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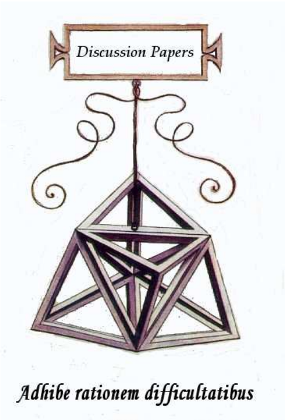

Luciano Fanti

Returns to labour and chaotic cycles of wage and employment.

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Indirizzo dell'Autore:

Luciano Fanti
Dipartimento di Scienze Economiche, Università di Pisa, Via Ridolfi 10, 56124 Pisa, ITALY
e-mail: lfanti@ec.unipi.it

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Returns to labour and chaotic cycles of wage and employment.

Abstract

This paper discusses the dynamics of a standard (double Cobb-Douglas) labour market under the circumstance of changes in returns to labour. Despite the simplicity as well as the vast diffusion of this model, such an issue has so far escaped closer scrutiny by economic dynamics literature. This investigation shows: i) possible chaotic behaviours in a simple walrasian market, ii) the multiple roles that returns to labour play on the stability, and iii) the corresponding implications for stabilization policy.

Keywords: chaos, walrasian labour market, returns to labor

JEL Classification: E3, J0

1- Introduction

This paper discusses the dynamics of a standard labour market (with Cobb-Douglas utility and production functions) under the circumstance of changes in returns to labour. This analysis may be of interest on the one side for the light it sheds on possible chaotic behaviours in a simple walrasian[1] market and on the multiple roles that returns to labour play on the stability, and on the other side for the corresponding implications as regards stabilization policies. It is in fact interesting that, despite this investigation is related to the very core of macroeconomics has so far escaped closer scrutiny by economic dynamics literature.

As is known, given a fixed labour supply, the magnitude of the change in employment induced by changes in wages depends on how sharp is the curvature of the production function: 1) if the curvature is sharp and returns to labour are rapidly diminishing, only a small employment effect will result; 2) on the contrary, if the production tends to be realised with an almost linear technology the effect of changing wages on the employment will be significant. We show that when the employment is either too scarcely responsive or too much responsive to wage changes the walrasian market will be destabilised and long run persistent fluctuations will appear. We will also show persistent chaotic fluctuations[2] emerge for a large sets of realistic

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[1] With the term "walrasian" in this dynamical context we intend that prices adjust for equating demand and supply.

[2] As regards market dynamics it has been largely investigated the cobweb (lagged) model (in general with ad-hoc – that is not microfounded – non-linearities) rather than a microfounded market model, such as the present labour market. As known such a model shows, interestingly, in some cases the possibility of chaotic price fluctuations (e.g. Chiarella, 1988, Hommes, 1994).

economic parameters, when returns to labour are sufficiently either low or high.

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 follow.

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.[3] 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: $R+L=T$, where T is the fixed time whose composition can be shared between leisure or labour. T is fixed, as usual, to one. The expenditure constraint is $Y=WL=pC$. In what follows, and without loss of generality, we fix $p=1$.

By substituting from the time constraint for L, the budget constraint is: $C+wR=w$.

Defining s as 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 $(s-1)$.

For the sake of analytical tractability we focus on the usual Cobb-Douglas preferences (i.e. $s=1$).[4]

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

[4] 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,

We deliberately use such preferences (jointly with a similar technology) because they are the most widespread as well the most algebraically simple in the literature, so that the result that they may generate complex behaviours and multiple dynamical roles of returns to labor is rather interesting. 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:

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

2.2 The firms

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

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

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

$$\Pi = pAD^b - wD \tag{4}$$

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

$$D = \left[\frac{Ab}{w}\right]^{\frac{1}{1-b}} \tag{5}$$

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

3 - The dynamic model: steady states and dynamical analysis

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.

We first derive the dynamical model from the equations given in the previous section and second 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:

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

where q is the speed of wage adjustment. [5]

3.1. The steady state analysis.

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

$$w^* = \frac{Ab}{a^{1-b}} \tag{7}$$

We focus the analysis on the parameter of interest in this paper, *b*, which is a measure of the curvature of the production function. In fact in the present case the curvature only depends on the values of the parameter *b*: 1) if *b* is low the curvature is sharp and returns to labour are rapidly diminishing, causing only a small employment effect; 2) on the contrary, if *b* tends to the unity (an almost linear technology) the effect of changing wages on the employment will be significant. The effects of the parameter *b* on the equilibrium points are given by the following:

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[5] Of course, 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, the equilibrium dynamics could also mean, according to the imaginative words of Puu, (1997, p.2), that "economic evolution merely becomes a cinema performance of a film produced beforehand". In any case 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).

$$\frac{\partial w^*}{\partial b} = -\frac{A\left[b\ln a^{-1} - 1\right]}{a^{1-b}} \underset{<}{\overset{>}{-}} 0 \quad \Leftrightarrow \quad b\ln a^{-1} - 1 \underset{>}{\overset{<}{-}} 0 \qquad (8)$$

Result 1: *Equilibrium wage may be increased (resp. reduced) by an increase in the returns to labour depending on whether 1) the initial returns to labour are sufficiently low (resp. high), and 2) the preference for "laziness" is sufficiently small (resp. large).*

The economic interpretation is noteworthy because it is not self-evident: a more productive labour input causes a higher wage when workers appreciate scarcely leisure time and labour supply is high (while at first sight it would be intuitive to associate higher wages to the case where workers are "lazy" and their supply of work is low).

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

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

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

As regards the role of parameter *b* on the local stability, the following holds:

$$\frac{\partial f'_w}{\partial b} = \frac{qa^{2-b}\left[b(b-1)^2\ln a - (1-b)(2b-1)\right]}{(1-b)^3 b^2 A} \qquad (11)$$

It is easy to see that the sign of derivative (11) may change more than one time as *b* is changing. By invoking the Descartes' rule of sign, it is ascertained that even three positive critical values of *b* may exist such that in correspondence of such critical values the effect of increasing returns to labour changes its own direction, as the inspection of the following eq. (12) – representing the locus where the derivative (eq. (11)) changes its sign - displays:

$$a_0 b^3 + a_1 b^2 + a_2 b + a_3 = 0, \qquad (12)$$

where $a_0 = \ln a < 0; \quad a_1 = 1 - \ln a > 0; \quad a_2 = \ln a - 3 < 0; \quad a_3 = 1.$

Result 2: *Both small and large returns to labour work for instability; on the contrary "intermediate" returns to labour work for stability.*

Eqs. (11) and (12) show us that at least one change in the role played on stability by returns to labour always exists. For instance by considering for illustrative purpose the special case for which the value of *a* tend to one, the following holds: $\operatorname{sgn}\frac{\partial f'_w}{\partial b} = \operatorname{sgn}(b-1)(2b-1)$, which neatly shows that a critical value of *b=0.5* exists, beyond which the stabilising role of increasing *b* becomes destabilising.

Now it should be shown that one, two or three changes occur for *0<b<1*, but this task is algebraically intractable and thus we resort to numerical simulation.

In particular we focus on the case *a=0.5* (i.e., as usual, the same weight both for the taste for leisure and for consumption) and with a sufficiently intermediate value of the "speed of adjustment", *q*: we find that in general there are three positive critical values of *b*, two of which are included between zero and one. This means that returns to labor play a multiple role on stability.

The condition for the local stability – i.e. $0 < qF'_{w|w*} < 2$ - is the following:

$$a - \left[\frac{2Ab(1-b)}{q}\right]^{\frac{1}{2-b}} < 0; \qquad (13)$$

and unfortunately it may not be expressed in closed form with respect to the parameter *b*.

In the next section we resort to numerical simulations to illustrate the main results of the steady state and dynamical analysis, showing that 1) at least two critical values of returns to labour (b_{1F},b_{2F}), for which a flip bifurcation at the equilibrium w^* occurs, do exist, and moreover that 2) an onset of chaotic behaviours via a period-doubling route to chaos does exist[6].

4 - Numerical simulations.

The simulations are performed to illustrate how the structure of the attractors evolve as the bifurcation parameter is varied while all other parameters are kept fixed. We consider for illustrative purposes the following parameter set: $a=0.5$, $A=1$, $q=1.2$.

The bifurcation diagram of a one-dimensional map shows an attractor of the map as a (possibly multi-valued) function of one chosen parameter. A bifurcation diagram with respect to the parameter *b*, with the other parameter fixed at the value above in the text, is shown in figure 1. Figure 1 suggests the following bifurcation scenario. If returns of labour are too low the trajectories explode. As *b* is increased wages and employment fluctuate in a chaotic way. Next, after infinitely many period halving bifurcations fluctuations, ending at $b=b_{1F}=0.28$, wages and employment behaviours become more regular. For intermediate *b* values (between 0.28 and 0.57 in the example) there exist a stable equilibrium. An indicated in the previous section, $b=0.451$ is a critical value for which the role of increasing *b*

[6] In what follows we will not to go into technical detail, but rather provide an intuitive description, being the paper economically rather than mathematically oriented.

exchanges from a stabilising role to a destabilising one. When returns to labour are further increased beyond $b_{2F}=0.57$ (where a 2-period cycle appears), once more, after infinitely many period doubling bifurcations, chaotic behaviours arises. Note that the period 3 cycle has particularly wide windows. Moreover it is easy to see by fig.1 that equilibrium wage is always increasing when b is increasing: this is in line with the condition (8) because in this simulation, where $a=0.5$, for whatever value of $0<b<1$ increasing returns to labour always cause an increase of the stationary state wage.

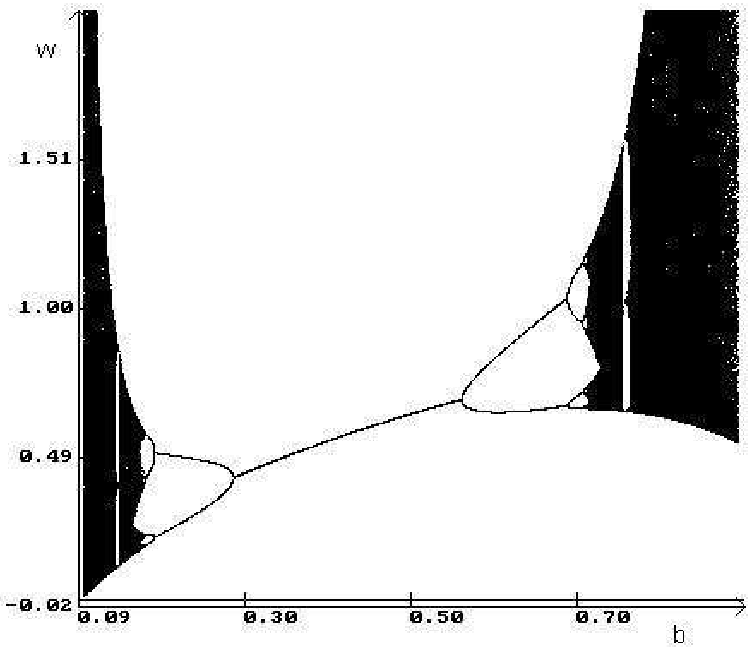

Fig.1- Bifurcation diagram of w for b (0.08<a<0.99) (a=0.5, A=1, q=1.2)

5- Conclusions

The dynamics of a walrasian labour market 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 supply and demand curves are monotonic and "well-behaved".

The possibility of instability in a walrasian market is not a new result.[7] However, the finding that a persistent business cycle may be the rule in a textbook “well-behaved” economy may be of importance for a modern theory of business cycle.

In particular, the dynamical effects of changing in returns to labour have been investigated. The main results are that 1) 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, and 2) high as well as low returns to labour may be dangerous for economic stability. This means that not only the case of a high responsiveness of the demand for labor to wage changes is destabilising, as it would be intuitively expected, but also a small responsiveness is dangerous for stability. This result has surely a policy implication: as regards possible policies[8] affecting the returns to labour of the technology, the stabilization rule should paraphrase the famous Aristoteles’ rule: “Virtus est medium vitiorum” [9].

Of course we should point out that the present model does not take account of the possible existence of: 1) an elasticity of intratemporal substitution between consumption and leisure different from one, 2) a subsistence consumption, 3) a minimal required leisure time, 4) a non-wage income, which obviously enriches the dynamical spectrum of the labour market outcomes and therefore might also enrich the effects of changes of returns to labour. This will be left for future research.

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[7] In fact Sonnenschein (1972), Mantel (1974) and Debreu (1974) showed that since aggregate demand functions can have "any shape", then the equilibrium stability is no longer warranted.

[8] Public policies may affect, especially in an indirect way, the returns to labor originated by technology (e.g. Nelson, 1967).

[9] “Virtue is a middle course between vices.”

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