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Technology and economic fluctuations in the US food sector (1958-2006)

An empirical approach from a political economy perspective

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Abstract

Purpose – The purpose of this paper is to deal with questions of instability and economic crises, deriving theoretical arguments from Marx's and Schumpeter's works and presenting relevant empirical evidence for the case of the US food manufacturing sector.

Design/methodology/approach – The paper attempts to interpret the economic fluctuations in the US food sector and find causal relationships between the crucial variables dictated by Schumpeterian and Marxian theory, such as technological change, output and profitability. In this context, a number of relevant techniques have been used, such as de-trending, cointegration analysis, white noise tests, periodograms, cross-correlations and Granger causality tests.

Findings – Most economic variables in the food manufacturing sector exhibit a similar pattern characterized by periodicities exhibiting a short-term cycle, a mid-term cycle and a long-term cycle. Also, the economic variables investigated follow patterns which are consistent with the total economy. Furthermore, a relatively rapid transmission of technology in the economy takes place along with bidirectional causality between technology and output/profitability, which can be interpreted as indicating an ambivalent relationship in the flow of cause and effect. These findings give credit to certain aspects of the Schumpeterian and Marxist theories of economic crises, respectively.

Originality/value – This paper contributes to the literature in the following ways: first, it introduces a relevant methodological framework building on Schumpeterian and Marxist insights. Second, it uses several variables to study the economic fluctuations instead of delimiting its analysis, for instance, to industrial output. Third, the results are discussed in a broader political economy context, related to the US economy, as a whole.

Keywords Economic conditions, Profit, Marxist economics, Economic theory, Food industry, United States of America

Paper type Research paper

1. Introduction

In this paper, we are dealing with questions of instability and economic crises, deriving arguments from Marxian and Schumpeterian theory and presenting relevant empirical

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evidence for the case of the US manufacturing sector in the time period 1958-2006, based on relevant quantitative techniques.

In the Marxist tradition a crisis is, usually, related to a fall in the profit rate. In a nutshell, one could argue that the profit rate seems to be driven by labour productivity, regardless of the specific approach adopted. On the other hand, the standard interpretation of Schumpeter's analysis is that long waves 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 indicators of economic and social welfare, such as profitability and output in the US food manufacturing sector (1958-2006). In Section 2, we begin by analyzing the stylized facts of the food manufacturing sector. In Section 3, a brief review of the literature takes place. Section 4 presents the theoretical framework and Section 5 sets out the methodological approach. Section 6 presents the empirical results, while Section 7 offers a brief discussion of the empirical findings. Finally, Section 8 concludes.

2. The US food sector (1958-2006): a brief overview

The food manufacturing sector is one of the largest in the USA. According to the Annual Survey of Manufacturers, around 28,000 establishments exist in the sector employing about 1,500,000 people or 11 percent of total employment in the manufacturing sector and more than 1 percent of the total employment in the US economy (2006 Annual Survey of Manufacturers). Meanwhile, it contributes more than 10.5 percent of the total manufacturing output and approximately 2 percent of the total US output (2006). The food production, processing, wholesale distribution, and retailing systems are important components of the US economy accounting for 12.8 percent of US gross domestic product (GDP) in 2000. Furthermore, the sector exports products equal to about 33 billion dollars. Also, the sector is one of high concentration, and food processing industries are among the most profitable industries in the USA (Wang *et al.*, 2006). Finally, market structure in the industry has changed significantly over the last 50 years mainly as a result of mergers and acquisitions.

The typical features characterizing the sector are: increased consolidation and concentration, changes in relative prices, shifts in consumer preferences and changes in government regulations (Adelaja *et al.*, 1999; Morrison, 1999; Rogers, 2001). It is a capital intensive sector, where materials contribute about 60 percent of total output (Huang, 2003), it is responsive to new technologies in processing, packaging and marketing of food product and has become increasingly high tech over the past decades (Morrison, 1999). Also, it experienced low productivity growth rates compared to other sectors (Huang, 2003) and total factor productivity (TFP) behaved cyclically (Heien, 1983).

In this context, there are several reasons for studying the US food manufacturing sector: first, it is a very important sector for the US economy; second, it has attracted limited attention in the literature, so far; third, the recent food crisis shed some light on different aspects of the food sector, its products and its influence on millions of people; Of course, there is an open debate on the nature and the roots of the recent food crisis. However, it is common place that the recent crisis has had several specific characteristics such as very high volatility in the prices of food and deprivation from food for increasing numbers of people from developing countries (Swan *et al.*, 2010; Lang, 2010; van der Ploeg, 2010).

Finally, the impact of the current financial and economic crisis on the food manufacturing sector is of great interest. More precisely, judging from previous crises, and knowing that profitability practically collapses during and/or after the crisis period (Duménil and Lévy, 2002; Wolff, 2003; Mohun, 2006), it is quite reasonable to expect a downward trend in profitability.

3. Review of the literature

Heien (1983) was probably the first who tried to measure productivity in the food manufacturing sector. The paper measured TFP using Theil-Törnqvist indexes of total outputs and total inputs, finding evidence of cyclical behaviour. Huang (2003) measured TFP and labour productivity growth in the time period 1975-1997. The paper argued that an important characteristic of the sector is its weak TFP growth compared to other sectors of US manufacturing, and this, the paper argued, is due to the low investment rate in R&D. Gopinath and Carver (2002) used data for 13 countries to examine the effects of productivity growth in agriculture on the processed food sector. One of their main findings is that the USA has the lowest food TFP growth level among the countries investigated, with the exception of Japan.

According to Azzam *et al.* (2002), the most important source of TFP growth in the food industry was demand growth, whereas the most important negative contributor to TFP growth was disembodied technological change. Also, Hossain *et al.* (2005) argued that the use of debt financing increased sharply, resulting in changes either in productivity or performance, while increased debt use reduced productivity growth. Morrison and Siegel (1997) investigated whether technological change and international competitiveness are responsible for the observed changes in productivity and input composition in the US food sector. The study suggested that the cost reduction was the result of increased competitiveness (trade) and knowledge capital (general technological advance or automation). Morrison (1999) examined the impact of capital investment and import penetration on firms' costs and prices. The analysis concluded that the increased cost efficiency arises from reduced labour use.

In a recent study, Geylani and Stefanou (2008) examined the relationship between productivity and investment spikes for the food manufacturing industry in the 1972-1995 time span. Gallo (1992) found that aggregate profitability of the sector, when measured as a return on the assets and stockholders' equity, is one of the highest in manufacturing. However, aggregate profitability on sales for food manufacturing is below the average for nondurable manufacturing because of a high sales turnover rate.

Finally, market structure has attracted increasing attention among researchers in the field (Roder *et al.*, 2000; Goodwin and Brester, 1995). In this framework, Roder *et al.* (2000) found that the degree of existing product differentiation and the market size affected positively the diffusion of innovations. Furthermore, Bhuyan and Lopez (1998) focused on the oligopoly power in US food industries and the allocative efficiency losses.

In a relatively recent study, Wang *et al.* (2006) analyzed the relationship between market concentration and other variables and one of their main findings was the increasing significance of the role of high-tech capital and the changes in production technology. In a similar vein, the increasing concentration is been analyzed in the food retailing industry (see further Dobson *et al.*, 2003). The study of Subervie (2008) analyzed the effect of world price instability on the agricultural supply and determined the extent to which this effect depended on the macroeconomic environment.

An interesting dimension that has emerged lately is the food choice and its impact on the food manufacturing industry and agriculture. In rich countries, the need for more healthy and nutritious food is evident and seems to be an important dimension affecting crucially the patterns of demand for food (see, for instance, Fine, 1998; Tiffin *et al.*, 2006). Finally, the role of public policy on the agricultural sector is another significant dimension (see, among others, Lio and Hu, 2009; Serra *et al.*, 2005; Thirtle *et al.*, 2004).

To sum up, there are several studies that make an attempt to link productivity growth in the US food sector to certain key economic and social variables. Most of them focus on technological change, while others emphasize market structure. However, to the best of our knowledge, no study deals with economic instability and the role of technological change in the US food sector, from a political economy perspective.

4. Theoretical framework

In this work, the "business cycle component" is regarded as the movement in the time series that exhibits periodicity within a certain range of time duration. This approach is based on Burns and Mitchell (1946) and the National Bureau of Economic Research (NBER) arguing that business cycles are characterized by the "turning point" which indicates, roughly speaking, the beginning of an expansionary period at the end of a recession. Another popular approach regards business cycles as fluctuations around a trend, the so-called deviation cycles. In this study we use both approaches.

In this context, we deal with questions of causality in business cycle theory deriving theoretical arguments from Schumpeter's and Marx's works. Both in the Marxist and in the Schumpeterian theoretical traditions, technological change is the crucial variable for economic evolution. In the Schumpeterian tradition, the standard interpretation is that long waves are caused by innovations (Schumpeter, 1934). Schumpeter conceptualized business cycles as disturbances in the equilibrium and a return to a new equilibrium point. The adjustment of the economic system after the introduction of innovations cannot take place smoothly and fluctuations rise.

On the other hand, in the Marxist tradition a matter of great importance is the explanation of the course of profitability as expressed through the average rate of profit. Marx, with his law of tendential fall in the rate of profit, showed that technological innovation aiming at increasing labour productivity, and induced through competition, could under certain presuppositions cause a downward movement in the rate of profit (Milios *et al.*, 2002). Typically, a crisis results in a fall in the profit rate and expresses a reduced ability of the capitalist class to exploit labour. Some Marxists, however, combine both processes and see crises as an outcome of the Marxian "law of the tendential fall". However, in both cases the rate of profit seems to be driven by labour productivity which is used as a proxy for technological innovation (see further Milios *et al.*, 2002). Of course, according to Duménil and Lévy (2002) there are not many innovations allowing for the simultaneous rise for labour productivity and the productivity of capital or in other words the rise of labour productivity is obtained at the cost of a decline of the productivity of capital.

Marx contends that the downward trend of the profit rate should not be understood as a profit squeeze by wages. Profit rate falls while the rate of surplus value remains constant because of the rising composition of capital. The assumption of a constant rate of surplus value is used to highlight that the fall of the profit rate is not due to excessive wages but to a specific feature of technological change (Duménil and Lévy, 2003).

Of course, given that profitability is the cornerstone of economic theory, a measure that is convenient, because it expresses profitability as a percentage rate, is the profit rate expressing the rate of return on capital invested (Moseley, 2003; Zachariah, 2009).

In this context, we investigate whether technological change has predictive power for profitability and output growth, respectively. 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 three most popular measures in order to quantify technological change. R&D expenditures along with TFP and labour productivity are used as a proxy for technology. TFP is based upon strong assumptions and approximates technological change as the residual of the growth equation. As a result this measure could lead to misleading interpretations of technology. Alternatively, it is widely argued that there is convincing evidence that cumulative R&D is an important determinant of technology. Finally, some theoreticians regard labour productivity as an expression of technological change.

Meanwhile, the use of causality tests is very extensive because they relate variables and find predictive powers among them. Causality test have been extensively used to count the effects of technology. There is a plethora of studies trying to link R&D expenditures with variables such as national output, trade, productivity, profitability, etc. (Salim and Bloch, 2007; Verbeek and Debackere, 2006; Färe *et al.*, 2005; Thirtle *et al.*, 2002; Heshmati and Lööf, 2005). In the same spirit, TFP has been widely used in the Granger causality test.

5. Methodological framework

First, we have to examine the stationarity characteristics of each time series. If the results suggest that a time series is stationary in the first differences then de-trending is highly recommended. As we know there are several ways to test for the existence of a unit root. In this paper, we use the popular Augmented Dickey-Fuller (ADF) methodology (Dickey and Fuller, 1979)[1].

The trend is important for the propagation of shocks (Nelson and Plosser, 1982). De-trending is highly recommended and the estimated residuals constitute the de-trended data series. Both linear, exponential and deterministic de-trending are used.

Meanwhile, the application of Granger tests to macroeconomic time series necessitates filtering the data to induce stationarity (MacDonald and Kearney, 1987).

Also, we use the following approaches.

(1) The Hodrick-Prescott filter

The linear, two-sided Hodrick-Prescott (HP) filter approach is a widely used 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. This method decomposes a series into a trend and a cyclical component. The parameter used for annual data is equal to $\lambda = 100$ (Hodrick and Prescott, 1997; Kydland and Prescott, 1990; Canova, 1998).

A large number of studies have used the HP filter de-trending method for different purposes (Danthine and Girardin, 1989; Blackburn and Ravn, 1992; Backus and Kehoe, 1992; Fiorito and Kollintzas, 1994)[2].

(2) The Baxter-King filter

Another popular method for extracting the business cycle component of macroeconomic time series is the Baxter-King filter (Baxter and King, 1999). The Baxter-King filter is based on the idea to construct a band-pass linear filter that extracts a frequency range dictated by economic reasoning. Here, this range corresponds to the minimum and maximum frequencies of the business cycle.

There is widespread agreement that a business cycle lasts between eight and 32 quarters and the length of the (moving) average is 12 quarters (Baxter and King, 1999). This is due to the seminal works of Burns and Mitchell (1946)[3]. Consequently, these are the values (two to eight years) that we use in the de-trending methods described above. A large number of studies have used the Baxter-King filtering method (Stock and Watson, 1999; Wynne and Koo, 2000; Agresti and Mojon, 2001; Benati, 2001; Massmann and Mitchell, 2004).

In order to test for autocorrelation (AC), we use the Ljung and Box (1978) test (Q-Stat.) which practically tests the null hypothesis of white noise for a maximum lag length k. The alternative hypothesis is that at least one of these ACs is non-zero, so that the series is not white noise. In case the null hypothesis is rejected, then the underlying time series is clearly not white noise and can be considered a cycle. In case we are dealing with a trending time series, then we study and test not the raw series but its deviations from trend, i.e. the residuals from which sample ACs can be computed.

As we know, white noise does not permit any temporal dependence[4] and so its autocovariance function is trivially equal to zero for the various lags. The sample AC function measures how a time series is correlated with its own past history. Its graphical illustration is the correlogram.

Here, we investigate the periodicities of business cycles assuming that the actual fluctuations of the data are chiefly of a periodic character. We are supposing that the presence of periodic elements in the given fluctuations is possible. 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.

The period is measured by constructing a graphical illustration of the value R in the time frequency and checking for the highest pick (Rudin, 1976).

In this context, we investigate whether technological change has predictive power for profitability and output growth, respectively, in the causal sense. Thus, we conduct bivariate causality tests between:

- technological change TFP and real output GDP;
- technological change R&D and real output GDP;
- technological change TFP and profitability (profit rate);
- technological change R&D and profitability (profit rate); and
- technological change (labour productivity) and profitability (profit rate).

The concept of causality, introduced by Granger (1969), has been widely used in economics. In general, we say that a variable X causes another variable Y if past changes in X help to explain current change in Y with past changes in Y. Of course, the general autoregressive model is appropriate for testing Granger causality only if the variables are not cointegrated. As is well known, cointegration implies that two or more variables have a long-run equilibrium relationship. Granger (1986) and Engle and Granger (1987) suggested a test based on cointegration and error-correction models. If cointegration is not detected, the autoregressive model is estimated. Otherwise, the Johansen (1988) error-correction model has to be estimated.

Thus, the empirical investigation of (Granger) causality is based on the general autoregressive model (Karasawoglou and Katrakilidis, 1993). The most frequently used testable hypotheses are expressed as follows:

- Y Granger-causes X;
- X Granger-causes Y;
- Y and Granger-cause each other; and
- neither variable Granger-causes the other.

Various lag lengths are tested. In order to identify the optimal lag length, we use the akaike information criterion (AIC) and the final prediction error (FPE) criteria (Thornton and Batten, 1985; Gutierrez *et al.*, 2007; Hsiao, 1981; Ahking and Miller, 1985; Khim and Liew, 2004; Hacker and Hatemi-J, 2008).

6. Empirical results

We implement the aforementioned quantitative techniques in order to investigate empirically the economic fluctuations in the US food manufacturing sector. The data used are on an annual basis and come from the NBER database and from the US Census Bureau, Department of Manufacturers and cover the period 1958-2006, just before the first signs of the global economic recession made their appearance. The data on capital stock stopped in 1996, and we estimated the rest of the time series based on Huang's (2003) popular methodology.

To begin with, the stationarity properties of the various macroeconomic variables were checked. Table I shows the results of the ADF test regarding the following time series: labour (L), i.e. number of employees; real output (Y), i.e. output in dollars at constant prices; stock of fixed capital (K), i.e. in dollars; TFP, i.e. in percentage change; real wages (W), i.e. total amount of wages in dollars; labour productivity (Y/L); research and development (R&D) expenditures, i.e. in dollars; profit rate (Π) defined as a percentage rate: $\Pi = (Y - W)/K$ (Duménil and Lévy, 2002; Milios *et al.*, 2002; Mohun, 2006; Wolff, 2003).

All macroeconomic variables in levels are non-stationary; however, their first differences are stationary (Table II). The next step was to de-trend the variables. Various de-trending approaches were employed and the graphs of the cyclical components are shown in Figure 1(a)-(h). Also, the results of the analysis based on the correlograms for the various economic time series are shown in Tables III-X. The results of the Ljung and Box test indicate a rejection of the null hypothesis of white noise for all the de-trended variables examined. In other words, the existence of fluctuations is a valid hypothesis from a statistical viewpoint.

The periodograms reveal the periodicity of the cycles and are shown in Figures 2-8. The de-trended real output seems to follow a short-term (one year), two mid-term (three and five years) and one long-term (seven years) cycle. The spectral content of the cyclical component of R&D (Figure 6) exhibits local maxima at the frequencies of three, five and seven years. Accordingly, the de-trended labour productivity is characterized by the same frequency peaks (Figure 5) (one, three and seven years) giving credit to

Variable	Lags	T-stat.	Probability	Stationary	Non-stationary
L	0-10	− 1.4315	0.5592	No	Yes
Y	0-10	− 1.9728	0.2975	No	Yes
K	1-10	0.1634	0.9673	No	Yes
TFP	0-10	− 1.2786	0.6295	No	Yes
R&D	0-10	− 0.6943	0.8380	No	Yes
W	1-10	− 0.4993	0.8822	No	Yes
Y/L	0-10	− 1.9215	0.3200	No	Yes
Profit rate	0-10	− 0.8313	0.8010	No	Yes

Notes: The ADF test is based on the following regression (Kaskarelis, 1993):

$$\Delta Y_t = a + bt + \rho Y_{t-1} + \sum_{i=1}^{m} \gamma_i \Delta Y_{t-i} + \varepsilon_t$$

where Δ is the first difference operator, t the time and ϵ_t the error term: (a) if $b \neq 0$ and $\rho = -1$ implies a trend stationary model; (b) if $b = 0$ and $-1 < \rho < 0$ implies an ARMA Box/Jenkins class of models; (c) if $b = 0$ and $\rho = 0$ implies a difference stationary model where Y variable is integrated of degree one $I(1)$; if we assume that the cyclical component is stationary, the secular component has a unit root and Y follows a random walk process, i.e. it revolves around the zero value in a random way (Heyman and Sobel, 2004, p. 263); furthermore, if $\alpha \neq 0$ Y follows a random walk process with a drift

Table I.
Variables (original)

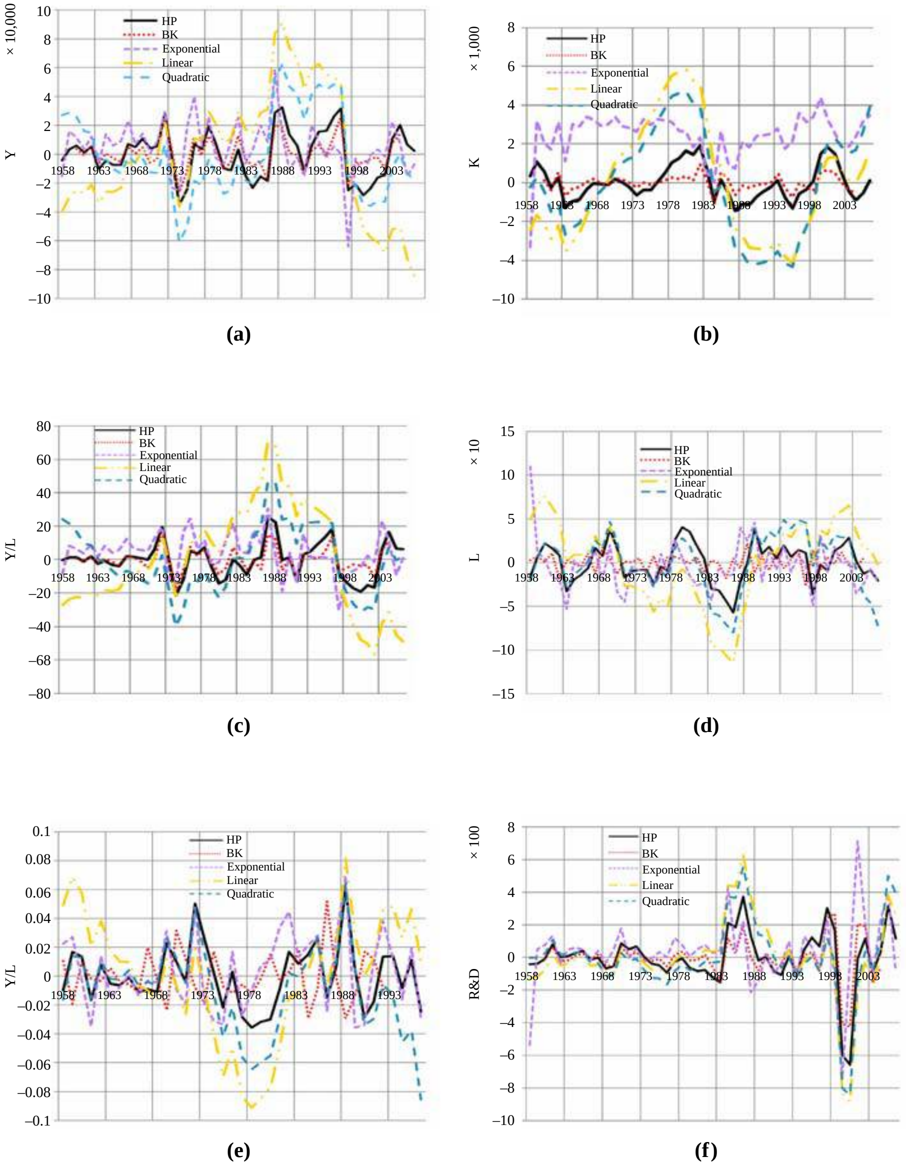
Variable	Lags	T-stat.	Probability	Stationary	Non-stationary
ΔL	0-10	− 6.4966	0.0000	Yes	No
ΔY	0-10	− 5.9666	0.0000	Yes	No
ΔK	1-10	− 4.0598	0.0026	Yes	No
ΔTFP	0-10	− 6.7144	0.0000	Yes	No
ΔR&D	0-10	− 7.1683	0.0000	Yes	No
ΔW	0-10	− 5.9564	0.0000	Yes	No
$\Delta Y/L$	0-10	− 5.5167	0.0000	Yes	No
ΔPR	0-10	− 5.8762	0.0000	Yes	No

Note: See notes in Table I

Table II.
Variables (first differences)

the belief that the movements of R&D and labour productivity seem to be synchronized, to a great extent. Also, the cycle of the profit rate is characterized by periodicities of one, three and seven years, as well. Finally, an interesting observation is that most economic time series follow, roughly speaking, a similar pattern characterized by periodicities exhibiting a short-term cycle (approximately one year), a mid-term cycle (approximately three years) and a long-term cycle (approximately seven years), same as the periodization of output. These results can be interpreted by economic theory as indications for the existence of cycles with different lengths (i.e. periods) that are synchronized for the different variables within the total economy.

Tables XI-XV show the correlation coefficients between the variables examined. It can be seen that in all cases peaks occur at moderate lags (and leads) implying a relatively rapid transmission process of technological shocks throughout the food manufacturing industry.



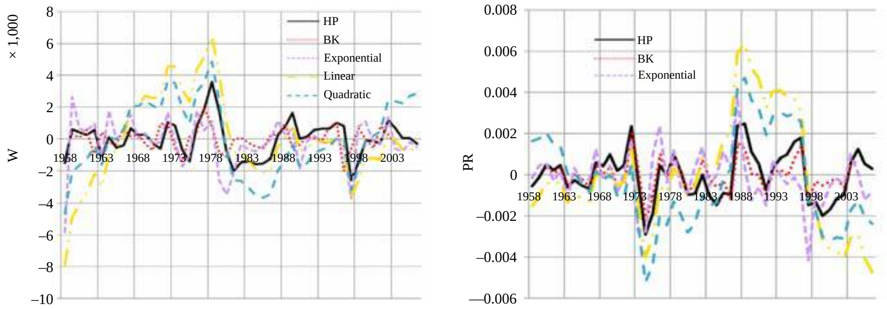
(a) (b)

(c) (d)

(e) (f)

(*continued*)

Figure 1.
Figures of economic fluctuations



(g) (h)

Notes: The trend is important for the propagation of shocks (Nelson and Plosser 1982). We use linear, quadratic and exponential de-trending. Also, we also use the following approaches: (a) The Hodrick-Prescott Filter The trend is obtained by minimizing the fluctuations of the actual data around it, i.e. by minimizing the following function:

$$\sum[\text{In } y\,(t) - \text{In } y^*\,(\text{t})]^2 - \lambda \sum\Big[[\text{In } y^*\,(t+1) - \text{In } y^*\,(t)] - [\text{In } y^*\,(t) - \text{In } y^*\,(t-1)]\Big]^2$$

where y* is the long-term trend of the variable y and the coefficient λ > o determines the smoothness of the long-term trend. (b) The Baxter-King Filter The algorithm consists in constructing two low-pass filters, the first passing through the frequency range $[0, \omega_{\max}]$ (denoted as $\bar{a}(L)$, where L is the lag operator) and the second through the range $[0, \omega_{\min}]$ denoted as $\underline{a}(L)$). Subtracting these two filters, the ideal frequency response is obtained and the de-trended time series is:

$$y^{BP}\,(t) = [\bar{a} - \underline{a}]\, y\,(t)$$

Figure 1.

Lag	AC	Partial autocorrelation	Q-stat.	Probability
1	0.548	0.548	15.654	0.000
2	0.219	−0.116	18.216	0.000
3	−0.187	−0.373	20.113	0.000
4	−0.414	−0.215	29.619	0.000
5	−0.424	−0.041	39.814	0.000
6	−0.464	−0.335	52.331	0.000
7	−0.294	−0.117	57.472	0.000
8	−0.147	−0.127	58.794	0.000

Notes: The sample AC function measures how a time series is correlated with its own past history; in order to test for AC we use the Ljung and Box (1978) test (Q-Stat.) which practically tests the null hypothesis of white noise for a maximum lag length k:

$$Q = n(n+2)\sum\nolimits_{j=1}^{h} \frac{\hat{p}_j^2}{n-1}$$

where n is the sample size, $\hat{p}_j$ the sample AC at lag j, and h the number of lags being tested; for significance level α, the critical region for rejection of the hypothesis of randomness is $Q > x^2_{1-a,h}$ where $x^2_{1-a,h}$ is the α-quantile of the chi-squared distribution with h degrees of freedom; the alternative hypothesis is that at least one of these ACs is non-zero, so that the series is not white noise. In case the null hypothesis is rejected, then the underlying time series is not white noise and is considered a cycle

Table III.
White noise test for L

Lag	AC	Partial autocorrelation	Q-stat.	Probability
1	0.486	0.486	12.306	0.000
2	0.006	− 0.302	12.308	0.002
3	− 0.200	− 0.082	14.482	0.002
4	− 0.296	− 0.192	19.340	0.001
5	− 0.190	0.029	21.388	0.001
6	0.025	0.069	21.423	0.002
7	0.039	− 0.135	21.514	0.003
8	0.015	0.002	21.527	0.006

Note: See notes in Table III

Table IV.
White noise test for Y

Lag	AC	Partial autocorrelation	Q-stat.	Probability
1	0.725	0.725	27.341	0.000
2	0.405	− 0.254	36.048	0.000
3	0.182	− 0.003	37.854	0.000
4	− 0.074	− 0.306	38.161	0.000
5	− 0.219	0.046	40.891	0.000
6	− 0.204	0.067	43.317	0.000
7	− 0.196	− 0.102	45.604	0.000
8	− 0.145	0.047	46.889	0.000

Note: See notes in Table III

Table V.
White noise test for K

Lag	AC	Partial autocorrelation	Q-stat.	Probability
1	− 0.169	− 0.169	10.914	0.296
2	− 0.569	− 0.615	13.792	0.001
3	0.166	− 0.155	14.910	0.002
4	0.263	− 0.129	17.798	0.001
5	− 0.121	− 0.055	18.426	0.002
6	− 0.099	− 0.005	18.861	0.004
7	0.090	0.028	19.232	0.007
8	− 0.131	− 0.252	20.051	0.010

Note: See notes in Table III

Table VI.
White noise test for TFP

Table XVI presents the results of the Granger causality tests. As can be inferred, the profit rate seems to be caused by TFP, R&D (Schumpeterian approach) and labour productivity (Marxist approach), while TFP and R&D cause, independently, real output.

Our findings are, in general terms, consistent with the majority of studies in the relevant literature. For instance, the cyclical behaviour of certain key variables such as profit rate and TFP is consistent with the findings by other researchers (Heien, 1983; Gallo, 1992). Also, according to our findings technological change goes hand in hand with output and profitability as (Goodwin and Brester, 1995; Morrison, 1999; Morrison and Siegel, 1997).

AG	AC	Partial autocorrelation	*Q*-stat.	Probability
1	0.394	0.394	80.804	0.004
2	−0.165	−0.380	95.357	0.008
3	−0.199	0.056	11.680	0.009
4	−0.196	−0.242	13.820	0.008
5	−0.180	−0.060	15.661	0.008
6	−0.067	−0.062	15.924	0.014
7	−0.074	−0.180	16.247	0.023
8	0.005	0.073	16.248	0.039

Note: See notes in Table III

Table VII.
White noise test for R&D

Lag	AC	Partial autocorrelation	*Q*-stat.	Probability
1	0.510	0.510	13.526	0.000
2	−0.014	−0.369	13.536	0.001
3	−0.187	0.017	15.438	0.001
4	−0.200	−0.128	17.654	0.001
5	−0.116	0.017	18.423	0.002
6	0.040	0.075	18.516	0.005
7	0.034	−0.130	18.583	0.010
8	0.021	0.094	18.611	0.017

Note: See notes in Table III

Table VIII.
White noise test for Y/L

Lag	AC	Partial autocorrelation	*Q*-stat.	Probability
1	0.489	0.489	12.441	0.000
2	0.017	−0.291	12.457	0.002
3	−0.212	−0.115	14.895	0.002
4	−0.250	−0.092	18.373	0.001
5	−0.101	0.061	18.950	0.002
6	−0.138	−0.257	20.058	0.003
7	−0.224	−0.157	23.055	0.002
8	−0.294	−0.228	28.328	0.000

Note: See notes in Table III

Table IX.
White noise test for W

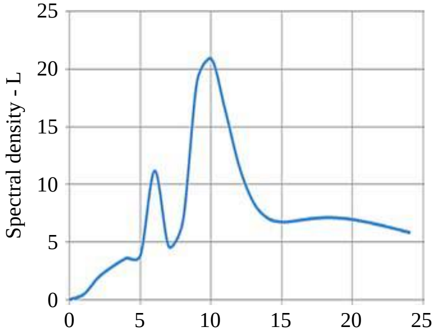
7. Result analysis and discussion

First, we note that fluctuations in the US food manufacturing sector are not very sharp although trends, upswings and falls do exist (Figure 1(a)). Also, one can infer that the output of the US food manufacturing sector seems to behave in a way analogous to US GDP (Bureau of Economic Analysis, US Department of Commerce). Analytically, the collapse of output following the first “oil crisis” is common in the US food manufacturing sector and the US economy in total. Between 1963 and 1972, there is a clear upward trend in the output of the industry that was stopped by the “oil crisis”, the effect of which is evident in the de-trended time series irrespectively of the filter used. Furthermore,

Table X.
White noise test for PR

Lag	AC	Partial autocorrelation	Q-stat.	Probability
1	0.494	0.494	12.681	0.000
2	0.001	−0.321	12.681	0.002
3	−0.174	−0.024	14.317	0.003
4	−0.245	−0.179	17.660	0.001
5	−0.149	0.051	18.929	0.002
6	0.023	0.038	18.961	0.004
7	0.040	−0.086	19.055	0.008
8	0.016	0.010	19.070	0.014

Note: See notes in Table III



Note: The period is measured by constructing a graphical illustration of the value R in the time frequency and checking for the highest pick:

$$R_i = \sqrt{a_i^2 + b_i^2},\ \alpha_t = \frac{2}{n}\sum_{t=1}^{n} X_t \cos(2\pi t/i),$$

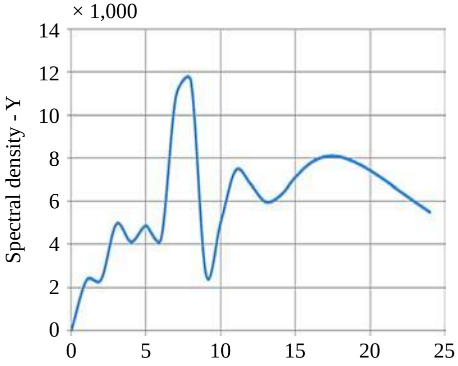
$$b_t = \frac{2}{n}\sum_{t=1}^{n} X_t \sin(2\pi t/i),\ i = 1,2,....m,\ m = n/2$$

where a_i, b_i are the coefficients of the Fourier-transformed function X_t (Rudin 1976)

Figure 2.
Periodogram for L (10^3)

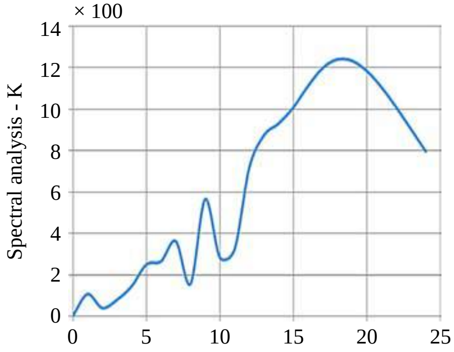
the cyclical component follows the same pattern both in the total economy and in the food sector between 1979-1982 and 1990-1991. The 1990s began with a shallow recession (Basu *et al.*, 2001) and, according to the Economic Report of the President (1994), the speed of recovery was very slow[5]. Furthermore, between 1991 and 1997 – the so-called "new economy" period – a sharp increase of output took place. Also, productivity growth in the sector coincided with an exceptionally good performance of the US economy (Mankiw, 2001)[6]. 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.

Regarding the de-trended profit rate (Figure 1(h)) it reached its highest level in 1972 and then it was affected by the negative macroeconomic environment of the 1970s



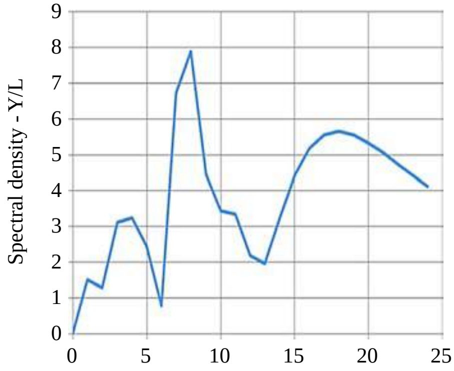
Note: See notes in Figure 2

Figure 3.
Periodogram for *Y* (10^6)



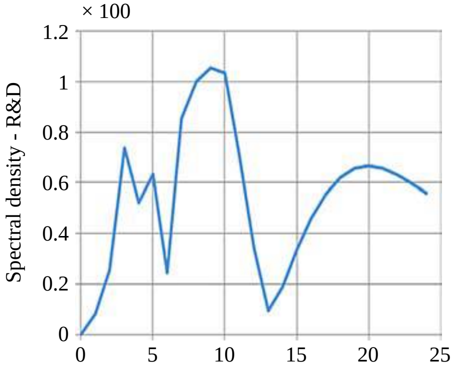
Note: See notes in Figure 2

Figure 4.
Periodogram for *K* (10^2)



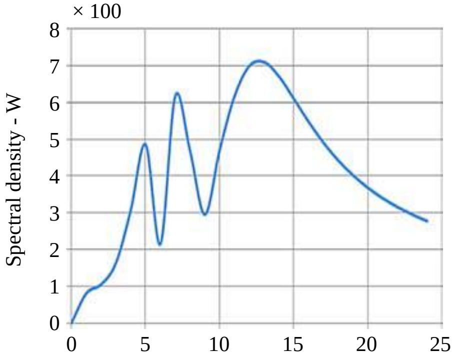
Note: See notes in Figure 2

Figure 5.
Periodogram for *Y/L* (10^2)



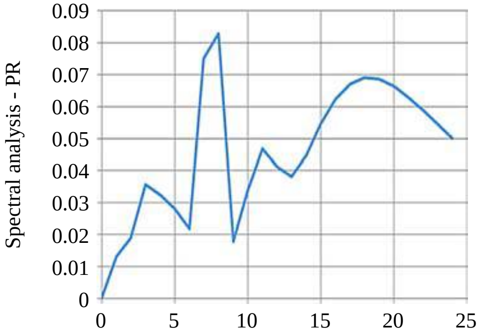
Note: See notes in Figure 2

Figure 6.
Periodogram for R&D (10^6)



Note: See notes in Figure 2

Figure 7.
Periodogram for W (10^6)



Note: See notes in Figure 2

Figure 8.
Periodogram for profit rate

Table XI. Correlation coefficients for Y and TFP

		Y and TFP	
i	Quadratic	HP	BK
8	−0.2188	−0.3231	−0.3095
7	−0.1722	−0.1522	−0.1151
6	−0.0795	0.0869	0.1667
5	0.0040	0.2002	0.1745
4	−0.0229	0.0530	0.0801
3	−0.0659	−0.0578	−0.0819
2	−0.0880	−0.2030	−0.4282
1	0.0295	0.0507	0.1629
0	0.0948	0.2418	0.5658
−1	0.0231	−0.1089	−0.3215
−2	0.0418	−0.1299	−0.2148
−3	0.1085	0.0205	0.0387
−4	0.1254	0.1021	0.0428
−5	0.1254	0.1826	0.0582
−6	0.1124	0.2561	0.1299
−7	0.0469	0.2385	0.0038
−8	−0.0774	0.1163	−0.1352

Note: We use the conventional correlation coefficient

Table XII. Correlation coefficients for Y and R&D

		Y and R&D	
i	Quadratic	HP	BK
8	−0.0708	0.1183	−0.0027
7	−0.1731	0.0855	0.0970
6	−0.3223	0.0501	0.0383
5	−0.3320	−0.0806	−0.4350
4	−0.3041	−0.0607	−0.0400
3	−0.0953	−0.0082	0.0364
2	0.1254	0.1387	0.1268
1	0.2163	0.2219	0.1003
0	0.2484	0.1604	−0.2305
−1	0.3953	0.2461	−0.0082
−2	0.4128	0.2415	0.3955
−3	0.3856	−0.0657	−0.0392
−4	0.2891	−0.3177	−0.3514
−5	0.2739	−0.1917	0.0649
−6	0.3014	−0.1241	−0.1252
−7	0.2752	0.0933	−0.0582
−8	0.2468	0.1949	0.0995

Note: We use the conventional correlation coefficient

and chiefly the oil crisis. This period is often documented as the second period of great decrease in the US profit rate after Second World War. Finally, an upward movement occurred in the beginning of the 1980s until 1986, reaching its peak in 1988 and 1997. This rise coincides with the third period of the US economy characterized by a period when profitability rose as a result of the rapid rise in the productivity of labour[7].

Table XIII.
Correlation coefficients for PR and TFP

	Profit rate and TFP		
i	Quadratic	HP	BK
8	− 0.2569	− 0.3458	0.0767
7	− 0.2002	− 0.1810	− 0.0311
6	− 0.1000	0.0449	− 0.1214
5	0.0101	0.1943	− 0.0212
4	0.0199	0.0733	0.1148
3	0.0078	− 0.0355	0.0410
2	0.0159	− 0.1527	− 0.2021
1	0.1485	0.1301	− 0.2014
0	0.2183	0.3145	0.0044
− 1	0.1251	− 0.0743	0.1467
− 2	0.1316	− 0.0756	0.2063
− 3	0.1672	0.0694	− 0.2284
− 4	0.1401	0.0989	− 0.0134
− 5	0.1032	0.1437	0.1973
− 6	0.0590	0.1967	0.0338
− 7	− 0.0281	0.1669	− 0.0307
− 8	− 0.1665	0.0174	− 0.0362

Note: We use the conventional correlation coefficient

Table XIV.
Correlation coefficients for PR and R&D

	Profit rate – R&D		
i	Quadratic	HP	BK
8	− 0.2188	− 0.3231	− 0.3095
7	− 0.1722	− 0.1522	− 0.1151
6	− 0.0795	0.0869	0.1667
5	0.0040	0.2002	0.1745
4	− 0.0229	0.0530	0.0801
3	− 0.0659	− 0.0578	− 0.0819
2	− 0.0880	− 0.2030	− 0.4282
1	0.0295	0.0507	0.1629
0	0.0948	0.2418	0.5658
− 1	0.0231	− 0.1089	− 0.3215
− 2	0.0418	− 0.1299	− 0.2148
− 3	0.1085	0.0205	0.0387
− 4	0.1254	0.1021	0.0428
− 5	0.1254	0.1826	0.0582
− 6	0.1124	0.2561	0.1299
− 7	0.0469	0.2385	0.0038
− 8	− 0.0774	0.1163	− 0.1352

Note: We use the conventional correlation coefficient

As for the labour force, during the 1970s and 1980s a structural change occurred, when huge numbers of workers entered the US labour force: baby boomers, women, immigrants, etc. Unemployment peaked during the lowest point of the business cycle, 1982-1983, reaching a high 10.8 percent. At the same time, there was an obvious trend of diminishing the number of employees in the food manufacturing industry beginning

		PR and *Y*/*L*	
i	Quadratic	HP	BK
8	− 0.1320	0.0312	0.0874
7	− 0.0645	0.0858	− 0.2093
6	− 0.0055	0.0834	− 0.1677
5	− 0.0250	− 0.0957	− 0.1148
4	0.1480	− 0.1956	0.2201
3	0.3126	− 0.1722	0.2784
2	0.4726	− 0.8090	− 0.1056
1	0.7146	0.4226	0.3522
0	0.9246	0.9199	0.0116
− 1	0.8405	0.5019	0.2113
− 2	0.7101	0.0428	0.3725
− 3	0.5553	− 0.1595	− 0.0331
− 4	0.4205	− 0.1904	− 0.3892
− 5	0.3172	− 0.1014	− 0.1269
− 6	0.2940	0.0474	0.2154
− 7	0.2211	0.0219	0.1073
− 8	0.1535	0.0115	0.0935

Note: We use the conventional correlation coefficient

Table XV.
Correlation coefficients for PR and *Y*/*L*

in the 1980-1986 time span (Figure 1(d)). The principal constraint on reducing unemployment was the fear of the Federal Reserve that too low an unemployment rate would lead to accelerating inflation. However, after 1983 there was a gradual decline in the unemployment rate reaching a minimum in 1989, a fact that is reflected in the increase of employment in the industry. This could be attributed to the introduction of "flexible forms" of labour, as a result of the Reagan economic policies, that reduced the official unemployment records. Finally, a slight increase in the number of unemployed took place right after the terrorist attacks of September 2001, which is depicted in the sectors' employment.

The value of labour power has a downward trend falling continuously from 1978 onwards (Mohun, 2006). Wages are squeezed on profits from the mid-1960s to the early 1980s and the wage share rose some 10 percent of money value added. The cyclical component of wages (Figure 1(g)) has its peak in 1978 and its lowest point in 1997. Between 1981 and 1987 de-trended wages remained at low levels a fact that may be related to Reagan's program for steady wages. After 1997, there is an upward trend.

Figure 1(b) shows the fluctuations of the net capital stock invested in the US food manufacturing. 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 follow the same 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.

Meanwhile, TFP quantifies the evolution of technological change (Figure 1(e)). Except for TFP, R&D expenditures are also used in order to quantify technological change (Figure 1(f)). The cyclical component of TFP in the food manufacturing has two obvious trends one downward from 1973 to 1980 and one upward from 1981 to 1988. Between 1948

	Criteria for lag selection						
Hypothesis to be tested	FPE	AIC	Hannan-quinn information criterion	Lags	Observed	*F*-statistic	Probability
TFP does not Granger-cause *Y*	2	2	1	2	37	2.81083	0.07506
Y does not Granger-cause TFP						2.85707	0.07217
R&D does not Granger-cause *Y*	1	3	1	1	48	2.76128	0.10352
Y does not Granger-cause R&D						2.11861	0.15246
Y/*L* does not Granger-cause profit rate	14	15	15	15	34	5.71204	0.08840
Profit rate does not Granger-cause *Y*/*L*						4.93451	0.10706
TFP does not Granger-cause profit rate	2	2	1	2	37	3.84397	0.03191
Profit rate does not Granger-cause TFP						1.71500	0.19609
R&D does not Granger-cause profit rate	3	3	3	3	34	6.11292	0.08079
Profit rate does not Granger-cause R&D						0.96827	0.59372

Notes: The empirical investigation of (Granger) causality is based on the following general autoregressive model (Karasawoglou and Katrakilidis, 1993):

$$\Delta \mathrm{Y}_t = a_0 + \sum_{i=1}^{m} a_{1i}\Delta Y_{t-i} + \sum_{i=0}^{n} a_{2i}\Delta X_{t-i} + \varepsilon_t$$

where Δ is the first difference operator, ΔY and ΔX the stationary time series and ε_t the white noise error term with zero mean and constant variance; the null hypothesis that X does not Granger-cause Y is rejected if the coefficient α_{2i} is statistically significant

Table XVI.
Granger causality test results

and 1973 TFP grew annually in the USA by 2.13 percent one of the highest growth rates ever recorded in US history. Also, US net investment grew substantially in the 1950s and the 1960s as US corporations went multinational (Krugman, 1990). This increase may be a reason for the high increase of TFP. After the "oil crisis" of 1973, the rate went down to 0.53 percent per year for the years 1973-1989. After 1989 there is a gradual increase going to 0.93 percent per year until 2000 and to 1.83 percent for 2000-2005. Also, 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 food sector R&D expenditures might be related to this policy.

Finally, labour productivity was more or less steady from 1958 to 1970 and increased until 1973, whereas the 1973 shock put an end to this upward trend (Figure 1(c)). After 1974, fluctuations were more acute. From Figures 1(e)-(g), it is obvious that the cyclical movements of labour productivity, TFP and R&D go hand in hand, as expected. This observation is consistent with the noted improvement in the investment performance of the food manufacturing sector and the more high-tech nature of the sector (Morrison and Siegel, 1997) and, of course, the increase in the 1950s and 1960s (Krugman, 1990).

8. Conclusions

In this paper, we built on Marxian and Schumpeterian insights to examine economic instability for the case of the US food manufacturing sector (1958-2006). As we know, in the Marxist tradition a crisis results in a fall in the profit rate that expresses a reduced ability to exploit labour. Marx, with his law of tendential fall in the rate of profit, showed that technological change aimed at increasing labour productivity and induced through competition could, under certain presuppositions, causes a downward movement in the rate of profit independently of the acute fluctuations connected with crises. Some Marxists, however, combine both processes and see crises as an outcome of the Marxian "law of tendential fall". In both cases, the rate of profit seems to be driven by labour productivity. On the other hand, as we know, the standard interpretation of Schumpeter's analysis is that long waves are caused by the clustering of innovations. Schumpeter conceptualized business cycle as disturbances in the equilibrium and a return to a new equilibrium point which gives the process its cyclical character.

We assessed the co-movements between the cyclical components of each time series observed and our reference series (real output and technological change) by the magnitude of the correlation coefficient, and found that technological change is transmitted in the economy relatively quickly. In the next step, we conducted bivariate (Granger) causality tests between real output/profitability and technological change. As regards technological change, there is a clear bidirectional relationship between technology and output/profitability, which can be interpreted as indicating an ambivalent relationship in the flow of cause and effect. Our empirical findings give credit to certain aspects of both the Schumpeterian and Marxist theories of economic crises, respectively.

Additionally, the economic time series in the food sector under investigation seem to follow patterns which are in line with the total economy. Also, another interesting finding is that most economic time series exhibit, roughly speaking, a similar pattern characterized by periodicities exhibiting a short-term cycle (approximately one year), a mid-term cycle (approximately three years) and a long-term cycle (approximately seven years). Finally, regarding the cyclical component of the profit rate (Figure 1(h)), it reached its highest level in 1972 and then it was adversely affected by the negative macroeconomic environment of the 1970s. A downward movement occurred in the beginning of the 1980s until 1986 reaching its historical high in 1988 and 1997. We believe that our findings could inspire future theoretical and empirical research on economic fluctuations and crises building on heterodox traditions.

Notes

1. Alternatively, the test of Zivot and Andrews (1992) could have been used or some other unit root tests such as the IPS test (Im *et al.*, 1997), the MW test (Maddala and Wu, 1999), or the Choi test (Choi, 2001).
2. For overviews of the Hodrick-Prescott filtering method shortcomings, see Harvey and Jaeger (1993), King and Rebelo (1993), Cogley and Nason (1995) and Billmeier (2004).
3. For a critique to this approach, see Agresti and Mojon (2001).
4. Actually, white noise is a data generating process where AC is zero between lagged versions of the signal (except when the lag is zero).
5. The speed of recovery was very slow both for output and labour, between the peak in the second quarter of 1990 and the trough of the first quarter of 1991. See Economic Report for the President (1991).

6. Mankiw (2001) argued that the macroeconomic performance of the 1990s was exceptional, food and energy prices were well behaved and productivity growth experienced an unexpected acceleration, i.e. the so-called "new economy" which was characterized by the increasing role of information technology.
7. Most economists define three broad periods in the US economy after Second Word War. According to Wolff (2003), these are: (1) 1947-1966, (2) 1966-1979, and (3) 1979-1997, the first as a period of rising profitability, the second as a decreasing one and the third as a recovery one.

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