ELSEVIER

Journal of Economic Behavior & Organization
Vol. 46 (2001) 39–55

JOURNAL OF
Economic Behavior
& Organization

www.elsevier.com/locate/econbase

On endogenous growth and increasing returns: modeling learning-by-doing and the division of labor

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Received 10 August 1999; received in revised form 10 November 2000; accepted 18 November 2000

Abstract

This paper discusses those sources of endogenous growth arising from *labor as labor*. It uses a production function which models the returns to scale as a function of the division of labor and learning. Smithian analysis of the labor process constitutes the basis upon which we build our own approach.

JEL classification: D24; J24; O41

Keywords: Endogenous growth; Returns to scale; Division of labor; Learning-by-doing

1. Introduction

Endogenous growth has become a widely used term, but different authors have used it to mean different things. Sometimes, it has been used synonymously with increasing returns to scale, at other times it has been used to describe endogenously created technological change, which in turn leads to increasing returns. The processes involve various explanations of the roles of human capital and R&D. All of them basically concentrate on a factor that can be accumulated; that is capital in a broad sense. As Mankiw has put it:

> [C]apital is a much broader concept than is suggested by the national income accounts. In the national income accounts, capital income includes only the return to *physical*

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0167-2681/01/$ – see front matter
PII: S0167-2681(01)00186-X

> *capital*... More generally, however, we accumulate capital whenever we forgo consumption today in order to produce more income tomorrow. In this sense, one of the most important forms of capital accumulation is the acquisition of skills. Such human capital includes both schooling and on-the-job-training (Mankiw, 1995, p. 293).

The role of capital, broadly defined, has been carefully examined in the context of endogenous growth. Indeed, it explains a good deal of endogenous growth. In the present work, however, we look at the sources of endogenous growth in *labor* rather than capital. That is, we will highlight the role of labor in a narrow sense by deliberately avoiding issues related to human capital. In this context, we can identify two sources of increasing returns to scale: the division of labor and learning-by-doing. Both these phenomena have been recognized as important since Adam Smith (1776), and have been repeatedly referred to by many authors, from Young to Arrow and others.

Our perspective is microeconomic and we will refer to those forms of division of labor and learning-by-doing which can be developed within a given firm or organization. It is worth remembering that there may be a trade-off between the exploitation of the available knowledge and the need for expanding and modifying that knowledge (Marengo, 1993), and that dynamic capabilities are necessary to cope with the shifting character of the markets (Teece and Pisano, 1994).

The mechanisms which will be referred to later in this work belong in the ones which contribute to extract as much as possible from a given body of knowledge [3], and this helps explain why, in such a context, neither the division of labor nor learning-by-doing can go on forever. The paper is organized as follows: Section 2 considers Arrow's analysis of learning-by-doing and points out some difficulties which arise from it; Section 3 contains the analysis and the model that we propose in order to deal with increasing returns to scale — we use a production function in which labor is the only variable; Section 4 illustrates the analytical properties of the mapping obtained in the previous section; Section 5 contains a maximization exercise characterized by our production function and a context in which wages are constant, while price decreases; finally, Section 6 contains the conclusions.

2. Arrow's analysis

In 1962, Arrow published his famous article on 'The economic implications of learning-by-doing'. His explicitly declared aim was to suggest an "*endogenous* theory of the changes in knowledge which underlie intertemporal and international shifts in production functions" (Arrow, 1962, p. 155, emphasis added). He made use of an aggregate production function in which both capital and labor were used, taking as a starting point examples found in both economic and technical literature.

The examples he uses, in which learning has occurred, and on which firms' managers can rely, include the production of particular types of airframe and the so-called "Horndal effect" observed by Lundberg in the Horndal iron works in Sweden. In the former case Arrow reports T.P. Wright's study, whose main result was that "the number of labor-hours expended in the production of an airframe... is a decreasing function of the total number of

[3] For an analysis of the firm as a knowledge-creating entity see Nonaka et al. (2000).