Technological Forecasting & Social Change 76 (2009) 433–446

Contents lists available at ScienceDirect

Technological Forecasting & Social Change

What is the optimal rate of R&D investment to maximize productivity growth?

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ARTICLE INFO

Article history:
Received 2 August 2007
Revised 5 February 2008
Accepted 25 February 2008

JEL Codes:
E60
H50
O40
O57

Keywords:
R&D investment
Productivity growth
Optimization

ABSTRACT

Governments in modern economies devote much policy attention to enhancing productivity and continue to emphasize its drivers such as investment in R&D. This paper analyzes the relationship between productivity growth and levels of R&D investments. The econometric analysis shows that more than 65 per cent of productivity growth variance is due to its dependence on gross domestic expenditure on R&D expressed as percentage of GDP (GERD). Economic analysis shows that *productivity growth=f(GERD)* is a concave function downwards due to diminishing returns to research investments. In addition, the research shows that the range of GERD between 2.3 per cent and 2.6 per cent maximizes the long-run impact on productivity growth and it is the key to sustained productivity and technology improvements that are becoming more and more necessary to modern economic growth.

1. Introduction

Scientific research today absorbs very considerable resource since it increases technological progress [1] and productivity growth [2] that have a central role as engines of economic growth in modern economies [3]. In fact, post-war growth, it is argued, was largely based on capital accumulation, while what is needed now for countries to shift towards the growth based on Research and Development (R&D) investments and innovation, which have a great influence on firms and countries to increase their competitive advantage [4]. Policy makers devote much attention to enhancing productivity and emphasize its drivers such as R&D investments but in order to put effective economic and industrial policies into practice, they must have satisfactory answer to the following question:

> what is the optimal amount of R&D investments that maximizes the productivity growth in the long run?

This economic problem has spawned a large theoretical and empirical literature [1,3,5,6,7]. However, theory alone is unable to provide an answer to optimal magnitude of R&D investment to boost productivity and economic growth. The purpose of this research is to analyze empirically the relation between levels of R&D investment and productivity growth which can both steer national decisions about economic policies in the right direction and improve the governments' ability in facilitating the process that leads to long run increases in the wealth of nations, as driven by accumulation and effective employment of knowledge and technologies [8]. Before discussing the main economic problem, let me introduce the theoretical framework and methodology of research.

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0040-1625/$ – see front matter
doi:10.1016/j.techfore.2008.02.008

2. Literature review

The current economic and political debate revolves around the understanding of the causes of certain countries' economic success, based on strategic drivers that should be triggered in order to increase economic growth in modern economies [9–12]. Patterns of economic growth involve the analysis and assessment of productivity[1]. Mayhew and Neely [2] describe productivity growth as stemming either from gains in static efficiency or gains in dynamic efficiency[2]. Since productivity growth plays a main role in increasing Gross Domestic Product (GDP), it is important to understand the factors underlying productivity growth, even though quantifying their importance is a difficult task. Much of the research that examines the relationship between some factors and productivity growth is limited to showing a correlation between productivity and variables that influence it, and does not determine the causality and magnitude.

There is a vast literature dealing with factors affecting productivity growth. Some of the factors that have recently been examined include managerial ability, technology and regulation [6]. UK government emphasizes the following five drivers of productivity growth: investment, innovation, skills, enterprise, and competition (Department of trade and industry-DTI [13]). Nelson [14] emphasizes the importance of technological change in firm productivity growth. Lichtenberg and Siegel [15], and Hall and Mairesse [5] documented the correlation between R&D and productivity. Amendola et al. [16] present well documented evidence that R&D has an important effect on productivity growth and also on competitiveness, whereas Hall [17] points out that R&D is often associated with product improvement. According to Brécard et al. [7], R&D produces its full effects on two forms of innovation: the aggregate productivity gains of factors and improvements in product quality.

New growth theory (in the Romer 1990 version [18]) introduces endogenous technological change (as a function of the level of human capital) into the Solow model. The first generation of this model considers the assumption of constant returns to technological knowledge and predicted that long run growth rate of an economy increases in the level of R&D inputs and thus larger economies should grow at higher rate [12]. Jones [19] finds that first-generation models of endogenous growth are inconsistent with empirical evidence for the USA and refuted the scale effect prediction. To solve the empirical problems associated with these models of economic growth, second-generation models of endogenous growth have been developed. In particular, economic literature offers two main approaches to remove scale effects: a) semi-endogenous theory of Jones, Kortum, and Segerstrom [19–21], which modifies the original theory by incorporating diminishing returns to the stock of knowledge in R&D. That is, as technology develops and becomes increasingly complex, sustained growth in R&D labour (and human capital such as share of researchers [22]) becomes necessary to maintain a given rate of Total Factor Productivity (TFP) growth. These models of economic growth have been motivated by graphical evidence of a decline in R&D productivity in the USA [23,24] and in the UK, Germany and France over 1970–1990 period [25]; b) fully endogenous Schumpeterian models of Aghion and Howitt, Dinopoulos and Thompson [26,27] maintains the assumption from the first-generation models of constant returns to technological knowledge, and assumes that as an economy grows, proliferation of product varieties reduces the effectiveness of R&D aimed at quality improvement, by causing it to be spread more thinly over a large number of different sectors. In addition, to ensure sustained TFP growth, R&D has to increase over time to counteract the increasing range of products that lowers the productivity effects of R&D activity. The theory is consistent with the observed coexistence of stationary TFP growth and growing R&D labour. Therefore R&D leads simultaneously to an increase in GDP and in the use of factors. In fact, Aghion and Howitt [26] recognise this by noting that “technological knowledge is itself a kind of capital good and it can be accumulated through R&D”.

Griffith et al. [1] argue that innovation and technology transfer provide two potential sources of productivity growth for countries behind technological frontier. They examine whether R&D has a direct effect on TFP growth (innovation) in a panel of industries across twelve OECD[3] countries. They state that the greater the potential for technologies to be transferred through R&D, the higher will be the rates of productivity growth. R&D contributes to TFP not only through innovation but also through technology transfer. These scholars argue that R&D has played a role in the convergence of TFP magnitudes within industries across OECD countries. The growth impact of R&D has also received considerable attention within the context of spillovers [28]. Grossman and Helpman [12] show that cross-country R&D spillovers are an important source of productivity growth. A consensus has emerged around the fact that R&D contributes significantly to cross-sectional variation in productivity. Hall [17] reports the elasticity in the range of 0.10 to 0.15, whereas Griliches [29] reports an estimated elasticity of output with respect to R&D capital of between 0.06 and 0.10. The impact of R&D on productivity assessed from a macroeconomic perspective is analyzed by Jones and Williams [3] that formalize a model similar to that of Romer [18]. They calibrate the model and estimate that optimal investment in R&D is two to four times larger than actual investment in the United States. In addition, Aghion and Howitt [26] argue that own-

[1] *Productivity* measures the ratio of outputs to inputs. Labour productivity is defined as ‘real’ (constant price) output divided by labour inputs (measured in terms of persons or hours). *Multi-Factor Productivity* (MFP) represents the residual portion of output growth that cannot be explained by changes in labour and capital. MFP growth is labour productivity growth minus the effect on productivity of change in the capital-labour ratio (usually more capital per worker, or in other words, capital deepening). MFP growth in the long-run is explained by factors such as technological progress, rising education standards and changes in the socioeconomic environment. In some of the literature MFP is referred to as Total Factor Productivity (TFP). *Capital deepening* measures the increase in the value of capital per worker. As capital deepening is measured in volume terms, it also captures the effect of falling Information and Communication Technology (ICT) prices on labour productivity growth. *Growth accounting* refers to the disaggregation of labour productivity growth into components, such as MFP growth, the effect of capital deepening and in some studies also the effect of rising education level.

[2] *Static efficiency* is equivalent to use existing factors of production as effectively as possible. This can be achieved by measures to make markets operate more competitively and efficiently. *Dynamic efficiency* is all about the investment. R&D Investment in knowledge, if translated into organizational operations, allows labour and capital to be put to more productive use.

[3] Organisation for Economic Co-operation and Development.