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A two-dimensional non-equilibrium dynamic model

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ABSTRACT

This paper develops a non-equilibrium dynamic model (NEDyM) with Keynesian features (it allows for a disequilibrium between output and demand and it considers a constant marginal propensity to consume), but where production is undertaken under plain neoclassical conditions (a constant returns to scale production function, with the stocks of capital and labor fully employed, is assumed). The model involves only two endogenous/prognostic variables: the stock of physical capital per unit of labor and a measure of market disequilibrium (MMD). The two-dimensional system allows for a careful analysis of local and global dynamics. Points of bifurcation and long-term cyclical motion are identified. The main conclusion is that the disequilibrium hypothesis leads to persistent fluctuations generated by intrinsic deterministic factors. These fluctuations may reflect some of the features frequently encountered in observed business cycles, once the model is conveniently adapted to this purpose.

1. Introduction

The long lasting debate on macroeconomics about the sources of business cycles has been built upon successive disagreements and also some consensus (see Mankiw (2006) for a survey). The Keynesian tradition, opposed to the classical view of market clearing markets and external shocks over fundamentals, stresses the presence of disequilibria in the economic system. Firms and households, instead of choosing optimally, often use rules of thumb when deciding about price adjustments, how much to invest, how to distribute consumption over time or how to allocate time between work and leisure.

This paper analyzes a two-dimensional macroeconomic model that combines classical and Keynesian features. The model is dynamic and purely deterministic. The main structure of the model is based on Hallegatte et al. (2008) (hereafter HGDH), who present a problem designated as NEDyM (non-equilibrium dynamic model). As in HGDH, the obtained long-term outcome will depend on the particular economic scenario that is furnished by a given array of parameter values; we can have both a fixed-point balanced growth outcome (as in the neoclassical growth model) and endogenous fluctuations generated by the nonlinear nature of the relation between endogenous variables (as in a Keynesian disequilibrium setup).

Our aim is to point out that, in opposition to what the Real Business Cycles theory claims, the presence of business cycles is not necessarily explained by random shocks on the supply side (e.g., technological innovation). A misalignment between supply and demand that persists over time may be the fundamental piece in explaining everlasting fluctuations that are not necessarily fed by exogenous perturbations. Although the endogenously generated fluctuations do not allow for a direct fit between the obtained time series and empirical evidence, after the character-

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ization of the model a last section discusses how the obtained chaotic series may be adapted in order to represent macroeconomic time series with the well known properties concerning volatility, co-movement and persistence that are found empirically.

According to HGDH, a NEDyM is a growth model built upon a standard Solow (1956) model, but where multiple inefficiencies arise in the several markets that are considered. In this analysis, agents do not have perfect foresight and markets do not clear, and the main reason pointed out for such is the inertia that the economic system undergoes. Inertia implies a delay on the adjustment between production and demand, on one hand, and, on the other hand, a suboptimal investment process. Investment decisions are linked with short-run profits and these may give signs that differ from the reality attached to the long-term optimal scenario. Furthermore, the labor market is subject to relevant inefficiencies, which are translated into a Phillips curve that relates nominal wages with labor supply. Consumer decisions are not optimal, instead they depend on the available stock of real balances and on the Solow's constant rate of savings.

The HGDH model is, therefore, a large collection of Keynesian relations built upon a minimal classical growth structure; this consists just on a production function that fully employs available inputs and on a conventional capital accumulation difference equation. The authors are able to find a route to chaotic motion and, thus, for different parameter values, it is analytically possible to observe a fixed-point stable equilibrium or cycles of any periodicity and completely a-periodic cycles. Such a co-existence can be interpreted under the idea that, for certain arrays of parameters, classical economics dominate, while for others the inertia factors become sufficiently relevant in order to generate endogenous business cycles. Under this interpretation, we encounter a two-fold explanation for the persistence of business cycles: in the scenario in which classical economics prevail, business cycles can only occur as the result of external shocks; when Keynesian economics dominate, the role of technology shocks (or others) will have a relatively smaller relevance since some market inefficiency or inertia is able, by itself, of producing and perpetuating fluctuations.

By modelling simultaneously the dynamics of the goods market, the labor market, the behavior of firms with investment as a function of profits and the behavior of households as a function of real balances, the problem proposed by HGDH become an eight-dimensional system with eight endogenous variables (or prognostic variables, as the authors call them). Additionally, 11 other variables (diagnostic variables) are modelled as functions of the endogenous state variables. With such a high dimension, the problem cannot be analyzed in general terms; only through numerical particular examples one may infer about the behavior of the economy. Thus, what the authors gain in terms of completeness they evidently lose in what concerns tractability.

Here, the main distinction relatively to the analysis of HGDH, is that our model is more compact (it is just a two-dimensional model), allowing for the general analysis of local dynamics, as well as for the investigation of the long-term global asymptotic behavior of the assumed endogenous variables.

The features we maintain in this version of the NEDyM are, on one hand, the neoclassical production function and the capital accumulation process that is present in any growth optimization problem and, on the other hand, the most relevant Keynesian features; basically, we assume, as in the HGDH model, that an element of inertia is present in the goods market: production and demand are not always adjusted to one another, and thus a market disequilibrium persists in time. This implies the need to assume a non-equilibrium variable, which plays a fundamental role in the obtained results. To this variable, we attribute the designation of measure of market disequilibrium (MMD).[1]

Differently from the HGDH model, investment and consumption decisions are not explicitly modelled; instead, consumption is given just as a constant share of income (the good old constant marginal propensity to consume is taken into account), while investment is the result of a behavioral rule that takes into account the firms' reaction to price changes and to variations on the value of the MMD. Demand is defined as consumption plus investment, and the dynamics of the system can be addressed once demand and output are connected through a short-run macroeconomic relation. This relation is the HGDH market equilibrium adjustment equation. The analysis of the labor market is neglected, by assuming that a fixed amount of labor is in every moment available to produce.

The framework that arises from the previous assumptions is a two-dimensional deterministic system with physical capital (per unit of labor) and the MMD (also per unit of labor) as endogenous variables. Relatively to this model, one can address both local and global dynamics. Local analysis allows for perceiving that bifurcation points are eventually crossed, a necessary requirement to encounter long-term nonlinear motion. The global analysis, although less generic, confirms the generation of areas of endogenous cycles, that occur with a flip bifurcation. As in the HGDH problem, areas of fixed-point stability can be interpreted as representing the balanced growth path that is characteristic of classical growth models, while regions where complex behavior is evidenced are the ones where the Keynesian features of the model (inertia, lack of alignment between production and demand, constant propensity to consume, IS curve relation) become dominant. The main additional contribution that the present paper achieves is that it is able to obtain such a set of results without departing from a simple two-equation model,

[1] In Hallegatte et al. (2008), this variable is called 'goods inventory'; we exclude this term because it can be equivocal in the sense that it is used. It is rather a measure of delivery lags or selling lags. We also avoid, at this level, the designation 'utilization rate'. Changes in the utilization rate of capital in time may generate this disequilibrium, but they are not the disequilibrium itself. Capacity utilization generally emerges with the modelling of the production function; it calls the attention for the fact that in booms equipments and machinery are used more intensively than in periods of recession. Although we will resort to a neoclassical production function with full employment of inputs, in Section 6 we make a brief reference to how different utilization rates can be inserted in the proposed framework in order to help making the model useful to address volatility properties of business cycles.