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Clusters of invention, life cycle of technologies and endogenous growth

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Abstract

This paper combines learning-by-doing with R&D activity that can be directed to either the discovery of new technologies (inventions) or the improvement of the quality of machines without altering their underlying technology (innovations). By doing so, it establishes that learning-by-doing is an important determinant of the relative share of resources allocated to inventive versus innovative activities. The dynamics of the model generates endogenous economic growth driven by cycles of technological change, where the pattern and timing of technological improvements are consistent with the historical evidence: (a) inventions and innovations play complementary roles in expanding the technology frontier; (b) when inventions occur they tend to arrive in clusters; and (c) all new technologies go through a life cycle, during the early stages of which a discovery is followed by a period of rapid economic growth and innovation and the late stages of which dwindling innovations and slower growth set the stage for new discoveries.

JEL classification: I20; J24; O11; O31; O40

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1. Introduction

This paper presents an endogenous economic growth model which combines *learning-by-doing* with R&D activity that can generate two types of technological progress: *inventions* and *innovations*. The novelty of this approach lies in the fact that disembodied technological progress, in the form of learning-by-doing, is combined with differentiated R&D that can generate both major and minor embodied technological change.[1]

All types of technical advance embedded into this model have been shown to influence economic growth in the long run.[2] It is also well documented that technical progress is clustered and economic growth is cyclical—two aspects of economic development that are not readily explained. In existing related work, in which at least one type of technical progress is omitted, some additional mechanism related to the timing and nature of R&D activity is usually invoked in order to derive the episodic and cyclical features of development.[3] The theory advanced below identifies that the dynamic interplay between learning-by-doing and R&D incentives can by itself account for the clusters of innovative and inventive activity, and hence, the cycles of endogenous growth.

Furthermore, incorporating learning-by-doing into a model of directed R&D with major and minor technological breakthroughs helps to explain some other well-established empirical regularities. For instance, Tratjenberg (1989, 1990) documents that the societal welfare gains of product innovations follow an inverted-U shape pattern over time. Relying on the introduction of tomography scanners in the 1970s and the refinements introduced in later generation CAT scanners, he shows that the gains start high with the introduction of a first commercial application, rise further still during the early and medium stages (during which newer generation machines are introduced), and then decline rapidly in the final maturity phase. He concludes, "Such a pattern...may be accounted for by an initial phase of scale economies, promptly followed by the setting-in of sharply diminishing returns." As the model below will show, one can conjecture that the initial phase of scale economies kick starts with the invention of new technologies while the subsequent gains and declines in welfare can be ascribed to the roles of innovations and bounded learning-by-doing in total factor productivity. In addition, a model of directed R&D with two types of embodied technical change, such as the one below, would predict that the amount of innovative R&D activities relative to that of inventive activities would also follow an

[1]Hereafter, I define *inventions* to encompass all kinds of major discoveries or leaps up the quality ladder a la Grossman and Helpman (1991) and Aghion and Howitt (1992). And I define *innovations* as Schumpeterian improvements in machine or production-process quality–neither of which profoundly alter the underlying sophistication of existing technologies.

[2]For the role of learning-by-doing, Arrow (1962) and Lucas (1988), for models of invention, Romer (1990), Grossman–Helpman (1991), and Aghion–Howitt (1992), and for the effect of innovations on the process of technological change and growth, Schumpeter (1934) are some of the leading examples of relevant work.

[3]For specific references, see Section 2.