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1. Theory.

- **Empirical question.**

How learning-by–doing and technological innovation relations impact on the long-run growth?

My objective is to explore the relations between production and two different technological changes such as discrete innovation and learning-by–doing.

- **Why is this question important to research?**

Why should we be interested in impact of two different technological changes such as discrete innovation and continuous-improvement (e.g. learning-by–doing)?

Generally, growth models of technical change fall into two broad categories: On the one hand, there are *models of "innovation"* (see Romer [1990] and Grossman and Helpman [1991]), in which technical change is the outcome of costly and deliberate research aimed at the development of new technologies. These models make the surprising assumption that new technologies attain their full productive potential at the moment of their introduction and are, at that point in time, superior to the older technologies for which they substitute. But one may recognise that most products of research at the moment of their introduction in the production of goods may be broadly inferior to more mature technologies. On the other hand, there are *models of "learning-by-doing*" (see Arrow [1962] and Lucas [1988]), in which technical change is the by-product of experience gained in the production of goods. One of the most surprising features of some existing learning-by-doing models is the assumption that the potential productivity gains from learning are essentially unbounded. Intuitively, it seems reasonable to assume that the potential for learning in the production of any particular good, using any particular process, is in fact finite and bounded.

For these two reasons, we may study growth models, which integrate discrete innovation and continuous improvement. That is why from theoretical relevance, this question may lead to more explication of growth problems.

- **<u>What has been written on the question?</u>**

Young [1993] developed a model which emphasises the interdependence between innovation and learning-by-doing. Learning depends on innovation in that learning-by-doing is viewed as the exploration of the finite and bounded productive potential of invented technologies. At the same time, the profitability of costly innovation is dependent on learning in that costs of production depend on cumulative learning experience. He shows that the incentives to engage in research and/or the incentives to produce different goods are binding constrains on growth.

Parente [1994] developed a model of endogenous growth in which firms adopt more advanced technologies, and subsequent to these adoptions accumulate expertise in those technologies with a firm-specific learning-by-doing.

In accordance with Schumpeter's line of thought, Aghion and Howitt [1998, chapter 6] placed technological change at the heart of economic growth in their endogenous growth model. They introduce an important element of heterogeneity in the structure of innovative activity, namely the distinction between the fundamental innovative activity (e.g. R&D) and the secondary activity (e.g. learning-by–doing).

In reaction to the wave of endogenous growth models, Solow [1997] criticises these models, because they are based on an hypothesis of a constant elasticity of learning-by-doing (e.g. constant fixed at one unit), and this hypothesis leads to a constant returns to scale, which is a borderline case. That is why he considers that elasticity of learning-by-doing is variable, and he introduces discrete innovation in Arrow's learning-by-doing model [1962]. Solow's model

[1997] has the particularity to be an exogenous growth model combining innovation and continuous improvement (e.g. learning-by-doing).

- **What policy implications can we draw from this research?**

Policy for economic growth must pay attention to fundamental interconnections. How much of production growth is continuous improvement and how much is R&D-induced technological innovation? The answer to that question would certainly be relevant to policy decisions aimed at accelerating the productivity trend. Two options for growth–oriented policy appear: One is to aim for temporary increases in the growth rate by increasing investment, particularly human-capital investment through education and training. The second option is to seek higher growth rates on a long-term basis by increasing research-and-development expenditure.

That is why from a political relevance, this question may incite some economical policies, which encourage to investment in R&D and training.

2. Methodology.

- **Research design: Modelling.**

In Solow's model [1997], the continuous-improvement is determined by the cumulative investment, and discrete innovation occurs at a Poisson process with a constant arrival rate. The Poisson process assumes that discoveries of innovations in any pair of nonoverlapping intervals of time are statistically independent events. Although some discoveries are isolated, other open up a whole field and make a further cluster of innovations more likely. To describe that would require a more complicated stochastic process, but it would yield a much wider range of possible histories.

My objective is to endogenize one source of productivity gain that is the discrete innovation in the Solow's model [1997]. In fact, the arrival rate of innovation is obvious thing to model, and may be function on economic variables such as investment.

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