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Electrification and productivity growth in Korean manufacturing plants

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ABSTRACT

This paper presents a theoretical model of firm-specific productivity growth that incorporates technological knowledge by electrification and tests the model empirically. Our theoretical explanations suggest that the energy-transformation from fossil fuel to electricity by electrification could cause a decrease in the short-term level of productivity but an increase in the long-term rate of productivity growth in firms. Our empirical evidence from a large panel of Korean manufacturing plants is generally consistent with the theoretical predictions on the relatedness of technological knowledge by the electrification to the level and rate effects of the firm's productivity. The electrification measured by the share of electricity results in lowering the short-term productivity level but in raising the long-term rate of productivity growth of firms.

1. Introduction

The share (weight) of electricity in the world's total energy consumption increased from 9.4% in 1973 to 17.7% in 2010 (International Energy Agency, 2012). The importance of electricity in the energy use is also evidenced in Korea. There has been a strong increase in electricity's share of total energy use for decades while fuel's share of total energy use in Korea has decreased (Fig. 1). For example, the share of electricity in total energy use in Korea grew from 7.2% in 1978 to 19.7% in 2010. The overall efficiency of energy use, as measured by GDP per total energy use, has also been persistently improving from 4.23[2] in 1978 to 5.38 in 2010. The improvement in the efficiency of energy use with the increase in electricity's share of total energy use plays an important role in the advancement of the production and hence it helps an economy grow. For example, in their study covering over 100 countries Ferguson et al. (2000) showed that electricity usage is highly associated with economic growth.

Since the work by Kraft and Kraft (1978) and Akarca and Long (1979, 1980), the causal relationship between energy consumption and output has been an important topic in energy economics. Most of these studies employed a neo-classical aggregate production model where the use of energy, in particular, the use of electricity, is treated as a separate input in production in addition to capital and labor inputs. However, causal examination of the relationship between electrical energy use and output has not reached a consensus on the direction of causality between the two because the results differ depending on approaches, time horizons and countries employed in the various empirical analyses (See Apergis and Payne (2011) for a detailed summary). Some empirical evidence is in favor of a positive effect of electrification on productivity while others are not. It is important to point out that empirical results are also affected by whether the analysis is based on short term or long term.

Apart from the causality issues, Schurr et al. (1983) and Jorgenson (1984) found that the electrification in the U.S. industry sector accounted for the rise in productivity and output. Schurr et al. (1990) also pointed out that the inter-relationships among electrification, productivity growth, and energy efficiency (Fig. 2). The electrification of plants and equipment has contributed to technological progress and helps account for the rising use of electricity relative to total energy. This technological progress has been a major factor supporting productivity and output growth. Productivity growth, in turn, has saved total input relative to output, including savings in energy input. The electrification and technological progress take place almost simultaneously and affect each other. The increase in electricity use by electrification and productivity gains by technological progress are linked to energy efficiency in the long run.

Several studies have explained the contribution of electrification to the improvement of productivity. For example, Berndt (1983) found that energy quality, specifically the electrification ratio in total energy, has had a positive and statistically significant impact on productivity growth in American manufacturing from 1958 to 1977, even though

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[2] The unit of value is one billion won per 1000 TOE.

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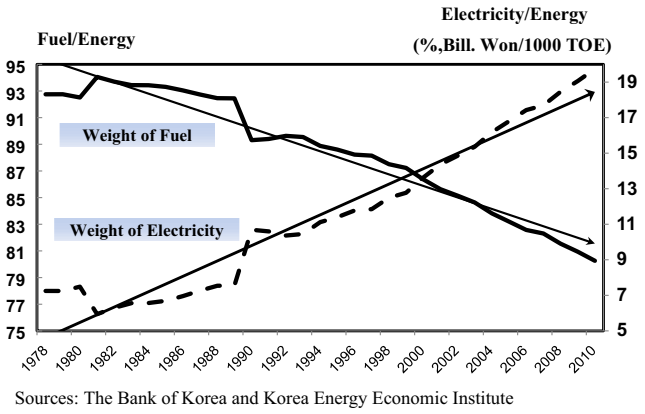


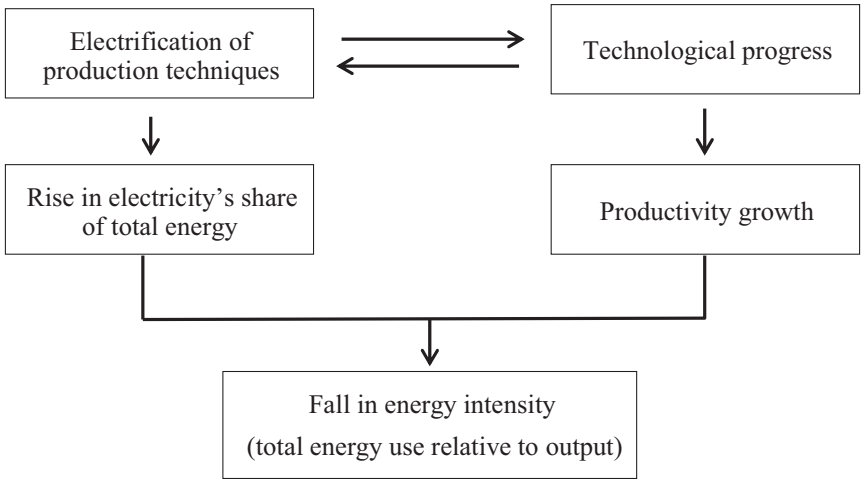
Fig. 1. The weight (share) comparison between fuel and electricity.
Sources: The Bank of Korea and Korea Energy Economic Institute.

this energy quality effect was found to be small for multi-factor productivity growth. Moreover, Berndt (1990) surveyed the most important aspects underlying the relationships among technical progress, productivity growth, and energy use. He found that the concepts of embodiment, diffusion, and learning are critical for understanding the forces linking energy use, technical progress, and productivity growth. Kahane and Squitieri (1987) and Schön (2000) argued that productivity and output growth depend on electrified production techniques, even though productivity and output growth will not necessarily require a proportional increase in electricity consumption. As a result, the evidence on the relationship between electrification and productivity is mixed. Stern (2011) also recognized energy as an important element of production and emphasized the role of a higher quality of energy, especially electricity, in improving productivities. He identified that when energy is scarce, it imposes a strong constraint on the economy's growth, and conversely, when energy is abundant, its effect on economic growth is reduced. In addition to the finding that the elasticity of the substitution of energy and capital is likely to be low, he emphasized that energy used per unit of output has declined in developed countries and in some developing countries because of both technological change and a shift from poor quality fuels to higher quality fuels, especially electricity. In particular, the improvement in energy efficiency in both developed and developing economies may be partly due to the shift to higher quality fuels and thus different energy qualities have differing levels of productivity.

The above studies, however, are limited in determining a clear relationship between electrification and productivity in that they analyzed the effect of electrification on economic growth aggregated data. To overcome this limitation, Doms and Dunne (1995) and Boyd and Pang (2000) employed plant-level data to examine the role of energy use in production. On the one hand, Doms and Dunne (1995) found that when using plant-level data plants using AMT (Advanced Manufacturing Technology) are less energy-intensive than plants not using AMT, although the former consume proportionately more electricity as an energy source. Additionally, older plants are generally more energy intensive and rely on fossil fuels to a greater extent than younger plants. The results by Doms and Dunne (1995) indicate that technology affects energy and electricity usage in a statistically and quantitatively critical manner. However, they are silent on the effects of electricity usage on productivity of plants. Boyd and Pang (2000) examined the link between productivity and energy efficiency, and tested this link empirically using plant-level data. They found that productivity differences are important determinants of energy efficiency and supported the proposition that energy intensity and productivity have at least a proportional link. However, their analysis does not explain the role of electrification in the advancement of technology even though they generally explain the relationship between energy efficiency and productivity, using plant-level data.

Moreover, the adoption of technical progress by electrification is not immediate. Schmidt (1987) asserted that the electrification of industry is a long-term process, occurring over decades and that the intensity, precision, and controllability of electrically-based processes become increasingly important factors in improving industrial productivity, lowering cost, and reducing energy consumption. Schön (2000) commented that productivity growth by electrification is resource-demanding in the short term but it depends on innovation in the long term. Goldfarb (2005) also argued that electrification as a general purpose technology could be delayed by the technical bottlenecks, but it could proceed rapidly upon finding solutions to particular technical problems.

In keeping with the analysis of electricity consumption and technology by Doms and Dunne (1995) and the study of productivity and energy efficiency by Boyd and Pang (2000) using U.S. manufacturing plant-level data, this research contributes to the literature by investigating the



Source: "Electricity in the American Economy", Schurr et al. (1990)

Fig. 2. Interrelationships among electrification, productivity growth, and energy efficiency.
Source: "Electricity in the American Economy", Schurr et al. (1990).