

The Energy-Management Nexus in Firms

Which Practices Matter, How Much and for Whom?

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Abstract

Management practices matter for firm performance. As energy is one input in firm production, management practices may interact with energy use. Using a comprehensive firm-level database covering 31 countries, this study documents the link between structured management practices, energy use, and firm performance. The paper reports several findings. *First*, although management is negatively correlated with energy expenditure, it bears a positive (or null) relationship with physical energy use, suggesting that management effort is directed toward saving costs but not reducing environmental impact. These results are primarily driven by the manufacturing sector. *Second*, among the

structured management practices examined, those relating to target-setting are associated with reduced energy expenditure intensity. *Third*, generic management practices are correlated with greater discipline around energy management. *Finally*, while generic practices are correlated with stronger firm performance in manufacturing and services, energy-centric practices show a positive association only in services. Vast heterogeneity in adoption and outcomes suggests that targeted approaches to encourage energy management practices in firms may be more effective than uniform ones.

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The Energy-Management Nexus in Firms: Which Practices Matter, How Much and for Whom?

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1 Introduction

The persistence in productivity differences among firms, even within the same narrowly-defined industry, is striking and puzzling. For example, within four-digit industries in the United States, labor productivity in manufacturing plants at the 90th percentile is four times as high as it is in plants at the 10th percentile (Syverson, 2011). A growing literature suggests that management practices play a key role in explaining the large variation in productivity across industries and countries (Bloom and Van Reenen, 2007; Bloom et al., 2012b). In a world facing climate change, patterns of energy use and associated greenhouse gas emissions have taken center stage in discussions on firm performance. To this end, methodologies have been adapted to study the relationship between management practices and energy demand at the firm level, albeit mostly in developed countries (Bloom et al., 2010a; Boyd and Curtis, 2014; Martin et al., 2012; Schweiger and Stepanov, 2019). Our paper builds on this nascent literature to explore the link between firms’ management practices and energy use.

Despite the implications of business decisions for climate change, and climate change for business, the firm as a unit of analysis is not common in the literature on energy efficiency. Energy use by firms is a major driver of greenhouse gas emissions worldwide. Direct emissions from manufacturing and construction account for 20% of global CO₂-equivalent emissions from fossil fuel combustion (World Bank Data, 2020), and is much larger once indirect (e.g., electricity and heat) emissions are included. Firm energy use decisions not only have implications for firms’ private costs, but also affect the global and local environmental impacts of economic activity. Prior studies focus heavily on individual decisions, or aggregated outcomes at the industry or country level, such as total production, given that energy data at the firm level are often aggregated into a firm’s materials inputs or not reported at all.

Management practices could interact with energy decisions via several channels. By easing information and coordination frictions, management practices may help reduce “hidden” administrative and time costs associated with energy efficiency investments (e.g. in identi-

fying and implementing programs or equipment for energy saving) (Gillingham and Palmer, 2014). Management practices may also help firms overcome uncertainty, for instance in energy price fluctuations or in the magnitude of future cost savings, if these disciplines enable firms to target and track historical energy use and accurately forecast future needs and payoffs. For instance, savvy firms may be able to optimally time energy purchases when prices are low.² Energy-centric management practices may raise energy efficiency by requiring managers to apply low hurdle rates and payback periods equivalent to or longer than those for traditional investments when assessing energy efficiency opportunities, increasing the likelihood of adoption (Martin et al., 2012). While management practices can contribute to reduced energy intensity, some generic practices, such as setting production targets or monitoring related indicators, serve other functions within the firm that may conflict with energy intensity reduction. Thus, the relationship between generic management practices and firms' energy intensity is an open empirical question.

The literature suggests that though general management practices are associated with lower output-normalized expenditures on energy in firms, the extent and drivers of variation in this relationship remain an empirical puzzle. Most prior work focused on developed countries (Bloom et al., 2010a; Boyd and Curtis, 2014; Martin et al., 2012). Bloom et al. (2010a) find an inverse relationship between measures of management practices and energy (expenditure) intensity, for instance, in the United Kingdom. In the United States, Boyd and Curtis (2014) find that conditional on adopting general (not energy-specific) target-setting practices, all other management disciplines, that is, operations, monitoring, and incentive practices, are associated with increased energy (expenditure) intensity. Martin et al. (2012) found that a set of climate-friendly management practices are associated with lower energy intensity, more efficiency-oriented R&D, and higher productivity in a sample of 190 randomly-sampled manufacturing firms in the United Kingdom.³ The only study to focus

²Even difficult-to-store energy carriers such as electricity are often subject to differences in fixed costs based on use and in time-of-day pricing, including in developing countries, creating opportunities for arbitrage by shifting production to off-peak hours.

³These practices are distinct from the energy management practices we evaluate in the present analysis.

on manufacturing firms in a broad set of countries (mainly in Eastern Europe) found that the negative correlation between management practices and energy (expenditure) intensity was much higher in magnitude when energy prices are low (subsidized) compared to when they are high (Schweiger and Stepanov, 2019). The basic argument is that management’s effect on energy intensity depends on factor costs; better managed firms conserve in the face of high prices but intensify use to take advantage of lower prices.

Firms in developing countries, where the energy-management nexus has been rarely explored, may show a different relationship when compared to their counterparts in the developed world. *First*, industry composition often varies with the level of development. Developing countries may possess inexpensive labor or natural resources, which may encourage relatively energy-intensive industrial production and discourage energy-saving investments. *Second*, firms in developing countries face more heavily subsidized costs of fossil energy. Nine out of the top ten countries that accounted for 61% (US \$272 billion) of the total fossil fuel subsidies globally in 2017 were developing or emerging markets (Taylor, 2020). *Third*, firms in developing countries may prioritize growth over environmental protection, although they may also be more sensitive to input costs. Evidence from a randomized controlled trial in Shandong Province, China, suggests that firms rarely considered energy efficiency interventions with a payback period longer than one year (Karplus and Zhang, 2020). In Ryan (2018), an experiment that raised energy productivity of Indian manufacturing plants led to longer operating hours and greater demand for skilled labor and electricity, which given the country’s high reliance on coal generation likely increased environmental impact.

The purpose of this study is to develop a deeper understanding of the link between management practices (both generic and energy-centric) and energy intensity in a large and diverse sample of firms operating globally. We use the data collected in a recent wave of World Bank Enterprise Surveys (WBES), which provides a representative cross-section of firms in 31 countries. We observe complete entries for over 6,000 out of more than 20,000 total firms, a sample three times larger than prior studies. A unique feature of this wave of

the WBES is that it includes not only a module measuring management practices of firms but an additional “Green Economy” module that solicits responses on firms’ energy use, type of pollution emissions, and (a limited set of) practices relating to energy conservation (e.g., energy target-setting, monitoring, and external audits).

Our analysis advances the literature on the energy-management nexus in the following ways. *First*, we characterize the variation in energy intensity with respect to generic management practices as well as energy-centric management practices. *Second*, the WBES Green Economy Module provides information on the physical quantity of energy used, which allows us to measure the association of management practices with a close proxy for environmental impact. *Third*, the presence of information on both general and energy-specific management practices within the same survey allows us to consider their separate and combined influence, since either could be an omitted variable when examining relationship with energy intensity. *Fourth*, our data allows us to explore the relationship of generic and energy-centric management practices and firm outcomes in services, a sector that remains largely ignored in such discussions. *Finally*, of the sample of 31 countries in WBES dataset, eight are in the “Lower Middle” or “Low” income categories. This enables us to also explore the similarities and differences in the relationship between management practices and energy intensity in advanced and developing economies.

We report four main findings. *First*, while generic management practices negatively correlate with energy expenditure, they bear either a positive or no relationship to physical energy use, suggesting that management can help firms save energy costs without significantly reducing environmental impacts. *Second*, among the structured management practices examined, target-setting practices are most strongly associated with reduced output-indexed energy expenditure. In both cases, these results are mainly driven by manufacturing firms, while the relationship between management practices and energy intensity is weaker in services.⁴ *Third*, general management practices are correlated with greater discipline around

⁴The coefficient on target-setting practices was negative but insignificant for services firms, with much noisier estimates.

energy management. *Finally*, the general management score is correlated with stronger firm performance for both manufacturing and services, while the energy management score shows a positive association for services firms only.⁵

This paper beyond this point is organized as follows. In the next section, we discuss the related literature on general and energy management in firms. The third section discusses the preparation of our data set and presents descriptive insights. The fourth section describes our regression specifications and results. The final section concludes with policy implications of our results and directions for future work.

2 Related Literature

2.1 General Management Practices

While persistent differences in productivity can be explained by a range of factors besides management, such as higher quality labor and capital, differential investment in information technology and research and development (R&D), learning by doing, firm structure, productivity spillovers, regulatory behavior, and differences in competitive regime, the quality of management remains a prominent explanation. Prior work has suggested that management practices may function as a “technology,” whereby management is conceptualized as intangible capital in which output is monotonically increasing (Bloom et al., 2016). Differences in managerial quality are important in explaining the cross-country differences in income levels, productivity, innovation and firm dynamism. For example, differences in productivity across firms in Asia, Europe, and North and South America have been attributed to the heterogeneity in management practices (Bloom et al., 2010b). Likewise, a study by Bloom and co-authors suggest that management practices account for nearly 30% of the differences

⁵The observed relationships between (generic or energy-centric) management practices and firm outcomes (energy intensity or output) do not imply causality. Although our empirical analysis adheres to the state of the art in the field, existing studies have also admitted the possibility that omitted variables could be correlated with both management and energy use. An advantage of our study is that both generic and energy-centric practices are observed, and can be controlled for in regressions.

in TFP across countries. Here, management practices are found to explain at least a fifth of within-country heterogeneity in firm performance, thereby suggesting that firm- and sector-specific factors are at least as important as the general business environment in shaping firm performance (Bloom et al., 2016).

The four sets of practices that comprise an overall management score in the World Management Survey include: operations, performance monitoring, incentives, and target-setting (Bloom and Van Reenen, 2007). Questions in the operations category seek to understand the production process and the adoption of lean manufacturing techniques, while those in monitoring category solicit responses on the types of production and input data that are collected as well as how the performance of capital and workers is measured. Questions on practices relating to the hiring and firing of workers as well as the criteria for bonuses and promotions comprise the incentives category. Finally, the target-setting category evaluates practices relating to defining and communicating organizational goals, setting a time frame for implementation, whether or not these goals are demanding, and if there are consequences for failing to achieve them. In prior studies, these scores are averaged to obtain an overall management score.

In addition to focusing on the composite management score, studies have also considered specific categories of management practices. Weaknesses in management practices, for example, relating to data driven performance monitoring cripples the overall management score in Croatia (Grover et al., 2019). Monitoring includes specific practices that help managers define their key performance indicators (e.g. inventory, sales, absenteeism) and track them periodically over time. By comparison, Croatia firms' average score on practices relating to target setting and incentives is relatively closer to that of United States firms. Incentive practices relate to how managers and non-managers are awarded bonuses and promotions. The findings for Croatia and the Russian Federation regarding the weaknesses of these sub-indices are similar, that is, monitoring practices are weaker (Grover et al., 2019; Grover and Torre, 2019). By comparison, in the United States and Mexico manufacturing firms

are stronger in monitoring vis-à-vis structured management practices relating to workers' incentives and target setting (Bloom et al., 2019a,b).

Structured management practices may affect productivity by interacting with a firm's input choices. Prior literature has focused mainly on labor and capital. Ichniowski and Shaw (1999) highlight the effectiveness of labor management practices, including problem-solving teams, orientation, training, job rotation, employment security, and profit sharing, and linked them to economic performance. Management practices also correlate positively with improved labor conditions in firms (Distelhorst et al., 2017). Bloom et al. (2016) find that a high capital-labor ratio is systematically correlated with higher monitoring and target scores, relative to incentive scores, suggesting that management styles may differ, depending upon the nature of a firm's productive activities.

A subset of this literature has attempted to explicitly discern the association of management with energy use. Bloom et al. (2010a) found that management practices were inversely correlated with energy intensity (measured as the proportion of expenditure on energy relative to the value of output), leading the authors to conclude that management may also be good for the environment. Boyd and Curtis (2014) conducted a similar study in the United States using the Annual Census of Manufactures, and found similarly that management practices are negatively related to energy intensity, but that the negative effect was conditional on a firm's level of broad target-setting practices. Using BEEPS data, Schweiger and Stepanov (2019) examine the relationship between generic management practices and energy intensity in 2,000 firms from 40 countries, differentiating between firms in countries with high and low fuel subsidies. They find a 23% reduction in fuel intensity as management score improves from the 25th to the 75th percentile of the distribution. In the face of high fuel subsidies, this decline in energy intensity is only 2%. Table A5 provides a survey of the available literature that relates management practices to firm outcomes.

2.2 Energy-Centric Management Practices

In contrast to general management practices, specialized management practices target a specific aspect of the firm’s operations. Some examples of energy management practices include the introduction of target-setting and monitoring practices related to energy use, an explicit requirement to adhere to energy conservation norms, rewards for employees that promote energy efficiency, emphasis on energy management as a priority, and encouraging innovation in controlling energy use. Based on data from 190 firms in the United Kingdom, Martin et al. (2012) find that climate-friendly management practices are associated with lower energy intensity and higher productivity. Climate-friendly practices in this setting included 33 practices, including the stringency of external GHG reduction targets faced, adaptation measures undertaken, and energy use target-setting and monitoring. Using surveys of environmental management practice adoption at 500 facilities, Delmas and Toffel (2008) find that distinct external constituents prompt firms to adopt specialized environmental management practices. In both cases, the emphasis is on studying the correlation of environment-friendly management practices with energy use, using a limited sample size. We are unaware of any study that explicitly measures energy-specific practices, such as tracking physical quantity alongside expenditures and encouraging cost-effective investments in energy efficiency. To the best of our knowledge, our study is the first to examine the emergence of these practices using data that include many developing country firms, and in this sense our work makes an important contribution to this literature.

3 Data Preparation and Exploration

3.1 Data Preparation

The recent wave of the World Bank Enterprise Surveys conducted in 2018 and 2019 for 31 countries collected nationally-representative firm data on a number of financial, operational,

managerial, and business environment measures. Within the WBES, the Green Economy module is rolled out by the World Bank Group, jointly with the EBRD-EIB.

Generic and Energy-centric Management Scores. General management scores are calculated using 11 questions from the management practice module. These questions map to eight questions from the U.S. Management and Organizational Practices Survey (U.S. Census Bureau, 2015). They cover four categories of practices: target-setting, monitoring, incentives, and operations (see Table A1). Firms’ responses to questions on management practices are aggregated into a single management score following Bloom et al. (2019a) in two steps. *First*, the responses to each of the management practice questions are normalized on a 0-1 scale: the response associated with the most structure is normalized to one, and the one associated with the least structured is normalized to zero. *Second*, overall management score is calculated as the unweighted average of the individual question scores as in Bloom et al. (2012c) in computing the average based on the z-scores of individual questions. We use these scores to compute descriptive statistics. About 2% of the firms with non-missing entries report a zero average score, while the average for all firms is 0.48 (standard deviation of 0.21). For regressions, we take the z-scores of individual questions, and compute the unweighted average. We then once again take the z-score to obtain a composite management score. General management score also separates the overall management index into four sub-indices to separately assess the importance of monitoring, incentives, targets and operations practices.

Energy management scores use questions from the Green Economy Module of the WBES that relate to monitoring, target setting, and relative emphasis on energy efficiency. Questions and scoring scales are listed in Table 1. All scores are normalized to a 0-1 scale. Six out of nine questions in the Green Economy Module require binary responses. More structured practices are those that are more specific, formal, frequent, or comprehensive and hence are assigned a higher score. Overall scores are computed as an unweighted average. Given that energy-centric practices are likely specific to firm energy requirements, it is not surprising

Table 1: Summary statistics and response rate for energy management questions.

Question	Scoring	Mean	Std Dev	Med	p25	p75	Score = 0	Responses
(1) Did the establishment monitor energy consumption?	0 - No or don't know, 1 - Yes	0.568	0.495	1.0	0.0	1.0	8,431	19,511
(2) How often did the establishment monitor its energy consumption?	0 - Don't know or no monitoring, increments of 0.125 from annually (0.125) to hourly (1)	0.253	0.245	0.3	0.0	0.5	8,493	19,518
(3) Was an external energy audit completed?	0 - No or don't know, 1 - Yes	0.265	0.441	0	0	1.0	8,146	11,087
(4) Did the establishment have targets for energy consumption?	0 - No or don't know, 1 - Yes	0.276	0.447	0	0	1.0	14,120	19,511
(5) What was targeted?	0 - Don't know, refuse to answer, or no targets, 0.5 - Quant or exp only, 1 - Both quant and exp	0.220	0.382	0	0	0.5	14,199	19,513
(6) Did the establishment adopt energy management?	0 - No or don't know or refuse to answer, 1 - Yes	0.308	0.462	0	0	1.0	13,494	19,511
(7) Did the establishment adopt any measures to enhance energy efficiency?	0 - No or don't know or refuse to answer, 1 - Yes	0.334	0.472	0	0	1.0	12,987	19,511
(8) Were any measures developed by establishment?	0 - No or don't know or refuse to answer, 1 - Yes	0.252	0.386	0	0	0.5	12,987	19,516
(9) What was the payback period vs. non-energy-efficiency measures?	0 - Did not implement, 0.25 - Don't know, 0.5 - Shorter, 0.75 - Equal payback, 1 - Longer	0.106	0.269	0	0	0	12,987	15,214
E Mgmt Average		0.287	0.292	0.167	0	0.5	6,540	18,621

that nearly one-third of the firms report zero score, while the average for all firms is 0.28 (standard deviation of 0.29).

Energy Intensity. Energy intensity is the amount of energy used (expenditure or physical quantity) normalized by output, measured using last fiscal-year sales. Studies suggest large heterogeneity in energy intensity within narrowly defined sectors, and these variations are higher than that in other inputs (Lyubich et al., 2018). This is larger than the productivity spread for relatively homogeneous industries, such as cement (Syverson, 2004).

Energy intensity in expenditure (and physical quantity) is calculated by summing energy expenditure (quantity) for firms that report electricity use and at least one out of three possible primary fuel types. More than half of the firms in the (>20,000 firm) sample report non-missing values for all fuel types. Summary statistics for both energy intensity and management measures are reported in Appendix Table A3. For a description of data preparation and cleaning, as well as the components of the generic and energy-centric management practices, see Appendix Section A1.

3.2 Stylized Facts about Management Practices and Energy Use

After cleaning data from the World Bank Enterprise Surveys for 31 countries, our sample includes 14,713 firms reporting energy consumption in value terms and 8,272 firms reporting energy consumption in physical quantity terms. For 8,476 firms, the generic management score can be computed, contingent on firms responding to at least six of the eight aggregated questions from the management practices module. The energy-centric management score can be computed for 18,621 firms that answer at least eight of the nine energy management practice questions from the Green Economy module. Appendix Table A3 presents descriptive statistics for key variables included in our regression analysis. In this section, we highlight the main stylized facts on management practices and energy use that emerge in our data.⁶

⁶For our regression, we use data that are winsorized at the top and bottom 1 percent. The composition of firms across countries and two-digit sectors before and after winsorization is similar. Notably, services firms do not generally report capital stock and share of high-skilled labor, and hence we omit these variables

There is striking variation in energy intensity within narrowly-defined sectors. Figure 1 shows that this heterogeneity is larger in terms of physical quantity per unit of output (shown in red) compared to expenditure per unit of output (shown in blue). Heterogeneity is nearly as large within three-digit sectors (panels (b)-(f)) as it is in the full sample (panel (a)), underscoring the importance of within-sector variation in energy use patterns, and the fact that sector definitions do not always neatly delineate firm energy requirements. Even after data cleaning (described in Appendix Section A1), a few firms with high physical energy intensity (outside the range shown) result in a sample mean that exceeds the median by two orders of magnitude for the energy intensity quantity measure (see summary statistics in Appendix Table A3). Sector panels are ordered from most (cement) to least (other retail) energy intensive. The distributions of expenditure- and physical use-based energy intensity generally grow narrower when moving from more to less energy intensive sectors. This may correspond to increased homogeneity in energy needs (due to, for instance, reliance primarily on electricity to power equipment and buildings) in light manufacturing and retail.

There is wide heterogeneity in management practices, both generic and energy-centric. As shown in Figure 2, there is large variation in both general management (shown in blue) and energy-specific management (shown in red).⁷ The general management distribution is normally distributed with slightly greater density in the left tail of the distribution, similar to prior studies (Bloom et al., 2012a). The shape of the distribution does not differ dramatically across sectors. The energy management score distribution is generally much flatter, with a much higher density at zero.

On average, manufacturing firms are better managed than services firms both in terms of generic and energy-centric management practices. On average, a services firm scores 0.514 (SD 0.182) in the adoption of the generic management practices, compared to an average of 0.524 (SD 0.178) for manufacturing firms.⁸ The difference in average scores is statistically

from the services regressions.

⁷Please note that the general and energy management scores are measured for overlapping but not identical subsets of firms in WBES.

⁸The distribution of scores by sub-categories of services and manufacturing is shown in Appendix Figure

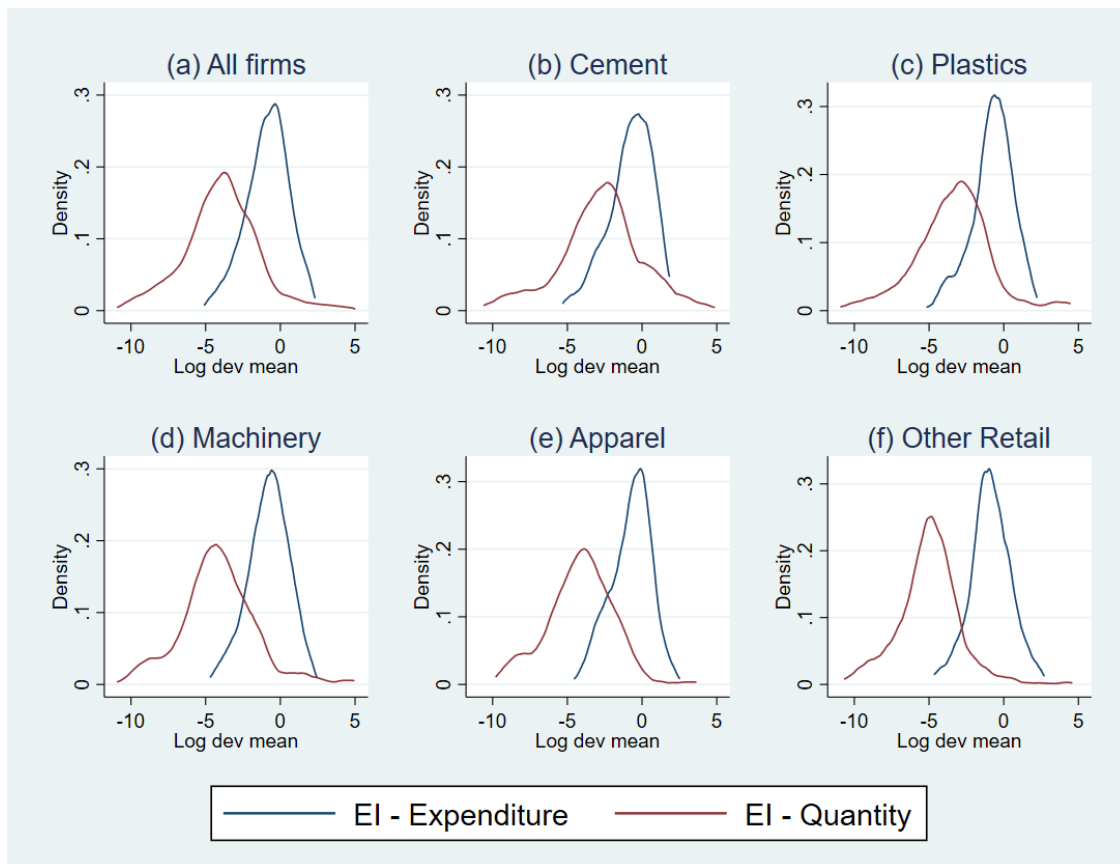


Figure 1: Variation in energy (expenditure) intensity within the full sample and specific industries, ordered from most to least energy intensive.

significant at the 5% level. This finding is similar to those in Croatia (Grover et al., 2019) and Mexico (Bloom et al., 2019b), where firms from the services sector were also included in MOPS framework. The lower management score in services is usually attributed to a lack of pro-competitive environment, which lowers the pay-off from adopting better management practices (Bloom et al., 2019b). In addition, the lower average score in services could also be a manifestation of a heavy left tail in the size distribution of services firms (that is, many small firms).

Relative to generic management practices, a relatively small share of firms develop energy-centric management practices. A summary of the energy management questions and responses is shown in Table 1. For most of the three-digit sectors shown in Figure 2, the

A1.

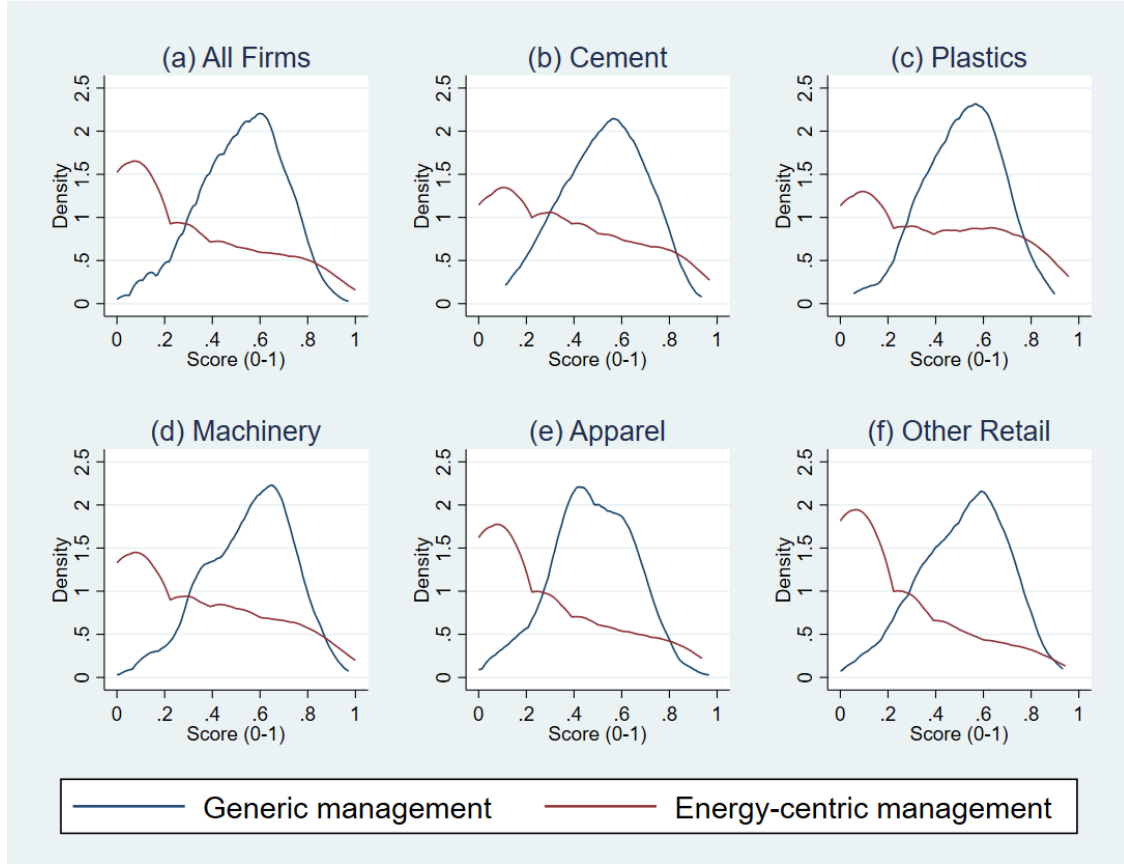


Figure 2: Distributions of generic and energy-centric management scores in the full sample and specific industries, ordered from most to least energy intensive.

energy management score distribution has its greatest density at zero. Moving from higher to lower energy intensity of a sector (from (b) to (f) in Figure 2), the concentration of “zero” scores increases substantially, suggesting that energy-centric practices are more prevalent in relatively energy-intensive sectors. Comparing the mean of energy-centric management scores for manufacturing at 0.319 (SD 0.301) and services at 0.233 (SD 0.270), differences in the adoption of management techniques are large, and statistically significant at the 1% level. Appendix Figure A1 shows that energy management scores are relatively low in the services sector, regardless of knowledge intensity.⁹ Some firms may perceive limited need

⁹The less-developed status of energy-centric practices in services may follow from the fact that firm managers vary in their perceptions of the importance of energy management, due for instance to differences in sensitivity to energy costs. Heterogeneity may further be a result of country-, size-, sectoral- or technology-specific characteristics, as well as a firm’s input decisions, especially purchases of capital or energy-intensive technology.

for energy management practices, if energy requirements and associated costs are very small relative to total costs or sales and thus have little impact on profit. Generic management practices, by contrast, may be more universal in their potential to help diverse firms excel. Moreover, energy is a subset of the strategic and operational concerns of a firm; stronger generic management practices may thus correlate with a propensity to invest in specialized energy-centric management practices. However, the need for energy-specific practices may be endogenous to energy requirements implied by a firm’s capital equipment choices or a function of factors beyond a firm’s control, such as local energy system characteristics.

Across high, upper middle, and lower middle income groups, average management scores are not statistically different, with high variation within country groups (see Appendix Table A4). Using the winsorized sample and computing generic management score as a straight average of non-missing entries, firms in the high income group average a generic management score of 0.491 (SD 0.209), upper middle a score of 0.481 (SD 0.211), and lower middle 0.477 (SD 0.200); differences are not statistically significant. Large standard deviations are consistent with the finding in (Bloom et al., 2012b) that score heterogeneity within countries is often greater than between them. All countries have roughly the same share of zeros, while high and upper middle income countries have a slightly larger share of firms scoring above 0.75 (4% versus 3%). For energy management, the high income group firms’ energy-centric management score average is 0.291 (SD 0.304), upper middle 0.237 (SD 0.273), and lower middle 0.365 (SD 0.296); the differences are statistically significant. Appendix Table A4 summarizes generic and energy-centric management scores by income group. Interestingly, firms in lower middle income countries have fewer zero entries for energy management score, and also have a higher share of high-scoring firms. This could be due either to the fact that these countries have higher shares of energy-intensive manufacturing firms, or firms in these settings may be more motivated to invest in energy management practices, e.g. to mitigate the impact of volatile prices or supply disruptions. Distributions of generic and energy management scores by country income group are shown in Appendix Figure A2.

Larger firms are better managed, both in terms of generic and energy-centric management practices. Appendix Figure A3 shows that within energy- / knowledge-intensity categories of manufacturing and services firms, there is a nearly monotonic increasing relationship between firm size and general management score, as prior work has noted (Bloom and Van Reenen, 2007). This finding is similar to that found in the United States by Bloom et al. (2014) who show that better managed firms are significantly larger: in their study, a one standard deviation increase in generic management is associated with a 40 log point increase in employment size. In this analysis, we find that a similar pattern holds for both general and energy management. It is also visible within income groups (see Appendix Figure A4).

4 Energy-Management Nexus: Empirical Analysis

The remainder of this paper focuses on four research questions. *First*, do general management practices matter for firms' use of energy in terms of both expenditure and physical units? *Second*, which practices matter most, and for which categories of firms? Are there significant differences between firms in the services and manufacturing sectors? *Third*, do better managed firms also adopt disciplines to conserve energy? *Fourth*, do better managed firms, either in terms of general, or energy-centric practices, or both, show superior performance?

4.1 Regression Specifications

Our main regression specification (Equation 1) focuses on the relationship between general or energy management ($M_i^{g,e}$ where M is a firm-specific measure of generic management M_i^g or energy-centric management (M_i^e)) and energy intensity in expenditure or physical units divided by output ($EI(v)_i$ and $ei(q)_i$, respectively). We further allow energy intensity to vary according to capital and labor inputs, gross output, and a vector of age, sector, and country controls (\mathbf{x}_{it}). Capital k_i , labor l_i , and gross output y_i are expressed in logs, as is

physical energy intensity, as indicated by the lower case variables in Equation 1. Energy intensity in value terms is expressed as a percentage (the total value of energy use is divided by total output, and multiplied by 100). All variables are observed only once for each firm, in year 2019.

We follow Bloom et al. (2010a) and Schweiger and Stepanov (2019) to examine the relationship between management practices and energy intensity. Our approach differs from the two-step methodology of Boyd and Curtis (2014), which requires the use of more detailed industry level data (at the six-digit industry code level). Boyd and Curtis (2014) first create a firm-level measure of relative energy intensity by comparing each firm to others in the same narrow industry group and then in the second step regress this relative intensity measure on management practices and other controls. This methodology resolves much of the variation in energy intensity due to industry differences, such as equipment- or process-related energy needs.¹⁰ We are unable to implement the methodology due to lack of six-digit industry specification information. Our analysis should therefore be interpreted as the net effect of both sources of variation, after controlling for 3-digit industry- and country-specific effects. Compared to Schweiger and Stepanov (2019), our approach is very similar but the specifications include different firm-level controls.¹¹

$$EI(v)_i \text{ or } ei(q)_i = \alpha_0 + \beta_k k_i + \beta_l l_i + \beta_y y_i + \beta_M M_i^{g,e} + \beta_x \mathbf{I}_x + \epsilon_{it}. \quad (1)$$

We examine the relationship of firm performance to generic and energy-centric management separately and also in a specification that includes both. In all settings, the production function estimation includes labor and (for manufacturing firms) capital.¹² This approach is

¹⁰Our approach captures both between and within variation across sectors, although we control for sector and country fixed effects, as well as firm age, in all specifications.

¹¹In addition to country and sector fixed effects and firm age (Schweiger and Stepanov, 2019) include percentage of employees with college degree, percentage of self-generated electricity, geo-location of firm, mean temperatures and night-lights around the firm, an indicator for the firm being listed, a measure of credit constraints, indicator variable for foreign and state ownership, exporter status, and electricity as a major or very severe obstacle.

¹²We do not consistently observe materials costs and therefore include only capital and labor, following other studies.

similar to Bloom and Van Reenen (2007), in which management enters directly into the production function as a covariate. The coefficient on management score β_Z suggests how much of the variation in output is explained by generic or energy-centric management practices.

$$y_{it} = \alpha_0 + \beta_k k_{it} + \beta_l l_{it} + \beta_M M_i^{g,e} + \boldsymbol{\beta}_x^T \mathbf{x}_{it} + \epsilon_{it}. \quad (2)$$

4.2 Energy Intensity and Generic Management Practices

Table 2 shows the relationship between generic management practices and energy (expenditure) intensity. All columns control for age and fixed effects pertaining to three-digit sector and country. Energy expenditure intensity is computed as energy divided by output, then multiplied by 100, as in Bloom et al. (2010a). Estimated coefficients for management score in columns (1)-(3) show that generic management practice scores are negatively correlated with energy expenditure in both manufacturing and services. However, in specifications shown in columns (4)-(6), which additionally control for employees, capital stock (only available for manufacturing firms), and sales, the coefficient on management becomes insignificant for manufacturing firms. Adding output (sales) in particular is strongly negatively correlated, with a 1% increase in firm sales reducing energy intensity by 1.7 percentage points. This suggests large economies of scale with respect to energy use, which is not surprising given the high fixed costs of shifting to energy-intensive production equipment and the sensitivity of energy requirements to utilization. In the most demanding specification (columns (4)-(6)), an increase in management score from the 25th to 75th percentile is associated with a decline in energy intensity expense by 15% in services (column (6)), and a 2.5% decline in manufacturing (in line with prior studies, but not statistically significant). Appendix Table A6 shows the results broken down by country income group, revealing that the negative effect is strongest among firms in lower middle income countries. Splitting this estimation, we do not find the relationship between management and energy expenditure intensity to vary much by sectoral energy intensity, although high energy-intensity firms and high knowledge-intensity

Table 2: Relationship between management and energy intensity (value).

	(1)	(2)	(3)	(4)	(5)	(6)
	All Firms	Manufacturing	Services	All Firms	Manufacturing	Services
General	-0.708*** (0.185)	-0.424* (0.222)	-1.092*** (0.356)	-0.015 (0.184)	0.017 (0.256)	-0.266 (0.341)
No. Employees				1.107*** (0.129)	0.920*** (0.171)	0.967*** (0.218)
Log(Sales)				-1.576*** (0.098)	-1.652*** (0.130)	-1.670*** (0.172)
Capital Stock					0.406*** (0.074)	
3-digit sector	✓	✓	✓	✓	✓	✓
Age	✓	✓	✓	✓	✓	✓
Country	✓	✓	✓	✓	✓	✓
Observations	6143	3880	2063	6133	3000	2059
Adjusted R^2	0.218	0.125	0.297	0.280	0.223	0.348
df.m	118	82	63	120	85	65

Standard errors in parentheses

Capital, labor, and output enter in logs. Management scores are the unweighted average of the z-scores for individual practices. We primarily observe capital input for firms in the manufacturing sector, and therefore have omitted capital from the pooled regression to avoid dropping services firms.

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

services firms show the larger coefficients. See Appendix Tables A7 and A8.

Turning to energy intensity in physical quantity terms, we find a striking divergence from the energy expenditure results. Here the coefficient on management score is positive and significant, primarily driven by the manufacturing sector (columns (2) and (5)) (see Table 3. These results suggest that although better management practices enable manufacturing firms to limit the cost of energy use, they may not have the same effect on the consumption of physical quantity. One potential reason is that using greater quantities of energy may help a better managed firm substitute away from increasingly expensive labor, or enable automation, which may be a particular concern for the manufacturing sector. Management efforts in this case may be directed towards optimizing energy purchasing conditions, to

Table 3: Relationship between management and energy intensity (quantity).

	(1)	(2)	(3)	(4)	(5)	(6)
	All Firms	Manufacturing	Services	All Firms	Manufacturing	Services
General	0.162* (0.085)	0.294*** (0.112)	-0.082 (0.130)	0.353*** (0.087)	0.518*** (0.132)	0.087 (0.134)
No. Employees				0.496*** (0.061)	0.312*** (0.089)	0.459*** (0.102)
Log(Sales)				-0.561*** (0.041)	-0.619*** (0.061)	-0.567*** (0.069)
Capital Stock					0.217*** (0.037)	
3-digit sector	✓	✓	✓	✓	✓	✓
Age	✓	✓	✓	✓	✓	✓
Country	✓	✓	✓	✓	✓	✓
Observations	3587	2338	1155	3582	1837	1153
Adjusted R^2	0.262	0.266	0.261	0.312	0.331	0.316
df.m	110	79	58	112	81	60

Standard errors in parentheses

Capital, labor, and output enter in logs.

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

ensure that the increased energy requirement does not result in a higher share of energy expenditure.¹³ The positive effect is concentrated among firms in high and upper middle income countries (see Appendix Table A9). As shown in Appendix Table A8, moderate and low energy-intensive manufacturing as well as high knowledge-intensive services all show a positive effect. To our knowledge, we are among the first to examine this relationship. More study is needed, especially to understand this effect in services firms ¹⁴

Which management practices matter for energy use? Examining the correlation between

¹³Although the samples used for estimation in Tables 2 and 3 are different, our results are robust to considering the set of firms that consistently report both energy value and quantity. These additional results are available upon request.

¹⁴(Karplus and Zhang, 2020) find a negative relationship between management score and energy intensity in quantity terms in a relatively small sample of firms in the metal machining sector in Shandong Province, but smaller in magnitude compared to the effect on energy intensity in value terms.

specific sub-components of generic management scores and energy intensity in value and quantity terms, we find that the practices that matter most seem to differ for manufacturing and services sectors. These practices also influence energy intensity in expenditure and physical units differently. Specifications (1)-(3) in Table 4 show the relationship between management sub-scores (target-setting, monitoring, operations and incentives) and energy intensity in value terms. While target-setting practices matter for reducing energy intensity (expenditure) in manufacturing, these practices have statistically insignificant correlation for energy use in services. None of the other management practices seem to matter for energy use in services. Our results differ from Boyd and Curtis (2014) for the United States, who document that effective monitoring, incentive structures and particularly lean manufacturing operations are associated with a reduction in energy use, while the implementation of production targets (conditional on other practices) is found to increase energy consumption. The reason may be due to the fact that the World Management Survey, which was used to measure management practices in the United States in Boyd and Curtis (2014), refers to production targets, whereas the WBES definition is broader and explicitly includes examples such as “production volume, quality, efficiency, waste, or on-time delivery” in the question on target-setting practices. Appendix Table A10, columns (1)-(5), reveals that the target-setting practices matter especially for moderate and low energy intensive firms.¹⁵

Specifications (4)-(6) in Table 4 show that there is a positive relationship in manufacturing firms between monitoring practices and energy intensity in physical quantity terms. While target-setting improves energy efficiency in value terms, monitoring production and performance of firms is actually associated with a worsening of the physical energy intensity in manufacturing, perhaps because more energy-intensive firms are more motivated to invest in monitoring capabilities. As for services, we do not find evidence of association of management with energy efficiency, both in value and in physical unit terms.

¹⁵Unlike high energy intensity firms, moderate and low energy intensive firms’ energy requirements are largely determined by core activities and long-lived capital equipment purchases, and thus may have less flexibility to adjust energy use through target setting.

Table 4: Relationship between management (all sub-scores) and energy intensity in value (1)-(3) and quantity (4)-(6) terms.

	(1)	(2)	(3)	(4)	(5)	(6)
	All Firms	Manufacturing	Services	All Firms	Manufacturing	Services
Targets z-score	-0.211* (0.114)	-0.584*** (0.144)	0.007 (0.227)	0.060 (0.057)	0.020 (0.077)	0.076 (0.102)
Monitor z-score	0.006 (0.095)	-0.013 (0.124)	-0.155 (0.198)	0.187*** (0.052)	0.268*** (0.075)	0.072 (0.092)
Operations z-score	-0.003 (0.094)	-0.043 (0.134)	0.074 (0.167)	0.078* (0.042)	0.043 (0.065)	0.086 (0.066)
Incentives z-score	0.023 (0.124)	0.218 (0.171)	0.054 (0.240)	-0.018 (0.060)	-0.054 (0.085)	0.010 (0.103)
No. Employees	1.124*** (0.130)	0.835*** (0.176)	1.138*** (0.221)	0.465*** (0.062)	0.286*** (0.091)	0.427*** (0.103)
Log(Sales)	-1.603*** (0.098)	-1.679*** (0.134)	-1.851*** (0.174)	-0.549*** (0.041)	-0.597*** (0.063)	-0.575*** (0.065)
Capital Stock		0.567*** (0.079)			0.234*** (0.042)	
3-digit sector	✓	✓	✓	✓	✓	✓
Age	✓	✓	✓	✓	✓	✓
Country	✓	✓	✓	✓	✓	✓
Observations	6124	3011	2055	3513	1805	1135
Adjusted R^2	0.264	0.215	0.339	0.299	0.323	0.310
df.m	124	88	69	116	85	63

Standard errors in parentheses

Capital, labor, and output enter in logs.

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Monitoring includes specific practices that help managers define their key performance indicators (e.g. inventory, sales, absenteeism) and appropriately track them periodically over time. The most energy-intensive firms may adopt monitoring practices to manage their sales, inventory, and costs as well as the performance of capital and workers, which may interfere with energy conservation, especially if there is no monitoring of energy use. These results can be viewed as an added dimension to the evidence on “energy-management gap” noted in Boyd and Curtis (2014) whereby the very management practices that improve firm performance may have eroded energy efficiency measured in physical units. In Appendix Table A10, columns (6)-(10) show that monitoring practices are positively correlated with energy use manufacturing, irrespective of sectoral energy intensity (columns (6)-(8)).

4.3 Generic and Energy-Centric Energy Management

Do firms with more developed management practices also have a higher propensity to develop specialized practices? In Table 5, we examine the correlation between generic and energy-centric management scores in manufacturing and services firms. Interestingly, overall manufacturing firms have a higher correlation between the two scores, compared to services firms, and this difference is statistically significant based on a two-sided t-test. Energy management practices concern whether or not the firm sets targets for energy use and monitors progress towards them, and the relative focus on conserving energy among a firm’s priorities. These are related to generic management practices and it appears that a firm evolves to adapt generic practices that are well-suited for its production setting into those that can also help conserve energy use, if conditions require it. In the case of services, the lower correlation may reflect the fact that there is greater variation in the value of energy intensity within services, given the wide heterogeneity in activities and in energy requirements in the sector.¹⁶

¹⁶As shown in Appendix Table A11, the positive association of energy management with generic management holds irrespective of sectoral energy intensity (in manufacturing) or knowledge intensity (in services).

Table 5: Relationship between general management practices and energy management practices.

	(1)	(2)	(3)
	All Firms	Manufacturing	Services
General	0.416*** (0.017)	0.482*** (0.027)	0.322*** (0.028)
No. Employees	0.053*** (0.011)	0.055*** (0.018)	0.030 (0.018)
Capital Stock		0.034*** (0.007)	
Log(Sales)	0.033*** (0.007)	0.018 (0.012)	0.036*** (0.011)
3-digit sector	✓	✓	✓
Age	✓	✓	✓
Country	✓	✓	✓
Observations	7080	3162	2363
Adjusted R^2	0.244	0.300	0.180
df_m	121	85	66

Standard errors in parentheses

Capital, labor, and output enter in logs.

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

4.4 Energy Intensity and Energy Management Practices

Table 6 indicates a negative and significant relationship between energy management practices and energy intensity (expenditure) for manufacturing firms (columns (2) and (5)). Increasing the energy management score from the 25th to the 75th percentile is associated with lower energy intensity (in value terms) by about 10% in manufacturing. While this relationship is also negative and significant for services in (3), the significance is lost once additional covariates are added in (6). Controlling for generic management practices reduces the sample size substantially. The relationship between energy management and energy expenditure intensity is no longer statistically significant when manufacturing is broken down by energy intensity and services by knowledge intensity (see Table A12).

Table 6: Relationship between energy management and energy intensity in value terms.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	All Firms	Manufacturing	Services	All Firms	Manufacturing	Services	All Firms	Manufacturing	Services
Energy	-0.392*** (0.089)	-0.379*** (0.110)	-0.362** (0.159)	0.106 (0.089)	-0.284** (0.128)	0.235 (0.156)	0.330*** (0.120)	0.107 (0.155)	0.286 (0.245)
General							-0.164 (0.193)	-0.049 (0.265)	-0.370 (0.355)
No. Employees				1.299*** (0.077)	0.883*** (0.111)	1.465*** (0.126)	1.095*** (0.129)	0.914*** (0.173)	0.973*** (0.219)
Capital Stock					0.513*** (0.059)			0.409*** (0.074)	
Log(Sales)				-1.793*** (0.062)	-1.802*** (0.091)	-1.952*** (0.101)	-1.591*** (0.098)	-1.659*** (0.130)	-1.689*** (0.171)
3-digit sector	✓	✓	✓	✓	✓	✓	✓	✓	✓
Age	✓	✓	✓	✓	✓	✓	✓	✓	✓
Country	✓	✓	✓	✓	✓	✓	✓	✓	✓
Observations	13472	7378	5734	13442	5567	5720	6094	2978	2047
Adjusted R^2	0.157	0.096	0.207	0.241	0.205	0.285	0.281	0.225	0.347
df.m	123	84	66	125	87	68	121	86	66

Standard errors in parentheses

Capital, labor, and output enter in logs.

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 7: Relationship between energy management and energy intensity in quantity terms.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	All Firms	Manufacturing	Services	All Firms	Manufacturing	Services	All Firms	Manufacturing	Services
Energy	0.064 (0.040)	0.054 (0.053)	0.068 (0.063)	0.192*** (0.040)	0.097 (0.061)	0.186*** (0.060)	0.261*** (0.060)	0.163* (0.088)	0.227** (0.094)
General							0.240*** (0.090)	0.435*** (0.139)	0.015 (0.138)
No. Employees				0.457*** (0.034)	0.319*** (0.054)	0.478*** (0.053)	0.480*** (0.061)	0.304*** (0.089)	0.447*** (0.101)
Capital Stock					0.210*** (0.027)			0.211*** (0.037)	
Log(Sales)				-0.534*** (0.024)	-0.591*** (0.039)	-0.569*** (0.036)	-0.573*** (0.041)	-0.626*** (0.061)	-0.574*** (0.068)
3-digit sector	✓	✓	✓	✓	✓	✓	✓	✓	✓
Age	✓	✓	✓	✓	✓	✓	✓	✓	✓
Country	✓	✓	✓	✓	✓	✓	✓	✓	✓
Observations	7666	4352	3166	7653	3326	3161	3582	1837	1153
Adjusted R^2	0.241	0.241	0.228	0.300	0.319	0.299	0.315	0.332	0.318
df.m	121	84	63	123	86	65	113	82	61

Standard errors in parentheses

Capital, labor, and output enter in logs.

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

In the case of energy intensity in physical units (Table 7), we find significant positive correlations with energy-centric management practices in all sectors, after controlling for a firm’s generic management practice level. Positive correlations with energy management measures likely reflect the fact that energy costs are more salient for these firms. To the extent that energy management helps firms disproportionately save costs relative to quantities of energy used, this positive correlation is expected to be even stronger. Interestingly, we see that correlations are positive for both generic and energy-centric management for manufacturing firms, but not for services firms. Given that on average manufacturing firms are more energy intensive than services firms, management practices may be tuned to address energy, whereas for services, only those firms that are relatively energy intensive develop energy management practices. In Table A13, we see that the effect in manufacturing runs mainly through energy management for high energy intensity firms (as they rely on energy-intensive capital equipment that may require specialized knowledge to realize improvements). However, for moderate and low energy intensity firms, generic management plays a dominant role, perhaps because energy costs are less salient and these practices are sufficient for the firm to achieve its energy conservation objectives. In services, the effect runs through high knowledge intensity firms, perhaps because sophisticated managers of relatively energy intensive firms see value in developing practices to minimize cost or other burdens energy imposes on daily operations.

4.5 Management Practices and Productivity

Results from the previous section suggest that both generic and energy-centric management practices, to a certain extent, can help mitigate the output-indexed cost of energy use. But can adoption of these practices help firms realize productivity gains? Table 8 shows that generic management is positively correlated with output, suggesting that better-managed firms produce more after controlling for their input use. Said differently, structured management explains variation in firm productivity, which is the residual of the production function,

consistent with prior studies. When energy-centric management scores enter into the regression with or without generic management, they exhibit a modest positive correlation with output in services but not in manufacturing. It may be that energy-saving opportunities in manufacturing firms are highly capital intensive, which imply large initial outlays and uncertain payback periods. By contrast, services firms may achieve energy savings through better coordination of knowledge and practice dissemination within the firm, without capital equipment modifications. The effect in the services sector is strongest among low knowledge intensity activities, which is comprised of transport, construction, retail trade, and hotels and restaurants (see Table A14). In these sectors, much of the energy use to be managed is related to building energy efficiency and electricity conservation; explicit practices may translate into changes in employee behavior and cost savings for the firms without machinery or infrastructure upgrades, driving productivity gains.

Table 8: Relationship between general management, energy management, and output.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	All Firms	Manufacturing	Services	All Firms	Manufacturing	Services	All Firms	Manufacturing	Services
General	0.305*** (0.031)	0.093** (0.044)	0.347*** (0.054)				0.265*** (0.032)	0.074 (0.045)	0.310*** (0.056)
Energy				0.158*** (0.015)	0.009 (0.022)	0.178*** (0.024)	0.099*** (0.021)	0.044 (0.028)	0.112*** (0.035)
No. Employees	0.971*** (0.015)	0.641*** (0.028)	0.924*** (0.026)	1.022*** (0.008)	0.609*** (0.022)	1.021*** (0.013)	0.963*** (0.015)	0.638*** (0.028)	0.916*** (0.026)
Capital Stock		0.088*** (0.015)			0.084*** (0.012)			0.086*** (0.015)	
Materials		0.302*** (0.026)			0.361*** (0.020)			0.301*** (0.026)	
3-digit sector	✓	✓	✓	✓	✓	✓	✓	✓	✓
Age	✓	✓	✓	✓	✓	✓	✓	✓	✓
Country	✓	✓	✓	✓	✓	✓	✓	✓	✓
Observations	7141	2265	2380	15627	4046	6579	7080	2246	2363
Adjusted R^2	0.623	0.809	0.606	0.679	0.854	0.652	0.624	0.808	0.607
df.m	120	84	65	125	86	68	121	85	66

Standard errors in parentheses

Capital, labor, and output enter in logs.

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

5 Conclusion

“Is management good for the environment, or just hot air?”¹⁷ Using firm-level data from 31 countries, our results suggest that management practices are associated with a reduction in energy expenditure intensity. However, these cost savings do not translate into reduced physical energy use, a close proxy for environmental impacts.

There may be several reasons for the divergence between the relationship of management practices to physical and expenditure measures of energy intensity. *First*, managers may be focused on saving costs, not limiting the environmental impacts of energy use *per se*. To the extent that management practices help managers reach their goals more expediently, it is perhaps not surprising that the correlation runs only through the energy expenditure intensity measure. *Second*, management may enable firms to take advantage of lower prices, e.g. through investments in self-generation or by allocating production hours to take advantage of favorable time-of-day pricing. Larger one-time or repeat energy purchases may be subject to subsidies or preferential pricing, relative to smaller outlays. For some firms, it may be economically attractive to increase physical energy use in order to save costs on other productive inputs, for instance, by automating certain processes. Therefore, our results suggest that although management practices are associated with reduced energy intensity in value terms, it does not mean that physical energy use, and its related environmental impacts, will follow the same pattern.

Turning to focus on energy management practices, we find they have no additional effect on reducing the intensity of energy expense over and above generic management practices. It is possible, given the diversity of firms in our sample, that the coefficient reflects reverse causality: energy-intensive firms have stronger incentives to develop energy management. The decision to develop energy management practices may be the result of selection by subset of firms most likely to profit from them. Supporting this notion, we find that energy management scores are on average higher in energy-intensive sectors. Energy-intensive man-

¹⁷This is the title of the paper by (Bloom et al., 2010a).

ufacturing firms also have a lower rate of “0” energy management scores at 2.6%, compared to 3.2% for moderate and 3.1% for low energy intensity firms. This is unsurprising, as energy costs are likely to be more salient for energy intensive firms, relative to the value of their output, leading them to invest in energy-specific management practices for their own sake, rather than benefiting from them as a spillover from generic management effort. By contrast, among services firms, the high and low knowledge intensity groups report 43% and 41% “0” scores, respectively.

Before controlling for generic management practices, our findings for manufacturing are similar to the results of Martin et al. (2012) (see Table 6, column (5)), who find that 190 U.K. firms exhibited lower energy expenditure intensity at higher levels of “climate-friendly” management practices. This study included a much longer list of practices, including exposure to climate policies, among them carbon pricing under the European Emissions Trading System, although negative effects were found for practice categories similar to the ones we examine, such as target-setting practices. It is difficult to assemble such detailed practices for a large number of firms in a cross-country setting. In this context, the Green Economy module can be improved to include additional practices relating to energy management, and to use a finer scoring scale, rather than relying on binary adoption measures.¹⁸

Finally, the generic management score is correlated with stronger firm performance for both manufacturing and services, while the energy-centric management score is only positively related in (low knowledge intensive) services. Given the high rate of “0” scores concentrated among small firms in services, it is possible that this pattern reflects that firms only consider introducing energy-centric practices once they are sufficiently large. Manufacturing firms, by contrast, show no relationship between energy management and productivity, suggesting limited incentive for firms to make further investments in energy-centric practices. Introducing CO₂ pricing or other pro-climate constraints on firm energy use may alter the calculus firms confront when deciding whether or not to invest in specialized energy

¹⁸For suggestions on how the energy management questions in the Green Economy Module of the WBES could be improved, please see Section A4.

management.

Taken together, our findings suggest that interventions aimed at improving energy management should be tailored to firm circumstances. Whether generic or energy-centric management translates into energy expenditure savings varies depending upon a firm’s circumstances, such as the extent to which reducing energy use requires capital expenditures or equipment upgrades, or can be adjusted through, for instance, team- or employee-level incentives for conservation. A deeper investigation of the barriers (e.g., administrative costs) that prevent firms from adopting energy management practices could aid in the design of informational or financial interventions that could help to overcome the energy-efficiency gap. However, without policy interventions that alter fundamental relationships among input prices or increase the salience of energy costs and climate concerns, management is likely to play a limited role in reducing energy-related environmental impacts.

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Supplementary Material

A1 Data Preparation

A1.1 World Bank Enterprise Surveys

We compile our data set from the World Bank Enterprise Surveys (World Bank, 2020a), a firm-level survey of a representative sample of an economy’s private sector, including both manufacturing and services firms. We used the 2019 surveys, which were conducted in 31 countries in Europe, the Middle East and North Africa, and the Russian Federation and Central Asia. In each country, firms responded to either the Manufacturing survey or the Services survey based on their self-identified sectors. The survey includes productive inputs, performance measures, business indicators, management practice scores, and a green economy module. This module covers energy and environmental impacts as well as energy- and climate-related management practices. We use the energy practices in the green economy module to compute the energy management score. This score is designed to capture the extent to which a firm has implemented structured practices aimed at reducing or raising the efficiency of energy use. The green economy module also covers the physical quantities of various forms of energy consumption such as electricity, petroleum, coal, and natural gas. We use these energy data to compute energy intensity in physical terms. To the best of our knowledge, this paper is the first to analyze the impact of general and energy management practices on physical and value measures of energy intensity.

Observations of services firms are generally missing capital stock and share of high-skilled labor. Using the World Bank classification (World Bank Data, 2020), only one country is classified as low-income (Tajikistan); we therefore group countries into three income categories: high, upper middle, and lower middle.

A1.2 Merging

We merge the firm-level responses from all the 31 countries into a combined dataset. For categorical variables such as region that are country-specific and thus inconsistent across surveys, we tagged the possible responses by country throughout the merge to ensure that the responses remained distinct in the final dataset. Additionally, for each country, we converted all financial variables into US dollars using the average market exchange rate in 2018 from World Bank (2020b). After merging, our sample included 20,156 observations.

A1.3 Management Measures

We develop a measure of structured management practices that takes 11 survey questions that quantify practices. These management practices can be divided into operations (1 practice), monitoring (2 practice), targeting (4 practices), and incentives (4 practices). The table below lists these management practices and the scoring scale applied for each. To better align with the methodology from (Bloom et al., 2010a), we map these 11 questions to the 8 questions used by the U.S. MOPS survey (U.S. Census Bureau, 2015). Thus, we combine:

- The two monitoring questions by keeping the latter
- "Did this establishment have production targets?" with "What best describes the time frame of production targets at this establishment?" to make "What best describes the company's production goals calendar?" (scored 1-4)
- "Did this establishment have performance bonuses for managers?" with "What were managers' performance bonuses mostly based on?" by only keeping the latter

We scale all scores between 0 and 1, with 1 best and 0 worst on performance. We apply a z-score normalization. First, each practice category is z-scored across all observations. Then the average is taken of these z-scored practices, conditional on at most 2 missing responses out of 8 management z-scores.

Table A1: Management Questions

Category	Question	Scoring Scale
Operations	What response best describes what happened in the company when a problem arose in its processes?	0 - No action, 0.33 - Fixed, 0.67 - Prevention, 1 - Continuous improvement
Monitoring	How many key performance indicators were monitored in the company?	0 - None, 0.33 - 1-2, 0.67 - 3-9, 1 - 10 or more
Targeting	Did this establishment have production targets? Examples of production targets are: production volume, quality, efficiency, waste, or on-time delivery.	0 - No, 1 - Yes
	What best describes the time frame of production targets at this establishment?	0 - No targets, 0.33 - Less than one year, 0.67 - One year or more, 1 - Combination of short- and long-term
	How easy or difficult was it for this establishment to achieve its production targets overall?	0 - Not achieved, 0.2 - Extraordinary effort, 0.4 - More than normal, 0.6 - Some effort, 0.8 - Normal effort, 1 - Not much effort
	Who was aware of the production targets at this establishment?	0 - Only senior managers, 0.33 - Most managers and some workers, 0.67 - Most managers and most workers, 1 - All managers and most workers

Incentives	What were the performance bonuses for managers based on?	0 - No bonuses, 0.25 - Firm performance, 0.5 - Establishment performance, 0.75 - Team performance, 1 - Their own performance
	What were the criteria with which the non-managers were promoted in the company?	0 - Non-managers not promoted, 0.33 - Factors such as tenure or family connections, 0.67 - Partly performance and ability and partly other factors, 1 - Solely performance and ability
	When a non-manager had a bad performance, was he or she reassigned or dismissed?	0 - Rarely or never, 0.5 - After 6 months, 1 - Within 6 months

A1.4 Energy Management Measures

For energy management, we identified seven management practices which can be categorized in monitoring (2 practices), targeting (1 practice), incentives (1 practice) and prioritization of energy management (3 practices). Each practice is scaled between 0 and 1, with 1 representing best management practice and 0 representing the worst. We use z-score normalization with the mean. First, each practice is z-scored across all observations. Then the average is taken of these z-scored practices. Energy management practices, scoring scale, and a detailed summary of responses are included in Table 1.

Table A2: Energy Management Questions

Category	Question	Scoring Scale
Monitoring	How often did this establishment monitor its energy consumption?	1-8
	Did this establishment complete an external audit of its energy consumption?	1-2
Targeting	What sort of targets for energy consumption did this establishment have?	1-4
Incentives	Is the manager responsible for environmental and climate change issues evaluated against how well the establishment performs on energy consumption, CO ₂ emissions or other pollution or environmental targets?	1-2
Energy as a Priority	Did this establishment adopt any measures to enhance energy efficiency?	1-2
	Were any of these measures developed by the establishment?	1-2
	Was there a maximum time period for the return on investment of the adopted energy efficiency measures?	1-2
	Was this maximum payback time longer than, equal to, or shorter than the average time applied to non-energy efficiency related measures?	1-3

A1.5 Energy Intensity

We use two measures of energy intensity, based on expenditure or physical quantities divided by output. A firm is included if expenditure or quantity is non-missing for electricity and at least one fuel type. To compute the energy intensity in value terms, we divide the total energy cost, summed over all energy types, by the sales of the firm. The total energy cost is computed by the sum of the reported total annual cost of electricity and fuel after conversion to the US\$. If either of the reported values is missing or marked as “don’t know,” we assume it to be zero and then sum it. We multiply the energy intensity by 100 to represent the energy intensity value measure in percentage.

We compute the energy intensity using physical quantities by dividing total energy consumed (in energy-equivalent units) by the sales of the firm. The total energy consumption in British Thermal Units (BTU) is found by first converting reported consumption in electricity, coal, natural gas and fuel made from petroleum to standard energy units (BTU) and then summing across them. Then if either of reported value is missing or don’t know, we assume it to be zero. We sum up these values if at least one of the values is non-zero. To

compute the energy intensity in physical terms, the total energy consumed is divided by the sales of the firm if the total energy consumed is non-zero. The units of energy intensity in physical terms is BTU per US\$.

A1.6 Treatment of Outliers

We winsorize observations in the main sample by excluding the top and bottom 1 percentile on energy intensity (physical), energy intensity (expenditure), and output measures. We retain 19,521 observations, although not every firm reports energy expenditure, physical energy use, and output. The management and green economy survey modules were administered to a subset of the randomly-selected firms in the full sample. Constructing our data set thus required trading off its size against a requirement that all major variables be observed. We do not systematically drop firms with missing observations of key variables, but instead remain mindful that our regression samples differ in composition. For instance, in the winsorized sample, we observe energy intensity (physical) for 8,272 firms and energy intensity (value) for 14,713 firms. We observe at least six out of eight general management practices for 8,476 firms, and energy management practices for 6,178 firms. Firms that have non-missing values for all covariates are included in each regression. If we limit the sample to only firms that observe both measures of energy intensity plus output, the sign of the results remains mostly unchanged (not shown). However, firms that report both physical energy use and expenditures may differ systematically from those that report only one or the other. For instance, these firms may have better developed general management or energy management practices that support monitoring of input use. The composition of firms across countries and two-digit sectors before and after winsorization is similar.

A1.7 Descriptive Statistics

The composition of firms across countries and two-digit sectors before and after winsorization is similar. Observations of services firms are generally missing capital stock and share of high-skilled labor. Using the World Bank classification (World Bank Data, 2020), only one country is classified as low-income (Tajikistan); we therefore group countries into three income categories: high, upper middle, and lower middle.

Table A3: Summary statistics of winsorized sample.

Variable	Obs	Mean	St. Dev	Min	p5	Median	p95	Max
Energy intensity exp (% of output)	14,076	5.04	7.39	0.03	0.16	2.36	20.19	51.75
Energy intensity quant (log) (BTU/USD)	7,695	6.53	2.52	-0.45	2.14	6.57	10.68	15.51
Elec intensity exp (% of output)	13,777	2.81	4.70	0.00	0.07	1.14	11.36	50.76
Elec intensity quant (log) (kWh/USD)	6,132	-5.74	3.16	-17.77	-11.23	-5.38	-1.16	4.39
Capital stock (log)	6,432	12.86	2.44	-1.07	8.96	12.83	16.89	33.66
Employees (log)	18,595	3.26	1.32	0	1.61	3.04	5.67	9.34
Sales (log)	16,410	13.70	2.09	4.31	10.32	13.66	17.17	19.01
General management score	9,853	0.48	0.21	0	0.08	0.51	0.78	1
Energy management score	17,347	0.28	0.29	0	0	0.17	0.83	1

Table A4: Generic and energy-centric management score statistics for high, upper middle, and lower middle income groups. (G) indicates generic management; (E) indicates energy-centric management. Uses the winsorized sample and computes management scores using straight averages of non-missing questions scores.

Income Group	Shr Obs = 0	Shr Obs < 0.25	Shr Obs > 0.75	Mean	SD	p10	Median	p90
(G) High	0.017	0.072	0.045	0.491	0.209	0.167	0.517	0.738
(G) Upper Middle	0.022	0.077	0.043	0.481	0.211	0.167	0.504	0.737
(G) Lower Middle	0.020	0.065	0.031	0.477	0.200	0.2	0.5	0.725
(E) High	0.345	0.209	0.122	0.291	0.304	0	0.167	0.778
(E) Upper Middle	0.387	0.283	0.070	0.237	0.273	0	0.167	0.719
(E) Lower Middle	0.213	0.162	0.102	0.365	0.296	0	0.359	0.806

A2 Supplementary Figures

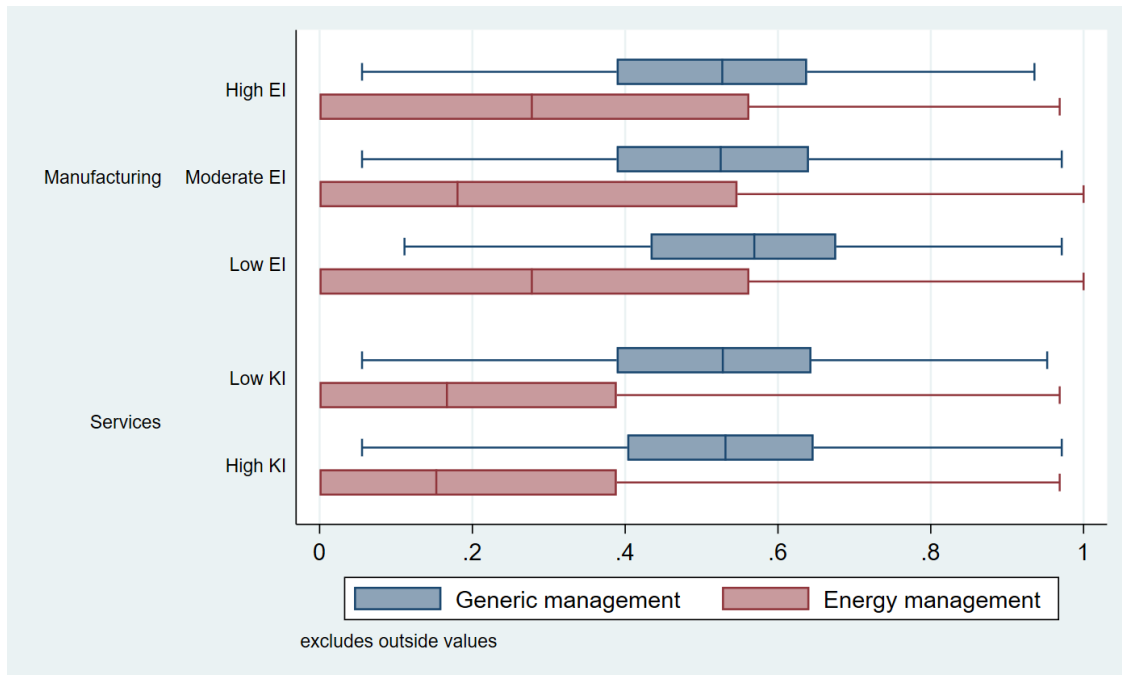


Figure A1: Variation in management and energy management scores. Manufacturing is further divided into high, medium, and low energy intensity; services are further divided into low and high knowledge intensity.

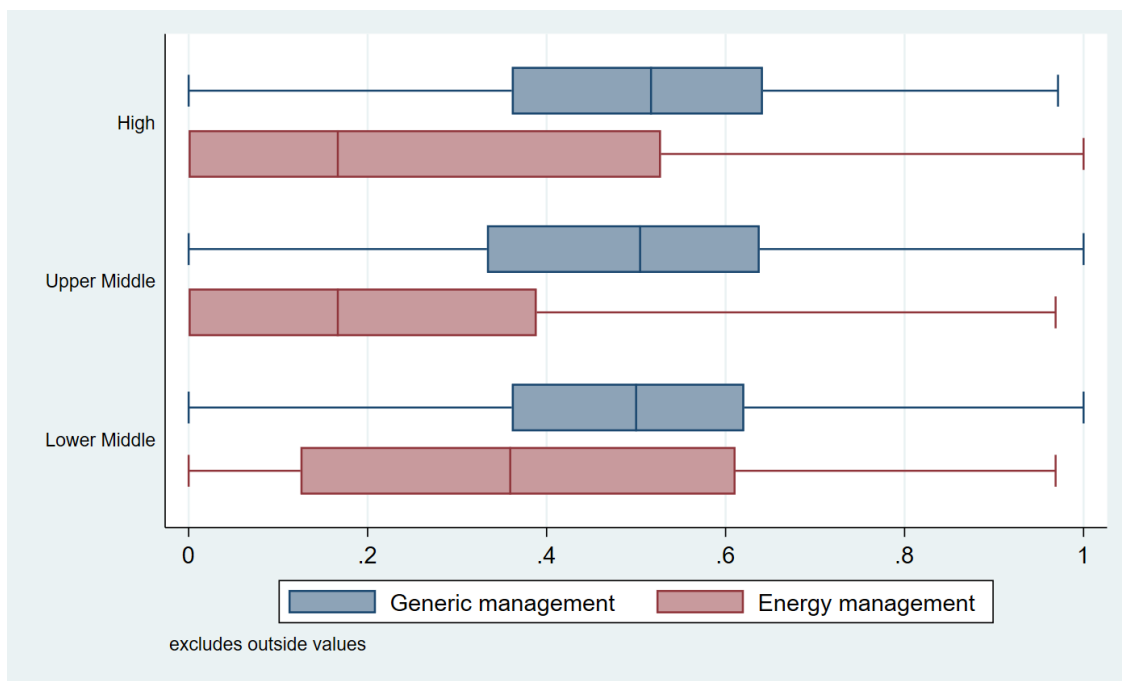
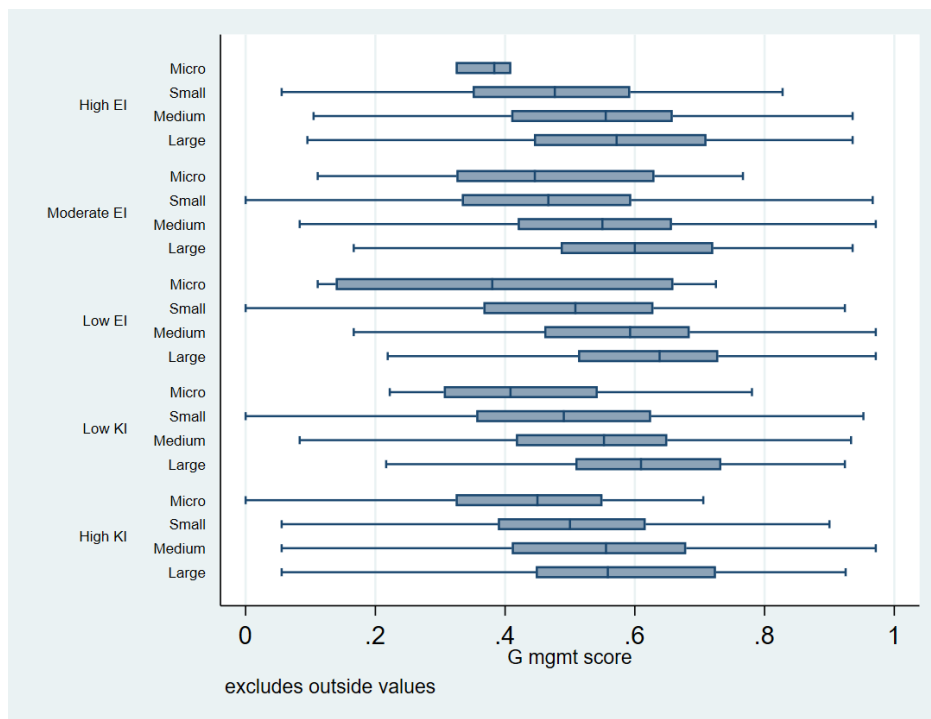
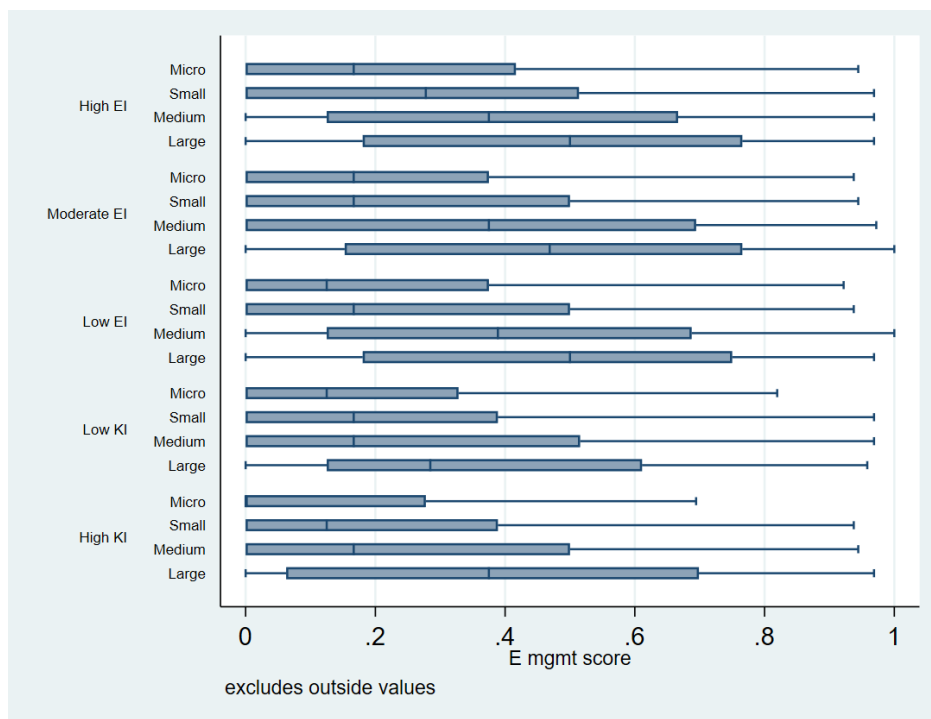


Figure A2: Variation in management and energy management scores, by country income group. Uses the non-winsorized sample with management scores computed as a straight average of non-missing entries.



(a) General management score



(b) Energy management score

Figure A3: Variation in (a) general management score and (b) energy management score by size and sector.

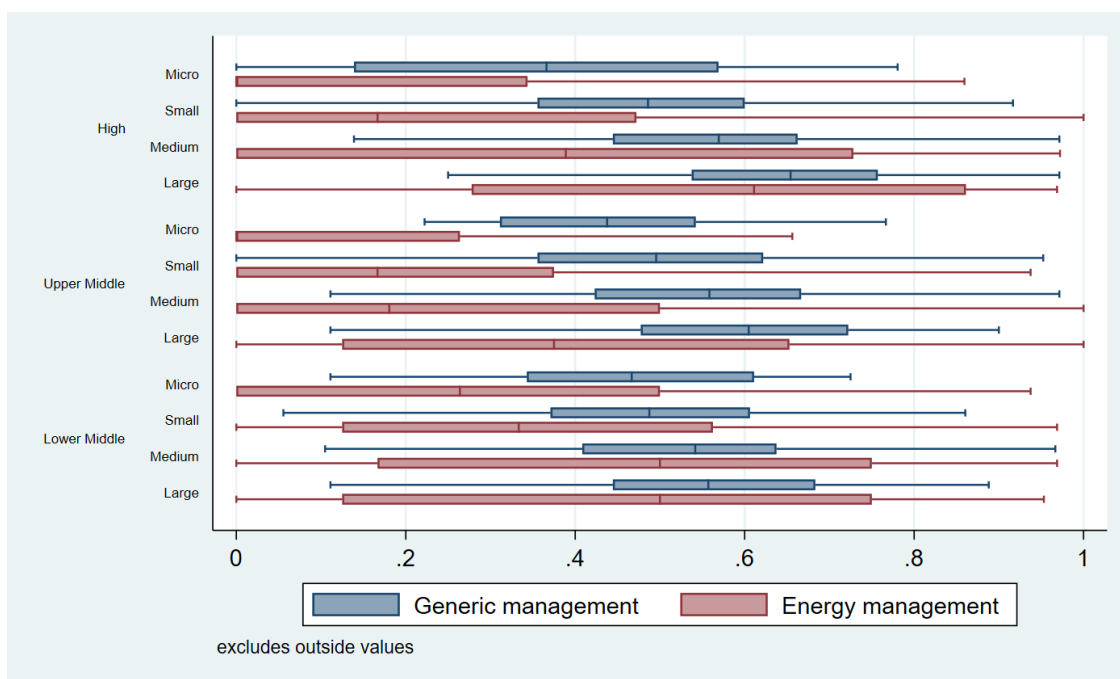


Figure A4: Variation in general and energy management scores by size and income group.

A3 Supplementary Tables

Table A5: Overview of prior literature on management practices, energy, and productivity.

Year	Authors	Country	Time Period	Outcome Variable	Methodology	Main Result
2012	Bloom, Schweiger and Van Reenen	Belarus, Bulgaria, Germany, India, Kazakhstan, Lithuania, Poland, Romania, Russian Federation, Serbia, Ukraine, Uzbekistan	October 2008 to April 2010	operating revenue, profit margin, EBIDTA, returns to total assets	measuring and scoring management practices, in areas of operations, monitoring, targets, and incentives	Average management score is positively and significantly correlated with total factor productivity.
2010	Bloom, Mahajan, McKenzie and Roberts	United States, United Kingdom, Japan, France, Germany, Greece, Poland, Brazil, Colombia, Ecuador, Morocco, China, Indonesia, Philippines, India		sales per employee		Firms in developing countries are often badly managed, which substantially reduces their productivity.
2012	Bloom, Genakos, Sadun and Van Reenen	Argentina, Australia, Brazil, Canada, Chile, China, France, Germany, Greece, India, Italy, Japan, Mexico, New Zealand, Poland, Portugal, Ireland, Sweden, United Kingdom, United States	2002 to 2012	sales, return on capital employed, sales growth, exit	double-blind survey technique for management scoring on 18 key practices	Higher management scores are robustly associated with better performance.
2010	Bloom, Genakos, Martin and Sadun	United Kingdom	summer 2006	real gross output (sales & inventory changes deflated with a sectoral producer price index)	match management data to production and energy usage information	Better managed firms are significantly more productive. Management practices that are associated with improved productivity are also linked to lower greenhouse gas emissions.

2007	Bloom and Van Reenen	United States, France, Germany, United Kingdom	summer 2004	total factor productivity, sales, return on capital employed	double-blind survey technique for management scoring on 18 key practices	Management practices are always positively and significantly associated with the longer-run component of TFP. Management also has a significant and positive association with ROCE.
2013	Bloom, Eifert, Mahajan, McKenzie and Roberts	India	August 2008 to August 2010; August 2011 to November 2011	quality, inventory, output, and total factor productivity (TFP)	exogenous consulting treatment intervention	The treatment intervention led to significant improvements in quality, inventory, and output.
2017	Bloom, Sadun and Van Reenen	34 countries	2004 to 2014	performance: value added	original survey data on management practices over 11,000 firms in four survey waves	Differences in management practices account for about 30% of total factor productivity differences both between countries and within countries across firms.
2018	Schweiger and Stepanov	38 countries in Central and Eastern Europe, Central Asia and Middle East and North Africa	2011 to 2016	energy intensity value measure	firm-level data on management practices and energy expenditures in about 2,000 manufacturing firms	An improvement in management from the 25th to the 75th percentile is associated with a 23% fuel intensity reduction when fuel subsidies are low (negative) and with a 2% fuel intensity reduction when fuel subsidies are high.

2014	Boyd and Curtis	United States	2006 to 2007	energy expenditure over gross output in percentage	merging survey of firm management practices with US Census data on manufacturing	Better managed firms produce more output and are larger. At best, findings show a modest relationship between management and energy efficiency, but standard errors are large.
2019	Grover, Iacovone, and Chakraborty	Croatia	2017	sales per employee, profit	survey on firm capabilities in Croatia, including a module for capturing management capabilities	Manufacturing firms are better managed than service firms. Better management is consistently and strongly associated with better performance.
2019	Bloom, Brynjolfsson, Foster, Jarmin, Patnaik, Saporta-Eksten, Van Reenen	United States	2010 to 2015	total factor productivity	survey of structured management practices in 35,000 manufacturing plants	The study finds large differences in productivity associated with variations in management practices.
2019	Bloom, Iacovone, Pereira-Lopez, Van Reenen	Mexico, United States	2014 to 2015	total factor productivity, profit	survey of management practices, combined with data from Mexico's National Survey on Productivity and Competitiveness in 2015	Management score is strongly and positively correlated with firm productivity.
2020	Karplus and Zhang	China	March and April 2016	energy efficiency, total energy use	two-part survey on management and energy management; electricity use and production information from SECA survey	Moving from the 25th to 75th percentile on management score reduces electricity intensity by 40% in value terms and by 33% in physical terms.

Table A6: Relationship between management and energy intensity (value), by country income group.

	(1) High	(2) Upper Middle	(3) Lower Middle	(4) High	(5) Upper Middle	(6) Lower Middle
General	-0.442* (0.239)	-0.389 (0.263)	-1.563*** (0.588)	0.339 (0.235)	0.229 (0.261)	-1.238** (0.579)
No. Employees				0.822*** (0.224)	1.052*** (0.173)	1.533*** (0.298)
Log(Sales)				-1.168*** (0.194)	-1.727*** (0.145)	-1.710*** (0.185)
3-digit sector	✓	✓	✓	✓	✓	✓
Age	✓	✓	✓	✓	✓	✓
Country	✓	✓	✓	✓	✓	✓
Observations	2013	2664	1394	2012	2656	1393
Adjusted R^2	0.266	0.234	0.135	0.302	0.306	0.208
df_m	85	89	73	87	91	75

Standard errors in parentheses

Capital, labor, and output enter in logs.

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table A7: Relationship between management and energy intensity (value) (split by energy intensity for manufacturing and knowledge intensity for service firms).

	(1)	(2)	(3)	(4)	(5)
	High EI	Moderate EI	Low EI	High KI	Low KI
General	-0.211 (0.804)	0.085 (0.340)	0.111 (0.369)	0.213 (0.341)	-1.050 (0.708)
No. Employees	0.921** (0.422)	0.909*** (0.245)	1.029*** (0.308)	1.251*** (0.233)	1.021** (0.417)
Capital Stock	0.490** (0.198)	0.335*** (0.087)	0.458*** (0.132)		
Log(Sales)	-1.536*** (0.311)	-1.727*** (0.173)	-1.672*** (0.281)	-1.972*** (0.195)	-1.576*** (0.312)
3-digit sector	✓	✓	✓	✓	✓
Age	✓	✓	✓	✓	✓
Country	✓	✓	✓	✓	✓
Observations	586	1693	666	1301	758
Adjusted R^2	0.189	0.237	0.268	0.189	0.444
df_m	43	46	54	43	52

Standard errors in parentheses

Capital, labor, and output enter in logs.

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table A8: Relationship between management and energy intensity (quantity) (split by energy intensity for manufacturing and knowledge intensity for service firms).

	(1)	(2)	(3)	(4)	(5)
	High EI	Moderate EI	Low EI	High KI	Low KI
General	0.358 (0.347)	0.416** (0.169)	0.975*** (0.286)	0.296* (0.158)	-0.213 (0.274)
No. Employees	0.471** (0.213)	0.314*** (0.117)	0.077 (0.178)	0.428*** (0.117)	0.561*** (0.178)
Capital Stock	0.362*** (0.082)	0.159*** (0.044)	0.250*** (0.081)		
Log(Sales)	-0.700*** (0.142)	-0.630*** (0.075)	-0.482*** (0.128)	-0.631*** (0.083)	-0.563*** (0.118)
3-digit sector	✓	✓	✓	✓	✓
Age	✓	✓	✓	✓	✓
Country	✓	✓	✓	✓	✓
Observations	381	1016	410	712	441
Adjusted R^2	0.371	0.320	0.359	0.332	0.293
df_m	42	46	45	42	47

Standard errors in parentheses

Capital, labor, and output enter in logs.

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table A9: Relationship between management and energy intensity (quantity), by country income group.

	(1) High	(2) Upper Middle	(3) Lower Middle	(4) High	(5) Upper Middle	(6) Lower Middle
General	0.170 (0.131)	0.214 (0.160)	0.304* (0.166)	0.550*** (0.139)	0.410** (0.164)	0.243 (0.165)
No. Employees				0.416*** (0.114)	0.412*** (0.103)	0.704*** (0.105)
Log(Sales)				-0.561*** (0.084)	-0.547*** (0.071)	-0.617*** (0.068)
3-digit sector	✓	✓	✓	✓	✓	✓
Age	✓	✓	✓	✓	✓	✓
Country	✓	✓	✓	✓	✓	✓
Observations	1218	1236	1080	1217	1233	1079
Adjusted R^2	0.206	0.240	0.094	0.249	0.285	0.185
df_m	81	76	67	83	78	69

Standard errors in parentheses

Capital, labor, and output enter in logs.

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table A10: Relationship between management (all sub-scores) and energy intensity in value (1)-(5) and quantity (6)-(10) terms (split by energy intensity for manufacturing and knowledge intensity for service firms).

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	High EI	Moderate EI	Low EI	High KI	Low KI	High EI	Moderate EI	Low EI	High KI	Low KI
Targets z-score	-0.058 (0.426)	-0.780*** (0.193)	-0.440* (0.229)	-0.083 (0.244)	0.533 (0.451)	0.352* (0.194)	-0.132 (0.108)	0.124 (0.138)	0.035 (0.119)	0.211 (0.196)
Monitor z-score	-0.165 (0.376)	-0.008 (0.162)	-0.080 (0.230)	0.042 (0.215)	-0.778* (0.407)	0.299 (0.183)	0.189* (0.099)	0.408*** (0.146)	0.071 (0.111)	0.041 (0.167)
Operations z-score	-0.268 (0.420)	-0.024 (0.161)	0.215 (0.204)	0.069 (0.167)	0.154 (0.345)	-0.082 (0.145)	0.154* (0.084)	-0.048 (0.144)	0.209*** (0.080)	-0.073 (0.118)
Incentives z-score	0.146 (0.499)	0.387* (0.225)	-0.202 (0.283)	-0.002 (0.257)	0.079 (0.462)	-0.288 (0.227)	0.027 (0.113)	-0.121 (0.171)	0.059 (0.122)	-0.106 (0.199)
No. Employees	0.697 (0.434)	0.841*** (0.253)	0.979*** (0.316)	1.311*** (0.234)	1.360*** (0.440)	0.313 (0.212)	0.318*** (0.123)	0.014 (0.163)	0.387*** (0.116)	0.498*** (0.186)
Capital Stock	0.667*** (0.204)	0.508*** (0.096)	0.691*** (0.143)			0.380*** (0.090)	0.174*** (0.051)	0.333*** (0.076)		
Log(Sales)	-1.435*** (0.311)	-1.760*** (0.184)	-1.754*** (0.279)	-1.954*** (0.197)	-2.084*** (0.333)	-0.656*** (0.147)	-0.604*** (0.081)	-0.446*** (0.120)	-0.607*** (0.077)	-0.579*** (0.118)
3-digit sector	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Age	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Country	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Observations	582	1680	688	1305	750	362	991	421	702	433
Adjusted R^2	0.182	0.228	0.244	0.191	0.440	0.409	0.297	0.357	0.326	0.278
df_m	46	49	54	46	56	45	49	47	45	49

Standard errors in parentheses

Capital, labor, and output enter in logs.

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table A11: Relationship between general management practices and energy management practices (split by energy intensity for manufacturing and knowledge intensity for service firms).

	(1)	(2)	(3)	(4)	(5)
	High EI	Moderate EI	Low EI	High KI	Low KI
General	0.403*** (0.057)	0.496*** (0.037)	0.503*** (0.062)	0.311*** (0.035)	0.350*** (0.051)
No. Employees	0.006 (0.036)	0.076*** (0.024)	0.037 (0.039)	0.023 (0.023)	0.050* (0.030)
Capital Stock	0.049*** (0.014)	0.022** (0.010)	0.049*** (0.017)		
Log(Sales)	0.031 (0.025)	0.026* (0.015)	0.002 (0.031)	0.038** (0.015)	0.024 (0.018)
3-digit sector	✓	✓	✓	✓	✓
Age	✓	✓	✓	✓	✓
Country	✓	✓	✓	✓	✓
Observations	621	1790	694	1509	854
Adjusted R^2	0.362	0.295	0.287	0.181	0.166
df_m	43	46	53	43	53

Standard errors in parentheses

Capital, labor, and output enter in logs.

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table A12: Relationship between energy management and energy intensity in value terms (split by energy intensity for manufacturing and knowledge intensity for service firms).

	(1) High EI	(2) Moderate EI	(3) Low EI	(4) High KI	(5) Low KI
Energy	-0.015 (0.460)	0.053 (0.199)	-0.002 (0.243)	-0.049 (0.263)	0.568 (0.467)
General	-0.346 (0.884)	0.060 (0.333)	0.159 (0.358)	0.220 (0.358)	-1.283* (0.737)
No. Employees	0.860** (0.420)	0.910*** (0.249)	1.052*** (0.306)	1.261*** (0.234)	1.044** (0.419)
Capital Stock	0.529*** (0.195)	0.333*** (0.088)	0.447*** (0.132)		
Log(Sales)	-1.534*** (0.310)	-1.732*** (0.173)	-1.673*** (0.280)	-1.972*** (0.194)	-1.619*** (0.313)
3-digit sector	✓	✓	✓	✓	✓
Age	✓	✓	✓	✓	✓
Country	✓	✓	✓	✓	✓
Observations	584	1684	656	1293	754
Adjusted R^2	0.190	0.236	0.286	0.188	0.444
df_m	44	47	54	44	53

Standard errors in parentheses

Capital, labor, and output enter in logs.

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table A13: Relationship between energy management and energy intensity in quantity terms (split by energy intensity for manufacturing and knowledge intensity for service firms).

	(1) High EI	(2) Moderate EI	(3) Low EI	(4) High KI	(5) Low KI
Energy	0.447* (0.245)	0.088 (0.113)	0.015 (0.178)	0.223* (0.116)	0.152 (0.162)
General	0.178 (0.367)	0.371** (0.177)	0.966*** (0.297)	0.214 (0.164)	-0.248 (0.280)
No. Employees	0.492** (0.217)	0.307*** (0.117)	0.076 (0.178)	0.420*** (0.117)	0.550*** (0.179)
Capital Stock	0.339*** (0.083)	0.157*** (0.043)	0.250*** (0.081)		
Log(Sales)	-0.735*** (0.145)	-0.633*** (0.076)	-0.482*** (0.129)	-0.636*** (0.083)	-0.568*** (0.118)
3-digit sector	✓	✓	✓	✓	✓
Age	✓	✓	✓	✓	✓
Country	✓	✓	✓	✓	✓
Observations	381	1016	410	712	441
Adjusted R^2	0.376	0.320	0.357	0.334	0.293
df_m	43	47	46	43	48

Standard errors in parentheses

Capital, labor, and output enter in logs.

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table A14: Relationship between general management, energy management, and output (split by energy intensity for manufacturing and knowledge intensity for service firms).

	(1)	(2)	(3)	(4)	(5)
	High EI	Moderate EI	Low EI	High KI	Low KI
General	0.035 (0.103)	0.048 (0.063)	0.135 (0.090)	0.285*** (0.067)	0.393*** (0.099)
Energy	0.056 (0.064)	0.085** (0.036)	-0.032 (0.061)	0.109** (0.043)	0.080 (0.060)
No. Employees	0.640*** (0.066)	0.644*** (0.038)	0.625*** (0.065)	0.957*** (0.030)	0.843*** (0.053)
Capital Stock	0.028 (0.035)	0.094*** (0.020)	0.101*** (0.032)		
Materials	0.412*** (0.045)	0.288*** (0.029)	0.255*** (0.066)		
3-digit sector	✓	✓	✓	✓	✓
Age	✓	✓	✓	✓	✓
Country	✓	✓	✓	✓	✓
Observations	420	1234	549	1509	854
Adjusted R^2	0.801	0.817	0.793	0.624	0.589
df_m	43	47	53	43	53

Standard errors in parentheses

Capital, labor, and output enter in logs.

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

A4 Expanding the WBES Green Economy Module

The WBES Green Economy Module largely focuses on binary measures of a firm's effort to improve energy efficiency. It largely does not distinguish between economic and non-economic motivations for adopting energy management. The areas below represent additional lines of questioning that could be built into future versions of the WBES Green Economy Module.

- Measure relative extent of practice adoption, rather than binary questions about whether a practice has been adopted. Sample question(s): At what scale do you measure the firm's physical energy use: by factory, production line, or specific equipment? How often do you hold meetings to review the firm's energy use?
- Measure the extent to which employees at all levels of the organization are aware of energy-saving targets. Sample question(s): If you hold meetings to review energy use, who typically attends? If I asked one of your factory floor employees what measures they take to manage energy inputs, what would they say?
- Understand the organization of energy management functions within the firm. Sample question(s): Does the firm have a dedicated energy manager? If yes, who does that individual report to? Is responsibility for energy management part of the regular training for your employees? Please describe.
- Determine whether or not the firm faces government energy efficiency mandates, and how it has responded to them. Sample question(s): Is the firm required by the government to limit its energy consumption? What measures has the firm taken in response? How difficult is it for the firm to implement these policies?
- Assess ease of access to inputs and pricing at the firm level. Sample question(s): Does the firm face tiered pricing? Does the firm receive its energy at a discount? Does buying on contract versus via the spot market affect the energy price the firm receives? Are frequent power outages a common problem for the firm? How often do they occur? What do you do to mitigate them?
- Evaluate relative emphasis on energy conservation, relative to other goals. Sample question(s): What are the firm's top five objectives against which top managers evaluate success? Is reducing energy cost is a high, medium, or low priority for the top management? Is conserving physical energy used is a high, medium, or low priority for the top management?