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# Endogenous expectations-driven business cycles in models with deterministic equilibrium dynamics: A survey*

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**Abstract**

This study is a survey of expectations-driven models of endogenous fluctuations with deterministic equilibrium dynamics. The mechanisms that give rise to the occurrence of these types of fluctuations are discussed in the context of both perfectly and imperfectly competitive economies in which agents optimize with perfect foresight. The study emphasizes the role of alternative mechanisms in the generation of complex, nonexplosive, deterministic expectations-driven business cycles.

## 1. Introduction

There are two traditional approaches to the workings of a market economy. The classical approach emphasizes the efficiency of free markets and their intrinsic internal stability. This approach resulted in the "new classical" models of Lucas (1975) and others and in the equilibrium real-business-cycle theories of such authors as Kydland and Prescott (1982). According to this approach fluctuations in the aggregate level of economic activity are the result of repeated

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exogenous macroeconomic shocks to the fundamental characteristics of a dynamically stable economic system (technology, tastes, resources). This approach emphasizes that productivity of capital equipment varies randomly by following an exogenously given stationary stochastic process. Exogenous aggregate random shocks affect demand for goods and services and labour supply. These models usually assume that expectations are self-fulfilling, i.e. every agent's assessment of the future (a probability distribution) in the economy is correct at any moment, given the available information. According to this approach expectations of agents cannot be an independent source of business cycles. Random exogenous shocks to the fundamental characteristics of the economy give rise to business cycles and without them there will be no chronic economic fluctuations.

The competing view to the classical approach is associated with Keynesian thinking that emphasizes the expectations of economic agents as an important source of internal instability of economic systems. Recent studies designed along this view such as Azariadis (1981) and Grandmont (1985) promote the idea that fluctuations would occur if economic agents collectively and rationally expect that they would be observed even though fundamental conditions were to remain unchanged over time. Grandmont (1994) terms such fluctuations as "expectations-driven fluctuations". These fluctuations endogenously arise from an inherently unstable economic system with constant fundamental characteristics.

These new models designed with the endogenous approach have two variants. The first looks for nonlinear economic mechanisms in which the economic system fails to settle down to a stationary state in the absence of shocks. Early Keynesian macroeconomic models of Goodwin (1951) and Kaldor (1940) modelled nonlinear multiplier-accelerator mechanisms that prevent activity from exploding or imploding and thus keep it fluctuating indefinitely. The source of cyclical paths that these models generate is not exogenous and they could be labelled as endogenous. Nevertheless, economic agents in these models are persistently myopic and they make systematic forecast errors along the periodic trajectories of the system. If agents had self-fulfilling expectations these cycles would disappear. However, the new class of models recently formalized by Grandmont (1985) and Benhabib and Day (1982) makes explicit the intertemporal behaviour of individual economic agents and shows that, given the fundamental characteristics of the system, complex, non-explosive and deterministic fluctuations can occur even when expectations of agents are self-fulfilling.

The second variant attributes fluctuations to random waves of optimism and pessimism that are independent from the fundamentals of the economic system: fluctuations arise from aggregate changes of expectations that occur rather frequently in an unpredictable way. This view is often attributed to John Maynard Keynes, who argued that fluctuations in investment expenditures are volatile because they are sensitive to speculative expectations, the "animal spirits" of entrepreneurs. Recently the work of Azariadis (1981), Woodford (1986), and others popularized this view as sunspot equilibria. "People condition their expectations about, say, investment on some extraneous random variable. Belief that this variable signals changes in the rate of return can be self-fulfilling. When it increases unexpectedly (that is, when animal spirits rise) people undertake actions that will, on average, make the equilibrium return rise as expected", Howitt and McAfee (1992: 494).

The purpose of this paper is to present briefly the mechanisms that give rise to expectations-driven fluctuations in the existing literature, which are useful when studying the emergence of endogenous fluctuations in nonlinear macroeconomic models. We especially consider the cases where the fundamental characteristics do not vary over time. The only sources of economic fluctuations are the possible variations in the state of expectations of agents. We focus on the cases where the agents have complete information and where their expectations are rational.

The central idea in these type of models is that economic fluctuations may be observed as. equilibrium phenomena simply because they are rationally expected to happen. Despite the absence of random exogenous shocks to preferences, technology, or other fundamentals, in these models the economy does not settle down to a steady-state equilibrium. Furthermore, exogenous random shocks to fundamentals can be incorporated into these expectations-driven endogenous business cycle models (see Evans and Honkapohja(1995)) although in this study we emphasize endogenous mechanisms that give rise to complex dynamic behaviour.

The insight that in economies whose fundamental characteristics remain the same over time, perfect foresight or rational expectations do not always eliminate fluctuations is clearly important. Recently the literature provided examples of models in which fluctuations may be either deterministic or stochastic. In models of stochastic fluctuations, economic agents condition their expectations on an extraneous random variable (a "sunspot"), a variable which has no effect on the fundamentals, by which the resulting equilibrium correspondingly becomes a random process.

In this paper, we consider the economic mechanisms that generate endogenous equilibrium fluctuations in models in which equilibrium dynamics are uniquely determined. In such models, all endogenous state variables can be written as a function of some vector $x_t$ of predetermined endogenous state variables. For example, the values of the predetermined endogenous variables in the following period may be written as follows:

$$x_{t+1}=f(x_t) \tag{1}$$

Given an initial condition $x_0$, (1) uniquely determines the evolution of the predetermined state variables. Then these predetermined state variables characterize the evolution of other endogenous state variables. In order to determine whether or not a given system gives rise to endogenous fluctuations, the dynamics of (1) must be analyzed. We deal with systems in which there is a compact set $X$ such that $f(X)$ is contained in $X$. Hence, given the initial condition in $X$, the dynamics is restricted forever to set $X$. Under such a specification, the equilibrium exhibits endogenous fluctuations if the sequence $\{x_t\}$ does not converge asymptotically to some fixed value $x^*$, although it remains forever bounded in set $X$. The dynamics of such a system is deterministic, because once the initial condition is given, the entire dynamics of (1) is determined and hence equilibrium dynamics is deterministic. Then the endogenous fluctuations can be observed as a convergence to a deterministic cycle, or to a deterministic chaos.

## 2. The existence of endogenous cycles in perfectly competitive economies

The possibility of the existence of endogenous equilibrium cycles in overlapping generations (OLG) models with complete and perfectly competitive intertemporal markets has been known since the publication of Gale's (1973) study in which interest rates and consumption allocations oscillate in a periodic fashion. Benhabib and Day (1982) and Grandmont (1985) employ bifurcation theory to analyze the dynamic properties of particular versions of this class of models. These studies provide the first general examples of the possibility of chaotic economic dynamics in OLG models under the presence of complete and perfectly competitive intertemporal markets.

As an example of how an economic system can generate endogenous fluctuations, a simplified version of Grandmont's (1985) model will be presented. Consider a simple OLG model in the presence of complete and

perfectly competitive markets. The economy consists of a constant population of overlapping generations of two-period-lived individuals, each identical in number. Assume that a single perishable consumption good, $y_t$, is produced with a constant returns to scale technology using labour as the sole input each period. For simplicity, assume also that the aggregate behaviour of all members of a generation can be represented by a representative individual. A representative individual born at date t supplies a quantity of labour $0 \leq l_t \leq \bar{l}$ (where $\bar{l} > 0$ is the labour endowment), saves the amount of money $m_t \geq 0$ when young and consumes $c_{t+1}$ when old. The utility function of the representative individual is separable in labour and consumption and is equal to $\mathcal{U}(c_{t+1}) - \vartheta(l_t)$. As for the properties of the utility function it is assumed that:

*Assumption:* $\mathcal{U}$ is a strictly increasing concave function from $\mathbb{R}_+$ into $\mathbb{R}$. It is smooth on the interior of $\mathbb{R}_+$ and $\lim_{c_{t+1} \to 0} [d\mathcal{U}(c_{t+1})/dc_{t+1}] = +\infty$. $\vartheta$ is a strictly increasing convex function from $[0, \bar{l}]$ into $\mathbb{R}$. It is smooth on $[0, \bar{l}]$, and $d\vartheta(l_t=0)/dl_t = 0$, $\lim_{l_t \to \bar{l}} d\vartheta(l_t)/dl_t = +\infty$.

In equilibrium, the real wage is equal to the marginal product of labour, which is one. Therefore in each period the money wage $\omega_t > 0$ is equal to the price of the good $p_t$. Then the behaviour of a representative individual born at time t is to maximize his utility function under the budget constraints $p_t l_t = m_t = p_{t+1} c_{t+1}$ in which $p_{t+1}$ is the price expected to prevail in the future. The first-order condition of this problem is

$$V(l_t) = U(c_{t+1}) \tag{2}$$

where $V(l_t) = l_t [d\vartheta(l_t)/dl_t]$, $\quad U(c_{t+1}) = c_{t+1} [d\mathcal{U}(c_{t+1})/dc_{t+1}]$.

Under the above assumption (2) can be rewritten as

$$l_t = V^{-1} [U(c_{t+1})] = \chi(c_{t+1}) \tag{3}$$

The graph of $\chi$ is the locus of all optimal pairs $(l_t, c_{t+1})$ chosen by an individual and represents, accordingly, his offer curve. Since, under perfect foresight, in equilibrium $l_t = y_t$, $c_{t+1} = y_{t+1}$, a deterministic equilibrium with perfect foresight is characterized by a sequence of outputs $y_t > 0$ that satisfy

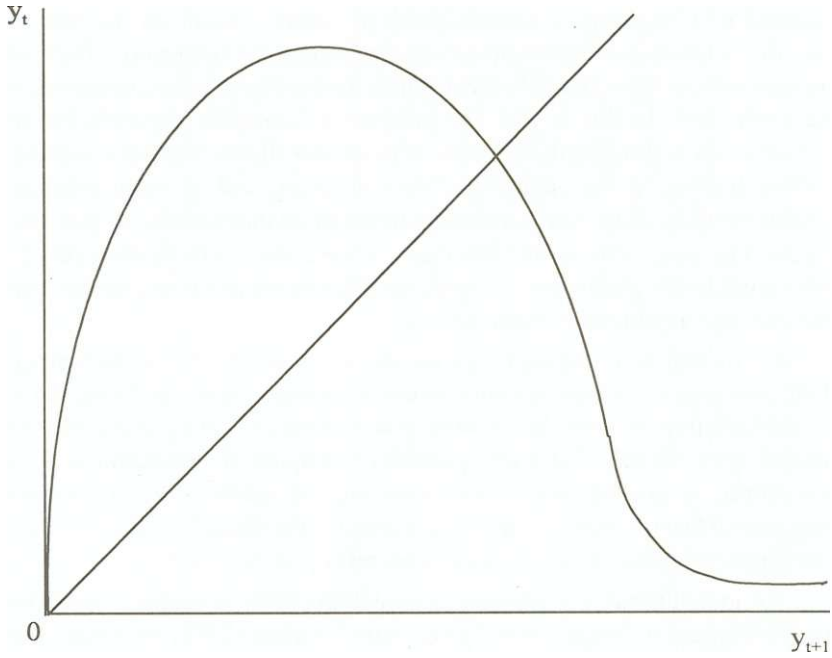
$$y_t = \chi(y_{t+1}) \quad (4)$$

for all $t \geq 1$.

The existence of cyclic deterministic equilibria depends, therefore upon the shape of the offer curve $\chi$. Increasing the price of future consumption induces substitution and income effects between future consumption and current leisure. If the substitution effect dominates everywhere, c is monotonically increasing everywhere also and there can be no cyclic equilibria. However, if there is extreme conflict between substitution and income effects, that is, the substitution effect donimates in some range and the income effect dominates in another range, c could have the shape given in Figure 1. In this figure c increases when the substitution effect dominates but decreases if the income effect dominates. In such a situation there emerges persistent, non-explosive, endogenous fluctuations. In other words, this sort of unimodal map occurs if preferences of young agents are such that the derivative of the agent's excess demand for the good consumed with respect to the real interest rate changes its sign from negative to positive as the interest rate increases; that is, desired saving in youth is a decreasing function of the expected real return on money for high levels of that return. Grandmont (1985) discusses in detail the order in which cycles of various periods occur as the unimodal map that determines the dynamics of the economic system is made progressively steeper by applying the theory of bifurcation. All such cycles obviously represent possible equilibria of the forward perfect foresight dynamics since they can be extended into the future as well as infinitely into the past.

In the Benhabib and Day (1982) version of the OLG model, the emphasis is to a greater extent on the existence of chaotic perfect foresight equilibria. Their model is similar to Grandmont's model, except that instead of assuming the presence of fixed nominal money balances, they consider a central authority that lends to the finite-lived consumers. Each period the central authority extends credit to the young, at a market-clearing interest rate, a quantity exactly equal to the amount currently being repaid by the old consumers by assuming that the initial group of old consumers owe to the central authority a real indebtness of $d_0$. Benhabib and Day's results are similar to those of Grandmont on the conditions under which complex dynamic behaviour occurs. The sharply downward bending unimodal map constructed in the model occurs if desired borrowing does not increase very much as the real rate of interest on loans falls, implying that the marginal utility of first period consumption falls sharply with increases in the first period consumption. The study employs the forward

**Figure 1**
A $\chi$ Function with Conflicting Income and Substitution Effects




foresight equilibrium dynamics in the investigation of the possibility of chaotic equilibrium trajectories starting from a given initial condition. It shows the existence of a unique perfect foresight equilibrium in the model under consideration, leading to the observation that the only possible equilibrium would be cyclic or chaotic under certain conditions.

Complicated dynamic behaviour can occur in these models only if desired saving is a decreasing function of the expected real return on money for high levels of that return leading to the sharply backward-bending supply of savings as a function of expected real return. In fact, no cycles can exist unless the elasticity of savings with respect to the interest rate at the stationary state is below -1/2. This is criticized as being empirically unlikely.

Some studies focus on OLG models with production, in the setting developed by Diamond (1965), in order to investigate whether the income effect is the only potential cause of endogenous fluctuations. Reichlin (1986) shows the possibility of the existence of self-sustaining fluctuations in an OLG economy with production when the saving function has a positive elasticity with

respect to the real interest rate, satisfying the gross substitutes condition, and labour supply is endogenous.

Reichlin (1986) employs both labour and capital as inputs in production instead of Grandmont's consideration of current labour as the only input required to produce output, and detects the existence of endogenous fluctuations using the Hopf bifurcation theorem, where the parameter of bifurcation is purely technological. In this model, the presence of complex dynamic behaviour depends on a sufficiently low elasticity of substitution between capital and labour leading to the opposing effects of saving out of wage income and intertemporal substitution, caused by factor price movements, to generate the cycle. The study also proves that there exists a fiscal stabilization policy rule that completely eliminates the cycle and drives the economy to the optimal steady state as soon as it is announced.

In contrast to the examples given above, Farmer (1986) deals with cycles that arise only if the government pursues a particular policy of fixing the value of the deficit rather than the value of government debt in a context of an OLG model with capital. The study provides examples of deterministic cyclical equilibria, associated with a low elasticity of substitution in production, suggesting that the way in which government expenditure is financed may have an important effect on the nature of competitive equilibrium.

As an additional complication to Reichlin (1986)'s model, where there is no nominal asset except the real asset capital, Jullien (1988) introduces money into an OLG model with capital accumulation. However, he employs a labour supply with zero wage elasticity as opposed to Reichlin's wage-elastic labour supply specification. The analysis of the global dynamics of the one-sector model with a well-behaved production function which allows substitutability between capital and labour reveals that the economy may induce excessive movements of investment that gives rise to periodic equilibria if and only if the response of the savings to the interest rate is not monotonic as in Grandmont (1985). The mechanisms explained are financial in that the demand for unproductive assets (money) resulting from savings and investment decisions generates cycles through self-fulfilling expectations. This study naturally is susceptible to the same critique, made for Grandmont (1985), that the negative elasticity of savings with respect to the interest rate is empirically unlikely.

In contrast to Jullien (1988), Benhabib and Laroque (1988) introduce an endogenous wage-elastic labour supply to the OLG model that contains both capital and a constant nominal quantity of outside money. The production in the

economy is carried out by using both capital and labour as inputs under a constant returns to scale technology and substitutability between inputs are allowed. The study proves that period two cycles are likely to occur when savings is a decreasing function of the interest rate. It also produces the result that there may exist Hopf cycles even when savings increase with the interest rate, provided that the quantity of outside money is negative at the steady state and there is enough complementarity in the production function. Benhabib and Laroque point out that these cycles seem to be linked with a destabilizing real balance effect.

As Reichlin (1992a) notes, the following statements can be derived from the results of the above studies carried out in the context of perfectly competitive economies with complete markets: first, cycles are either associated with a negative interest elasticity of savings or a low elasticity of substitution between factors in production and an increased elasticity of substitution reduces the scope for cycles; second, when the interest elasticity of savings is positive, a nonpositive outside money is necessary for a low elasticity of substitution between factors to be associated with endogenous fluctuations. Therefore, the role of complementarity in production is not clearly separated from the existence of a negative outside money (the existence of an evolving private sector debt over time causing private agents' wealth to be negative) and/or a labour supply response to wage fluctuations in these economies.

Reichlin (1992a) slightly modifies Diamond's framework in order to evaluate the generality of the above statements. As a departure from the models considered so far, he assumes the existence of a two-sector technology producing a consumption and a capital good. He also considers an exogenously fixed labour supply and a zero elasticity of substitution in both sectors in order to isolate the role of complementarity in production from any factor intensity reversal between sectors. The analysis shows that periodic and chaotic dynamics are possible with a positive interest elasticity of savings, and Hopf cycles are not necessarily associated with a wage-elastic labour supply or nonpositive outside money. The interest elasticity of savings, a purely technological parameter whose magnitude depends on the relative factor intensities in the two sectors of production, and the rate of depreciation of capital stock are shown to be crucial in providing these results.

All the models mentioned so far, that provide mechanisms creating deterministic endogenous fluctuations with or without capital, rely on constant returns to scale technologies. However, Huang and Madden (1996) consider decreasing returns to scale technologies allowing profits to be observed in the

context of a perfectly competitive monetary economy without capital. This study shows the existence of cycles associated with a positive interest elasticity of savings when returns to scale are decreasing which emphasizes the role of a sufficiently low elasticity of demand for labour.

All the discussions concerning the work of Benhabib and Day (1982), and Grandmont (1985), and the following models, are in the context of a two period- lived agent OLG model, and thus all of the cycles in their models have periods greater than or equal to the agents' lifespan. This led to the criticism that "short period cycles would either be unlikely to exist or to be quantitatively insignificant in amplitude in OLG models with long lived agents" (Sims, 1986). This criticism brings out the questions of the existence of any relationship between periodicity of competitive deterministic fluctuations and agents' lifespan, and of the possibility of the survival of competitive endogenous cycles in economies where agents' lifespan becomes longer and longer.

Aiyagari (1989) focuses on a family of pure exchange one-good deterministic OLG models in which the number of periods that each generation lives is made progressively longer, holding unchanged any other characteristics of the economy. The rate of time preference and the elasticity of intertemporal substitution of consumption between periods that generate strong income effects (relative to substitution effects) remain constant while each period's endowment continues to fall between the same upper and lower bounds. Aiyagari's basic result is that, under certain assumptions $k$ period deterministic cycles eventually cease to exist, once the lifetime T is made large enough. The discussion supports the view that short period cycles are not likely to occur in economies with long-lived consumers. However, the relevance of the above results is restricted to the particular class of models that Aiyagari considers, namely, models where there is no multiplicity of consumption goods or factors of production. Furthermore, the result is obtained only under certain assumptions: a special class of intertemporal preferences with a fixed discount rate, lifetime endowment patterns bounded above and away from zero, and no production.

Reichlin (1992b), on the other hand, shows that periodic equilibria and complex dynamics may exist even in pure exchange one-good OLG economies where agents have arbitrarily long lifespans, by slightly modifying Aiyagari's model both to allow for some degree of uncertainty about the agent's lifespan, and to abandon the assumption that endowments must remain bounded away from zero for all T. The conditions under which periodic cycles are shown to exist with agents having arbitrarily long lifespans are connected with the existence of a high enough degree of relative risk aversion and discounting of

agent's future utilities. Moreover, it is shown that the sequence of lifetime endowments cannot be monotonically increasing or constant. The paper emphasizes that what causes the emergence of endogenous cycles is not really linked to the length of agents' lifespans, and the amount and the distribution of individual endowments seem to be more important. Whitesell (1986) also shows the existence of relatively short period cycles in OLG models with relatively long-lived consumers by using a continuous time model with stochastic lifetimes for individuals, but a deterministic rate of death for each generation where the production technology employs both labour and capital with an endogenous labour supply.

## 3. The existence of endogenous cycles in imperfectly competitive economies

Grandmont (1985) suggests relaxing the ad hoc Walrasian continuous market-clearing assumption by introducing imperfect competition in the model, and looking for the kind of mechanisms that may give rise to endogenous economic fluctuations. He stresses that in a Walrasian framework, one may get economic fluctuations only through a variation of relative prices. However with the introduction of imperfect competition quantity adjustment, and thus effects such as the multiplier or accelerator have a role to play. Accordingly, he hopes that a sound non-Walrasian business cycle theory could then be developed.

Following Grandmont's suggestion, in the framework of an OLG model using labour as the only input in production, d'Aspremont *et al.* (1994) investigate the existence of endogenous fluctuations in economies with imperfectly competitive product markets and perfectly competitive input markets. D'Aspremont *et al.* (1994) analyze an OLG economy, involving several goods, each produced by several producers with Cournotian monopolistic competition on the goods market but perfect competition on the labour market with perfectly flexible prices. The emphasis, in investigating the role of various economic mechanisms that may be responsible for generating endogenous fluctuations in an OLG model with endogenous labour supply, is on increasing returns to scale and market power. The analysis introduces increasing returns by allowing decreasing marginal costs, and captures the variability of the market power with the variability of the elasticity of demand. The OLG model used allows incorporation of income, substitution and redistributional effects in the demand elasticity of income by specifying firms to have non-negligible effects not only on their own sector but also on other

sectors and on the aggregate economy. In the economy, firms take into account the repercussions of their output/price decisions on the incomes of consumers so that income effects or Ford effects are taken into account in the equilibrium analysis of the model. Such a specification makes firms face variable market power in imperfectly competitive output markets.

The results show that increasing returns or the variability of oligopolistic market power in the product market induce the multiplicity of Pareto-ranked equilibria obtained by the intersection of the (oligopolistic) demand for labour curve with the labour supply more than once. Following the multiplicity of (temporary) equilibria at each period, the study investigates the existence of complex dynamics generating different types of intertemporal equilibria stressing that imperfect competition may contribute to the emergence of cycles. New results emerge from the study: first, there exist Pareto-ranked stationary multiple equilibria; second there exist endogenous cycles. The results depend on two conditions. One is related to the specification of technology and independent of the degree of competitiveness of output markets as being increasing returns to scale to labour input elastically provided by consumers/workers in a perfectly competitive labour market. The other one is the variability of oligopolistic market power in product markets associated with the variability of demand elasticity resulting from Ford effects.

In the context of a non-monetary economy characterized by perfectly competitive factor markets but imperfectly competitive product markets, Gaygısız (1995a) analyzes the cycle generating economic mechanisms using both labour and capital in the production technology, which exhibit non-constant returns to scale. It assumes away labour substitution and allows consumption to take place both in the first and second period of life of consumers. By using the Flip Bifurcation Theorem, the study shows that in the case of a positive interest elasticity of savings the cycles are associated with a high elasticity of substitution in production when returns to scale are increasing.

In order to identify the role of elasticity of labour supply in the range of economies generating cycles, Gaygısız (1995b) extends the previous specification by only modifying the intertemporal preferences of young consumers and leaves other things the same by allowing the agents to substitute leisure for work. The study shows that when returns to scale are decreasing, the low elasticity of substitution in production is the source of cycles. On the other hand, when returns to scale are increasing, the cycles are associated with a high elasticity of substitution in production.

The main contribution of the study to the existing literature is that it shows that cycles can exist with a high elasticity of substitution in production when returns to scale are increasing. This is contrary to the existing literature where no cycles associated with a positive interest elasticity of saving exist with a high elasticity of substitution in production. This brings to light the importance of increasing returns to scale technologies as another crucial mechanism in the generation of cycles.

Gaygısız (1995a, 1995b) uses a multisectoral approach and assumes non-zero profits, distributed to the old agents in the economy, where there is no entry and exit. Lloyd-Braga (1995) and Cazzavillan, Lloyd-Braga and Pintus (1998), do not use a multisectoral approach and find similar results for an economy with zero profits, with entry and exis.

## 4. Concluding remarks

The studies reviewed here show that complex, endogenous, expectations-driven business cycles can arise under quite plausible assumptions in models with nonlinear deterministic equilibrium dynamics. These types of endogenous business-cycle models present some basic facts and tools that provide credible alternatives to understand observed fluctuations in economies.

The empirical results obtained by Hall (1986,1988, 1990) and Domowitz *et al.* (1988) suggest that monopoly power and increasing returns to scale are prevalent across actual economies. These results highlight the relevance of the theoretical models developed by d'Aspremont *et al.* (1994), Gaygısız (1995), Lloyd-Braga (1995) and Cazzavillan *et al.* (1998), which show that monopoly power and increasing returns to scale are crucial mechanisms in the occurrence of endogenous business cycles in imperfectly competitive economies.

The endogenous approach to business cycle modelling analyzed here has important policy implications: The theories about endogenous cycles suggest that regulatory economic policies may be a necessary (and desirable) way to stabilize the economy. In this sense the endogenous cycle approach is more consistent with Keynesian ideas in contrast to the real business cycle approach, which is explicitly anti-Keynesian.

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## Özet

### Deterministik dinamik denge modellerinde beklentilerin yönlendirdiği içsel konjonktürel dalgalanımlar: Bir inceleme

Bu makale beklentilerin yönlendirdiği içsel dalgalanımların deterministik dinamik denge modelleri üzerine bir incelemedir. Birimlerin tam öngörü ile optimizasyon yaptıkları tam rekabet ve eksik rekabet ekonomileri çerçevesinde bu tür dalgalanımların oluşumlarına neden olan mekanizmalar tartışılmaktadır. Bu çalışma karmaşık, deterministik. belli değerler dışına çıkmayan, beklentilerin yönlendirdiği konjonktür çevirimlerinin oluşumunda alternatif mekanizmaların rolünü vurgulamaktadır.