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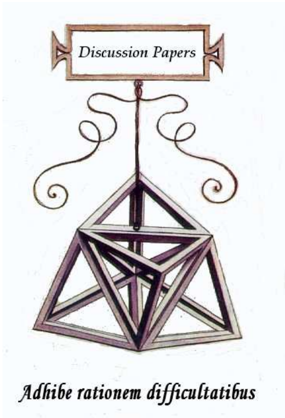

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Prices, productivity and irregular cycles in a walrasian labour market

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Abstract

A standard Cobb Douglas labour market model is used to examine the role of changes in prices and productivity on the stability. It is shown that in this walrasian labour market deterministic endogenous economic fluctuations, which are seemingly stochastic, emerge. Therefore it may be argued that the controversial - in empirical as well as theoretical recent literature – co-movement between variables does not necessarily ground on stochastic shocks on prices and technology as retained in the prevailing business cycle theory. In particular, we show that negative shocks on prices and productivity are always destabilising and trigger robust chaotic fluctuations.

1-Introduction

Recent contributions have focused on the analysis of the co-movement between productivity and labour input at business cycle frequencies, useful to obtain empirical tests of alternative models of economic fluctuations in the frame of stochastically driven business cycle theory. The results are controversial because, after a positive technology shock, employment and output result either increased or reduced. The increase and the reduction may be interpreted as evidence in favour either of sticky price models or of standard flexible price models, respectively (e.g. Galì, 1999; Francis-Ramey, 2002; Marchetti-Nucci, 2005).

The motivation of this paper stems from the importance of evaluating whether and how deterministic endogenous economic fluctuations, which are seemingly stochastic, may occur in a standard textbook walrasian[1] labour market, therefore arguing that the controversial - in empirical as well as theoretical recent literature – co-movement between variables not necessarily grounds on stochastic shocks on prices and technology as retained in the prevailing real business cycle (RBC) theory.

More in detail, the purpose of this paper is to investigate the effect of changes in product prices and in the productivity index in a dynamic walrasian labour market, by using the simple standard textbook formulations of preferences and technology (the Cobb-Douglas ones). Although a vast literature has been developed with this simplified "well-behaved" economy, its dynamic properties have not been entirely investigated under some realistic circumstances such as the occurrence of negative shocks on prices and/or on productivity. Although the analysis regards only the labour market, we note that it is at the "core" of the modern neoclassical macroeconomics, and therefore irregular economic fluctuations arising in this market (namely fluctuating wages and employment) may drive more general business cycles.

[1] The term "walrasian" in this context means that prices adjust for eliminating a possible excess demand.

We will show that negative shocks on prices as well as on productivity may destabilise a walrasian labour market.

The result of a possible instability in a “walrasian” market may seem hardly surprising at the light of the Sonnenschein (1972) –Mantel (1974) –Debreu (1974) theorem. [2] Nevertheless, the novelty is that a persistent chaotic fluctuation may be the rule in the very basic textbook walrasian labour market with “well-behaved” agents’ functions:[3] any (temporary) sufficiently negative productivity (price) shocks will cause the convergence not back to the same outcome that prevailed before the shock but to a long term irregular trajectories set (i.e. the seemingly stochastic business cycles).

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We will also show that persistent chaotic fluctuations emerge for a large sets of realistic economic parameters. The economic interpretation is the following: negative changes of prices and productivity, on the one side, reduce both labour input and output, and as a consequence, on the other side, increase real wages as well as wage share, determining an “overshooting” of the nominal wages dynamics and the trigger of persistent irregular economic fluctuations. This also means that a negative shock on productivity is followed by both increases and decreases of the (fluctuating) labour input, thus embodying both behaviours predicted by the seemingly alternative models postulated by RBC theory and providing a possible endogenous deterministic explanation of the controversial nature of the co-movement between productivity and labour input.

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[2] In a nutshell: since the excess demand function for an economy is not restricted by the usual rationality restrictions on individual demands, then aggregate demand functions can have "any shape", and this means, among other consequences for the microeconomic theory, that both uniqueness and stability of the equilibrium are no longer guaranteed.

[3] Recently Fanti and Manfredi (2010) have shown that the continuous time dynamics of a “walrasian” labour market may lead to a limit cycle but only if the labour supply is not “well-behaved” (i.e. there is a negative relationship between labour supply and wage).

Furthermore, the paper is also a contribute to the strand of the literature, that, traditionally, in economic dynamics has discovered chaotic behaviours in market models. However we note that the present labour market model is entirely microfounded, in contrast with, for instance, the largely investigated cobweb model (generally with ad-hoc – that is not microfounded – non-linearities) in which, in some cases, the possibility of chaotic price fluctuations has been shown (e.g. Chiarella, 1988, Hommes, 1994).

To conclude, a main message is that the belief of a stable labour market as "core" of the entire walrasian macroeconomics may be strongly weakened even in the very usual frame of Cobb-Douglas preferences and technology when the possibility of negative shocks on prices and productivity are taken into account.

The plan of the paper is the following. Section 2 develops the model, section 3 shows the dynamical analysis, section 4 shows graphical and numerical results. Concluding comments follows.

2. The model.

We consider a one-good economy with a single representative firm and a single representative worker-consumer.

2.1 Individuals

As usual an individual derives utility from the consumption of two goods, consumption, C, and leisure, R.[4] Let's define L=supply of labour, W= money wage per unit of time worked, Y= money income, p= price of consumption good, $w=W/p$=real wage. The time constraint is: $R+L=d$, where d is the fixed time which can be shared between leisure or labour.[5] The expenditure constraint is $Y=WL=pC$. By substituting from the time constraint for L, the budget constraint is: $C+wR=wd$.

[4] A complete analysis of labour supply is shown for instance in Barzel-McDonald (1973).

[5] Notice that Barzel-McDonald (1973) argue that survival considerations may dictate a certain minimal level both of leisure time and of consumption and moreover that "the roles played

Denoting with *s* the elasticity of substitution between consumption and leisure, it is easy to see that *sign dL/(dw)= sign [C(s-1)]*, that is the slope of the supply curve depends on the sign of *(s-1)*. If *s* is a not constant value (in general *s* will vary with the ratio *C/R*), then "the supply curve can assume virtually any shape" (Barzel-McDonald, p. 624). Even by constraining *s* to a constant value, nine different diagrams of the curve may be drawn (Barzel-McDonald, fig. 1, p. 625): monotonically rising and falling, perfectly inelastic, and both backward and forward bending.

For the sake of analytical tractability and for the purpose to derive our results in the textbook "core" of a walrasian market, we focus on the usual Cobb-Douglas preferences (i.e. *s=1*).[6]

The individuals maximise the following utility function

$$U = C^a R^{1-a}, \qquad 0 < a < 1 \tag{1}$$

under the constraints above described.

Standard calculations provide the labour supply function:

$$L = da \tag{2}$$

2.2 Firms

Labour employed *D* is the only input. The technology is represented by the following Cobb-Douglas production function:

$$Y = AD^b, \qquad 0 < b < 1, \quad A > 0 \tag{3}$$

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by the two survival requirements are not symmetric since all individuals are endowed with more time than is needed for survival but not all have sufficient assets for survival."(Barzel-McDonald, p. 622). However the introduction of survival considerations is beyond the scope of this paper and is left for future research.

[6] The empirical validity of Cobb-Douglas functional forms are largely documented: for instance, Barzel-McDonald (1973, p.29) investigating the relation between the number of weekly hours of work and the corresponding real hourly wage for *U .S.* 1901-61 time-series, argue that " this corresponds to the Cobb-Douglas utility function where the supply curve approaches asymptotically a positive number of hours."

Let Π and w respectively define the total profit and the wage rate. The profit function is defined[7] as

$$\Pi = pAD^b - wD \qquad (4)$$

A standard maximization of (4) gives the optimal demand for labour, D :

$$D = \left[\frac{pAb}{w}\right]^{\frac{1}{1-b}} \qquad (5)$$

As usual, at the equilibrium $L=D$ must hold.

3- The dynamic model: steady states and dynamical analysis

We first derive the dynamical model from the equations given in the previous section and secondly we will analyse some of the dynamic properties of the model itself. Wage dynamics is governed by the following equation, which is the usual discrete Walrasian adjustment process, according to which wages adjust proportionally to the excess demand of the current period (e.g. Chichilnisky et al., 1995):

$$w_{t+1} = f(w_t) = w_t - q[ad - D_t] = w_t - qF(w_t) \qquad (6)$$

where q is the speed of wage adjustment.[8]

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[7] In this model prices are exogenously given, allowing for the investigation of the effects of their exogenous shocks. However it would be straightforward to amend the model by adding the price sector (for instance by means of a mark-up relation, as in Fanti 2002). This would imply the complication due to the introduction of the price sector without modifying in a substantial manner the structure of the model.

[8] Note that the presence of finite adjustment speeds and the use of static maximization rather than full intertemporal optimisation to derive demand for and supply of labour, constitute departures from the strict neoclassical equilibrium dynamics. However an unambiguous warning on the intrinsic complexity of the standard, although not intertemporal, neoclassical model may be a substantive result, as Baumol (2000) argues: "if the analysis demonstrates that a wage reduction, while it may sometimes stimulate employment, can in other circumstances exacerbate it and lead to dangerous oscillations, the result is surely substantive. It is a clear and unambiguous warning to be disregarded by policy designers at the economy's peril."(p.231).

3.1. The steady state analysis.

The existence and uniqueness of the equilibrium of the map *f(w)* is easily derived by equation *F(w*)=0*:

$$w^* = \frac{Abp}{(ad)^{1-b}} \qquad (7)$$

We focus the analysis on the parameters of interest in this paper, that is product price and productivity. The effects of the parameters *p* and *A* on the equilibrium points are given by the following:

$$\frac{\partial w^*}{\partial p} = \frac{Ab}{(ad)^{1-b}} > 0; \qquad \frac{\partial w^*}{\partial A} = \frac{pb}{(ad)^{1-b}} > 0 \qquad (8)$$

Result 1: *Both increasing price and increasing productivity increase the equilibrium wage.*

3.2 The dynamical analysis.

As regards the stability issue, the local stability condition of map (6) is

$$\left|\frac{\partial w_{t+1}}{\partial w_t}\right|_{w=w^*} = \left|f'_w\right|_{w=w^*} = \left|1 - q\frac{\partial F}{\partial w}\right|_{w=w^*} < 1 \qquad (9)$$

Result 2: *Given* $\frac{\partial F}{\partial w} = \frac{(ad)^{2-b}}{(1-b)Ap^{\frac{2-b}{1-b}}b} > 0$, *then the stability condition (9) boils down to the following :*

$$0 < q\frac{\partial F}{\partial w}_{|w=w^*} = q\frac{(ad)^{2-b}}{(1-b)Ap^{\frac{2-b}{1-b}}b} < 2 \qquad (10)$$

and therefore a loss of stability of the equilibrium of (7) may occur only through a flip bifurcation[9] *(i.e. when* $\left(1 - q\frac{\partial F}{\partial w}\right) = -1$).

As regards the role of the parameters *A* and *p* on the local stability, the following holds:

Result 3: *Both increasing prices and productivity work for stability.*

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[9] Broadly speaking, a flip bifurcation is a local bifurcation occurring when the derivative of the uni-dimensional map is equal to -1.

Result 3 straightforwardly derives from the following derivatives:

$$\frac{\partial f'_w}{\partial p} = \frac{q(ad)^{2-b}(2-b)}{(1-b)^2 bAp^{\frac{1}{1-b}}} > 0; \qquad \frac{\partial f'_w}{\partial A} = \frac{q(ad)^{2-b}}{(1-b)bA^2 p^{\frac{2-b}{1-b}}} > 0 \qquad (11)$$

The condition for the local stability (i.e. the inequality (10)) may be re-expressed in terms of the parameters *p* and *A* in the following way:

$$p > \left[\frac{q(ad)^{2-b}}{2(1-b)Ab}\right]^{\frac{1-b}{2-b}}; \qquad A > \frac{q(ad)^{2-b}}{2(1-b)p^{\frac{2-b}{1-b}}b} \qquad (12)$$

Moreover a flip bifurcation at the equilibrium *w** occurs when

$$p = p_{Flip} = \left[\frac{q(ad)^{2-b}}{2(1-b)Ab}\right]^{\frac{1-b}{2-b}}; \qquad A = A_{Flip} = \frac{q(ad)^{2-b}}{2(1-b)p^{\frac{2-b}{1-b}}b} \qquad (13)$$

In the next section we resort to numerical simulations to illustrate the main results of the steady state and dynamical analysis, showing, furthermore, that an onset of chaotic behaviours via a period-doubling route to chaos does exist.

4 - Numerical illustrations.

The simulations are performed to illustrate how the structure of the attractors evolve as the bifurcation parameter is varied while all the other parameters are kept fixed. We consider for illustrative purposes the following parameter set*: a= b=0.5, q=0.8 d=1*.

The bifurcation diagram of a one-dimensional map shows an attractor of the map as a (possibly multi-valued) function of one chosen parameter. The first bifurcation diagram is drawn with respect to the parameter *p*, with the other parameters fixed at the values above in the text and *A=1*, and it is shown in figure 1. Figure 1 suggests the following bifurcation scenario. If price is sufficiently high there exist a stable equilibrium. If price decreases then the equilibrium becomes unstable and period doubling bifurcations occur. After many period doubling bifurcations the wage behaviour becomes chaotic as *p* is further decreased.[10]

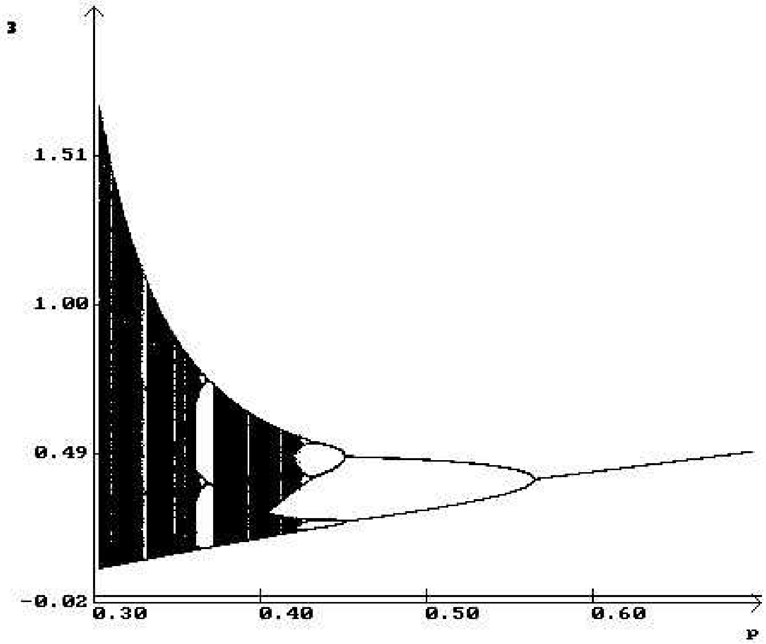

Fig.1- Bifurcation diagram of w for p (0.30<p<0.70) (a=b=0.5, A=d=1, q=0.8)

The second bifurcation diagram is drawn with respect to the parameter *A* and is shown in figure 2. Figure 2 suggests a bifurcation scenario very similar to that regarding *p*. Indeed, if the index of productivity A is sufficiently high a stable equilibrium does exist. If the value of *A* decreases then the equilibrium becomes unstable and period doubling bifurcations occur, which represent the onset of wage chaotic dynamics when *A* is further decreased.

[10] Note that the period 3 cycle has a particularly wide window (in fig. 1 as well as in fig.2).

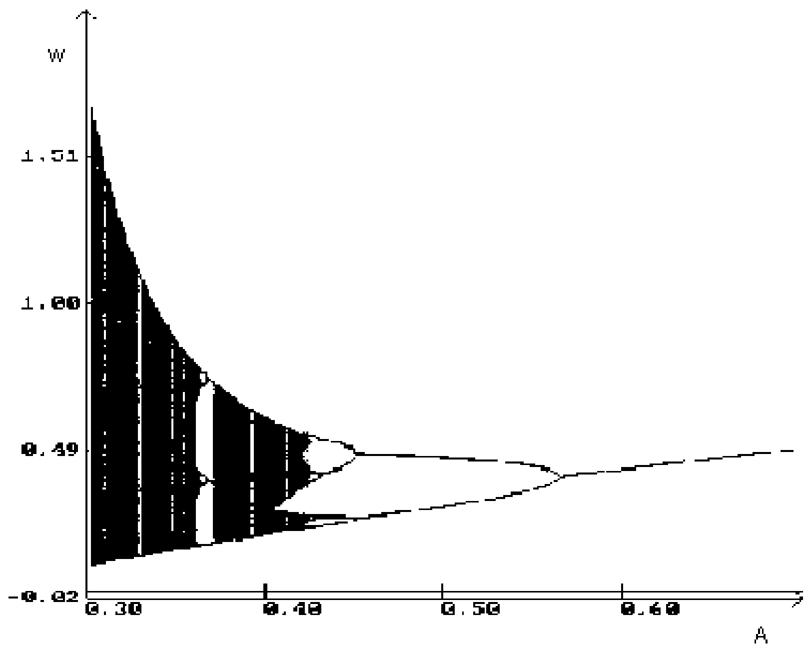

Fig.2- Bifurcation diagram of w for A (0.30<A<0.70) (a=b=0.5, d=p=1, q=0.8)

As regards the evidence of chaotic behaviour displayed in the bifurcation diagram, we note that simple constructive chaos conditions may be determined resorting the so-called Li-Yorke (1975) overshoot conditions.

Let's invoke the following theorem:

Theorem 1 (Theorem 5.4, Day, 1994, p.85)[11]: *Let's define Z as domain of definition for the process represented by the map f and let (f, Z) be a closed continuous system: if there exists a point x=z such that* $f^3(z) \le z \le f^1(z) \le f^2(z)$ *or conversely such that* $f^3(z) \ge z \ge f^1(z) \ge f^2(z)$, *then there exist a cycle of every order n=1,2,3……in Z.*

[11] This theorem allows for a simple computational task, consisting in the computation of a finite sequence and search for a point *z* with subsequent points satisfying the inequalities in the theorem. Obviously, although analytical conditions for which the Li-Yorke conditions hold has been provided for some classes of maps, such constructive conditions for chaos must make use of numerical and graphical techniques for the most part of the specific maps emerging from economic problems, such as the present map *f*, which are not belonging at well investigated classes of maps. Therefore such constructive results are subject to the round-off error involved in numerical simulations of the non-linear map.

Following Li and Yorke (1975) it follows that when the map *f* has a period 3 orbit such a map is topological chaotic, in the sense that: 1) there exist infinitely many periodic points with different periods, and 2) there exists an uncountable set of aperiodic points, for which there is sensitive dependence on initial conditions.

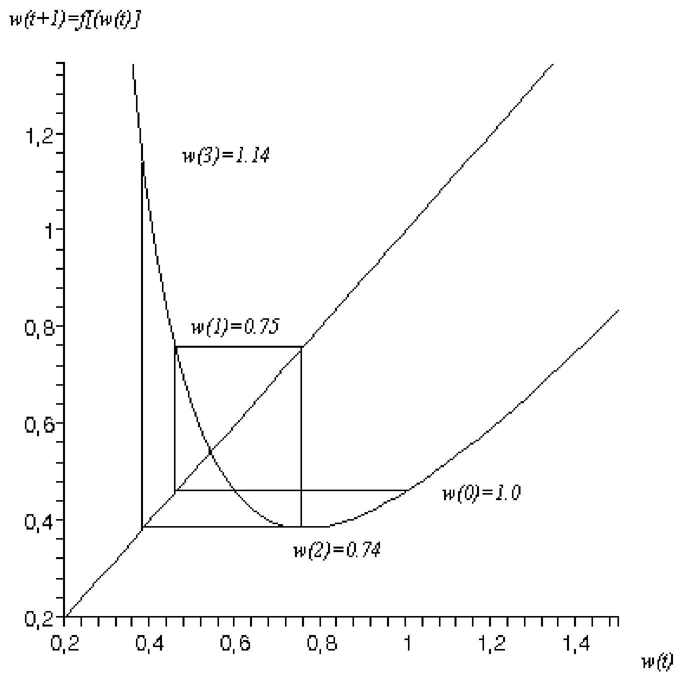

FIG. 3 - Orbits showing a period-three cycle around the unstable equilibrium w=0.54,(a=0.85, b=0.5, A=p=d=1, q=0.9)*

Figure 3 neatly illustrates that the conditions of theorem 1 are satisfied:[12] indeed, starting from a value of the dependent variable *w=1.0*, the values of the first three iterates of the map *f* are *f(1)=0.75, f(2)=0.74, f(3)=1.14.*

5- Conclusions

[12] We note that the detection of period three surely implies the presence of very complex transients but not necessarily of a stable chaotic attractor which would render chaos not only existing but also observable (for instance the three period windows of the map shown in figs. 1 and 2 do not appear chaotic). Jointly considered, figs. 1, 2 and 3 show that the chaotic behaviour does exist and is observable.

The dynamics of a walrasian labour market model with standard Cobb Douglas supply of labour and demand for labour curves is analysed. We prove that chaotic dynamical behaviour can occur, even if both the supply and demand curves are monotonic and “well-behaved”. In the spirit of the recent literature developed in the different frame of (stochastically driven) business cycles theory, the dynamic effects of exogenous changes of 1) product prices and 2) productivity, have been investigated, showing that: 1) negative changes of prices as well as productivity play a destabilising role and trigger persistent economic fluctuations which may be chaotic and therefore seemingly stochastic as retained by the business cycle theory. The interest of these results lies in the relevance of their messages and in the simplicity with which are obtained: 1) the most standard model (i.e. based on Cobb Douglas functions) of the “core” market of the walrasian macroeconomics (that is the labour market), may generate deterministic endogenous business cycles; 2) negative shocks on prices and productivity are always destabilising and trigger robust chaotic fluctuations.

In particular, since in our model a negative shock on productivity may be followed by both increases and decreases of the (fluctuating) labour input, then it provides a possible endogenous deterministic explanation of the nature of the co-movement between productivity and labour input in both directions, so reconciling the controversial evidence emerged in the empirical applications of the RBC theory.

Finally, in order to investigate in a deep way in the frame of our simple deterministic walrasian market another main issue of the recent literature on (stochastically driven) business cycles – i.e. if the comovement between labor input and productivity shocks is also, and in what extent, significantly affected by the degree of price stickiness – both, on the technical side, a codimension two bifurcation analysis[13] and, on the economic side, an extension to other markets (e.g. goods and money markets), would be necessary. This seems to be a promising topic for future research.

[13] Broadly speaking, the analysis of the dynamical evolution when both prices and productivity are simultaneously changing.

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