Monetary Model of Entrainment between Economic Cycles

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Abstract

Entrainment between economic cycles has been a source of modeling since the first studies of Sterman and Mosekilde (1993). This initial model has been successively extended incorporating more sectors and substitution between productive factors (Kampmann 1996). Money is an essential asset not introduced in last studies yet. This work incorporates the role of monetary factors in the multi-sector model using some classical Tobin hypotheses. The introduction of money carries on the possibility to simulate some new economic facts. The expectations hypothesis and the neutrality of money are tested in this paper, obtaining in general results according to the economic theory.

1. Introduction

Entrainment between economic cycles has been a source of interest through last decade. Starting from the seminal long wave model (Sterman 1985), several extensions incorporating entrainment have arisen (Sterman and Mosekilde 1993, Kampmann et al. 1994, Haxholdt et al. 1994, Kampmann 1996). In few words, the entrainment phenomenon is produced when two oscillators initially different in phase and frequency adjust their parameters in such a way that, in the long term, one oscillator describes *m* cycles while the another oscillator describes *n* cycles (*m:n* entrainment). Thus, the existence of few cyclical modes observed in economy can be explained by means of this nonlinear phenomenon. Particularly, *1:1* entrainment can explain the synchronization produced among the cyclical behaviors of different sectors or industries.

The long wave disaggregated model (Kampmann et al. 1994) includes two capital producing sectors in the economy. Entrainment arises endogenously by the nonlinear interactions between these two capital producing sectors. There have been successive new works around this model, analyzing its dynamical motion (Hernández-Guerra and Fernández-Rodríguez 1997) or incorporating more sectors and the price system (Kampmann 1996).

This model is a good endogenous and nonlinear approximation to the entrainment between economic cycles, but it doesn't incorporate any monetary factor in its hypotheses. This fact is also presented in the first nonlinear models (e.g. Goodwin 1951). However, money has had an important role in the economic theories. Thus, question of neutrality of money has been a source of controversy through decades (compare Zhang 1990 for a historical revision of the theories concerning the influence of money in the economy). So, the inclusion of money as a new asset in the model, together with the inflation rates, interest rate and expectations, would approach it closer

to reality and would make possible to test the influence of monetary factors in the entrainment among economic cycles.

In order to incorporate money in the long wave disaggregated model we use the hypotheses developed in Tobin (1965) and its posterior extensions (Hadjimichalakis 1971a, 1971b, Benhabib and Miyao 1981). These hypotheses are well adjusted to an endogenous and nonlinear description of the economy. In few words, these hypotheses assume a cleared labor market and wealth can be kept by means of two kinds of assets: capital and money. Money is introduced by the monetary authorities without cost. Savings are divided between the two assets according to the investor decisions. The production side is based on the neoclassical growth model.

Our model, called *monetary long wave disaggregated model*, assumes the economy divided in *n*-sectors. So, it has been necessary to disaggregate some macroeconomic variables through sectors. These variables include the nominal quantity of money and the demand for money, considered nonlinear. By another side, some nonlinear hypotheses of the long wave disaggregated model are held. So, a Cobb-Douglas function is assumed to describe the input-output process in this economy. However, the production function includes the ability to produce more than indicated by the Cobb-Douglas function when the desired output is higher. The decision rules of each sector's productive side to make up their desired orders are based on the bounded rationality theory (Simon 1980).

Price of each good is influenced by the disequilibrium in markets. There are two markets in disequilibrium in the model, the money and the goods markets. So, money supply excess will originate an increase in prices, such as a goods demand excess. Prices also evolve according to the expectations formed by the economic agents. Although rational expectations have attracted many actual theories, there are also some economists considering the adaptive expectations hypothesis as true in their models (Day 1994). So, we incorporate both expectations hypothesis in our model.

The model represents an endogenous and nonlinear approximation of a multisectorial economy with the inclusion of money. It has been built using a system dynamics approach, as the Sterman's (1985) model. This way to build the economic dynamical model has been of a great help for the comprehension of the relationships existing among variables.

Thus, this new model let to test the influence of money in the entrainment among economic cycles. Particularly, we present in this paper the effect of money over the entrainment regions (Arnol'd tongues) as compared with previous models and a test of neutrality of money in the entrainment model framework. We will compare the results assuming one or another expectations hypothesis.

2. Results

Multiple simulations have been designed to check the influence of money on the economy shown in the model. As it is extensively known, the influence of money is tightly related with the inflation expectations formation by the economic agents. So, the results obtained assuming the adaptive expectations hypothesis will completely differ from assuming the rational expectations hypothesis (perfect forecasting). Consequently, we will detail the simulation results considering both expectations hypotheses independently. For simplicity, we have considered the existence of

exclusively two sectors in the economy. POWERSIM 2.01 software have been used to carry on the simulations. This software is designed for building and simulation of system dynamics models. A fourth order Runge-Kutta integration with a fixed step size (approximately *0.1*) has been chosen as a numerical method.

2.1 Adaptive expectations

In figure 1 we show the simulation results for certain values of the parameters and initial conditions close to a real situation and similar to previous models. We have chosen a time horizon of 200 years. The dynamical motion is sensitive to changes in the initial conditions, but the general growth and periodicity is preserved.

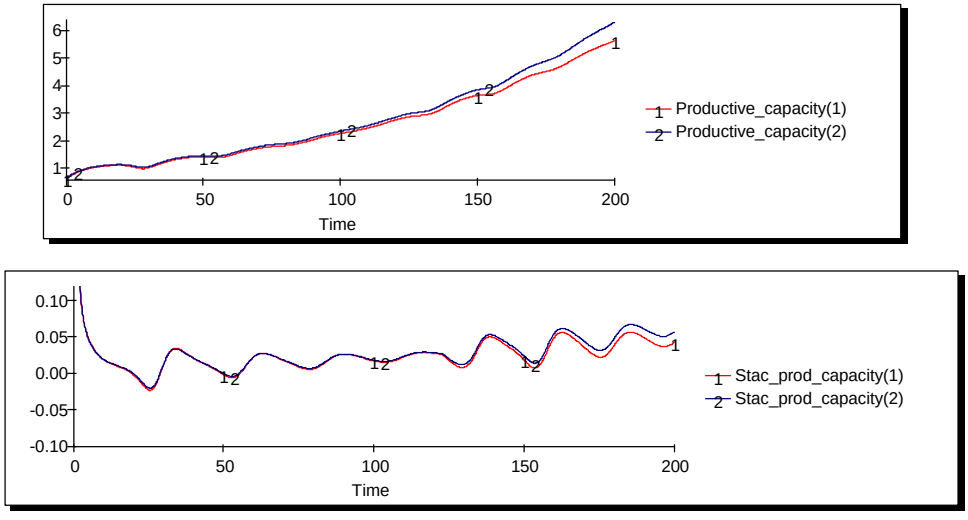

Figure 1. Adaptive expectations. Evolution of each sector's productive capacity through a time horizon of 200 years. Subindex 1 corresponds to the longest average capital lifetime sector and subindex 2 to the least average capital lifetime sector. Abbreviation "Stac_prod_capacity(i), i ∈ {1,2} means *sector i's stationary productive capacity.*

Observe that after 200 years, the productive capacity level in both sectors is six times higher than the original level. The introduction of the Tobin hypotheses in the long wave disaggregated model has originated that the new model presents a long-term growth. The second graphic illustrates the stationary series obtained from each sector's productive capacity (Stac_prod_capacity(*i*), *i* ¸ *{1,2}*). An oscillatory and irregular motion of sectors can be observed. However, these fluctuations are strongly synchronized (entrainment *1:1*).

As the previous models, we present in figure 2 the regions, called Arnol'd tongues, where the same entrainment mode is presented and the same parametric phase portrait than in the long wave disaggregated model. The phase portrait include the difference between the average capital lifetime of each sector, $\Delta\tau$, and the factor share between sectors, α. As it can be observed, synchronization between the cyclical modes of each sector fills all the parametric phase portrait for realistic values

of the parameters. The period of the synchronized cycles is approximately 25 years long. This period is not perturbed by changes in the $(\Delta\tau,\alpha)$ phase portrait. So, money has arisen as a factor reinforcing the coupling between sectors. The rest of the parametric phase portrait has numerical problems to simulate due to the huge differences between the average capital lifetimes. Anyway, these situations are far from reality.

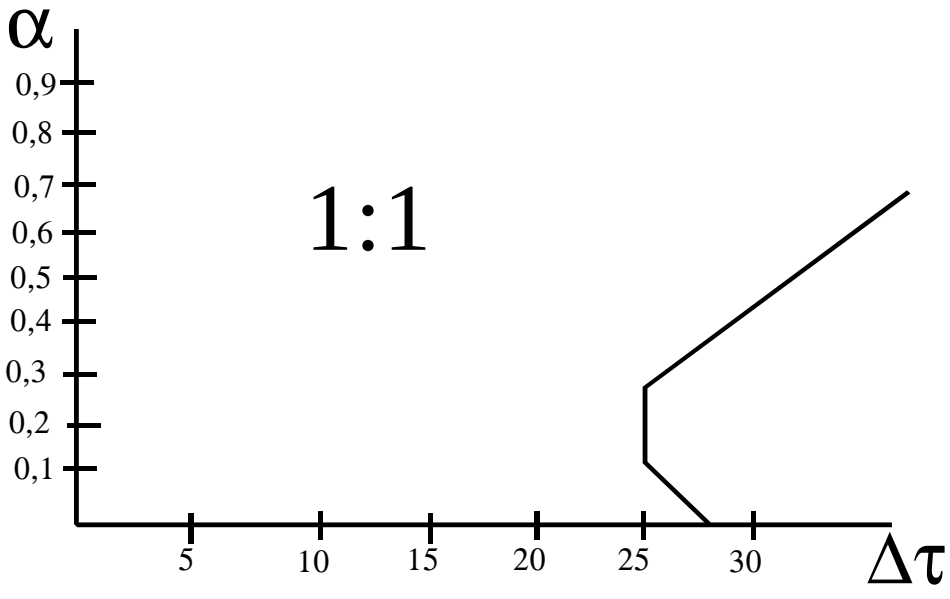

Figure 2. Adaptive expectations. Arnol'd tongues for the monetary long wave disaggregated model.

Thus, differently to the long wave disaggregated model, this extension doesn't incorporate several entrained cyclical modes. There exists just only one entrained cyclical mode, which each sector's fluctuations converge to. Therefore, this model leads to think that the difference between each sector's average capital lifetime and the factor share between sectors are not essential factors in the cyclical modes diversification.

Moreover, the introduction of money has conveyed that the synchronized cyclical motions are completely irregular. Each cycle's amplitude, and less strongly the period, is different from the other ones. The trajectories of each sector are very sensitive to the initial conditions, although the synchronization is always persistent. These cyclical motions are more adjusted to reality than a regular oscillating motion.

The monetary long wave disaggregated model also let to test the neutrality of money for different values in the parametric phase portrait $(\Delta\tau,\alpha)$. Figure 3 illustrates the regions where the same response about the neutrality of money occurs. So, if there were low and medium difference between the average capital lifetime of each sector, together with a quite high dependence degree between them, variations in money growth has only inflationary effects.

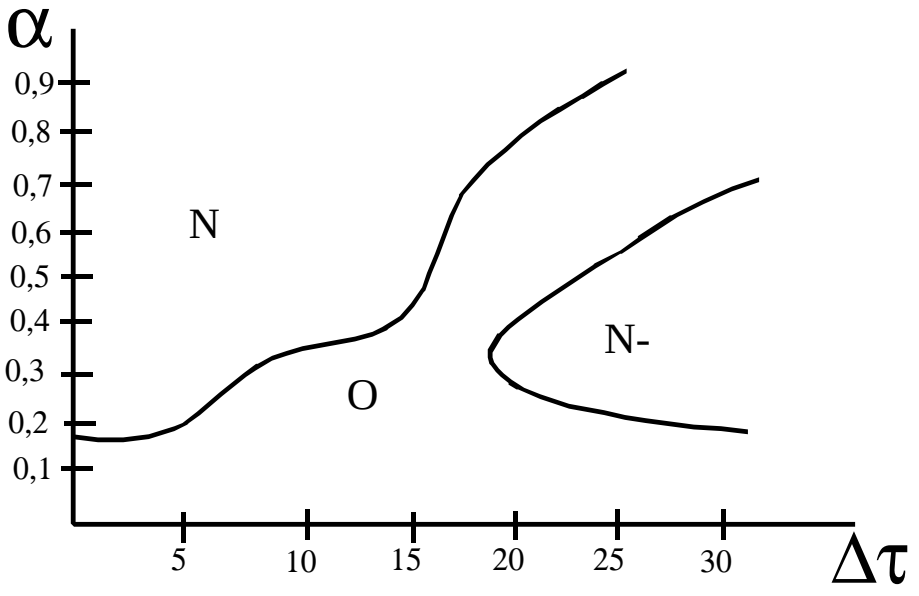

Figure 3. Adaptive expectations. Regions in the parametric phase portrait where the same response to changes in the money growth is produced. N ≡ neutrality of money. O ≡ existence of an optimum money growth rate. N- ≡ Changes in money growth rate only produces opposite direction changes in prices.

However, there is other region where a rather high increase in money growth originates less long-term productive capacity growth rate than before, together with an increase in inflation. Analogously, if the money growth rate is strongly decreased, a less productive capacity growth rate is also observed. Therefore, an optimum money growth rate is shown in this region. This optimum is defined as the money growth rate generating the maximum long-term productive capacity growth rate in both sectors.

There also exist other regions in the parametric phase portrait where prices evolve to opposite direction of the money growth. This is due to a highly perturbing effect of huge differences in the average capital lifetime.

2.2 Rational expectations

In case of agents use all the disposable information to form their expectations, that is, the rational expectations hypothesis is assumed (perfect forecasting), the simulations result is completely different. Each sector's productive capacity grows at the same rate than in case of adaptive expectations, but fluctuations disappear. This stable motion is persistent for any change in parameters and initial conditions. This behavior is according with the theory around the rational expectations hypothesis. This theory defends that fluctuations are originated fundamentally by errors in forecasting due to unexpected monetary growth changes.

Neutrality of money is also expected in this case. In fact, simulations confirm it. Figure 4 illustrates the regions in the parametric phase portrait where the same response about the neutrality of money is produced. As it can be observed, prices adjust immediately to changes in money supply for any value of $(\Delta\tau,\alpha)$. Thus, inflation incorporates all the monetary change. In case of adaptive expectations, changes in money supply could softly increase the growth rate. This increase also carries on a more irregular change in prices.

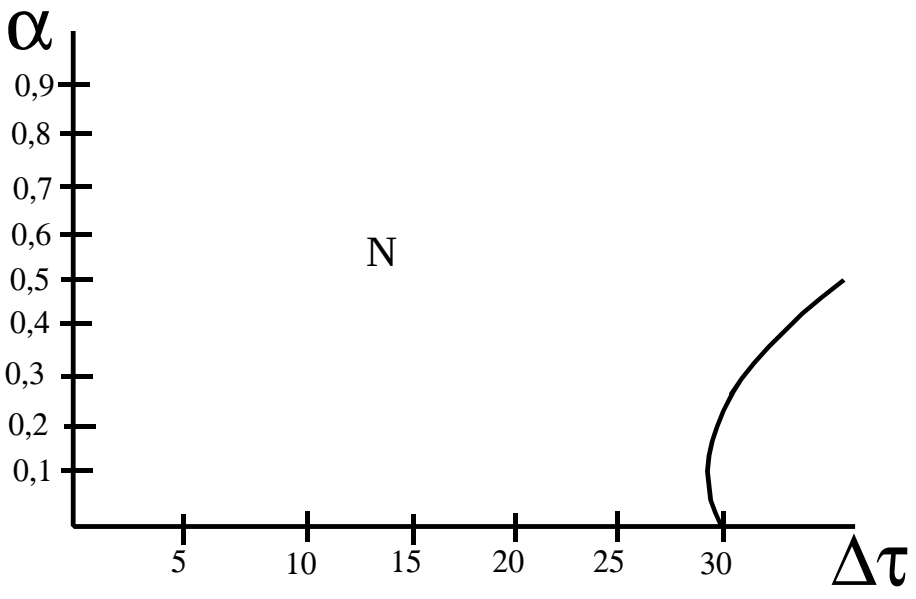

Figure 4. Rational expectations. Regions in the parametric phase portrait where the same response to changes in the money growth is produced.

Then, the assumed expectations hypothesis certainly influences the existence of cycles itself. Assuming adaptive expectations, the economic fluctuations are endogenously generated. These cyclical modes are synchronized, whatever the degree of dependence and the difference between the average capital lifetime of each sector were. Instead of this, if expectations were rational, fluctuations completely disappear.

3. Conclusions

We present in this work the simulations result of the monetary long wave disaggregated model, that is an extension of the long wave disaggregated model incorporating money and the price system. The incorporation of money has originated the possibility of testing some classical controversies about the role of money in the economy in the entrainment framework.

The results lead to several conclusions about this issue. First of all, money is shown, in case of assuming adaptive expectations hypothesis, as a factor reinforcing the entrainment between the cyclical motions of sectors. Thus, synchronization is observed since any value the parameter governing the productive relationships between sectors takes. In the long wave disaggregated model, the difference between each sector's average capital lifetime is an essential factor to explain

the variability of the cyclical modes in economy. However, the introduction of money in the model has modified this fact. It is necessary to incorporate new factors to explain the cyclical diversity. One of these factors, following Sterman and Mosekilde (1993), may be the fluctuation in the demand for consumption goods.

By another side, fluctuations exhibited by productive capacities in case of assuming the adaptive expectations hypothesis are irregular. Then, the model can be considered as a better representation of the real fluctuations in economy than other ones exhibiting more regular oscillations. This property is also presented in other models, as Goodwin (1991).

The results are also according with the economic theory. So, in case of adaptive expectations, the economy exhibits fluctuations around the long-term growth rate. However, if the rational expectations hypothesis is assumed, the model exhibits a sustained growth with no fluctuations at all. Simulations show a stable growth rate in the economy, without cyclical fluctuations. Question of neutrality of money is also dependent on the assumed expectations hypothesis. If adaptive expectations hypothesis is assumed, money is not, in general, neutral. It depends on the specific productive relationships existing between sectors. We can find in this case situations where an optimum monetary growth rate exists, in the sense of maximizing the productive capacities growth rate. In case of rational expectations, money is logically neutral.

Then, the monetary long wave disaggregated model presents a nonlinear and endogenous approximation of the influence of monetary factors in the entrainment between economic cycles. The existing nonlinearities among variables have conveyed to different responses of the economy depending on the specific productive structure between sectors and the expectations hypothesis.

This work has opened different new investigations around the entrainment and the role of money in the economy. First of all, more sectors can be considered. Then, a chaotic behavior is expected. We can also include new economic linkages in the model, as the labor market, wages, etc. Finally, checking real data with the simulated data is also a very desirable objective to test the entrainment in the real economy. Searching and handling this empirical data is not an easy task, due to the very specific aspects represented in the model.

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