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Investment in vintage capital ☆

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Abstract

We study an economy in which firms use labor and various vintages of capital in a CES production function for the final good. We explicitly solve for the investment in capital of a given vintage as a function of its age, and for the resulting stocks of capital. We show that for reasonable parameter values, inverted-U-shaped dynamics of investment and S-shaped dynamics for capital arise in equilibrium. We view the model as an explanation of intra-firm adoption lags, i.e., the observation that firms adopt innovations over time and not instantaneously.

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1. Introduction

This volume is a welcome occasion to recall the contributions that David Cass made to the analysis of economies with heterogeneous capital. Growth models that feature many types of capital come in two forms: The putty-clay model of Johansen [24] and Arrow [2] and the vintage-capital model of Solow [39]. The models are often lumped together because they all have the feature that once a machine is constructed, its production characteristics – as described by the

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machine's labor-input requirement, or by the number of its efficiency units – are fixed and cannot be changed *ex post*. The difference, however, is that the putty-clay models endogenize the quality of capital; in this sense they are models of endogenous technological change.

Cass and Stiglitz [9] construct a putty-clay model in which technological change is endogenous. In their model labor-intensive capital is cheaper to build. In the initial stages when capital of any type is scarce, firms invest in such technology. Over time capital labor ratio grows, and with it the equilibrium wage, and firms find it optimal to invest in more capital-intensive technology. Moreover, as the wage rises, the old labor-intensive capital is scrapped. The authors analyze the perfect-foresight equilibrium that features rich transitional dynamics. The analysis has a thoroughly modern feel to it, and with minor modifications of the model, the technological change could be made to persist even in the long run.

The present paper is motivated the observation that all the models discussed above including the Cass and Stiglitz [9] model entail no interaction in production among capital of different vintages. All investment flows into capital of the latest vintage, and none into any earlier vintage. A second generation of vintage-capital models such as Domar [16], Jorgenson [30], Greenwood, Hercowitz and Krusell [19], Xepapadeas and de Zeeuw [42], and Goetz, Hritonenko and Yatsenko [18] assumes that while capital of different vintages can participate in the same production process, the elasticity of substitution in production between capital of different vintages is infinite so that, again, all investment is in the latest-vintage capital where the efficiency of investment is highest.

The implication that all investment should flow into capital of the latest vintage is in conflict with experience. Old structures are refurbished, old machines are repaired, old workers are retrained. In other words, firms invest in old capital while also investing in new, more efficient capital. Evidently, old and new capitals interact and the productivity of one depends on the quantity of the other.

In this paper we study an economy in which firms face a CES production function whose inputs are labor and different vintages of capital. Ethier [17] introduced a production function that was an aggregate of intermediate goods, and one that has been used in growth models by Romer [38] and others. We suppose that some of these goods are durable, and that they are invented at different dates. That is, the heterogeneous durable goods are capital of different types, and the capital is of various vintages.

Such a production function has been estimated at various levels of aggregation. At the industry level, Boddy and Gort [6] estimate a production function that includes equipment and structures the average ages of which differ. At the firm level, Colombo and Mosconi [12] study the gradual adoption of various flexible-production and design-engineering technologies in the Italian metalworking industry, emphasizing that the technologies are complementary, that they are embodied in capital, and that they entail productivity growth as a result of learning by using.

Our model explains the staggered adoption of new technologies by firms, i.e., the fact that a firm usually adopts an innovation over time, not instantaneously. This phenomenon is sometimes referred to as *intra*-firm diffusion lags. It was first documented systematically by Mansfield [33, Table 1], who found that in the U.S. railroad industry, the time interval between 10 and 90% usage of diesel locomotives ranged from three to more than 14 years for firms in the U.S. railroad industry, with the median delay of 8–10 years. Similar within-firm delays occur in ten other U.S. industries by Romeo [37, Table 4]. Within firm adoption also tends to follow an S shape [23], with a firm's rate of spending on the technology in question peaks some years after investment in it begins.