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Energy saving technical progress and optimal capital stock: the role of embodiment

Raouf Boucekkine[a,]*, Aude Pommeret[b]

[a]IRES and CORE, Université Catholique de Louvain, Place Montesquieu, 3, Louvain-la-Neuve, B-1348, Belgium
[b]DEEP-HEC, Université de Lausanne, Lausanne 1015, Switzerland

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Abstract

We study optimal capital accumulation at the firm level when technical progress is energy saving. Energy and capital are complementary. First we solve a benchmark case with disembodied technical progress. Then, we turn to the model with embodiment. We characterize the optimal replacement of obsolete capital, and the optimal capital stock. The latter is shown to be lower under embodiment compared to the benchmark case. Moreover, we demonstrate that a rising energy price has two opposite effects on the optimal capital stock under embodiment: the traditional direct negative effects, but also an indirect positive effect via the optimal scrapping rule. Nevertheless, the optimal capital stock is shown to remain a decreasing function of the energy cost.

JEL classifications: E22; E32; O40; C63

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1. Introduction

It is widely admitted that rising oil prices have a negative impact on economic activity. Indeed, eight of the nine recessions experienced by the US economy after the World War II (until the early 1990s) were preceded by an increase in the oil

*Corresponding author. Tel.: +32-10-47-38-48; fax: +32-10-47-39-45.
E-mail addresses: boucekkine@ires.ucl.ac.be (R. Boucekkine), aude.pommeret@hec.unil.ch (A. Pommeret).

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price (see Brown and Yucel, 2001, for a survey, and Hamilton, 1983, for a seminal inspection into how the energy cost affected the US economy over this period). Obviously, this argument is not correct in the opposite direction, as the declining oil prices in the mid-1980s did not induce any expansion for example. However, the inverse relationship between the oil price and economic activity when the former is rising sounds as a robust empirical regularity. It suggested a number of theoretical contributions, especially after the first oil shock in 1973, which caused a dramatic slowdown in the economic activity of the major industrialized countries.

There are several explanations of the inverse relationship between oil prices and economic activity (see again Brown and Yucel, 2001, for a survey). Some invoke income transfers from oil importing countries to oil exporting countries; others are based on the monetary policy implemented after the oil shocks, etc. The most known (and accepted) explanation relies on a classic supply side effect: rising oil prices are indicative of the reduced availability of basic inputs to production. This concerns the energy input itself but also and specially, the capital input as advocated by Baily (1981). In particular, Baily argued that the productivity slowdown experienced by the US economy and the other industrialized countries after the first oil shock might well be due to a reduction in the utilization rate of capital, namely in the decrease of the effective stock of capital.

The keywords, said Baily, are embodied technological change, obsolescence of capital goods and the energy cost. Technical advances are typically embodied in the capital goods, implying that investment is the unique channel through which these innovations could be incorporated into the productive sectors. As a corollary, the old capital goods get less and less efficient over time, which might well induce the firms to scrap them (obsolescence). Therefore, the implications of embodied technical change are extremely different from those of the typical neutral and *disembodied* technological progress specifications adopted in the neoclassical theory. According to Baily, embodiment is behind the productivity slowdown. The rising energy cost following the first oil shock caused a massive capital obsolescence and a subsequent decline in capital services: '...Energy-inefficient vintages of capital will be utilized less intensively and scrapped earlier following a rise in energy prices'. Robert Gordon (1981), after recognizing that Baily's hypothesis is indeed highly attractive, pointed at the difficulty of its empirical validation in the macroeconomy (as measuring the utilization rate is rather hard for certain sectors, like the non-farm non-manufacturing sectors) and reported that in any case, it does not seem to be supported systematically by the evidence available from certain energy-consuming industries like the airline industry.

Our paper is devoted to the study of the supply side effect depicted above in the presence of **energy saving** technological progress. Indeed, there are two major departures with respect to Baily's setting. In the latter, obsolescence is simply modelled through a decreasing effective output (at a given constant rate) as capital ages, and there is no explicit scrapping decision (of the oldest capital goods). In our model, the scrapping decision is endogenous, and since we assume complementarity between capital and energy inputs, finite scrapping time is indeed optimal. Secondly, in Baily's set-up, embodied technological progress makes capital goods