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Analysis of transition dynamics caused by technological breakthroughs: Cause of productivity slowdown and drop in existing firms' stock prices☆

Kazuyoshi Ohki *

Graduate School of Economics, Osaka University, 1-7, Machikaneyama, Toyonaka, Osaka 560-0043, Japan

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ABSTRACT

This paper examines the transition dynamics caused by technological breakthroughs. Our results show that technological breakthroughs cause a productivity slowdown and a drop in the stock prices of existing firms; these findings are consistent with observations in the 1970s. We explain how technological breakthroughs cause these phenomena. The emergence of a new technology creates new business opportunities, which reduces existing firms' profits, thus causing their stock prices to drop. This decline in existing firms' profits discourages R&D-intensive firms from entering the sector; this decreases aggregate R&D activity, and thus the growth rate of productivity declines.

1. Introduction

Since the beginning of the Industrial Revolution in Britain (1760–1850), we have witnessed a number of dramatic technological breakthroughs, which have had enormous and long-term impacts on economies. Schumpeter refers to these as Kondratieff cycles, caused by technological factors. For example, electrical technologies had a major influence between 1890 and 1930, and the impact of information technology (IT) during the second half of the 20th century was also important, which Bresnahan and Trajtenberg (1995) characterized as general purpose technology (GPT). These technologies created new markets that opened up new business opportunities, and induced a sequence of secondary augmented innovation, which is called as radical innovation in Henderson and Clark (1990), Meyer et al. (1990) and Herbig (1994). For example, household electrical appliance manufacturers and electric power companies both arose as a consequence of electricity, and now continue to improve the quality of their products to sustain consumer demand. Similarly, PC manufacturers, software companies and Internet service providers were set up following the emergence of IT. These companies also continually improve the quality of their products.

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* Tel.: +81 8014294979.
E-mail address: kazuyoshi.ohki@gmail.com

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The purpose of this paper is to analyze the transition from the emergence of a new technology to its maturity. In particular, we consider the growth rate of productivity, the stock price of incumbents in the preexisting sector and aggregate stock price. Jovanovic and Rousseau (2005) present evidence that, following the emergence of a new and transforming technology, the growth rate of productivity declines for some decades, after which it begins to rise again. Indeed, the productivity slowdown is now recognized as a stylized fact. Our model describes these changes and shows that the slowdown is caused by declining R&D in existing technology. Greenwood and Jovanovic (1999) present evidence that, upon the arrival of a new technology, existing firms' stock prices fall, never to recover. They also show that several years after the emergence of a new technology, aggregate stock prices rise because of the rise of the prices of the stock of new firms exploiting the new technology. Our model describes these facts and shows that the decline in the stock prices of existing firms is caused by the decline in their profits, while the aggregate stock price rises with the new sector's maturity.

The model is the extension of Segerstrom (1998), which is a quality-ladder R&D model, freed from scale effects by assuming that the difficulty of R&D increases as R&D accumulates.[1] His model is a semi-endogenous growth model, where the long-run growth rate is never influenced by political variables or preferences. More recently, the short-run effects in semi-endogenous growth models have received more attention. Steger (2003) found that the speed of convergence in Segerstrom (1998) was only 0.019, which means that it takes about 38 years for half the initial gap to vanish (this is a very long time!). Therefore, analyzing the transition dynamics is very important. In this paper, we examine the technological cycle by analyzing the transition dynamics of an extended Segerstrom (1998) model, which has very long transition dynamics.

In this paper, we expand Segerstrom (1998) by introducing heterogeneity across sectors in four ways: efficiency, difficulty and cost of R&D, and market size.[2] This extension enables the model to simultaneously analyze both the "old sector" and the "new sector", where the old sector has low R&D costs and a high difficulty of R&D, and the new sector has high R&D costs but a low difficulty of R&D. We examine the process caused by a technological breakthrough to analyze the transition dynamics from the existing old-sector equilibrium alone to the equilibrium of both the old and new sectors.

Consider the following situation. At stage 1, there exists only an "old sector" with a continuum of products. At the beginning of stage 2, an exogenous unexpected technological breakthrough occurs, leading to emergence of a "new sector" with a continuum of products. The initial cost of R&D in the new sector is high enough that no R&D is conducted in this new sector. Stage 3 is reached later, when another exogenous unexpected shock occurs, which drastically reduces the cost of R&D in the new sector. Then R&D activity begins to be conducted in new sector. This paper examines how economically important variables such as the growth rate of productivity and stock prices respond to these two enormous exogenous shocks.[3,4]

Some stage 2 results are consistent with empirical facts. First, the growth rate of productivity declines. New technology creates new business opportunities, thus forming the new sector, which captures market share from old-sector firms, thus causing their profits to decrease. This decreases the incentive to enter the old sector, reducing R&D in the old sector. Thus, the instantaneous probability of successful R&D in the old sector decreases. On the other hand, R&D is not being conducted in the new sector because of the very high cost of R&D. Therefore, aggregate R&D decreases, which leads to a decrease in the aggregate probability of successful R&D. Because the growth rate of productivity is calculated as the weighted sum of probabilities of successful R&D, this reduces growth rate of productivity. Second, old-sector incumbents' stock prices decrease because their discounted stream of profits has decreased.

Stage 3 results are also consistent with empirical facts. First, the growth rate of productivity rises. Several years after a new technology is born, the cost of R&D falls. Aggressive R&D activity then begins in the new sector, which dominates the effect of the decline of R&D activity conducted in the old sector. Therefore, aggregate R&D increases, which leads to an increase in the aggregate probability of successful R&D, and the growth rate of productivity rises. Second, old-sector incumbents' stock prices remain low. Because old-sector market share does not change between stages 2 and 3, the discounted profits of old-sector incumbents remain small and hence their stock prices remain low. Third, the aggregate stock price rises when we include the new-sector firms, which were created in response to the new technology. As the new technology matures, the status of new-sector firms stabilizes, raising their discounted profits. Hence, new-sector firms' stock prices rise, dominating the decline of old-sector incumbents' stock prices. Therefore, the aggregate stock price rises.

The contributions of this paper are as follows. First, we explain the transition of economically important variables such as growth rate of productivity and stock price that is observed empirically using a typical R&D growth model. Second, we construct a quality-ladder R&D model with ex ante heterogeneity (efficiency, difficulty and cost of R&D, and market share differences across sectors evaluated before R&D is conducted). The recent literature examines quality-ladder R&D models with ex post heterogeneity (efficiency of product technology, degree of increment quality, shadow price and profits differ across firms

[1] Aghion and Howitt (1992), Grossman and Helpman (1991) and Romer (1990) pioneered these R&D models.

[2] Smulders and van de Klundert (1995), Startz (1998), Li (2000), Boucekkine and de la Croix (2003), Doi and Mino (2005) and Chu (2011) have investigated growth models with multiple sectors.

[3] By assuming that R&D cost decreases due to learning by doing, we can extend the model so that the time of initial new-sector R&D investment is determined endogenously; however, including these would complicate the model significantly and so is left for further research.

[4] Kuwahara (2013) studies growth model with the regime change from no R&D regime to with R&D regime.