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Energy efficiency barriers in commercial and industrial firms in Ukraine: An empirical analysis☆

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ABSTRACT

Improvement in energy efficiency is one of the main options to reduce energy demand and greenhouse gas emissions. However, large-scale deployment of energy-efficient technologies is constrained by several factors. Employing a survey of 509 industrial and commercial firms throughout Ukraine and a generalized ordered logit model, we quantified the economic, behavioral, and institutional barriers that may impede the deployment of energy-efficient technologies. Our analysis shows that behavioral barriers resulted from lack of information, knowledge, and awareness are major impediments to the adoption of energy-efficient technologies in Ukraine, and that financial barriers may further impede investments in these technologies especially for small firms. This suggests that carefully targeted information provisions and energy audits will enhance Ukrainian firms' investments in energy-efficient technologies to save energy consumption, improve productivity, and reduce carbon emissions from the productive sectors.

1. Introduction

The adoption of energy-efficient technologies has been touted as a major policy option to save energy consumption and reduce greenhouse gas (GHG) emissions. The International Energy Agency estimates that energy-efficient technologies offer the highest potential in the total GHG mitigation required to limit global temperature rise by 2050 to 2 °C above pre-industrial levels (International Energy Agency, 2012). Many of the studies that develop marginal abatement cost curves for GHG mitigation demonstrate that energy-efficient technologies entail negative costs (i.e., value of energy savings exceeds investment costs even if GHG mitigation benefits are not accounted for) and therefore these options are interpreted as “low-hanging fruit” for climate mitigation (Asian Development Bank, 1998; McKinsey and Company, 2009; Energy Sector Management Assistance Program, 2012). Energy-efficient technologies save firm's expenditures on energy resulting in their overall cost efficiency.

In practice, however, the scale of implementation of such seemingly win-win options is small in relation to their apparent economic potential. The rationale for this disparity is that implementation of these options is constrained by economic and institutional barriers (Jaffe and Stavins, 1994; Howarth and Sanstad, 1995; Sorrell et al., 2004; Mundaca et al., 2013). Moreover, the estimated benefits of deployment of energy efficient technologies may not be realized in practice. This is because the economics of energy-efficient technologies is normally evaluated using engineering benefit–cost analysis (e.g., Goldstein et al., 1990; Blumstein and Stoft, 1995; Brown et al., 1998; McKinsey and Company, 2009; Gillingham and Sweeney, 2012), which usually omits variables such as opportunity costs of investment and also the transaction costs of the deployment (Allcott and Greenstone, 2012). If the transaction costs imposed by the economic and institutional barriers are accounted for, the net benefits that can be achieved from energy-efficient technologies would be smaller as compared to the opportunity costs of the investment thereby causing firms to lose interest in adopting them (Anderson and Newell, 2004).

The gap between the level of energy efficiency actually realized and that achieved in theory via the implementation of cost-effective energy-efficient technologies is called the “energy efficiency gap” (Blumstein et al., 1980; DeCanio, 1993; Jaffe and Stavins, 1994; Sanstad and

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Howarth, 1994; Sorrell et al., 2004; Schleich, 2009). In this paper, we revisit this gap while employing survey data collected in 2012 from 509 Ukraine firms. We use the data to empirically examine barriers to the adoption of energy-efficient technologies in Ukraine for both commercial and industrial firms. The empirical analysis employs a generalized ordered logit model (GOL model; Williams, 2006). The selection of the model is based on the fact that GOL models are less restrictive than ordered logit models, whose assumptions are often violated, but are more parsimonious than the multinomial logit models that ignore the ordering of categories.

The empirical analysis is carried out for Ukraine, a small developing Eastern European country, located between Russia and Europe. Its geographic position led it to become transit country of natural gas imported from Russia to Europe (Correlje and van der Linde, 2006; Goldthau, 2008; Soderberghn et al., 2010). Although historically Russia has supplied Ukraine with natural gas and petroleum at prices much lower than market prices (Dimitrova, 2009), recently Russia has begun pushing for higher prices, resulting in several disputes. The culmination of these disputes came when exports to Ukraine of 90 million m^3 of natural gas per day were halted on January 1, 2009. Increases in energy prices may result in long-run effects that yield significant changes to the economy's production structure (Schubert and Turnovsky, 2011).

The aging infrastructure and the inefficiencies have led Ukraine to call for increased penetration of clean energy and improved efficiency in utilizing energy. The government has enacted several policies to promote the adoption of clean and energy-efficient technologies (Trypolska, 2012). Adoption of alternative energy technologies and the introduction of energy-efficient technologies can address Ukraine's structural problems, and energy-efficient technologies reduce energy costs and generate economic growth (Gillingham et al., 2014).[1]

However, are current investments in energy-efficient technologies in Ukraine optimal? Do barriers to the adoption of the energy efficient technologies lead to underinvestment? A number of studies attempted, through empirical analysis, to understand the energy efficiency barriers in different countries, sectors, and energy end uses (see, e.g., Rohdin and Thollander, 2006; Sardianou, 2008; Schleich, 2009). The literature suggests that financial barriers such as high upfront costs, lack of information, and priority setting of upper management impede the adoption of energy-efficient technologies. However, to our knowledge, this literature focuses mostly on Organization for Economic Cooperation and Development (OECD) countries, and an in-depth analysis has not been performed to better understand barriers to improvements in energy efficiency among industrial and commercial firms in small developing economies. Our study aims to contribute to filling this research gap. Moreover, the importance of such an analysis has increased tremendously with the current political situation in Ukraine, as energy security has become a key concern.

Our analysis shows that financial and economic barriers (e.g., high upfront costs of energy-efficient devices and processes, high costs of financing due mainly to higher risks perceived by financial institutions in new and emerging technologies) may hamper firms' investments in energy-efficient technologies especially for small firms (measured via revenues). It also shows that, contrary to our intuition, firms do not perceive government regulations and internal corporate bureaucracy as barriers to the adoption of energy-efficient technologies. However, the analysis does suggest that behavioral constraints such as lack of knowledge are major barriers that hamper adoption of energy-efficient technologies and lead to underinvestment in such technologies. Furthermore, we found that the commercial sector, which includes the public sector, is less likely to invest in energy-efficient technologies in the absence of policy interventions, but that mandatory energy audits have a larger effect on the commercial sector.

[1] Although we still do not understand the magnitude of the rebound effect, current literature offers little support to the Jevons hypothesis whereby the introduction of energy efficiency results in a net increase of energy use (Gillingham et al., 2014).

We organized the paper as follows: Section 2 discusses firms' investment decisions regarding energy-efficient technologies and possible barriers that hinder the adoption of such technology. Section 3 presents the cross-sectional survey data and the empirical analysis, followed by concluding remarks in Section 4.

2. The firm investment decision model

We assume a profit-maximizing firm that contemplates whether to invest in energy-efficient technologies. This firm faces two alternative technologies: an energy-*inefficient* technology (henceforth, denoted with subscript 0) and an energy-*efficient* technology (henceforth, denoted with subscript 1). For simplicity, we assume the production function is of fixed proportions and let E denote the fixed-proportion energy-output coefficient; that is, E energy units are used to produce one unit of output Q. Also, let p_Q denote output price and let p_E denote energy price. In addition, we assume a risk adjustment discount rate of i.

When modeling the firm's investment decisions, we assumed the firm first decides whether to invest in the energy-efficient technology and then, given its choice, the firm produces and generates profits. That is, we assumed two periods: In period 1, the firm decides whether to invest $I > 0$ in the energy-efficient technology, while in period 2, the firm consumes energy and incurs the operating costs of using the energy. The model can be made more complex to include other inputs (e.g., labor), other production functions, and uncertainty, as the literature on the adoption of new technologies suggests (e.g., Sunding and Zilberman, 2001). However, for our purposes, this basic stylized model suffices.

The model contains several economic factors affecting the firm's decision whether to adopt the energy-efficient technology. We assume that an investment of I lowers the firm's energy intensity from E_0 to E_1. In addition, we assume that adoption of the energy-efficient technology encompasses hidden or transaction costs $H > 0$ that are unobserved by the econometrician. Other sources of economic costs include the opportunity cost of capital that affects the risk-adjusted discount rate, which can be affected by imperfect credit markets that prevent firms from accessing the capital needed to upgrade a plant and adopt energy-efficient technologies. We denote these types of barriers as *economic barriers*. These economic costs suggest that firms may elect not to invest in energy-efficient technologies because the cost of implementing such technologies is greater than the benefits to the firm.

Economic barriers may limit firms' investment in energy-efficient technologies. Although the investment may be optimal from the firm's point of view, these investments may be socially suboptimal because the calculation leading to firms' investment decisions do not include market distortions caused by environmental externalities (e.g., pollution generated from energy consumption). Thus, market failure results in underinvestment in energy-efficient technologies. On the other hand, imperfect capital markets suggest that firms face capital constraints that reduce the amount invested in energy-efficient technologies. Then, if imperfect credit markets are of concern, development of informal credit markets (Deb and Suri, 2013) and introduction of state-owned development banks (David, 1984; Pulley, 1989) should be contemplated as mechanisms that alleviate the financial constraint. These barriers can be reduced via the introduction of better governance and best practices.

We let *institutional barriers* denote a second group of barriers that may impede the adoption of energy-efficient technologies. The literature suggests that regulation can become a barrier to the adoption of new technologies (Djankov et al., 2002; Graff et al., 2009).[2] Regulation may impose a cost (e.g., licensing, permits), as well as delays to the implementation of the new technology, which may negatively affect firms'

[2] Regulation may also facilitate the adoption of new technologies. However, this will not contribute to an energy efficiency gap and thus is not included in the stylized model.