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Learning, scale effects, and (very) long-run growth ☆

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Abstract

We develop a tractable model of endogenous growth that emphasises learning and the relevance of assimilated knowledge (as opposed to frontier knowledge) in research. The model is able to limit the scope of (level) scale effects, without degenerating into a model of "semi-endogenous" growth. We reassert the long-run potency of government policies that promote thrift, training, R&D and enhancement of productivity. We also show the relevance of learning for growth in the very long run, and its potential in accounting for the transition from stagnation to the secular growth of the industrial era.

JEL classification: O110; O310; O400

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1. Introduction

A central feature of endogenous growth models is their account of purposeful R&D by firms seeking to reap the rents arising from exploiting the patented inventions. Whether used for variety-enhancing "horizontal" differentiation (as in the vintage model of Romer, 1987, 1990), or for quality-enhancing "vertical" differentiation (Grossman and Helpman, 1991; Aghion and Howitt, 1992), or finally in models that combine both (Howitt, 1999; Young, 1998), R&D and technological invention are the main engines of growth. In placing this emphasis, most of the literature implicitly assumes that all the technological improvements can be instantly assimilated and fully exploited. Yet, as Young (1993) and Mokyr (2005) convincingly argue, economic history around the globe gives us ample instances of

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technological inventions that reached their full potential with a great delay, or in some cases never in their places of origin.[1,2]

A common feature of all of these models is the focus on the role, nature and degree of research spillovers. Because the product of researcher can be utilised infinitely many times at zero extra cost, R&D models typically give rise to a "scale effect", whereby a measure of the scale of the economy affects (or even completely determines) the *rate of growth* of an economy. The idea that an economy's size may be among the primary determinants of its growth rate is rather disquieting, and has given rise to a fair amount of research effort which cannot be summarised here; an overview of empirical evidence and theoretical arguments is given in Jones (1999, 2005); Dinopoulos and Sener (2006); Eicher and Turnovsky (1999) for more abstract two-sector models; and a longer version of this paper, Tsoukis and Miller (2006). In avoiding such scale effects, many models have resorted to "semi-endogenous" growth, in which population growth is the only determinant of growth, which may arguably be a no more desirable situation than the original scale effects. Yet others pursue different insights, without however appearing as yet to give rise to any common ground.

The empirical evidence is also not clear-cut. Jones (1995) strongly disputes the existence of scale effects, Zachariadis (2003) is also against them, yet Kremer (1993) offers evidence in support of them, Barro and Sala-i-Martin (1995, 1999, Tables 1 2 and 3, col. 17) offers very weak but positive support, while Backus et al. (1992) is also not conclusive.[3] On the theoretical level, there are similar ambiguities, e.g. over what is the appropriate scale effect; for example, it is possible that the scale variable does not relate to measures of scale at the country level but to the world, as in Kremer (1993). Such ambiguities imply that it is difficult to correctly identify and interpret scale effects in empirical work. Hence, the debate does not seem to be closed, either on theoretical or empirical grounds; furthermore, there are reasonable intuitive and empirical reasons to argue that a weak scale effect must not be excluded from models of growth.

In this paper, we offer a simple formal framework for understanding learning, its interactions with research, its implications for scale effects and growth. In particular, we show that learning is an important element in understanding not only the steady state, but also what may be termed "the great transition", issue. To be precise, by "learning", we mean the gradual familiarisation with the available technology and techniques; thus, only gradually do the latter reach their potential in aiding production.[4] The paper is motivated by the observation that new technology emerges all the time, so producers always lag behind in digesting what is available, and an equilibrium degree of familiarisation with the state-of-the art technology emerges; we call this (the degree of) "learning". Examples of this abound in every day life: New gadgets and software (phones, faxes, DVD players, MP3s; new IT software; and so on) emerge all the time, and as a result, the average degree of familiarisation with them is less than ideal.

The paper adds to our understanding of endogenous growth in various ways. Firstly, it goes towards re-establishing the concept of learning in the endogenous growth literature. In particular, our model emphasises the interaction between the two and the joint externalities in research by assuming that learning raises the expected profitability of research (by speeding up the rate of assimilation of new products) and lowers the cost of research; in turn, new research

[1] Economic historians have generated an exciting body of literature on the interplay between knowledge, technology and industrialisation. A nice starting point is Mokyr (2000), who illustrates the importance of knowledge and makes the distinction between "useful knowledge" and "techniques", or "*episteme*" and "*techne*". The distinction is well epitomised by Denis Diderot cited at the heading of this paper: "[…] Every 'art' (technique) has its speculative and practical side. Its speculation is the theoretical knowledge of the principles of the technique; its practice is but the habitual and instinctive application of these principles (from an article on 'Arts' in the *Encyclopedie*)". Mokyr (2000) points out the complex (but importantly: two-way) interactions between them and argues that, while the British Industrial Revolution owed little directly to scientific knowledge (contrary to the consensus, see p. 14), it roughly coincided with expansion of both sets and a strengthening of interactions between them. Mokyr (2005) further elaborates on the distinction between technique, and theoretical or scientific advances; while the former (many examples from the Industrial Revolution are available) did require a measure of practical knowledge and awareness, the latter were only seriously developed after the first and second waves of the Industrial Revolution. More generally, Mokyr (2005) seems to suggest a "ladder", at one end of which is pure practical application (what he calls "competence"), in the middle is the curiosity-driven practical skills of the mechanic–inventor, and at the other extreme lies high brow theory.

[2] Felipe (1999) is not miles away from this idea when he sums up his review of East Asian total factor productivity growth with the conclusion that "to represent innovation processes as linear and science-driven is inaccurate".

[3] At an informal level, one must ultimately ascribe the drive towards greater integration and globalisation in the world economy (including EU integration) to the desire to benefit from a larger scale.

[4] Our two key notions of "knowledge" and "learning".(or assimilation) correspond fairly well to Mokyr's (2005) distinction between theoretical vs. practical skills if it is understood that practical application, or learning-by-doing gives rise to the latter. On the other hand, theoretical skills or knowledge are identified with state-of-the-art technology; the two jointly influence research.