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Energy intensity and firm growth

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ABSTRACT

Using micro-level data, we attempt to identify the causal relationship between improvement (decline) in energy intensity and firm growth in six countries, namely, France, Germany, Japan, Korea, the U.K., and the U.S., and 21 manufacturing industries during the period 1991 to 2005. We run a panel regression of firm growth using the inverse of a country- and industry-specific relative energy intensity (REI) measure with the corresponding industrial sector in the reference case (the U.S. industry) in addition to the inverse of the traditional energy intensity measure (EI) after controlling several firm, industry, and country variables.

We find that EI and REI may have somewhat different impacts on firm growth in terms of profits and capital accumulation. When we control the heterogeneity in industrial dependence on energy, firm profits in the industry club with lower REI grow faster than the six-country average. Compared to the six country case, we find that the efficient use of energy inputs has made a smaller contribution to firm growth in Korea.

1. Introduction

The patterns of energy use vary with the phases of economic development. Several researchers have argued that the energy intensity of an economy resembles an inverted U-shape across increasing levels of per capita income, where energy intensity is defined as the quantity of energy consumed per unit of economic output (Medlock and Soligo, 2001). This argument could be based on inter-industry structural changes as well as variations in intra-industry energy efficiency improvements during the course of economic development. Specifically, industrialization at an early stage results in large increases in industrial energy use. Then, as economies move into the post-industrial phase of economic development, the service sector grows faster than the manufacturing sector and energy demand grows at a slower rate for given increases in the GDP. Conversely, more energy-efficient capital is deployed as technology advances, and the energy requirements for a given level of output decline, thus allowing economic activities to expand without much increase in energy demand, thereby falling energy intensity. For example, the trend in energy intensity for the U.S. from 1880 to 1920 was upward, while from 1920 to 2005, it was downward, thus indicating lower energy consumption units per capita income (Hunt and Evans 2011, p.93).[1]

Energy intensity is the most commonly used aggregate indicator of a nation's efficient energy uses, although there has been widespread criticism on using this simple ratio for this purpose.[2] Enhancing efficient energy use is one of the top priorities for economic growth during the post-industrial phase of economic development. More specifically, it has received growing attention as a key component of sustainable development. In almost all sectors in all countries, there are considerable gaps between what is being achieved and the economic potentials. Although there are considerable variations in the definition of efficient energy uses, it is clear that in all sectors of all economies, including industry, there is significant potential for improvements in the efficiency through utilization of existing technologies at rates of return which attract investment. For both academia and policy makers, therefore energy efficiency is considered one of the most important factors in strengthening industrial competitiveness and energy security as well as in tackling potential environmental risks associated with reducing CO_2 emissions (Metcalf, 2014; Oda et al., 2007).

This paper provides firm-level evidence for the effect of productive use patterns of energy on economic growth by industry. We attempt to estimate the impact of improvement (decline) in energy intensity

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[1] Wing (2008) argued that the main driver of the decline in the energy intensity of the U.S. economy during the period 1958–2000 was inter-industry structural change, whereas intra-industry efficiency improvements played a more important role in the post-1980 period.

[2] Lots of literature criticized to use energy intensity as a proxy for energy efficiency. Wilson et al. (1994), Patterson (1996), and Ang (2006) pointed out that energy intensity does not only measure the underlying technical energy efficiency, but also changes in industry structure and in energy for labor substitution, and in energy input mix. Proskuryakova and Kovalev (2015) discussed that the use of energy intensity can only provide indirect and delayed evidence of technological and engineering energy efficiency of energy conversion processes, which entails shortcomings for management and policymaking.

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at the industry-level on firm growth using firm-level data from 21 manufacturing industries and six countries, namely, France, Germany Japan, Korea, the U.K., and the U.S., from 1991 to 2005. Our primary goal is to test the hypothesis that firms in the industry club with low energy intensity grow faster than those in other industry clubs. The firm-industry level analysis allows us to avoid aggregation errors and achieve a deeper understanding on the mutually reinforcing relationship between energy use patterns and economic growth.

Firm-level growth is measured in terms of capital accumulation and operating profits (EBIT: earnings before interest and taxes; labeled profits). The firm-level data are obtained from the *Osiris* database, which provides firm-level information on balance sheets and income statements for publicly traded firms throughout the world. The sample includes 9344 firm-industry country-year observations. To calculate the industry-level energy intensity of the sample countries, we use the databases served by the EU KLEMS and IEA. Energy intensity is defined as the ratio of real energy uses (unit: tons of oil equivalent, toe) to real value added, where real energy use is obtained by using the EU KLEMS energy input volume indices to re-calculate IEA final energy consumption data in toe.[3]

The use of the traditional energy intensity (EI) at the industry-level overlooks the heterogeneity in industrial dependence on energy. Unless we control it, the contribution of improvement in energy intensity to the growth of energy-intensive industries may well be relatively larger than it is to the growth of other industries. For example, machinery and chemical industries require substantially more energy input to produce unit output and, thereby, can save significantly more energy input costs with a decline in energy intensity. In addition to using EI, we introduce a relative measure of energy intensity compared to the reference case; we term this relative energy intensity (REI). We have chosen the energy consumption structure of the U.S. industries as the reference because the relatively open, resource-abundant, and developed U.S. energy markets should allow the U.S. firms to face the fewest obstacles to using their desired energy consumption. Thus, the reference case indicates the amount of energy naturally demanded by technology.

We then run a panel regression of firm growth in terms of profits and capital accumulation on the inverse of energy intensity measures after controlling for several firm, industry, and country variables. We find that the EI and REI may have somewhat different impacts on firm growth in terms of profits and capital accumulation. According to the estimation results, firms in industry with low REI grow faster than firms in industry with high REI, whereas this finding does not hold with EI. In particular, the EI is sensitive to the bias from specific industry selection; e.g., there has been a dramatic change in the industries producing ICT equipment, such as office, accounting, and computing machinery (30), which have greatly benefited from the ICT revolutionary boom. This result highlights one merit of REI, which prevents the measure from imposing large weights on specific industries influenced by other events, not enhancing energy productivity. Our findings indicate that the cross-country and cross-industry heterogeneity in energy intensity shows different patterns of firm growth. The main finding on the profit growth is robust to the cross-country heterogeneity in structure change and efficiency, derived by logarithmic mean Divisia index (LMDI), while the capital growth is not robust due to the input substitution.

Unlike empirical findings for full country sample, we find when using only Korean panel data that neither EI nor REI have any statistically significant impact on firm profits in Korea, despite having a positive impact on their capital growth, thus implying that the efficient use of energy input has had only a minimal positive effect on firm growth.

This paper contributes to the literature on the cross-country and cross-industry relation between energy use and the economy. Many empirical studies on the energy-economy nexus have examined the evolution of energy intensity as the economy develops. By and large, energy intensity has changed over time and across countries (Duro et al., 2010; Liddle, 2010; Liu and Ang, 2007; Nilsson, 1993; Voigt et al., 2014; Warr and Ayres, 2010). With respect to growth theory, Stern (2011) argues that energy input is also a critical factor in the production process together with capital and labor. In this respect, it has been documented that energy efficiency contributes to economic growth through an increase in total factor productivity (Inhaber and Saunders, 1994; Jorgenson, 1986; Murillo-Zamorano, 2005; Schurr, 1982). However, there are many papers that argue that improved energy efficiency can reduce the cost of producing energy-intensive goods and thus create an increase in energy demand, which are known as rebound effects (Azevedo et al., 2012; Borenstein, 2013; Greening et al., 2000; Sorrell, 2009).

This paper focuses on the within-sector or within–industry energy-growth nexus. Duro et al. (2010) argue that the disparities between countries regarding energy efficiency levels are primarily related to differences in sectoral structure and the degree of energy efficiency itself. Mulder and Groot (2012) find that aggregate convergence patterns are caused by the convergence of within-sector energy intensity levels, which implies that a sectoral approach may be necessary in this area. In the aforementioned literature, much attention is paid to comparing the factors that account for changes in energy consumption across industries and countries, while the study of the mechanism of the impact of improvements in energy intensity on firm growth, even though important, remains relatively nonexistent.

This paper is organized as follows. We discuss the measurement and comparison of energy efficiency by country and industry in Section 2 and then describe the empirical model and data construction used in our research in Section 3. Section 4 documents the estimation results, and we conclude the paper in Section 5.

2. Measurement and comparison of energy intensity

2.1. Measurement of energy intensity

In much of the literature on energy economics and policy, improvements in efficient energy uses are typically measured by the decline in energy intensity (EI) though the measure suffers from several drawbacks.[4] It usually be calculated as units of energy per unit of the industry's value added or the country's GDP.

$$\text{Energy Intensity (EI)} = \frac{units\ of\ energy}{units\ of\ the\ Value\ Added\ (or\ GDP)} \tag{1}$$

One of the most important issues in measurement is to identify industrial energy intensity with respect to its natural own energy demand, not industry-specific energy dependence and energy use patterns. As energy intensity improves, more energy-dependent industries are relatively more affected by the efficient use of resources than are other industries, and thereby can save significantly more energy input costs with a decline in energy intensity. For example, the trend of energy intensity in the office, accounting and computing industry (NACE 30) is particularly exceptional, as it reveals a magnitude of EE that is 50 times less than that of other industries (see Fig. 2). Furthermore, energy use patterns are different across industries, thus the energy-use technology in one industry is unavailable to other industries.

A change in energy intensity may not by derived by industry's own factors, but also by country-specific factors, such as the abundance of

[3] NACE rev.1, the industrial definition used in EU KLEMS, is overall more disaggregated than the industries in the Energy Balance. We redistribute the industry-level real energy uses in IEA on the EU KLEMS energy input volume indices.

[4] A better understanding of the factors affecting energy use over time, including the role of energy efficiency, requires that indicators be based on more detailed data than are available in the IEA energy balances. Such detailed information is currently available, on a comparable basis, for 11 IEA countries for the period 1974 to 2008 and for 16 IEA countries for the period 1990 to 2008.