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Aggregate returns to scale and embodied technical change: theory and measurement using stock market data ☆

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Abstract

We develop a new general equilibrium growth accounting framework that features increasing returns to scale, imperfect competition and incorporates technological revolutions into the description of technical progress. We propose a way to tell apart revolutionary changes in technology and incremental innovations using stock market data. We use our framework to jointly estimate the overall embodied TFP change during 1953–1995 and the aggregate output elasticity. We find that the IT revolution raised the aggregate TFP level by about 20%. We suggest a 1.09–1.11 range for the aggregate returns to scale.

JEL classification: E44; O3; O41; O47

Keywords: Embodied technological change; Technological revolutions; Aggregate returns to scale; Productivity analysis

1. Introduction

Economic history provides a number of examples of progress resulting from inventions that transform production (Landes, 1969; Rosenberg, 1982; Mokyr,

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1990). Many commentators characterize the recent information technology revolution as such a transforming change. This paper develops a new general equilibrium growth accounting framework with embodied technical progress that can incorporate technological revolutions as well as continuous change and also features increasing returns to scale and imperfect competition. Using data on stock market values, financial rates of return, input and output quantities, and investment good prices, we attempt to estimate the degree of aggregate returns to scale in the U.S. economy and the relative importance of incremental progress and technological revolutions in the last 50 years.

Following Solow (1960) and more recent work of Hulten (1992), Greenwood et al. (1997), Greenwood and Jovanovic (2001), and others, this paper assumes that new capital goods embody technological change. Although invention comes for free, the economy must invest in new physical capital and applied knowledge in order for a new technology to enhance production. Given the process for the basic technology, our general equilibrium framework determines time paths of prices and quantities.

Despite the complexity of our model, the aggregate properties and, surprisingly, the simple equation of motion of Solow (1960) carry over. This makes it straightforward to use our model as a general equilibrium growth accounting framework. The model has three elements distinct from Solow's (1960) analysis: (1) we incorporate drastic technological innovations into the description of technological change; (2) we generalize the notion of capital to include intangible stocks of applied knowledge as well as physical plant and equipment; and, (3) we allow the possibility of increasing returns to scale. The first new element makes our framework potentially consistent with the popular idea that the U.S. economy underwent a profound change due to the IT revolution, and it relates transforming changes to low frequency stock market cycles. The second element allows our model to match recent large discrepancies between the market value of businesses and the production cost of their physical capital (see, for example, Hall, 2001; Laitner and Stolyarov, 2003). The third element enables us to derive new estimates of aggregate returns to scale and to identify separately the contribution of input accumulation to growth.

Our work links to three different literatures on productivity analysis, technological change, and growth. First, this paper is related to the productivity analysis literature based on general equilibrium models of embodiment, such as Greenwood et al. (1997), Gort et al. (1999), and Greenwood and Jovanovic (2001). From a theoretical perspective, our model differs from existing models of embodiment in the three ways mentioned above. Also, we use a calibration procedure that matches the time paths of macroeconomic variables rather than just the variables' long-run average values. Lastly, we bring stock market and financial rate of return data into the analysis.

Second, our model relates to the literature on general purpose technologies (GPT), particularly Helpman and Trajtenberg (1998) and Howitt (1998). The GPT literature explicitly models the invention process that generates endogenous growth. We instead take the process for basic technology to be exogenous, and focus on setting up the production sector in a way that is suitable for bringing our model to data.