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Estimating the changes in the distribution of energy efficiency in the U.S. automobile assembly industry

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ABSTRACT

This paper describes the EPA's voluntary ENERGY STAR program and the results of the automobile manufacturing industry's efforts to advance energy management as measured by the updated ENERGY STAR Energy Performance Indicator (EPI). A stochastic single-factor input frontier estimation using the gamma error distribution is applied to separately estimate the distribution of the electricity and fossil fuel efficiency of assembly plants using data from 2003 to 2005 and then compared to model results from a prior analysis conducted for the 1997–2000 time period. This comparison provides an assessment of how the industry has changed over time. The frontier analysis shows a modest improvement (reduction) in "best practice" for electricity use and a larger one for fossil fuels. This is accompanied by a large reduction in the variance of fossil fuel efficiency distribution. The results provide evidence of a shift in the frontier, in addition to some "catching up" of poor performing plants over time.

1. Introduction

The environmental policy implications of lower energy use have led to the development of voluntary government programs for energy efficiency, particularly in the absence of, or supplement to, other types of climate policy. These programs arose in the early 1990s (Storey et al., 1997) and expanded in the US with the introduction of EPA ENERGY STAR for Industry (Environmental Protection Agency, 2013). In 2001, EPA created a new partnership as part of the ENERGY STAR buildings program (originally launched in 1999), the ENERGY STAR Focus on Energy Efficiency in Industry (hereafter "the Focus"). The initiative identified barriers to energy efficiency, developed approaches for removing these barriers, and facilitated a support group of energy professionals within the industry. EPA's goal was to cultivate energy management functions within companies. EPA approached senior executives to establish the business case for energy management, secure assignment of a responsible energy director for each corporation, and help the companies build the necessary internal supporting functions and networks. ENERGY STAR energy management tools such as program evaluation checklists, energy management guidelines, and information on forming energy management teams guided refinement of the energy management programs in participating companies. Voluntary programs like ENERGY STAR may require company commitments to specific energy reduction targets, or "energy management" generally. For example, a company joining ENERGY STAR as a Partner agrees to[1]

- Measure, track, and benchmark energy performance
- Develop and implement a plan to improve energy performance, adopting the ENERGY STAR strategy
- Educate your staff and the public about your partnership and achievements with ENERGY STAR.

Recently the International Standards Organization (ISO) has established requirements for "establishing, implementing, maintaining and improving an energy management system, whose purpose is to enable an organization to follow a systematic approach in achieving continual improvement of energy performance, including energy efficiency,

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[1] See http://www.energystar.gov/buildings/about-us/become-energy-star-partner/online-partnership-agreement for the complete process.

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energy use and consumption" as ISO 50001, which largely formalized the first two elements of the ENERGY STAR partner agreement (International Organization for Standardization, 2011).

The US based voluntary energy programs typically involve some type of government recognition for "good" performance. ENERGY STAR provides recognition for plants that reduce energy (ENERGY STAR Challenge for Industry) or that are in the upper quartile of performance (ENERGY STAR Certification). There is also a corporate level award for overall achievements (ENERGY STAR Partner of the Year). Similar DOE programs such as Superior Energy Performance (SEP) (Therkelsen et al., 2013), established in 2005, use the third party ISO 50001 certification as a core requirement and set various levels of performance to achieve formal recognition. International programs may have binding agreements for reductions in energy use or intensity in exchange for a variety of other incentives such as audits and assessments, financial assistance and incentives, exemption from regulation and taxes, in addition to government and public recognition (Price et al., 2003).

In addition to the management tools and facilitation of networking between the energy directors, ENERGY STAR developed industry specific tools, which include the Energy Performance Indicator (EPI), a stochastic frontier inter-plant energy benchmarking tool. Boyd et al. (2008) provide a discussion of the evolution of the EPI approach. Boyd and Tunnessen (2013) provide a summary of the industries, approaches, and results of the EPI benchmarking to date. The EPI is developed for and reviewed by knowledgeable representatives from companies that participate in the Focus. Since the motor vehicle industry focus and corresponding assembly plant EPI development began over ten years ago (Boyd, 2005a, 2005b), a second version of the EPI was prepared and made available to the public by EPA. Re-estimating the motor vehicle assembly EPI and comparing the two versions allow for the improvement in the industry to be quantified. This contributes to a greater understanding of how the industry has changed over time.[2]

This paper discusses the data and the underlying stochastic frontier analysis used to estimate version two of the ENERGY STAR EPI for motor vehicle assembly plants. The next sections discus the motivation behind measuring efficiency, the data and specification used in this version, and how the parameter estimates of the two models have changed over time; in particular the treatment of climate impacts from plant locations and from capacity utilization. The paper then computes several measures, based on the two models to illustrate how the distribution of energy efficiency has shifted over time.

2. Energy performance indicator

Efficiency is a measure of relative performance; but relative to what? Defining energy efficiency requires a choice of a reference point against which to compare energy use. The difference between the observed level and potential level of performance has been called the "efficiency gap." Jaffe and Stavins (1994) discuss a range of concepts from which to define "potential," including economic, technical, social and hypothetical. The first market failure they identify that leads to an efficiency gap is lack of information. It is the lack of information regarding economic potential for lower energy use that is the focus here. In other words, we are interested in *measuring economic potential based on* "observed best practice", which is by definition economically feasible. By providing this information, ENERGY STAR hopes to lower the barrier to more widespread adoption of economic potential for lower energy use. The reference point for economic potential (observed best practice) depends, in part, on the reason for measuring efficiency as well at the available information to create a reference. Generally, the *Ceteris Paribus* principle ("all other things being equal or held constant") is usually desired in creating the reference point, or benchmark. From a practical perspective there is a hierarchy of measures and methods by which one can "hold constant" things that influence the level of *energy use* that are not *energy efficiency*. The first is a measure of production activity. This is most commonly done by computing the ratio of energy use to production output, a measure of energy intensity. Energy intensity is a common metric that controls for changes in production and is commonly confused with energy efficiency, as in the statement "the plant's energy efficiency has improved based on the observation that the energy intensity has declined". This type of statement brings us to the second way that one may approach the ceteris paribus principle for measuring efficiency, comparing energy intensity a particular plant, firm, or industry to itself over time. This approach is a plant (firm, etc.)[3] specific *baseline* comparison, or *intra-plant* efficiency benchmark. ISO 50001 recommends developing such a baseline for measurement and tracking.[4] Baselines have the advantage of controlling for some plant specific conditions that do not change during the comparison period. The next level of this ceteris paribus principle is an *inter-plant* comparison that may include a variety of factors that influence energy use, but may not be viewed as efficiency. Factors may include difference in the types of product and materials used, as well as location specific conditions. Inter-plant comparisons within an industry also get us closer to the notion of an observed best-practice benchmark of economic energy efficiency, since by definition there is some group of plants that are the best performers.

To measure energy intensity you need a measure of energy in the numerator, and a measure of output for the denominator. Murray (1996) raises issues about both the numerator and dominator. For the numerator in our case we use total purchased energy, defined as the net Btu total of the fuels (Btu) and electricity (kWh). The choice of the denominator is a major issue for measuring intensity. Freeman et al. (1997) show that industry level trends in energy intensity based on value, both total and value added, can differ dramatically from those based on physical quantities. At the simplest level value, the value of output is simply price times physical quantity —so price movements account for these differences. Freeman et al. observe

> "For an industry producing a single, well-defined, homogeneous good, it is relatively easy to construct an accurate price index. Most industries, however, produce many poorly-defined, heterogeneous goods. For a variety of reasons, the more diverse the slate of products produced by an industry, the more difficult it becomes to construct an accurate price index. …the accuracy of industrial price indexes is of extreme importance to industrial energy analysts and policy makers who use value-based indicators of energy intensity."

Out of 450 Census 4-digit Standard Industrial Classifications (SIC) Freeman et al. analyze physical output data for only 14. This choice may be driven by the available data, but is in part based on the diverse types of production that may be included within the Census classifications. For physical production to be meaningful it needs to be at a high level of industry homogeneity. For example, the "Dairy" industry produces many products that could not be aggregated, but "Fluid Milk" might.

Freeman et al. employ a commonly used approach by comparing energy intensities over time within specific sectors, i.e. industry level intensity baselines. Companies commonly employ plant level energy intensity baselines to assess performance. EPA ENERGY STAR Challenge for industry[5] is also based on a plant level intensity baseline. Specifically, "The Challenge for Industry recognizes industrial sites that improve their energy efficiency by 10% within 5 years." A site with a 10%

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[2] A similar analysis, but for the cement industry, is detailed in Boyd and Zhang (2012) and Boyd et al. (2011).

[3] Throughout the paper we will refer to the plant level as the unit of observation, but the concept may also apply to more aggregate levels like firms and industries, and disaggregate process units.

[4] ISO uses the term Energy Performance Indicator to refer to baselines. However, ISO uses the acronym EnPI, to differentiate it from the Energy Star EPI.

[5] EPA web site —http://www.energystar.gov/index.cfm?c=industry_challenge.industry_challenge.