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Optimal learning and new technology bubbles ☆

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Abstract

It is widely believed that there is a fundamental linkage between major technological innovations, speculative fever, and wasteful overinvestment. This paper presents an equilibrium model of investment in a new industry, whose return-to-scale is not known in advance. Overinvestment relative to the full-information case is then optimal as the most efficient way to learn about the new technology. Moreover, the initial overinvestment is accompanied by apparently inflated stock prices and apparently negative expected excess returns in the new industry, which are also fully rational. This suggests a new interpretation of what seems to be stock market driven real bubbles.

JEL classification: G12; D8

Keywords: Adaptive control; Investment; New technology; Bubbles; Learning

> *Every previous technological revolution has created a speculative bubble, and there is no reason why IT should be different.*
>
> Economist, 2000

1. Introduction

It has recently become widely believed that technological breakthroughs inevitably entail economic excess. The pattern of the recent IT-driven boom and bust has led many

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commentators and historians to note parallels with earlier technological revolutions—railroads, canals, electric power—which ignited a burst of apparent overbuilding by, and apparent overvaluation of, innovating firms.[1] These rapid expansions were all followed by longer adjustment phases during which the initial excesses were damped toward long-run equilibrium values. The description does not fit all waves of innovation or all financial bubbles. But the recurrence of the pattern does raise the question of what it is about the technological innovations that induced these dynamics.

From a business cycle perspective, such episodes are unusual for a number of reasons. In general, overinvestment in response to a technology shock, large or small, is not a feature of standard models. Likewise, the subsequent disinvestment—without any technological regress—is hard to explain as an optimizing policy. Moreover, these responses reverse the normal asymmetry in which sharp recessions are followed by gradual expansions. Similarly reversed is the usual pattern of investment seeming to respond too strongly to cash-flow and not strongly enough to Tobin's q. From an asset pricing perspective, any pattern of apparently predictable negative returns is also very difficult to explain.

This paper suggests one mechanism that can account for these facts. It studies the short-run equilibrium dynamics following the introduction of a new production technology in a standard equilibrium setting. In this context, I show that, when the return-to-scale of the new technology are not known *a priori*, optimal policies can feature both initial overshooting of real investment and predictable deflation in the price of claims to the new sector. This behavior is driven by the incentive to efficiently learn the curvature of the production function—and hence the optimal long-run scale of the new industry—about which agents are uncertain. Indeed, this particular type of uncertainty could be said to be the distinguishing feature of a truly revolutionary technology: there is no historical experience of how it will scale up. No one knows how the interplay of competition, regulation, and costs will work out at vastly greater levels of production than have ever been seen before.

In general, adaptive learning models can induce either caution or experimentation. In my formulation, agents have an incentive to push investment beyond the level that would seem optimal with full information in order to efficiently learn the shape of the production function. As experience grows, this incentive diminishes and investment declines. Market prices of installed capital mirror the gains to be had from learning. Tobin's q for the new industry starts high and then predictably subsides. The model is not intended as a general theory of booms and busts. Nor does it attempt to model either the evolution of the new technology or the process of its adoption.[2] Instead, the goal is to focus on the apparent overshooting of both real and financial quantities that seems to have characterized several important historical periods.

Given the enormous literature on financial bubbles and the still larger one on technology-driven business cycles, it is not surprising that alternative explanations for real bubbles already exist.

[1]See the surveys of Perez (2003) and Bordo (2003).

[2]Models of endogenous growth and "learning-by-doing" also incorporate learning into the optimizing decisions of agents (see Jovanovic, 1997). In contrast to the adaptive control approach, however, there learning is modeled as the accumulated output of a production function for "knowledge", not as the Bayesian evolution of a probability distribution.