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2014

Online at <https://mpra.ub.uni-muenchen.de/90037/>
MPRA Paper No. 90037, posted 18 Nov 2018 08:11 UTC

Sector size, technical change and stability in the USA (1957-2006): a Schumpeterian approach

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Abstract: The main purpose of this paper is to investigate two famous postulates of the Schumpeter hypothesis and its implications for the U.S. economy. Analytically, we investigate whether sector size matters for sectoral (i) technological change and (ii) stability, as expressed through the relevant quantitative measures and variables. To this end, we test a number of relevant models that express the various forms of this relationship. More precisely, we use panel data for the fourteen main sectors of economic activity in the U.S.A. over the period 1957-2006, just before the first signs of the US and global recession made their appearance. The results seem to be in line with the Schumpeterian postulate that market size matters for technological change and economic stability, for the US economy (1957-2006). Clearly, further research would be of great interest.

Keywords: Schumpeter, sector size, technology, stability, cycles, USA.

1. Introduction

When examining which market structure favours technological change and innovation, we often refer to Joseph Schumpeter (Schumpeter 1939, 1942, 1976) who put technology in the center of his theoretical system. Here, we are about to examine whether the empirical evidence seem to support two famous postulates of the Schumpeterian doctrine for the US economy. In fact, over the last decades one of the most interesting debates has to do with the so-called Schumpeterian hypothesis (Schumpeter 1939, 1942, 1976). In brief, the Schumpeter hypothesis argues that ‘large firms with considerable market power, rather than perfectly competitive firms were the “most powerful engine of technological progress”’ (Mokyr 1990, 267). This famous hypothesis argues that large economic units are more likely to promote innovation. It also claims that, in a generally unstable market structure, only large economic units could guarantee the stability that is necessary for technological change and development.

To this end, we test a variety of models that express the various forms of this relationship. More precisely, we use panel data for the fourteen (14) main sectors of economic activity in the U.S.A. over the period 1957-2006, just before the first signs of the US and global recession made their appearance. The results seem to give credit to the Schumpeterian postulate that market size matters for technological change and economic stability for the US economy.

In a nutshell, this work contributes to the literature in the following ways: First, it provides an extensive review of the literature on the subject and adopts two relevant methodological approaches. Second, based on these quantitative approaches, the paper offers a complete investigation of two famous postulates of the Schumpeterian theory for the US economy, and it is the first, to the best of our knowledge, to do so by sector of economic activity, in a panel data framework. Third, the paper uses a wide dataset (1957-2006) to examine the U.S economy up until the first signs of the US and global economic recession made their appearance.

The outline of this paper is as follows: section 2 presents the theoretical framework which draws on Schumpeter’s original works; section 3 offers an extensive review of the literature on technological change; section 4 sets out the methodology employed; section describes 5 the estimation method and the available data; section 6 presents the empirical analysis, whereas section 7 discusses the results; finally, section 8 concludes the paper.

2. Theoretical Framework

Despite Joseph Schumpeter's inspired dream of developing what he called an "exact economics" (McCraw 2007, 5), it is true that the basic differences between Schumpeter and other great economists go much deeper than plain and simple mathematical economic theorems. He saw a different economic reality and defined economics differently. The flamboyant Austrian economist rejected the assumption that the "healthy" economy is one in (static) equilibrium. He argued that a modern economy is always in dynamic (dis)equilibrium, and the economy he envisaged was not a closed system. It is forever changing and is rather open than closed, in nature. Of course, such an approach to economic reality is mostly ignored, because it has proven too difficult to formalize, i.e. to fit into the maximization methodology of economics as a science (McCraw 2007, 500).

According to Schumpeter economic development is accompanied by growth, i.e. sustained increases in national income; however quantitative growth does not constitute development *per se*. He famously wrote: '[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.' (Schumpeter 1912, 64, emphasis added). Real economic growth and development depend primarily upon productivity increases based on 'innovation'. More precisely, for Schumpeter this concept covered the following five 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 context, he used the term 'technological progress' to characterize these changes (Scherer 1992, 1417), which account for the greater part of economic development. Of course, he distinguished this process from growth due to the gradual increase in population and capital by writing: '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).

Nevertheless, the famous Schumpeterian¹ postulate regarding the relationship between innovativeness and firm size is characterized by some controversy even in Schumpeter's original work, according to Degne (2010). In fact, the "early" Schumpeter denies the existence of a trade-off between competition and technological change, while the "late" Schumpeter sees the same relationship as controversial². The Schumpeterian hypothesis was formulated along this line of reasoning, as a response to the question of 'who is actually the vehicle of innovation and technological progress', and could be summarized as follows (Mokyr 1990, 267, emphasis added): '*large firms with considerable market power, rather than perfectly competitive firms* were the 'most powerful engine of technological progress'' (Schumpeter 1942, 106). In his book *Capitalism, Socialism and Democracy*, Schumpeter rejected perfect competition as an ideal market structure in capitalism, and dismissed the idea of 'an entirely golden age of perfect competition' as 'wishful thinking' (1942, 81), since :'[P]erfect competition is not only impossible but inferior' (Schumpeter 1942, 106).

Schumpeter believed that smaller units within the framework of perfect competition are not favourable to technological progress, for two reasons: (a) they cannot lead to high profitability and thus they cannot create real incentives for innovation; (b) they cannot create incentives for the capitalist and the enterprise to undertake risky and uncertain projects, because they are unable to guarantee, as a reward, an extra profit. More precisely, by incorporating new technologies, new types of organization, etc, innovations create surpluses of revenues over costs. Competition, however, tends to eliminate these extra revenues (extra profits), but the 'spread of monopolist structures' and the ability of big enterprises to promote innovation constantly recreates them (Schumpeter 1942, 81 ff.).

In his *Theory of Economic Development* (1912), the predominant role of large oligopolistic firms in technical innovation had been already acknowledged: 'And if the competitive economy is broken up by the growth of great combines, as it is increasingly the case today in all countries, then this must become more and more true of real life, and the carrying out of new combinations must become in ever greater measure the internal concern of one and the

¹ *Business Cycles* is often regarded as an inflection point in Schumpeter's intellectual life, in the sense that it was the last time Schumpeter attempted to join economic history and economic theory. In fact, according to McCraw (2007), it signified the turning point "in Schumpeter's decades-long intellectual wrestling match with himself".

² Langlois (2007) argues that this controversy cannot be found explicitly in Schumpeter's work.

same economic body. The difference so made is great enough to serve as the water-shed between *two epochs in the social history of capitalism*' (Schumpeter 1912, 67, emphasis added).

As far as the other aspect of the Schumpeterian hypothesis is concerned, it argues that perfect competition is an unstable market structure where only large enterprises can push technological progress forward. For Schumpeter, once big corporations are formed, the imperfectly competitive market structure becomes stable, as large firms become increasingly conducive to technological progress and change. 'There are superior methods available to the monopolist which either are not available at all to a crowd of competitors or are not available to them so readily' (Schumpeter 1942, p. 101). 'The perfectly bureaucratized giant industrial unit [...] ousts the small or medium-sized firm' (Schumpeter 1942, 134). In the same line of reasoning, the large firm is considered to possess the ability to attract superior 'brains', to secure a high financial standing (Schumpeter 1942, 110), and to deploy an array of practices to protect their risk-bearing investments.

The thesis regarding the limited ability of free competition to promote technological progress is supposed to be a conclusion drawn from past historical experience. More precisely, Schumpeter argued that the capitalist era could be divided into two distinct periods (Screpanti and Zamagni 1993, 243 ff.): (a) The era 'competitive capitalism' when small enterprises dominated, an era which declines in the 1880s and (b), the era of monopolistic or 'big-business capitalism', during which large enterprises, trusts and cartels dominated, starting roughly from the 1880s and having consolidated its fully fledged form by the time Schumpeter's book was written.

3. Background Literature

Throughout the years the Schumpeterian hypothesis has attracted the growing attention of economists and researchers. Arrow (1962) argued that larger firms have greater incentive for R&D investments due to the fact that they have a better ability to catch the property rights from their innovations. One of the first empirical attempts was made by Mansfield (1964) with the use of U.S sectoral data. However, the findings were inconclusive. Scherer (1965) provided an analytical econometric framework under which the Schumpeterian hypothesis could be properly tested. Also, Scherer (1967) examined the optimal degree of market concentration that promotes

the level of innovative activity under a game-theoretic framework and concluded that an increase in the number of economic units in the market increases the marginal payoff of R&D.

Next, Fisher and Temin (1973) constructed a model with R&D investments under profit maximization and showed that there was no reason for a positive relation between innovation and firm size. Kamien and Schwartz (1976) showed that intense rivalry would lead to an initial increase of the R&D expenditures by a firm, but at a later stage the expenditures would decline. They concluded that there is an optimal degree of rivalry that promotes innovation. Rodriguez (1979) argued that based on Fisher and Temin (1973), profit maximization implied negative profits and so their model is fundamentally flawed. Lury (1979) managed to construct an equilibrium model which showed that, under certain conditions, intense rivalry reduces firm individual incentives to innovate. Dasgupta and Stiglitz (1980) made an attempt to establish the microeconomic foundation of the Schumpeterian hypothesis by connecting the market concentration with the incentives in innovative activity.

In a seminal work for the US, Link (1980) provided empirical evidence which support the hypothesis by using data from the chemical industry of US, showing that firm size is a prerequisite for successful innovative activity. In a different framework, Griliches (1980) examined whether the slowdown in productivity that was witnessed in the U.S economy could be attributed to the drop of R&D expenditures. Despite his efforts, the results seem to be inconclusive. Again, Link (1981) provided evidence in favour of a positive relation between R&D expenditures and the productivity growth using data of fifty one (51) manufacturing firms in the U.S. Kamien and Schwartz (1982) introduced a model that incorporated the elements of market structure that could affect innovation. Their model offered interesting insights on the interdependence of market size and innovation with predominant the non-existence of a monotonically increasing relation between concentration and innovation.

Scherer (1983) investigated the relationship between R&D expenditures and patenting. The results showed that there is a positive relationship between the two, but also a trend that shows that large firms do not seem to promote innovation more than smaller ones. On the other hand, Bound et al. (1984) provided an investigation on R&D expenditures and patenting which showed that both large and small firms are more R&D intensive than average firms. Again, Griliches (1984) investigated the relationship between R&D intensity and TFP using data from 1960 to mid 1970s showing a significant relationship between the two.

Levin et al. (1984) provided a thorough analysis of a model that incorporated R&D spillovers. According to their findings R&D spillovers tend to promote technological adoption. Again, Levin et al. (1985) showed that new born industries seem to promote innovation more. Another important attempt to provide evidence on the linkage between firm size and innovation was made by Acs and Audretsch (1987). Their findings suggest that there is a set of conditions that seems to control which type of firms, small or large, promote innovation. Cohen et al. (1987) found that business size has no effect on R&D intensity but only on the probability of conducting R&D. Pavitt et al. (1987) investigated the distribution of units' size that develop important innovations and concluded that units with less than 1000 workers or more than 10,000 workers have an above average share of innovations per employ. In addition, Cohen and Levin (1989) concluded that 'the empirical results concerning how firm size and market structure relate to innovation are perhaps most accurately described as fragile'.

More recently, 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. Thus, not all innovations are the same. Tirolle and Aghion (1994), established a game theoretic framework under which the Schumpeterian hypothesis can be both rationalized and endogeneized. Furthermore, Symeonidis (1996), in a survey article, argued that under certain circumstances there could be a positive relationship between market concentration, size of the firm and innovative activity.

Furthermore, Streb (1999) in a seminal paper examined the conditions under which a national industry could succeed in international competition. Andersen (2000) using a game-theoretic framework based on evolutionary games tried to investigate the role of pioneers as opposed to imitators in simple games in an attempt to examine whether the hypothesis works in certain games. However, the results were inconclusive. Furthermore, Gayle (2001) provided further evidence on the inconclusive nature of the results on the Schumpeterian hypothesis. Dhawan (2001), in an inspired approach, measured the differences in productivity of both small and large firms according to their profitability which was related to the probability to survive. The findings suggested that small firms tend to be more profitable but less likely to survive.

Moreover, Nahm (2001), with the use of a data set from the bank of Korea, managed to separate Korean firms to scientific and non-scientific according to their R&D expenditures. The results showed that there is a threshold in firm size and independent R&D activity. Zachariadis

(2002) used U.S manufacturing industry data to econometrically test the link of R&D to patenting, patenting to technological progress and technological progress to growth. Under this framework he found evidence of a positive linkage between R&D and growth. Nicholas (2003) provided an extended survey of the cliometric literature regarding the Schumpeterian hypothesis. According to his findings American firms of the 1920's exhibit a positive relationship between market power and innovative activities.

Relatively recently, Aghion et al. (2005) managed to derive an inverted U-shape relationship between innovation and competition in a general equilibrium framework which is in favour of the hypothesis. In addition, Aghion and Griffith (2005) showed that in industries working very close to their technological frontier, innovation is driven by competition. Acs and Audretsch (2005) showed that the small firms play a vital role for R&D. In addition, Baudisch (2006) provided evidence in favour of the hypothesized relationship using data for the U.S footwear company. Hashmi and Biesebroeck (2010) provided empirical evidence, under a game theoretic framework established by Ericson and Pakes (1995), in support of the Schumpeterian hypothesis for the global automobile industry (1980-2005). Salies (2009), in the E.U. electrical utilities sector, showed a positive relationship between market structure, firm size and innovative activity. Mohnen et al. (2009), using panel data, provided evidence in favour of the hypothesis in specific sectors. Finally, Jinyoung et al. (2009) re-examined the relationship between R&D and productivity in small and large firms in the pharmaceutical and semiconductor industries. They found that R&D productivity is increasing in firm size, in the pharmaceutical industry. In a nutshell, the relevant literature seems to be controversial and inconclusive.

4. Methodology

As we know, Schumpeter famously argued 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” (Schumpeter 1912, 64). Real economic growth and development depend primarily upon productivity increases based on technology and innovation. Thus, strictly speaking, Schumpeter did not discriminate between growth trend and business cycle fluctuations, so the observed raw data have been used to test the Schumpeterian hypothesis. In a next step, one has to decide about the time series representing the

capitalist process. Although Schumpeter (1939) used many different series, nowadays it is commonly agreed to use aggregate output as an indicator of the capitalist dynamics. Of course, it has to be mentioned critically that this reduction of reality was not in the spirit of research at the time Schumpeter wrote his book on *Business Cycles*.

First, we focus on the part of the Schumpeterian hypothesis which relates large economic units with increasing technological change. Specifically, we examine the relationship between the aggregate output of each sector (Y) as an expression of its size and its: (i) R&D expenses (R), and (ii) Total Factor Productivity (TFP).

The model that we employ here is based on Bound et al. (1984) with the use of cross-section Seemingly Unrelated Regression (SUR) model, following Arellano (1987).

R&D expenses

- $R_t = aY_t^b$ or $\ln R_t = \ln a + b \ln Y_t$ (1)

where $a > 0$, $b \in \mathbb{R}$ is the R&D elasticity with respect to the aggregate output.

For the Total Factor Productivity index we will have that:

TFP

- $(\text{tfp})_t = aY_t^b$ or $\ln(\text{tfp})_t = \ln a + b \ln Y_t$ (2)

Next, our investigation focuses on the postulate of the Schumpeterian doctrine which claims that large units tend to fluctuate more than smaller ones. Although in the original spirit of Schumpeter's work, there exists no clear distinction between trend and cyclical component, we have to separate between growth and secular component in order to quantify the "economic

fluctuations”. In this context, we adopt a popular approach which regards cycles as fluctuations around a trend, the so-called “deviation cycles” (Lucas 1997). Meanwhile, the business cycle component is regarded as the movement in the time series that exhibits periodicity within a certain range of time duration based on the seminal work by Burns and Mitchell (1946), and in line with the National Bureau of Economic Research (NBER).

Given that the trend is important for the propagation of shocks (Nelson and Plosser 1982), we first have to examine the stationarity characteristics of each time series. If the results suggest that the time series are stationary in their first differences, then de-trending is highly relevant. The estimation of this trend for each time series is of great importance because it is necessary for the extraction of the cyclical component.

There are several ways to test for the existence of unit roots. We used panel data unit root tests that are relevant for the investigation of the statistical properties in a panel data framework. Since panel data increases the power of the test by enhancing the time series dimension of the data by the cross section, the results could be considered as being more reliable. The most popular panel unit root tests are the LLC (Levin, Lin and Chu, 2002), the IPS (Im, Pesaran and Shin 2003), the ADF - Fisher Chi-square (Maddala and Wu 1999) and the PP – Fisher Chi-square (Choi 2001).

In case the time series is non-stationary, then detrending based on Hodrick - Prescott (HP) filtering would be relevant, due to its widespread acceptance in the literature. See, for instance, Montoya and de Haan (2008), Danthine and Girardin (1989), Danthine and Donaldson (1993), Blackburn and Ravn (1992), Backus and Kehoe (1992), Dimelis *et al.* (1992), Fiorito and Kollintzas (1994), Christodoulakis *et al.* 1998, Dickerson *et al.* 1998). The robustness of the HP de-trending method is confirmed, among others, by Artis and Zhang (1997) and Dickerson *et al.* (1998). The linear, two-sided HP-filter approach is a method by which the long-term trend of a series is obtained using actual data. The trend is obtained by minimizing the fluctuations of the actual data around it, i.e. by minimizing the following function:

$$\sum [\ln y(t) - \ln y^*(t)]^2 - \lambda \sum \left[[\ln y^*(t+1) - \ln y^*(t)] - [\ln y^*(t) - \ln y^*(t-1)] \right]^2$$

where y^* is the long-term trend of the variable y and the coefficient $\lambda > 0$ determines the smoothness of the long-term trend. This method decomposes a series into a trend and a cyclical component. The parameter used for annual data equals to $\lambda = 100$ (Baum *et al.* 2001; Hodrick and

Prescott, 1997; Kydland and Prescott, 1990). Thus, after the estimation of the cyclical components, we proceed to the empirical specification of the model.

Here, we test the Schumpeterian postulate which claims that large units tend to fluctuate more than smaller ones. In this context, we are based on Scherer's (1983) approach which is suitable for business cycles movements due to its quadratic form, able to capture the fluctuations. So the model is as follows:

- $\ln(\text{Cycle})_{it} = b_0 + b_1 \ln Y_{it} \quad (3)$

and

- $(\text{Cycle})_{it} = b_0 + b_1 Y_{it} + b_2 Y_{it}^2 \quad (4)$

In brief, this work contributes to the literature in three distinct ways. First, it provides a well rounded review of the literature and adopts two relevant methodological approaches; second, based on these approaches the paper offers a complete investigation of two famous postulates of the Schumpeterian theory for the US economy. In the meantime, it is the first, to the best of our knowledge, to do so by sector of economic activity, in a panel data framework. Third, the paper makes use of a wide dataset to examine the U.S economy for the period 1957-2006, just before the first signs of the US and global economic recession made their appearance.

5. Estimation Method and Data

5.1 Estimation method

Fixed-effects methods have become increasingly popular in the analysis of longitudinal data for one compelling reason. They make it possible to control for all stable characteristics of the individual, even if those characteristics cannot be measured (Halaby 2004; Allison 2005).³

³ Fixed-effects methods can naturally be applied to linear models (Greene 1990), logistic regression models (Chamberlain 1980), Poisson regression models (Cameron and Trivedi 1998) and linear dynamic panel-data and contain unobserved panel-level effects, fixed or random.

By construction, the unobserved panel-level effects are correlated with the lagged dependent variables, making standard estimators inconsistent. Arellano and Bond (1991)⁴ derived a consistent generalized method of moments (GMM) estimator for this model. Building on the work of Arellano and Bover (1995), Blundell and Bond (1998) developed a system estimator that uses additional moment conditions. However, according to Arellano (1987), when using OLS in panel data, cross section weights should be used. In fact, if the number of periods (T) is two times greater than the number of cross sections (2N) then cross-section SUR should be used, where all individuals have their own regression parameters, but these are restricted to be constant over time. The regression relations for the different individuals are only related via the correlation of the error terms, but the error covariance across individuals is unrestricted. Baltagi (2008) noticed that the OLS estimator is biased and inconsistent even if the error terms are not serially correlated; the random effects estimator is also biased in a dynamic panel data model. Nevertheless, as T gets large, the fixed effects estimator becomes consistent. As Judson and Owen (1999) notice, for T=30 the bias could be significant. However, in this work, the number of periods is equal to T=50 and the number of sectors is fourteen (14), a fact which clearly implies that only a minor bias would be expected.

Also, fixed effects were calculated for the equations estimated for the fourteen (14) sectors under investigation. Furthermore, the model was estimated using the Generalized Linear Model (GLM). Formulated by Nelder and Wedderburn (1972), the GLM constitutes an extension of familiar regression models. A generalized linear model is defined as a model where the linear combination of X-variables is related to the outcome variable Y using a link function g and where the variance of the response variable is proportional to some function of the mean (Newson, 2001).

At this point, a major problem in examining technological change and one that makes it difficult to define or characterize it is that it can take many different forms (Rosenberg, 1982). In that sense, there is no generally accepted measure of technological change and all measures are imperfect. As a result, we use the two most popular measures in order to quantify technological

⁴ The Arellano and Bond (1991) estimator can perform poorly if the autoregressive parameters are too large or the ratio of the variance of the panel-level effect to the variance of idiosyncratic error is too large.

change. R&D expenditures along with TFP⁵ are typically used as proxies for technology. It is widely argued that there is convincing evidence supporting the cumulative R&D is the most important endogenous measure⁶ of technology⁷ whereas TFP is an exogenous measure of technology. Of course, another variable that could serve as an alternative indicator for technological change is patents⁸. However, as Smith (2006) has argued, patents reflect inventions rather than innovations. Therefore, patent data would provide only a crude proxy, at best, for what Schumpeter meant by technological innovation and technological change. In addition, sectoral data on patents were not readily available to us, based on the classification at hand. No doubt, further investigation based on patents would be useful.

Now, another important measure is sector size. In the literature, one can find a variety of measures that represent the size of a firm, such as the number of employees, the revenue and the capital stock. The advantages and disadvantages of each measure are thoroughly discussed in Degne (2010). In this study, following Scherer (1985) we express the size of the sector through its output, due to data availability.

5.2 Data

We make use of data regarding the U.S economy for the period 1957-2006, just before the first signs of the US and global recession made their appearance, based on the fourteen main sectors of economic activity: (*RD*) expresses the aggregate R&D expenses, (*Y*) expresses the gross sectoral output, (*L*) expresses the full time equivalent employees, and (*K*) expresses the net stock of physical capital. All data are in billions of US dollars (1957 prices), except for (*L*) that is measured in thousands of employees. The data come from various sources: *K* comes from the Bureau of Economic Activity, *L* from the Bureau of Labour Statistics, *RD* from the National Scientific Foundation of the U.S. and *Y* from the National Bureau of Economic Activity. In the next table (Table 1) there is a detailed description of the data that we used including the sectors of the U.S.A economy that we investigated.

⁵ TFP approximates technological change as the residual of the growth equation.

⁶ For an extensive discussion on the determinants of technology in the Schumpeterian tradition, see Degne (2011).

⁷ Of course, a typical drawback, is that R&D expenses of a firm can capture only the input size and do not provide any information regarding the output side (Kleinknecht 2001).

⁸ For an extensive discussion on patents see Griliches (2008), Degne and Streb (2010).

Table 1				
INDUSTRIAL SECTORS (U.S. ECONOMY)				
SECTORS	DESCRIPTION	NACE CLASSIFICATION	VARIABLES AVAILABLE	SOURCE
1	AGRICULTURE, FORESTRY AND FISHING	A01, A02, A03	OUTPUT (Y)	National Bureau of Economic Activity
2	MINING, PETROLEUM AND COAL PRODUCTS	B, C10-C12, C13-C15, C16, C17, C18, C19, C20, C21, C22, C23, C24, C25, C26, C27, C28, C29, C30, C31-C32, C33		
3	ELECTRICITY, GAS AND WATER	D, E36, E37-E39		
4	CONSTRUCTION	F		
5	FOOD & BEVERAGES, WOOD PRODUCTS AND FURNITURE, METAL PRODUCTS	I	CAPITAL (K)	Bureau of Economic Activity
6	WHOLESALE TRADE	G45, G46		
7	RETAIL TRADE	G47		
8	TRANSPORT AND STORAGE	H49, H50, H51, H52, H53		
9	INFORMATION & TECHNOLOGY INDUSTRY	J58, J59-J60, J61, J62-J63, S95	R&D EXPENSES	National Scientific Foundation of the U.S
10	REAL ESTATE AND BUSINESS SERVICES, FINANCE AND INSURANCE	K64, K65, K66, L, L68A, M71, M72, N77		
11	COMMUNICATION SOCIAL AND PERSONAL SERVICES	M73, M74-M75, N79, N80-N82, O, Q87-Q88, R90-R92, R93, S94, S96, T, U		
12	BUSINESS MANAGEMENT SERVICES	M69-M70, N78	LABOR (L)	Bureau of Labour Statistics
13	EDUCATIONAL ORGANIZATIONS	P		
14	HEALTH SERVICES	Q86		

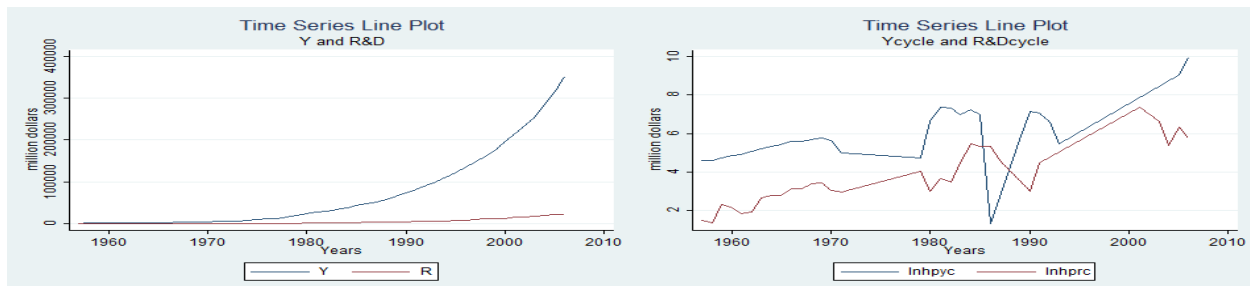
Next, there is a Table 2 which presents the aggregate annual growth rates of the variables under consideration. It is worth mentioning that the growth rates of the variables are positive and significant. On the other hand, the growth of R&D intensity index has a negative sign, which in turn indicates that there is a decrease of the proportion of R&D expenses on output over time.

Table 2	
Annual growth rate (1957-2006)	
Variable	Growth (%)
Y	11.6
RD	11.5
(RD/Y)	-4.1

6. Empirical Results

The stationarity properties of the various macroeconomic time series have been checked by means of the ADF test for panel data and the empirical results are available upon request by the authors. The ADF test was applied both on the original variables and their first differences. All the variables of interest are non-stationary; however all their first differences are stationary.

According to the following graphs on total output and RD expenses, it is evident that both variables are increasing but do not follow a very similar pattern. In this context, an investigation under the prism of the Schumpeterian hypothesis seems to be highly relevant. Now, as far as the cyclical components of R&D expenses and total output are concerned, we can see that the fluctuations in total output and the fluctuations in R&D expenses do follow a similar pattern.



Graph 1: Aggregate data on Total output and R&D expenses in the U.S. economy (1960-2010).

Graph 2: Aggregate data on the cyclical components of Total output and R&D expenses in the U.S. economy (1960-2010).

Based on the methodology set out earlier, the first two models are estimated. See Table 3.⁹ And, after extracting the cyclical component, we estimate the remaining two models. See Table 4.

⁹ A Hausmann test to confirm the suitability of the fixed effects model over the random effects model would be relevant here and is available upon request by the authors.

Table 3

	<i>equation 1</i>	<i>equation 2</i>
Dependent Variables	lnRD	lnTFP
<i>constant</i>	6.762	12.713
	(0.000)	(0.000)
<i>ln (Sector Size)_{it}</i>	0.156	0.076
	(0.002)	(0.000)
<i>D₁ (1st oil crisis)</i>	0.001	0.001
	(0.000)	(0.004)
<i>D₂ (2nd oil crisis)</i>	-0.001	-0.001
	(0.000)	(0.010)
<i>R-squared</i>	0.570	0.830
<i>F-test</i>	15.79	206.47
<i>Durbin Watson Statistic</i>	1.410	1.550

p-values in parenthesis

D₁: A dummy variable that takes the value of 1 during the first oil crisis & 0 elsewhere

D₂: A dummy variable that takes the value of 1 during the second oil crisis & 0 elsewhere

Table 4

	<i>equation 3</i>	<i>equation 4</i>
Dependent Variables	lnCycle	lnCycle
<i>constant</i>	9,387	247,821.30
	(0.000)	(0.000)
<i>ln(Sector Size)_{it}</i>	0.207	
	(0.000)	
<i>(Sector Size)_{it}</i>		-0.734
		(0.000)
<i>(Sector Size)_{it}²</i>		0.000
		(0.000)
<i>D₁ (1st oil crisis)</i>	0.001	0.003
	(0.041)	(0.033)
<i>D₂ (2nd oil crisis)</i>	-0.001	-0.001
	(0.001)	(0.332)
<i>R-squared</i>	0.490	0.560
<i>F-test</i>	42.670	52.040
<i>Durbin Watson Statistic</i>	1.821	1.440

p-values in parenthesis

D₁: A dummy variable that takes the value of 1 during the first oil crisis & 0 elsewhere

D₂: A dummy variable that takes the value of 1 during the second oil crisis & 0 elsewhere

We observe that the significance of the factors entering the estimated panel data models is tested using the available dataset and the framework proposed by Bound et al. (1984). The estimated coefficients are statistically significant in all cases, and consistent with the implied hypotheses. Meanwhile, the estimated models account, in most cases, for a satisfactory percentage of the variability of the dependent variable in the different sectors of economic activity in the USA, which - given the inevitable imperfections in this sort of panel data - is satisfactory (Mankiw et al. 1992, 408).¹⁰

7. Discussion

To begin with, we observe that the collapse of output following the first oil crisis is evident for the U.S economy (see Graph 2). Between 1963 and 1972, there is a clear upward pattern in output that was stopped by the oil crisis, the effect of which is evident in the de-trended time series. Furthermore, the cyclical component follows the same pattern both in the total economy and in most of the sectors between 1979-1982 and 1990-1991. The 1990s began with a shallow recession (Basu et al. 2001) and, according to the Economic Report of the President (1994), the speed of recovery was very slow. Furthermore, between 1991 and 1997 – the so-called “new economy” period – a sharp increase of output took place. Also, productivity growth coincided with an exceptionally good performance of the US economy (Mankiw 2001). According to Norrbin and Schlagenhauf (1990), differences exist with respect to the magnitude of the fluctuations because of aggregate (national) shocks, industry group specific shocks and idiosyncratic factors. According to Basu et al. (2001) the 1990s experienced a boom in business investment of unprecedented size and duration. The 1970s was a decade characterized by an investment boom (just like the 1990s) but less prolonged that was due to investment in information technology (IT) equipment (computers plus communications equipment). Our findings are fully consistent with the aforementioned patterns. Finally, a clear decreasing pattern is evident after 2001, which may be related to the IT technology bubble and the terrorist attacks of 2001. The downward trend could be an early indicator of the then forthcoming U.S crisis.

¹⁰ We should stress the fact that all estimates of R&D and T.F.P. are subject to a margin error and the T.F.P. estimate is obviously contingent on an estimate of the capital stock (Stikuts 2003). In other words, the methodology we used is popular and appropriate, but it should be treated with caution since the various parameters are estimated figures, and therefore, there is some uncertainty in their estimation and should not be treated as firm, precise measures.

Regarding R&D expenditures the “oil crisis” caused the contraction of R&D expenditures until 1983. The tax-cut policy introduced by the Reagan government pushed profitability upwards and gave motives for investment. The increase in the US sectoral R&D expenditures might be related to this policy.

Our findings suggest that the Schumpeterian postulate seems to have some valid ground in the U.S sectoral economy regarding the time span under consideration. The majority of our findings exhibit a positive relationship between the size of sectors, expressed by their aggregate output, and innovative activity. More precisely, the R&D expenses are positively affected by a change in the size of aggregate output, due to the positive and significant sign of the estimate. The model, in general, seems to be satisfactory and the remaining statistics suggest that there is no serious evidence for any econometric abnormality.

As far as the relationship between sector size and TFP is concerned, our empirical findings suggest that the Schumpeterian hypothesis is valid. This is due to the fact that the elasticity of R&D with respect to T.F.P is positive and statistically significant which, in turn, implies that a change in output is accompanied by a change in T.F.P. The model’s goodness of fit is over 80% accompanied by a high F-stat confirming the appropriability of the model. Also, there are no econometric problems present in our analysis.

Regarding the relationship between the size of aggregate output and the fluctuation of the output in a quadratic framework (Scherer 1983), once again the results seem to confirm the hypotheses under consideration. The positive sign of the quadratic term in our model dominates the negative sign of the linear component. Therefore, in total there is a positive relationship between the dependent and the independents variables which is statistically significant. The values of the F-stat and the goodness of fit of the model suggest that our analysis is satisfactory from an econometric point of view. Once again, no evidence of econometric abnormalities is present in the results.

The relationship between the same variables but in a linear framework, which is in line with the work of Bound et al. (1984), exhibits a positive relationship. The statistical significance of the sign suggests that a change in aggregate output would be accompanied by a change in fluctuations. Thus, large sectors tend to fluctuate more, which is an immediate outcome of the Schumpeterian hypothesis. According to the results of our analysis, the model is satisfactory.

The dummy variables that are used in our analysis capture the effect of the two oil crises. The estimates are statistically significant but their impact, i.e. the value of the coefficient is minimal. The sign of the dummy variables remains unaffected throughout the econometric analysis suggesting that the relationship between innovation and the two oil crises is constant. The dummy variables are statistically significant in the majority of our models. The first oil crisis has a positive impact on the determinants of innovative activity since there was a major increase in the innovative activities of the sectors during the crisis in an attempt of the U.S economy to decrease its dependence from oil as an energy source towards other energy sources (Ikenberry 1986). In specific, President Carter in 1976 dedicated unprecedented funding, to developing alternative energy in order to make the United States energy self-sufficient to reduce the volatility of the U.S. economy because of its dependence on oil (Brown 2011). The negative sign of the second oil crises is attributed to the fact that, a number of high profile energy technology development programs such as the breeder reactor program, the sun fuels program and the program of large scale solar energy demonstrations were all terminated (Dooley 2008). This occurred during the Reagan Administration, which maintained that “only in areas where these market forces are not likely to bring about desirable new energy technologies and practices within a reasonable amount of time is there a *potential need for federal involvement*”¹¹. As a consequence, a sharp decline in R&D expenses is evident after the second oil crisis¹².

To sum up, in general our results are consistent¹³ with a large part of the literature that partly validate the Schumpeterian hypothesis. Our analysis of the hypothesis with the use of aggregate output and innovative activity suggests that there is a positive significant relationship between the two in the U.S economy. Our analysis, regarding the fluctuations’ components of the aggregate output suggests that the relationship between the variables remains positive and significant, which in turn validates the hypothesis under consideration.

¹¹ U.S. Secretary of Energy James Edwards before the Senate Energy and Natural Resources Committee. February 23, 1981, as quoted in Fehner and Hall (1994).

¹² See, among others, Scherer (1992), Margolis and Kammen (1999), Helfat (1997), Dooley (1998), Margolis (1998), Kilian and Park (2009), Laitner and Stolyarov (2003).

¹³ See, for instance, Meisel and Lin (1983), Malecki (1980), Link (1980).

8. Conclusion

The main purpose of this paper has been to investigate two famous postulates of the Schumpeterian hypothesis and its implications for the U.S. economy. Analytically, we investigated whether sector size matters for sectoral (i) technological change and (ii) stability, as expressed through the relevant quantitative measures and variables. We tested a number of relevant models that express the various forms of this relationship. We used panel data for the fourteen (14) main sectors of economic activity in the U.S.A. over the period 1957-2006, just before the first signs of the US and global recession made their appearance.

Our research results give credit to the hypothesis originating in the Schumpeterian doctrine that large economic units tend to invest more on R&D, but the units' propensity to invest in R&D declines for larger units in the US economy (1957-2006). The same is in force for Total Factor Productivity. Also, a rise in the sector size would lead to a subsequent rise in the sectoral fluctuations which is consistent with the, respective, hypothesis based on the Schumpeterian doctrine that large sectors tend to fluctuate more intensely than smaller ones due to the increasing amount of innovations introduced, which is inherently unstable and causes business cycles.

Consequently, if the answer to Joel Mokyr's (1997, 1) question "Are we living in the middle of an industrial revolution?" is positive, then all these questions need to be further investigated and answered in order to determine whether the current industrial structure, which in some cases is similar to the one proposed by Schumpeter, might be a determining factor of the rapid technological change that the global economy is facing.

Our findings are consistent with Scherer (1992, 1421) who argued that "The only simple conclusion stemming from this and much other theoretical research stimulated by Schumpeter's original conjectures is that the links between market structure, innovation and economic welfare are extremely complex". To conclude, we fully agree with the same author that "Half a century after the publication of *Capitalism, Socialism and, Democracy*, Schumpeter's vision of the industrial structure most conducive to technological progress and hence to economic growth remains both relevant and controversial" (Scherer 1992, 1430). No doubt, further research on the subject would be of great interest.

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