sectors (such as oil refineries and the steel industry). Of course, as Kurz and Salvadori (1995) have argued, whether an invention will be transformed into an innovation lies on the distribution of income. In fact, Kurz (2007) presented a model that could incorporate two distinct industries so as to investigate the role of invention and innovation and their interrelationship in a (neo-) Schumpeterian framework.

Schumpeter also famously argued that economic systems do not achieve equilibrium. They just move into "neighborhoods of equilibrium [...] in which the system approaches a state which would, if reached, fulfill equilibrium conditions" (Schumpeter 1936, 45). In fact, in his *Business Cycles* Schumpeter (1939, 106) emphasized that major innovations are introduced around the neighborhood of equilibrium given that conditions are ideal. For him economic development is the result of innovation, i.e. "the outstanding fact in the economic history of capitalist society" (Schumpeter 1939, 61) and innovation is the leading force in what he calls "evolution". Economic evolution is however discontinuous because "innovations are not evenly distributed over time, but appear if at all discontinuously in groups, swarms or clusters" (Schumpeter 1939, p. 223). These discontinuities make innovations a force in the economic system and innovations which do not produce them cannot be a force in the economic evolution of a social formation: "[The] historic and irreversible changes in the way of doing things we call "innovation" [...] *The kind of wave-like movement, which we call the business cycle, is incident to industrial change and would be impossible in an economic world displaying nothing except unchanging repetition of the productive and consumptive process*" (Schumpeter 1935, 4; emphasis added).

The crystallization of technical change in the Schumpeterian system is the business cycle. In fact, for Schumpeter the business cycle is defined as the wave-like movement which is incident to industrial change. The way in which Schumpeter conceived of the cyclical features of the economic process is summarized by Elliot (1993, p. 14): "development occurs through a cyclical process" and as a result "cyclical fluctuations are no barrier to economic growth and recessions are not necessarily indicators of capitalism failure or breakdown".

The typical interpretation of Schumpeter's analysis is that long waves are caused by the clustering of innovations.Schumpeter conceptualized long waves as disturbances in the equilibrium and a return to a new equilibrium point which gives the process its cyclical character. All economic systems have an esoteric tendency towards equilibrium moving toward these "neighborhoods" after the disruptions have exhausted themselves. The most important characteristic of these "neighbourhoods" is that conditions are stable (Schumpeter 1912, 214).

Of course, in the Schumpeterian doctrine, the main force behind the cyclical behavior of economic activity is innovative activity. According to Hanusch and Pyka (2007), Schumpeter conceptualized Kontradieff's long waves which consist of long lasting cycles of a length of approximately 60 years, to be triggered by a constellation of interdependent and mutually supportive technical and organizational innovations (Louca 2007). Such a long run cycle is overlapped by the so-called 'Juglar cycle' that has an approximate length of 10 years and is caused by the clustering of innovations mainly in infrastructure. For Schumpeter, Juglar cycles again are overlapped by the so-called ‘Kitchen cycles’ with a length of approximately 40 months, which are caused by investment in inventory.

Therefore, in Schumpeterian business cycles theory there are three[4] (3) overlapping cycles that dictate the ongoing, eternal process of the economy to jump discontinuously from one equilibrium point to another[5], while the locomotive behind both the cycles’ creation and equilibrium jumps lies on the clustering of technological and innovative activity that is inherently an endogenous characteristic. Innovations tend to cluster because when something fundamentally new and untried has been succeeded it is much easier not only to do the same thing again but also to do similar things in different ways.

4. Methodology

The main purpose of this section is to test the Schumpeterian business cycles theory using modern econometric techniques. In fact our work builds on the work of Galbraith (1998,1999) and it partly complements the works of Noori et al. (2016) and Oner and Kunday (2016). Analytically, in this work, we provide a framework under which the investigation of business cycles is examined in the context developed by Joseph Schumpeter.

Our analysis begins with the clustering of the manufacturing sub-industries into distinct clusters using an appropriate measure that is able to capture the differences between the clusters formed. Based on the pathbreaking work of Galbraith (1998, 1999), we will make use of the hourly earnings per worker for each sub-industry as the primary measure for the clustering of the various sub-industries. The use of such a measure for the analysis of industrial performance is fully justified by the work of Galbraith and Calmon (1996) who proposed the year-to-year change of average wages by standard industrial classification (SIC) category as a performance measure. The theoretical justification behind the use this measure is based on the notion of industry specific labor rents. More precisely, based on Galbraith (1999, p.3) “if capital markets clear, but labor markets don't, we should expect that rates of return on investment equalize across

[4] Nevertheless, several authors (e.g. Ambramovitz 1968, Fenoaltea 1988) suggest that there is a fourth cycle, the Kuznet's cycle with a length of approximately 30 years that could be included in Schumpeter's theory.
[5] For an extensive review of cycle dynamics in a Schumpeterian spirit see, among others, Silverberg (2007).

industries but that rates of pay will not. Hence, there will be industry-specific pay differentials".[6] Thus, the main argument behind this view is "that scarce factors, such as human skill, eventually capture the monopoly rents that an industry's market position may earn" (Galbraith 1999, p.3).

In this context, despite the fact that the Katz-Summers argument is static, if degrees of monopoly change then the sub-industry-specific labor rents will also change. Therefore, "…the patterns of change through time can serve as markers of similarity and difference in economic performance among and between industries. When a pattern of wage changes is essentially identical in two separate industrial subclassifications over a long period of time, it becomes unlikely that this is accidental. Instead, similar effects result from structural characteristics that produce like reactions to common causes. That being so, patterns of similar effects can be used to classify industries according to structural similarity, even if one has no direct measure of what the structural similarities may be." (Galbraith 1999, p.4). Notice, that the above view is perfectly compatible with the Schumpeterian doctrine, since technological innovations go hand-in-hand with increased market power as we have seen and, thus, with monopoly labor rents.

Cluster and Discriminant analysis

Following Galbraith (1998, 1999), we begin our analysis by clustering the US manufacturing sub-industries into distinct clusters using the p-measure i.e. change of total earnings per hour worker. To do so, we make use of agglomerative hierarchical clustering using Ward's (1963) method. Ward's linkage is distinct from all the other methods because it uses an analysis of variance approach to evaluate the distances between clusters. In brief, this method attempts to minimize the Sum of Squares (SS) of any two (hypothetical) clusters that can be formed at each step. Ward's method has the advantage that it maximizes between-group variance and minimizes within-group variance at each step in the clustering.

Once clusters have been determined, we continue by performing a discriminant analysis in order to find out the factors that yielded the clustering pattern (Galbraith 1998, 1999). In this context, if each discriminant function can be thought of as a function that expresses a force that underlies the pooled wage variation across industries see *inter alia* Tatsuoka (1988), Klecka

[6] This view of also validated by the work of other researcher see for instance Katz and Summers (1989) and Blanchflower, et al. (1996).

(1980), Galbraith and Calmon (1990, 1996), Morrison (1969). Next, we select the statistically significant canonical roots obtained by the discriminant function, i.e. eigenvectors of a matrix of between-group variations standardized by the within-group variations, which are matched with real world economic data series in the later stage of this research. Note that smaller roots have less discriminant power and vice versa. Of course, in this stage of analysis according to the Schumpeterian doctrine one would expect that the crucial variable behind the distinction of clusters is the variable that captures the technological change of the sub-industries.

Stationarity test

According to the Schumpeterian tradition, business cycles are perceived as deviations from an equilibrium point towards a new one. In order to indentify this deviation we first need to know whether the data at hand are stationary or not. First, we examine the stationarity characteristics of each time series. Due to the fact that trend stationarity is a much stronger characteristic of the system than proposed by Schumpeter, who did not specify the transition from one circular flow position to another, it is an expected result of Schumpeterian doctrine that the time series that characterize the production are non-stationary as Foster (2007) suggested, in order to be consistent with the Schumpeterian view of business cycles. In this work, in order to test for the existence of a unit root and thus stationarity we make use of Phillips-Perron (1989) unit root test.

Spectral Analysis

Next, Schumpeter conceptualized business cycles as disturbances in the equilibrium and a return to a new equilibrium point which gives the process a periodic character. Thus, from an econometric perspective we are about to examine the periodical pattern in the data. If periodicity is not present in our analysis then any Schumpeterian argument could not possibly have any valid ground.

In this context, we investigate the periodicities of business cycles assuming that the actual fluctuations of the data are chiefly of a periodic character. The length of the period in an economic series may, in general, be variable. Therefore, we understand by the term “period” the average length of the cycles and the periodogram can assist in finding these average lengths. Our work is consistent with Metz (2010) and Baubeau (2008) who argue that, in the presence of regular cycles in the time series, spectral analysis is appropriate for testing for cycles. In this context, peaks in the periodogram represent the cyclical behavior (frequencies) in the data.

Cointegration

Next, we have to check for cointegration between the variables that enter the model, since if cointegrating relationships are present then there exists a long run equilibrium relationship between the variables under investigation. It is exactly upon the existence of this equilibrium relationship that Schumpeterian business cycles were founded, since progressive evolution of innovative activity expressed through technology, leads to the evolution of economic activity as a whole. In this work, in order to test for cointegration among the variables we make use of Johansen cointegration test.

Causality Test

Furthermore, we conduct bivariate causality tests between technology, as expressed through TFP, and real output GDP. The notion of causality especially between TFP and real output is very crucial in Schumpeterian business cycle theory, since according to Schumpeter the main force behind the eternal movement of economic activity from one equilibrium point to another is technology, which is expressed as the clustering of innovative activity. Meanwhile, the use of causality tests is very extensive because they relate variables and find predictive powers among them. Causality tests have been extensively used to count the effects of technology.

5. Empirical Results and Discussion

5.1 Data and Variables

As we have seen, a major problem in examining technological change is that it takes many different forms. In that sense, there is no generally accepted measure of technological change and all measures are imperfect (Rosenberg, 1982). As a result, based on data availability, we use the most popular measure in order to quantify technological change, i.e. Total factor Productivity (TFP) that it is widely argued to be an important determinant of technology.[7]

We make use of data for the U.S manufacturing sector for the period 1958-2006 just before the first signs of the US and global economic recession made their appearance referring to twenty one (21) subsectors which are disaggregated at a level of four hundred and seventy three (473) industries based on the NAICS classifications. For the Subsector Classification see Table I. Our investigation stops in 2006 since, at post-2006 era, the dynamics of the traditional economic structures changed dramatically, both in the USA and globally, a fact consistent with the work of Urbano and Aparicio (2016), who found significant evidence of disruption in global economic growth in particular and global dynamics in general in the pre- and post- crisis periods, respectively. Hence, any examination beyond this period would produce skewed and biased results. In terms of the variables employed: (TFP) is the Total factor Productivity, (Y) is the gross domestic product, (Π) Profitrate accounts for profitability, (L) Labour is the number of employees, (K) is Fixed Capital. All observations are in billions of dollars in 1958 prices with the exception of (L) which represents thousands of employees and all data come from the US Census bureau.

5.2 Result Analysis

Our analysis begins with the agglomerative clustering of the various industries using the p-measure developed by Galbraith (1998). In this context, the top braches of the hierarchical cluster dendrogram using Ward's (1963) method is presented in Figure I. Based on the dendrogram we can safely infer that five clusters are formed. The five clusters are compactly presented in Table II. Note that based on the members of each cluster, the last two clusters namely cluster 4 and cluster 3 are considered to be outliers. Having determined the number of clusters, we proceed with the canonical discriminant analysis of the various clusters in order to identify the latent structural variables behind the cluster formation. In this context, we make use

[7]Of course, another variable that could serve as an alternative indicator for technological change is patents. However, as several authors have convincingly argued (e.g. Smith 2006), patent data would provide only a very crude proxy, at best, for what is meant by technological change and innovation. After all, sectoral data on patents were not readily available to us, based on the classification at hand. Of course, further investigation based on patents could be helpful.

of the latent variables of TFP, Productivity of Labour, Output, Wages, Capital and Profitability. Based on our findings, (Table III), all canonical dimensions are statistically significant in explaining the clusters formed. Next, we present the statistically significant coefficients of the standard canonical discriminant functions in Table IV.

Having determined the basic clusters of the analysis using the p-measure in the first step, and having validated that TFP as well as Productivity of labour are among the statistically significant factors behind cluster formation, we proceed with the investigation of technological business cycles based on the Schumpeterian doctrine. To this end, based on the methodology presented earlier we investigate the stationarity properties of the various macroeconomic times series based on their cluster. As expected, the time series of output were found to be I(1) i.e. stationary in first differences, while the main technological variable i.e. TFP was found to be I(0) i.e. stationary in levels.. See Table V.

The periodograms reveal the periodicities of the time series and are shown in Tables VI-VII. The Aggregate Output in most clusters seems to follow the same pattern since a short term cycle (3-6 years) is evident. The existence of such a cycle gives credit to the Schumpeterian doctrine since it accounts for a Kitchin cycle which is an inventory cycle. In contrast, TFP exhibits in all clusters a short-term cycle (1-3 years), a mid-term cycle (12-15 years) and a long term cycle (30-35 years) with the exception of the fifth cluster. See de Groot and Franses (2012). The existence of such cycles that account for Juglar and Kuznets cycles, are the effect of fixed and infrastructure investment activity, respectively (Low, 1984). The fact that a Kondrantieff cycle is not directly observable in our empirical results is naturally attributed to the limited time span of our investigation (50 years), which is not long enough to capture a cycle that has a period of 60 years. In fact our finding is consistent with the prominent work of Korotayev et al. (2011) who also found that in the US patent dynamics the K-wave pattern is significantly less pronounced than in the world dynamics. In fact, based on their findings the K-wave pattern of the US economy is rather vague since it is not as clear and regular as in the world invention dynamics. However, it is widely argued (e.g. Krafft, 2007, Perez 2007, Korotayev 2011 and Wilenius and Casti 2015) that that the development of the US economy in the early 90's is the effect of a 5th Kondratieff cycle which was triggered among others by the extensive use of microprocessors in all sectors of economic activity. In general our empirical findings are consistent with the findings of de Groot and Frances (2008) who argue that economic variables always display multiple cycles, with cycle periods that apparently do not interfere. The sum of all these cycles mimics erratic behavior, but underlying constellations of cycles are of such a nature that stability of economic variables is preserved. Hence, due to these sets of cycles, economies can handle exogenous shocks that might otherwise put them off balance.

Next, the results of the Johansen co-integration test for all sectors of economic activity (see Table VIII) show that the variables that capture technology and output are co-integrated for the first, the second and the fifth cluster. Thus, the existence of a long run equilibrium relationship between TFP and Aggregate Output is evident in these clusters. This, in turn, is consistent with the Schumpeterian view of business cycles where technology forces output to move from one equilibrium point to another, since in lack of cointegration any long run relationship between the variables would have no valid grounds.

The coefficients α and β of the cointegrating relation among the variables of Output and TFP for all five (5) clusters are presented in tables IX. The coefficient α denotes the speed of adjustment (convergence) towards equilibrium. Values of α negative and close to zero imply strong convergence. Coefficient β denotes the long run relationships among the variables or the level of equilibrium between the variables. In brief, based on our findings that are consistent with the Johansen cointegration test conducted in the previous stage of the research, the first, second and fifth cluster are characterized by a negative small value of the adjustment parameter, implying strong convergence to a long run relationship between the variable of technology as expressed through the TFP and output. This, in turn, is consistent with the Schumpeterian doctrine, since the long-run relationship between technology and output validates a large part of Schumpeter's theoretical contribution where technology and output are heavily linked.

Furthermore, due to the existence of cointegration among the variables for every model under investigation, the Granger causality test was conducted using the appropriate Error Correction Model (ECM), where the optimal lag length was selected according to Hsiao's (1981) methodology, as extended by Ahking and Miller (1985) according to which the lag length should be chosen based on with Akaike's Final Prediction Error (FPE) criterion.

The results of the Granger causality tests (see Tables X-XI) reveal straightforward bidirectional causality in all clusters between TFP and Real Output with no exceptions. The fact that in all clusters TFP dictates the evolution of aggregate output gives credit to the Schumpeterian view of business cycles, since clustering of innovations force economic activity to shift from one equilibrium point to another, a finding consistent with the work of Rasiah et al. (2016) and Noori et al. (2016) who also validated this Schumpeterian view using data on the Taiwanese semiconductor industry and Iranian firms, respectively.

6. Conclusions

In this paper, we built on Schumpeterian insights to examine economic instability for the case of the US manufacturing sector for the period 1958-2006. Schumpeter conceptualized business cycle as disturbances in the equilibrium and a return to a new equilibrium point which gives the process its cyclical character. In this context, based on the methodology of Galbraith (1998, 1999), we employed agglomerative clustering using the percentage change in hour earning of each worker as the key indicator for cluster formation. Next, using canonical discriminant analysis we showed that technology as expressed through TFP is among the main latent variables that could statistically significantly explain the clusters formed in the previous step, a fact that is in line with the Schumpeterian doctrine. In addition, in order to sufficiently investigate the Schumpeterian doctrine in the US manufacturing sector, for each cluster we assessed the co-movements between the raw variables of each time series observed through co-integration tests and found that technological change is strongly related to output. Also, we conducted bivariate Granger causality tests between real output and technological change in order to assess causality.

Our empirical findings give credit to certain aspects of the Schumpeterian theory of business cycles. An interesting finding is that most economic time series exhibit, roughly speaking, a similar pattern characterized by periodicities exhibiting a short-term cycle (Kitchin cycle); a mid-term cycle (Juglar cycle) and a long term cycle (Kuznets cycle). Finally, the results have been discussed in a broader context, related to the US economy.

This work contributes to the literature in the following ways: first, it introduces a relevant methodological framework; second, based on these econometric techniques, the paper offers a complete investigation of Schumpeterian business cycle theory for the US manufacturing sector, and it is the first, to do so by industry of economic activity. Third, the paper uses a wide dataset to examine the U.S manufacturing sector for the period 1958-2006, just before the first signs of the US and global economic recession made their appearance, in order to avoid getting skewed and biased results.

Given the fact that technology is crucial for economic growth, our estimates are important. We hope that that our research could help inspire further research on economic fluctuations. Last, but certainly not least, we hope that this works could help in promoting dialogue between researchers of technology and economic analysis, working in various strands and schools of economic thought. No doubt, future research on the subject would be necessary.

References

Abrahamson M. (1978), *Functionalism*, Englewood Cliffs N.J: Prentice –Hall.

Abramovitz, M (1986), Catching up, Forging Ahead, and Falling Behind, *Journal of Economic History*, 46(2), June σσ.386-406.

Abramovitz, M. (1956), Resource and Output Trends in the United States since 1980, *American Economic Review*, 46(2), May, pp 5-23.

Abramovitz, M. (1994), Catch-Up and Convergence in the Postwar Growth Boom and After, in *Convergence of Productivity*: Cross-Country Studies and Historical Evidence, ed. W. Baumol, R. Nelson and E. Wolff, Oxford: Oxford University Press. 86-125.

Abramovsky, L., Harrison, R., & Simpson, H. (2007), University Research and the Location of Business R&D*. The Economic Journal, 117(519): C114-C141.

Acosta, M., Coronado, D., & Flores, E. (2011), University spillovers and new business location in high-technology sectors: Spanish evidence. Small Business Economics, 36(3): 365-376.

Aghion, P. and Howitt, P. (1997), 'A Schumpeterian perspective on growth and competition', in D. Kreps and K. Wallis (eds), *Advances in Economics and Econometrics: Theory andApplication*, Vol. 2, Cambridge: Cambridge University Press.

Agrawal, A., & Cockburn, I. (2003,) The anchor tenant hypothesis: exploring the role of large, local, R&D-intensive firms in regional innovation systems. International Journal of Industrial Organization, 21(9): 1227-1253.

Agresti, A-M. and Mojon, B. (2001), Some stylized facts on the euro area business cycle, ECB Working Paper No. 95.

Ambramovitz, M (1968), The passing of the Kuznets' cycle, *Economica,* Vol 35(140), pp 349-367.

Anselin, L., Varga, A., &Acs, Z. (1997), Local geographic spillovers between university research and high technology innovations. Journal of Urban Economics, 42(3): 422-448.

Anselin, L., Varga, A., &Acs, Z. J. (2000), Geographic and sectoral characteristics of academic knowledge externalities. Papers in Regional Science, 79(4): 435-443.

Audretsch, D. B., Lehmann, E. E., & Warning, S. (2005), University spillovers and new firm location. Research Policy, 34(7): 1113-1122.

Backus, D.K. and Kehoe, P.J. (1992), International evidence on the historical properties on business cycles, *American Economic Review*, Vol. 82 No. 4, pp. 864-88.

Baubeau P. and Cazelles B. (2008), French economic cycles: a wavelet analysis of French retrospective GNP series, *Cliometrica, Journal of Historical Economics and Econometric History*, vol 3(3), pp. 275-300.

Baxter, M. and King, R.G. (1999), Measuring business cycles: approximate band-pass filters for economic time series, *Review of Economic and Statistics*, Vol. 81 No. 4, pp. 575-93.

Benati, L. (2001), *Band-pass filtering cointegration and business cycle analysis*, Working Paper No. 142, Bank of England, London.

Bernal, J. (1971), *Science in History*, MIT Press, Cambridge, Mass. 4 vols.

Bhuyan, S. and Lopez, R. (1998), Oligopoly power and allocative efficiency in US food and tobacco industries, *Journal of Agricultural Economics*, Vol. 49 No. 3, pp. 434-42.

Blackburn, K. and Ravn, M. (1992), Business cycles in the United Kingdom: facts and frictions, *Economica*, Vol. 59, pp. 382-401.

Burns, A.F. and Mitchell, W.C. (1946), *Measuring Business Cycles*, National Bureau of Economic Research, New York, NY.

Calmon, Paulo Du Pin, Conceicao, Pedro, Galbraith, James K., Garza-Cantu, Vidal and Hibert, Abel, The Evolution of Industrial Earnings Inequality in Mexico and Brazil, *Review of Development Economics*, Vol. 4, Issue 2, June 2000.

Canova, F. (1998), Detrending and business cycle facts, *Journal of Monetary Economics*, Vol. 41, pp. 475-512.

Carayannis G.E and Jeffrey A and Ioannidis A (2000), Leveraging Knowledge, learning, and innovation in forming strategic goverment-university-industry (GUI) R&D parternships in the US, Germany and France, *Technovation,* Vol(20),pp 477-488.

Catner,U& Kruger, JJ (2007), Empirical tools for analysis of technological heterogeneity and change: some basic building blocks of 'evolumetrics', in Hanusch,H and Pyka, A (ed), (2007), Elgar Companion to neo-Schumpeterian Economics, Edward Elgar Publishing.

Chang, C. C. and McCarl, B. A (1993) ,*Documentation of ASM: The U.S. Agricultural Sector Model*, Texas A & M University, Department of Agricultural Economics.

Clemence, R. V. 1951. *Essays of Economic Topics of J. A. Schumpeter*. Port Washington, Kennikat Press.

Cohen, W. M., Florida, R., Randazzese, L., & Walsh, J. P. (1998), Industry and the Academy: Unease partners in the cause of technological advance In R. G. Noll (Ed.), Challenges to Research Universities. Washington, DC.: Brookings Institute Press

Comanor, W. S (1967), Market Structure, Product Differentiation and Industrial Research, *Quarterly Journal of Economics, 81*.

Danthine, J.P. and Girardin, M. (1989), Business cycles in Switzerland. A comparative study, *European Economic Review*, Vol. 33, pp. 31-50.

Darné O. and A. Charles, (2011), Large shocks in U.S. macroeconomic time series: 1860-1988, *Cliometrica, Journal of Historical Economics and Econometric History*, vol. 5(1), pp. 79-100.

Degner H. (2010), Do technological booms matter? New evidence on the relationship between firm size and innovativeness", *Cliometrica, Journal of Historical Economics and Econometric History*, vol 5(2), pp. 121-144.

De Groot B and Franses H.P. (2008), Stability through Cycles, *Technological Forecasting and Social Change,*Vol 75, pp. 301-311.

De Groot B. and Franses H. P. (2012), Common socioeconomic cycle periods, *Technological Forecasting and Social Change,* Vol 79, pp. 59-68.

Denison, E and Chung, W. (1976), *How Japan's economy grew so fast: The sources of postwar expansion*, Washington D.C Brookings Institution.

Denison, E. (1962a), United States Economic Growth, *Journal of Business*, August.

Denison, E. (1962b), *The Sources of Economic Growth in the U.S. and the Alternatives before Us*, Committee for economic Development, New York.

Denison, E. (1967), *Why Growth Rates Differ*, Washington D.C.: The Brookings Institution.

Denison, E. (1985), *Trends in American Economic Growth, 1929-1982*, Washington, D.C.: The Brookings Institution.

Dickey, D.A. and Fuller, W.A. (1979), *Distribution of the estimates for autoregressive time series with a unit root*, Journal of the American Statistical Association, Vol. 74, pp. 427-31.

Dobson, P., Waterson, M. and Davies, S. (2003), The patterns and implications of increasing concentration in European food retailing, *Journal of Agricultural Economics*, Vol. 54 No. 1, pp. 111-25.

Dosi, G. (1988), Sources, Procedures and Microeconomic Effects of Innovation, *Journal of Economic Literature*, XXVI, September, σσ. 1120-1171.

Elliot J. 1993, "Schumpeter's Theory of Economic Development and Social Change: Exposition and Assessment", *International Journal of Social Economics*, Vol. 12, No. 6/7: 6 – 33.

Enos, J. (1958), A Measure of the Rate of Technical Progress in the Petroleum Refining Industry, *Journal of Industrial Economics*, June.

Faere, R., Grosskopf, S. and Margaritis, D. (2005), US productivity in agriculture and R&D, paper presented at NZESG Meetings at University of Canterbury, Christchurch, New Zealand.

Fenoaltea, S (1988),International resource flows and construction movements in the atlantic economy: the Kuznets cycle in Italy 1861-1913, *The Journal of Economic History,*vol null (3), pp 605-637.

Field J. A. (2007), The origins of US total factor productivity growth in the golden age, *Cliometrica, Journal of Historical Economics and Econometric History*, vol. 1(1), pp. 63-90.

Fine, B. (1998), *The Political Economy of Diet, Health and Food Policy*, Routledge, London.

Fiorito, R. and Kollintzas, T. (1994), Stylized facts of business cycles in the G7 from a real business cycle perspective, *European Economic Review*, Vol. 38, pp. 235-69.

Fishlow, A. (1966), Productivity and Technological in the Railroad Sector, 1840-1910", in *Output, Employment and Productivity in the U.S. after 1800*, Studies in Income and Wealth No. 30, New York: National Bureau of Economic Research.

Foster, J (2007), Macro-econometrics, in Hanusch,H and Pyka, A (ed), (2007), Elgar Companion to neo-Schumpeterian Economics, Edward Elgar Publishing.

Freeman C (2007), A Schumpeterian renaissance?, in Hanusch,H and Pyka, A (ed), (2007), Elgar Companion to neo-Schumpeterian Economics, Edward Elgar Publishing.

Freeman, C. and F. Louçã (2001), As Time Goes By. From the Industrial Revolution to the Information Revolution. Oxford University Press: Oxford.

Galbraith, J.K., and P.D.P. Calmon (1996), Wage Change and Trade Performance in U.S. Manufacturing Industries, *Cambridge Journal of Economics*, Vol. 20, No. pp. 433-450.

Galbraith J. K. (1998), Created Unequal: The crisis in American Pay, New York: The Free Press, 1998. A Twentieth Century Fund Book. Paperback edition, University of Chicago Press 2000.

Galbraith J. K. (1998), The distribution of Income, UTIP working paper.

Galbraith J. K. (1999), Cluster and Discriminant Analysis on Time-Series as a Research Tool, UTIP working paper.

Gerschencron, A. (1962), *Economic backwardness in historical perspective*, Cambridge, MA: Belknap Press.

Gilfillan, S. (1935a), *Inventing the Ship*, Follett, Chicago.

Gilfillan, S. (1935b), *The Sociology of Invention*, Cambridge, MA: MIT Press.

Gomulka, S. (1970), Extensions of the Golden Rule of Research of Phelps, *Review of Economic Studies*, 37(1), January, σσ. 73-93.

Gomulka, S. (1971), *Inventive Activity, Diffusion, and the stages of Economic Growth*, Aarhus Institute of Economics.

Goodwin, B. and Brester, G. (1995), Structural change in factor demand relationships in the US food and kindred products industry, *American Journal of Agricultural Economics*, Vol. 77, pp. 69-79.

Gopinath, M. and Carver, J. (2002), "Total factor productivity and processed food trade: a cross country analysis", Journal of Agricultural and Resource Economics, Vol. 27 No. 2, pp. 539-53

Granger, C.W.J. (1969), Investigating causal relations by econometric models and cross-spectral methods, *Econometrica*, Vol. 37, July, pp. 424-38.

Griliches, (1957), Hybrid Corn: An Exploration in the Economics of Technological Change, *Econometrica*, October.

Grossman, G and Helpman, E (1991), *Innovation and growth in the global economy*, Cambridge, MA: MIT Press.

Grupp, H (2007), Topology of science and technology indicators, in Hanusch,H and Pyka, A (ed), (2007), Elgar Companion to neo-Schumpeterian Economics, Edward Elgar Publishing.

Gualerzi D and Edward Nelly (2011), The crisis, long term depression and new markets'', *International Journal of Management Concepts and Philosophy*, Vol. 5, No. 3.

Hall, A. (1963), *The Historical Relations of Science and Technology*, London.

Hanusch, H&Pyka, A (2007), Schumpeter Joseph Alois (1883-1950), in Hanusch,H and Pyka, A (2007) (ed) Elgar Companion to neo-Schumpeterian Economics, Edward Elgar Publishing.

Hanusch,H and Pyka, A (2007), Elgar Companion to neo-Schumpeterian Economics, *Edward Elgar Publishing.*

Hart, P.E. (1996) Accounting for the Economic Growth of Firms in UK Manufacturing since 1973. *Cambridge Journal of Economics*, 20, 225–242.

Heshmati, A. and Lo¨o¨f, H. (2005), Forward or backward causality – or just a correlation?, paper presented at The Keith PavittHonour Conference, Sussex.

Hobsbawn, E. (1968), *Industry and Empire*, Harmondsworth, England: Penguin Books.

Hodrick, R.J. and Prescott, E.C. (1997), Post-war US business cycles: an empirical investigation, *Journal of Money, Credit, and Banking*, Vol. 29, pp. 1-16.

Hollander, S. (1965), *The Sources of Increased Efficiency: The Study of du Pont Rayon Plants*, MIT Press, Cambridge, Mass.

Hsiao, C. (1981), Autoregressive modelling of Canadian money income data, *Journal of the American Statistical Association*, Vol. 74, pp. 85-106.

Huang, K. (2003), "Food manufacturing productivity and its economic implications", Technical Bulletin 1905, United States Department of Agriculture, Economic Research Service.

Jaffe, A. (1989) Real effects of academic research. American Economic Review, 79(5): 957-970.

Jaffe, A., Trajtenberg, M., & Henderson, R. (1993), Geographic localization of spillovers as evidenced by patent citations. Quarterly Journal of Economics, 79(3): 577-598.

Johansen, L. (1959), Substitution versus Fixed Production Coefficients in the Theroy of Economic Growth: a Synthesis, *Econometrica*, 27(2), April, σσ. 157-76.

Johansen, S. (1988), Statistical analysis of cointegation vectors, *Journal of Economic Dynamics and Control*, Vol. 12, pp. 231-54.

Jorgenson, D.W. and Z. Griliches (1967) The Explanation of Productivity Change. *Review of Economic Studies*, 34, 249–283

Kaldor, Nicholas and Mirlees, James A. (1962), A new Model of Economic Growth, *Review of Economic Studies*, 29(3), June, σσ.174-92.

Karasawoglou, A. and Katrakilidis, K. (1993), The accommodation hypothesis in Greece. A tri-variate Granger-causality approach, *SPOUDAI*, Vol. 43 No. 1, pp. 3-18.

Karasawoglou, A., and Katrakilidis, K. (1993), The Accommodation Hypothesis in Greece. A Tri-VariateGrangerCausality Approach, SPOUDAI, Vol. 43, No 1, pp. 3-18.

Khim, V. and Liew, S. (2004), Which lag length selection criteria should we employ?,*Economics Bulletin*, Vol. 3 No. 33, pp. 1-9.

Korotayev A. and Zinkina J. and Bogevolnov J. (2011), Kondratieff waves in global invention activity (1900-2008), *Tecnological Forecasting and Social Change*, Vol 78, pp1280-1284.

Krafft, J (2007), Telecommunications, the Internet and Mr Schumpeter, in Hanusch,H and Pyka, A (ed), (2007), Elgar Companion to neo-Schumpeterian Economics, Edward Elgar Publishing.

Kurz H.D, Salvadori N (1995), Theory of production.Along-period analysis. Cambridge University Press, Cambridge

Kurz, H.D (2007), Innovations and Profits Schumpeter and the Classical Heritage, Journal of Economic Behavior and Organization, doi:10.1016/j.jebo.2007.08.003

Kuznets, S (1930), Secular Movements in Production and Prices. New York: Houghton Mifflin.

Kuznets, S. (1930), *Secular Movements in Production and Prices,* Boston: Houghton Mifflin.

Kydland, F.E. and Prescott, E.C. (1990), Business cycles: real facts and a monetary myth, *Federal Reserve Bank of Minneapolis Quarterly Review*, Vol. 14, pp. 3-18.

Lio, M. and Hu, J. (2009), "Governance and agricultural production efficiency: a cross-country aggregate frontier analysis", Journal of Agricultural Economics, Vol. 60 No. 1, pp. 40-61.

Ljung, G. and Box, G.E.P. (1978), On a measure of lack of fit in time series models, *Biometrika*, Vol. 65, pp. 297-303.

Los, B and Verspagen, B (2007), Technology spillovers and their impact on productivity, in Hanusch,H and Pyka, A (ed), (2007), Elgar Companion to neo-Schumpeterian Economics, Edward Elgar Publishing.

Louca, F (2007), Long waves the pulsation of modern capitalism, in Hanusch,H and Pyka, A (ed), (2007), Elgar Companion to neo-Schumpeterian Economics, Edward Elgar Publishing.

Low W. (1984), Discoveries, Innovations, and Business Cycles, Technological Forecasting and Social Change, Vol 26, pp. 355-373.

Lundvall, B. (1992), *National systems of innovation: Towards a theory of innovation and interactive learning*, London: Pinter.

MacDonald, R. and Kearney, C. (1987), On the specification of Granger causality tests using the cointegration methodology, *Economics Letters*, Vol. 25, pp. 149-53.

Malecki, E. J. (1980), Firm Size, Location and Industrial R&D: A Disaggregated Analysis, *Review of Business and Economic Research*, 16, 29-42.

Marx, K. (1867), *Capital*, Modern Library, New York.

Marx, K. (1867), *Capital*, Vol. I, London: Penguin Classics [1990].

Marx, K. and Engels, F. (1848), *The Communist Manifesto*, όπωςανατυπώθηκεστο Marx K. and F. Engels, *Selected Works*, Foreign Languages Publishing House,

Massmann, M. and Mitchell, J. (2004), "Reconsidering the evidence: are Eurozone business cycles converging?", *Journal of Business Cycle Measurement and Analysis*, Vol. 1, pp. 275-307.

Mathias, P. (1972), Who Unbound Prometheus? Science and Technical Change, 1600-1800, in P. Mathias, ed., *Science and Society, 1600-1900*, Cambridge University Press, Cambridge.

Meisel, J.B and Lin, S.A Y. (1983), The impact of market structure on the firm's allocation of resources to research and development, *Quarterly Review of Economics and Business*, 23, σσ.28-43.

Metz R (2010a) Filter-design and model-based analysis of trends and cycles in the presence of outliers and structural breaks, Cliometrica, Journal of Historical Economics and Econometric History, vol 4(1), pp. 53–71.

Metz R. (2010b), Do Kondratieffwavesexist? How time series techniques can help to solve the problem, *Cliometrica, Journal of Historical Economics and Econometric History*, vol. 5(3), pp.205-238.

Mills C.T. (2008), Modelling trends and cycles in economic time series: historical perspective and future developments", *Cliometrica, Journal of Historical Economics and Econometric History*, vol 3(2), pp. 221-224.

Mokyr J (1990), Twenty five centuries of technological change: A Historical survey,A Volume in the Economics of Technological Change Section, edited by F.M. Scherer. Part of the series "Fundamentals of Pure and Applied Economics" edited by Hugo Sonnenschein and Jacques Lesourne. Chur-London-Paris-NewYorkMelbourne: Harwood Academic Publishers, 1990.

Nason M. James & Shaun P. Vahey, (2012), UK World War I and interwar data for business cycle and growth analysis, *Cliometrica, Journal of Historical Economics and Econometric History*, vol. 6(2), pp. 115-142.

Nelson R. (1964), Aggregate Production Functions and Medium- Range Growth Projections, *American Economic Review*, 54(5), September, σσ. 575-606.

Nelson, C.R. and Plosser, C.I. (1982), Trends and random walks in macroeconomics time series: some evidence and implications, *Journal of Monetary Economics*, Vol. 10, pp. 139-67.

Nelson, R. (1987), *Understanding Technical Change as an Evolutionary Process*, Amsterdam, North Holland.

Nelson, R. (1993), *National Innovation Systems: A Comparative Analysis*, Oxford University Press.

Nunes L.B. (2016), Schumpeter's entrepreneurs in the 20th century: The Tucker automobile, *Technological Forecasting and Social Change*, Vol. 102, pp. 14-20.

Noori J. and Nasrabadi M.B. and Yazdi N. and Babakhan A.R. (2016), Innovative performance of Iranian knowledge-based firms: Large firms or SMEs?, *Technological Forecasting and Social Change*, In Press, Corrected Proof, Available online 13 May 2016.

Landström, H., (2005), Pioneers in Entrepreneurship and Small Business Research. International Studies in Entrepreneurship Series vol. 8. Springer

Ohkawa, K. and Rosovsky, H. (1973), *Japanese economic growth*, Stanford: Stanford University Press.

Oner M.A, and Kunday O. (2016), A study on Schumpeterian and Kirznerian entrepreneurship in Turkey: 2006–2013, *Technological Forecasting and Social Change*, Vol. 102, pp. 62-71.

Ouyanh, M. (2011), On the cyclicality of R&D, *The Review of Economics and Statistics Journal,* 93(2): 542-553.

Parker, W. (1967), Sources of Agricultural Productivity in the 19th Century, *Journal of Farm Economics*, December.

Pensieroso L. (2011), Real business cycle models of the Great Depression, *Cliometrica, Journal of Historical Economics and Econometric History*, , vol. 5(2), pp. 101-119.

Perez, C. (2007), Finance and technical change: a long term view, in Hanusch,H and Pyka, A (ed), (2007), Elgar Companion to neo-Schumpeterian Economics, Edward Elgar Publishing.

Phelps, E. (1966), Models of Technical Progress and the Golden Rule of Research, *Review of Economic Studies*, 33(2), April, 133-145.

Philips, L. (1971), Effects of Industrial Concentration: *A cross- section analysis for the Common Market*, Amsterdam, North Holland.

Rasiah R. and Shahrivar R B. and Yap X-S.(2016), Institutional support, innovation capabilities and exports: Evidence from the semiconductor industry in Taiwan, *Technological Forecasting and Social Change*, Vol. 109, pp. 69-75.

Rosenberg, N. (1982), *Inside the Black Box: Technology and Economics*, Cambridge University Press, New York, NY.

Rostow, W. (1952), *The Process of Economic Growth*, Oxford University Press, Oxford.

Rostow, W. (1975), *How it All Began*, McGraw-Hill, New York.

Rostow, W. W. (1960), *The Stages of Economic Growth*, Cambridge: Cambridge University Press.

Rudin, W. (1976), *Principles of Mathematical Analysis*, McGraw-Hill International Edition, New York, NY.

Ruttan, W. 1959, "Usher and Schumpeter on Invention, Innovation, and Technological Change," *Quarterly Journal of Economics,* Vol. 73: 596-606.

Cajaiba-Santana G (2014), Social innovation: Moving the field forward. A conceptual framework,*Technological Forecasting and Social Change*, Vol. 82, pp. 42-51.

Salim, R. and Bloch, H. (2007), Business expenditures on R&D and trade performances in Australia: is there a link?, *Applied Economics*, Vol. 41, pp. 1-11.

Scherer, F. (1984), *Innovation and Growth: Schumpeterian Perspectives*, Cambridge, Mass., MIT Press.

Schumpeter, J. A. [1912] 1934, 1951, 1961. *The Theory of Economic Development*. Cambridge: Harvard University Press.

Schumpeter, J. A. 1950. *Capitalism, Socialism and Democracy*. New York: Harper and Row[1942].

Schumpeter, J. A. 1964. *Business Cycles*. New York: McGraw-Hill[1939].

Scott, M. F. (1989), *A New View of Economic Growth*, New York and Oxford: Oxford University Press [1998].

Serra, T., Goodwin, B. and Feathertone, M. (2005), Agricultural policy reform and off-farm labor decisions, *Journal of Agricultural Economics*, Vol. 56 No. 2, pp. 271-85.

Shell, K. (1967), A Model of Inventive Activity and Capital Accumulation, in K. Shell (ed*.), Essays on the theory of optimal growth*, Cambridge MA: MIT Press, σσ. 67-85.

Silverberg, G (2007), Long waves: conceptual, empirical and modeling issues, in Hanusch,H and Pyka, A (ed), (2007), Elgar Companion to neo-Schumpeterian Economics, Edward Elgar Publishing.

Smythe J. D. (2010), A Schumpeterian view of the Great Merger Movement in American manufacturing, *Cliometrica, Journal of Historical Economics and Econometric History,* vol. 4(2), pp. 141-170.

Solow, R. (1956), A Contribution to the Theory of Economic Growth, *Quarterly Journal of Economics*, LXX, σσ. 65-94.

Solow, R. (1957), Technical Change and the Aggregate Production Function, *Review of Economics and Statistics*, 39(3), August, 312-320.

Solow, R. (1960), Investment and Technical Progress, in K. Arrow, S. Kablin and P. Suppes (eds), *Mathematical methods in the social sciences*, Stanford: Stanford U. Press, σσ. 89-104.

Stock, M. and Watson, M. (1999), Business cycles fluctuations in US macroeconomic time series, in Taylor, J.B. and Woodford, M. (Eds), Handbook of Macroeconomics, Ch. 1,

Stoneman, P. (2002), *The Economics of Technological Diffusion*, Oxford: Basil Blackwell.

Strassmann, P (1959), Creative Destruction and Partial Obsolescence in American Economic Development, *The Journal of Economic History*, Vol 19, pp. 335-353.

Strassmann, W. (1959), Creative Destruction and Partial Obsolescence in American Economic Development, *Journal of Economic History*, September.

Subervie, J. (2008), The variable response of agricultural supply to world price instability in developing countries, *Journal of Agricultural Economics*, Vol. 59 No. 1, pp. 72-92.

Thirtle, C., Lin, L., Holding, J., Jenkins, L. and Piesse, J. (2004), Explaining the decline in UK agricultural productivity growth, *Journal of Agricultural Economics*, Vol. 55, No. 2, pp. 343-66.

Thirtle, C., Schimmelpfennig, D. and Townsend, R. (2002), Induced innovation in United States, 1880–1990: time series tests and error correction model, *American Journal of Agricultural Economics*, Vol. 84 No. 3, pp. 598-614.

Thornton, D.L. and Batten, D.S. (1985), Lag-length selection and tests of Granger causality between money and income, *Journal of Money Credit and Banking*, Vol. 17, pp. 164-78.

Tiffin, R., Traill, W.B. and Mortimer, S. (2006), Food choice in an interdisciplinary context, *Journal of Agricultural Economics*, Vol. 57 No. 2, pp. 213-20.

Urbano D. and Aparicio S. (2016), Entrepreneurship capital types and economic growth: International evidence, Technological Forecasting and Social Change, Vol 102, pp. 34-44.

Usher, A. (1954), *A History of Mechanical Inventions*, Cambridge Massachusetts: Harvard University Press.

Uzawa, H. (1965), Optimum Technical Change in an Aggregative Model of Economic Growth, *International Economic Review*, 6(1), January, σσ.18-31.

van Duijn, J. J. (1983), The Long Wave in Economic Life. London: George Allen and Unwin.

VAR models with weak form of common cyclical features", Working Paper Series No. 139,

Verbeek, A. and Debackere, K. (2006), Patent evolution in relation to public/private R&D investment and corporate profitability: evidence from the United States, *Scientometrics*, Vol. 35 No. 6, pp. 601-15. Vol. 66 No. 2, pp. 279-94.

Wang, S.S., Stiegert, K. and Rogers, R. (2006), Structural change in the US food manufacturing industry, paper presented at American Agricultural Economics Association Annual Meeting, Long Beach, CA, July 23-26.

Wilenius M. and Casti J. (2015), Seizing the X-events. The sixth K-wave and the shocks that may upend it, *Techonological Forecasting and Social Change,* Vol 94, pp335-349.

Woodrow W.Clark, and Xing Li (2004), 'Social capitalism: an economic paradigm for the transfer and commercialisation of technology',*International Journal of Technology Transfer and Commercialisation*, Vol. 3, No. 1

Wynne, M. and Koo, J. (2000), Business cycles under monetary union: a comparison of the EU and US, *Economica,* Vol. 67, pp. 347-74.

APPENDIX A: Result Appendix

Table I: Sub-sector Classification NAICS

Sub sector	Classification Code
Food manufacturing	311
Beverage and tobacco product manufacturing	312
Textile mills	313
Textile product mills	314
Clothing manufacturing	315
Leather and allied product manufacturing	316
Wood product manufacturing	321
Paper manufacturing	322
Printing and related support activities	323
Petroleum and coal product manufacturing	324
Chemical manufacturing	325
Plastics and rubber products manufacturing	326
Non-metallic mineral product manufacturing	327
Primary metal manufacturing	331
Fabricated metal product manufacturing	332
Machinery manufacturing	333
Computer and electronic product manufacturing	334
Electrical equipment, appliance and component manufacturing	335
Transportation equipment manufacturing	336
Furniture and related product manufacturing	337
Miscellaneous manufacturing	339

Figure I- Dendrogram using Hierarchical Clustering

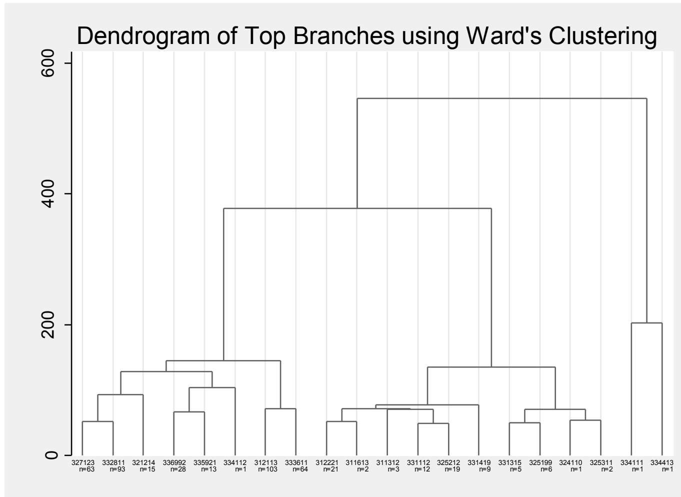


Table II-Clusters Formed

<u>Cluster 1</u>

311111	311320	311411	311421	311511	311513	311520	311611	311711	311712	311822	311823
311930	312120	312130	312140	312210	312229	313111	313112	313113	313210	313221	313222
313230	313241	313249	313312	313320	314110	314129	314911	314912	314991	314992	314999
315111	315119	315191	315192	315211	315212	315221	315222	315223	315224	315225	315228
315231	315232	315233	315234	315239	315291	315299	315991	315992	315993	316110	316211
316212	316213	316214	316219	316991	316992	316993	316999	321113	321114	321211	321212
321213	321214	321219	321911	321912	321918	321920	321992	321999	323113	323122	325221
325222	325411	325412	325413	325611	325612	325613	325620	325991	325992	326191	326291
327111	327112	327121	327122	327123	327124	327211	327212	327213	327215	327910	327999
331525	332115	332116	332211	332213	332214	332811	332812	332992	332993	332994	333112
333210	333292	333294	333295	333311	333314	333315	333319	333414	333415	333912	333921
333991	333992	333997	334112	334113	334119	334210	334220	334290	334310	334411	334412
334414	334415	334416	334417	334418	334419	334510	334511	334512	334514	334515	334516
334517	334518	334613	335110	335121	335122	335211	335212	335221	335222	335224	335311
335314	335912	335921	335991	335999	336111	336112	336120	336213	336312	336321	336322
336330	336340	336350	336360	336370	336391	336399	336411	336413	336419	336612	336991
336992	337121	337124	337125	337129	337211	337910	339111	339112	339115	339913	339914
339920	339931	339932	339941	339942	339944	339993	339995	339999			

<u>Cluster 2</u>

311230	311340	311412	311422	311615	311812	311813	311821	311830	311911	311919	311941
311942	311991	311999	312111	312112	312113	321991	322212	322215	322221	322222	322225
322231	322232	322291	322299	323110	323111	323112	323114	323115	323116	323117	323118
323119	323121	325131	325188	325320	325414	325510	325520	325920	326112	326113	326121
326122	326130	326140	326150	326160	326192	326199	326211	326220	326299	327113	327125
327310	327320	327331	327332	327390	327410	327991	327992	327993	331222	331316	331511
331512	331513	331521	331524	332111	332114	332117	332212	332311	332312	332313	332321

332322 332323 332410 332420 332431 332439 332510 332611 332612 332618 332710 332721
332722 332813 332911 332912 332919 332991 332996 332997 332999 333111 333120 333131
333132 333220 333291 333293 333298 333312 333411 333412 333511 333512 333513 333514
333515 333516 333518 333611 333612 333613 333618 333911 333913 333922 333923 333924
333993 333994 333995 333996 333999 334513 334519 335129 335228 335312 335313 335911
335931 336211 336212 336214 336311 336412 336415 336510 336611 336999 337122 337127
337212 337214 337215 337920 339113 339114 339943 339950 339991 339992 339994

Cluster 3

311119 311211 311212 311213 311221 311222 311223 311225 311311 311312 311313 311423
311512 311514 311613 311920 312221 315292 322110 322121 322122 322130 322211 322213
322214 322223 322224 322226 322233 324110 324121 324122 324191 324199 325110 325120
325132 325181 325182 325191 325192 325193 325199 325211 325212 325311 325312 325314
325910 325998 326111 327420 331111 331112 331210 331221 331311 331312 331314 331315
331319 331411 331419 331421 331422 331423 331491 331492 331522 331528 332112 332913
332995 332998 333313 335929 335932 336414 339911 339912

Cluster 4

334111

Cluster 5

334413

Table III-Canonical Discriminant Analysis

Canonical Discriminant Analysis							
Function	Canonical Correlation	Eigen-value	Variance		Likelihood Ratio	F-stat	p-value
			Proportion	Cumulative			
1	0.47	0.29	0.70	0.70	0.69	351.76	0.00
2	0.23	0.05	0.13	0.83	0.89	176.31	0.00
3	0.21	0.05	0.12	0.95	0.94	184.05	0.00
4	0.14	0.02	0.05	1.00	0.98	151.18	0.00

Table IV-Canonical Discriminant Analysis Function Coefficients

Standard Canonical Discriminant Function Coefficients				
Variables	Function			
	1	2	3	4
TFP	0.02	0.02	0.04	-0.04
Productivity of Labour	-1.24	0.26	-0.12	0.23
Output	0.96	-0.52	1.20	0.78
Wages	-0.02	-0.31	-0.85	0.43
Capital	-0.58	-0.34	-0.07	-1.36
Profit Rate	0.30	0.20	0.65	-0.54

V- Phillips-Perron Unit Root Test

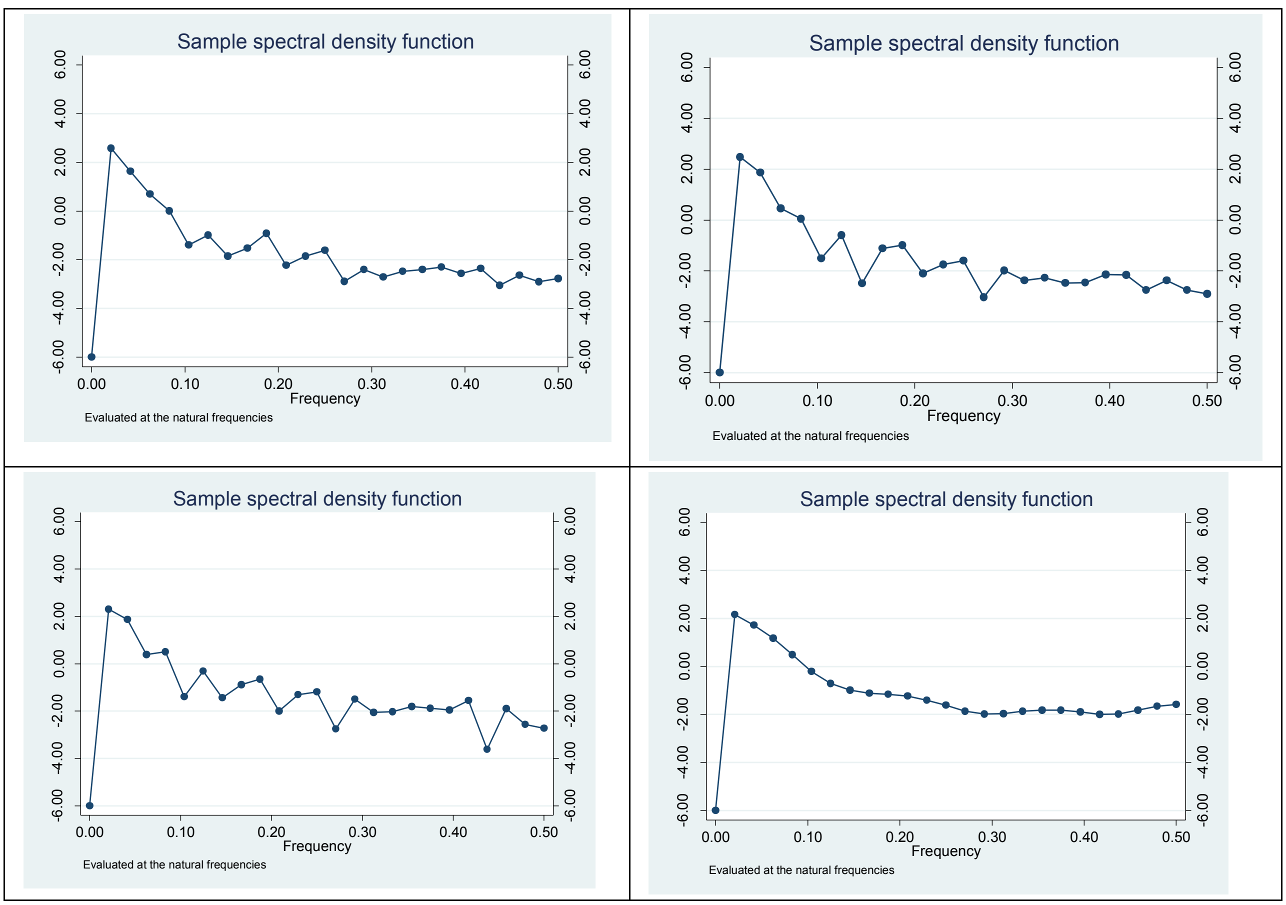
Table I: Phillips Perron Unit Root Test: Variables in Level

Cluster	Variable	p-value	Unit root existence
1	Y	0.37	Yes
	TFP	0	No
2	Y	0.29	Yes
	TFP	0	No
3	Y	0.19	Yes
	TFP	0	No
4	Y	0.78	Yes
	TFP	0.03	No
5	Y	0.69	Yes
	TFP	0	No

Table II: Phillips Perron Unit Root Test: Variables in First Differences

Cluster	Variable	p-value	Unit root existence
1	Y	0	No
2		0	
3		0	
4		0.02	
5		0.01	

Table VI: Periodogram Output (Y) for the various Clusters



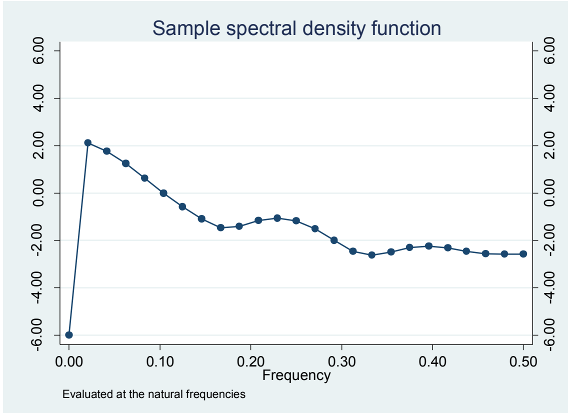
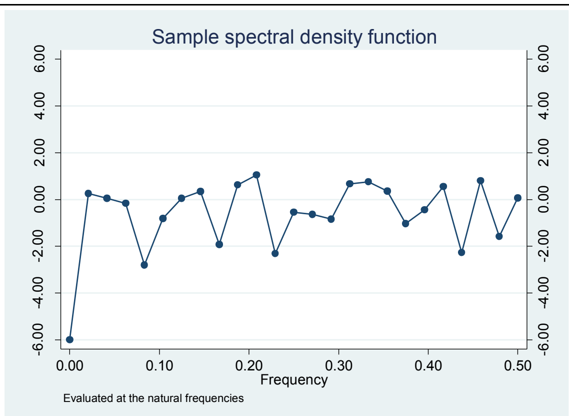
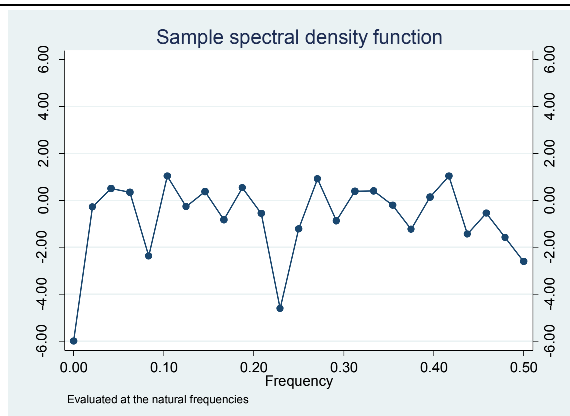
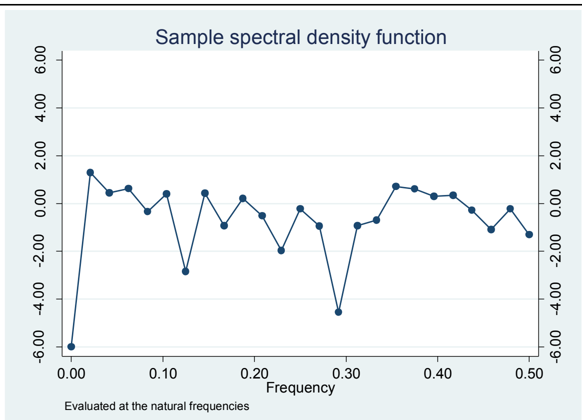
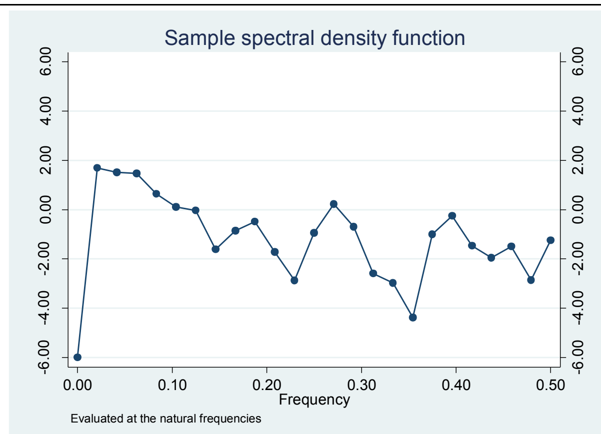


Table VII: Periodogram TFP for the various clusters









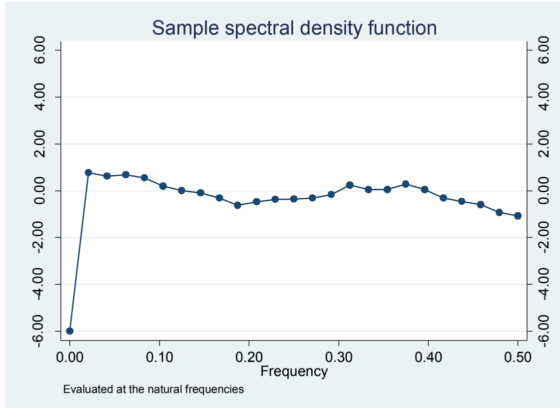


Table VIII- Johansen Test for Cointegration rank ($\leq k$)

Johansen Cointegration Test: Cluster 1				
Max Rank	**LL**	**eigenvalue**	**Trace statistic**	**5% Critical Value**
0	-1009.16	.	35.15	15.41
1	-991.64	0.53	0.09*	3.76
2	-991.59	0.00		

Johansen Cointegration Test: Cluster 2				
Max Rank	**LL**	**Eigenvalue**	**Trace statistic**	**5% Critical Value**
0	-981.75	.	25.43	15.41
1	-969.22	0.42	0.37*	3.76
2	-969.04	0.01		

Johansen Cointegration Test: Cluster 3				
Max Rank	**LL**	**Eigenvalue**	**Trace statistic**	**5% Critical Value**
0	-932.65	.	14.02*	15.41
1	-926.36	0.24	1.44	3.76
2	-925.64	0.03		

Johansen Cointegration Test: Cluster 4				
Max Rank	**LL**	**Eigenvalue**	**Trace statistic**	**5% Critical Value**
0	-643.90	.	65.11	15.41
1	-624.14	0.58	25.58	3.76
2	-611.35	0.43		

Johansen Cointegration Test: Cluster 5				
Max Rank	**LL**	**Eigenvalue**	**Trace statistic**	**5% Critical Value**
0	-731.76	.	47.57	15.41
1	-709.77	0.62	3.61*	3.76
2	-707.97	0.08		

Tables IX – Speed(a) and level (b) of Equilibrium Convergence between Aggregate Output (Y) and TFP

Cluster	Α	β	α*β
1	-3.12	0.03	-0.0936
2	-4.14	0.04	-0.1656
3	1.56	2.34	3.6504
4	1.34	3.28	4.3952
5	-1.33	0.04	-0.0532

Tables X &XI- Granger causality

Table X

TFP does not Granger cause Aggregate output (Y)				
Clusters	FPE criteria	obs	F-stat	p-value
1	3	45	14.31	0
2	2	46	15.22	0
3	2	46	7.69	0
4	3	45	3.12	0
5	3	45	12.13	0

Table XI

Aggregate output (Y) does not Granger cause TFP				
Clusters	FPE criteria	obs	F-stat	p-value
1	3	45	11.32	0
2	2	46	10.67	0
3	2	46	6,97	0
4	3	45	9.88	0
5	3	45	10.33	0