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R&D policy in a volatile economy

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ABSTRACT

The literature on R&D-based growth establishes that market equilibrium is inefficient and derives optimal R&D policy. Normative analyses of this type use the assumption of steady state, largely motivated by analytical convenience. This paper questions this steady-state approach by introducing endogenous cycles as long-run equilibria. We show that the government fails to maximize welfare if policy which is optimal in steady state is myopically applied in cyclical equilibria. More specifically, we demonstrate that (i) cycles arise in the (very) standard R&D-based model of Grossman and Helpman [1991. Innovation and Growth in the Global Economy. MIT Press, Cambridge, MA (Chapter 3)] once the model is framed in discrete time, (ii) these cycles are inefficient in the sense that they prevent welfare maximization, (iii) optimal steady-state R&D policy fails to eliminate cycles, and can even create inefficient cycles, (iv) the application of R&D subsidies leads to a trade-off between growth and macroeconomic stability, and (v) optimal R&D policy in a fluctuating economy is state-dependent, which generalizes optimal steady-state R&D policy.

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1. Introduction

The literature on R&D-based growth establishes that market equilibrium is inefficient due to several types of market failures. When firms or individuals decide on the amount of resources allocated to their R&D activities, for example, they generally fail to consider how their research outcomes will improve future R&D productivity and benefit society as a whole. Effects of this type and others lead to under- or over-investment in R&D in the market economy. This calls for some kind of policy measure to improve overall welfare.

An important aspect of this widely accepted result is that the normative analysis is conducted in steady state, a condition in which the resource allocation remains constant over time. This paper questions this steady-state approach of normative analysis by introducing the possibility of endogenous cycles as long-run equilibria.[1] As a central thesis, the paper argues that policy implications derived in steady state lose relevance and can even be misleading to the restoration of Pareto efficiency in a fluctuating economy. In short, our study demonstrates an important qualification to the assumption of steady state, which is widely used in normative analysis without much consideration of its consequence on policy. Indeed, welfare cannot be maximized, if the rate of R&D subsidy, which would restore Pareto optimum in steady state, is myopically applied to a fluctuating economy. We establish that an optimal R&D policy in the presence of cycles must be

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[1] It is important to note that steady state and endogenous cycles considered in this paper are two different types of *long-run* equilibria. We do not consider transitional dynamics for the reasons given in footnote 3.

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contingent on the state of the economy. That is, the rate of R&D subsidy must alter in response to the number of R&D workers which change over cycles.

At least two issues compel us to take a skeptical view of steady-state normative analysis. First, many studies on nonlinear dynamics demonstrate that endogenous cycles can arise as long-run equilibria. In fact, endogenous cycles are one of leading explanations for persistent GDP fluctuation.[2] Second, data show that total R&D expenditure exhibits procyclicality in the U.S. Moreover, growth in applied R&D expenditure in the U.S. is more volatile than growth in the real GDP (see Fatas, 2000). It is also well known that TFP growth follows persistent cycles, which are considered as major driving forces of business cycles in Real Business Cycle theory. Given these considerations, it is imperative to examine whether optimal steady-state R&D policy is robust to the existence of cycles.

To clarify the objectives of this paper, let us briefly summarize five questions posed in the following pages and the answers offered.

Question 1. *Does a standard R&D-based model of growth exhibit cycles*? We attempt to answer this question, by introducing only one minimal modification into the (very) standard R&D-based model of Grossman and Helpman (1991, Chapter 3), namely the assumption of discrete time. One of the present paper's contributions is to show that the use of discrete time, albeit a trivial departure from the original model, allows us to detect endogenous cycles in the popular R&D-based growth model.[3]Indeed, the use of continuous time, as assumed by Grossman and Helpman, limits the possibility of complicated non-linear dynamics.[4]Our approach to generate endogenous cycles is also much simpler than the existing approaches to R&D-based models, all of which employ highly complicated mechanisms (e.g. Evans et al., 1999; Lloyd-Ellis, 1999). The use of discrete time allows us to highlight the existence of endogenous cycles in a much simpler way.

Question 2. *If cycles exist*, *are they inefficient*? *If so*, *in what sense*? Here we consider two concepts of efficiency, termed "global" and "local". We demonstrate that socially optimal equilibrium is necessarily steady state in the long run. This means that cycles in the market economy are due to market failures and reduce welfare. Cycles are therefore said to be *globally* inefficient in the sense that welfare is not maximized. As an alternative, we can examine the normative properties of cycles on the basis of local information around a given steady state in the market economy. Cycles are said to be *locally* inefficient, if welfare improves after steady state is imposed and the cycles are removed. This paper will show that welfare is strictly concave in a fluctuating variable (more precisely, manufacturing workers), hence cycles with a "small" variance are always locally inefficient.

Question 3. *To what extent are the R&D policy implications based on steady-state analysis relevant to a volatile economy*? Recall that under- or over-investment in R&D takes place in the market economy in the R&D-based models, hence R&D subsidies/taxes are required to restore Pareto optimum in steady state. Unsurprisingly, this approach is valid. But the result is somewhat less straightforward in cyclical equilibria for the following reasons. First, optimal policy from the steady-state perspective fails to eliminate cycles that exist at the outset. In fact, the policy magnifies the amplitude of existing cycles. Accordingly, optimal steady-state policy does not maximize welfare if cycles initially exist. Second, even in the absence of cycles, a policy intended to achieve an efficient steady-state allocation of resources can create cycles, which in turn prevent the maximization of welfare. The upshot is that normative results obtained in steady state are not robust to the stability of long-run equilibria. The possibility of cycles changes the effects and desirability of optimal steady-state R&D policy.

Question 4. *Does the policy to promote the average long-run growth in any way conflict with the policy to stabilize the economy*? Our analysis suggests that there are conflicts. Consider R&D subsidies again. Note that the policy generates greater R&D incentive, boosting long-run growth. As mentioned in the preceding paragraph, however, the policy also magnifies the amplitude of existing cycles or even creates cycles if they do not exist in the first place. Policymakers, therefore, face a trade-off between growth and macroeconomic stability (measured by the variance of growth).

Question 5. *What is an optimal R&D policy when cycles actually or potentially exist*? Optimal R&D policy in a volatile economy must tackle two problems, namely to eliminate (the possibility of) inefficient cycles and to restore efficient resource allocation. This paper will show that state-contingent R&D policy can deal with these problems simultaneously. In general, the optimal R&D subsidy must be large when relatively small amounts of resources are devoted to innovative activity, and vice versa, over cycles. Such policy rule stabilizes an economy by making cycles inconsistent with rational expectations. The absence of inefficient cycles enables the realization of socially optimal resource allocation in steady state.

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[2] See Brock and Dechert (1991) for deterministic cycles and Benhabib and Farmer (1999) for stochastic cycles. For R&D-based growth models, see Helpman and Trajtenberg (1998), Matsuyama (1999), Evans et al. (1999), Francois and Lloyd-Ellis (2003), Francois and Shi (1999), Drugeon and Wigniolle (1996), Deissenberg and Nyssen (1998), and Wälde (2005).

[3] Grossman and Helpman (1991, Chapter 3) show that their model does not exhibit transitional dynamics. This property remains in our discrete-time model. Therefore, analysis in the present paper concerns *long-run* equilibria. On the other hand, Arnold (2000) examines optimal R&D subsidy in transitional dynamics, using the model of Romer (1990).

[4] Cycles of arbitrary length can generally arise in one-dimensional difference equations, but not in one-dimensional differential equations. A cyclical equilibrium in differential equations requires at least two dimensions. Aperiodic cycles (i.e. "chaos") can arise in one-dimensional difference equations. For differential equations, a dimension of at least three is required for aperiodic equilibria.

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