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MODERN MANAGEMENT: GOOD FOR THE ENVIRONMENT OR JUST HOT AIR?*

Nicholas Bloom, Christos Genakos, Ralf Martin and Raffaella Sadun

We use an innovative methodology to measure management practices in over 300 manufacturing firms in the UK. We then match this management data to production and energy usage information for establishments owned by these firms. We find that establishments in better managed firms are significantly less energy intensive. This effect is quantitatively substantial: going from the 25th to the 75th percentile of management practices is associated with a 17.4% reduction in energy intensity. Better managed firms are also significantly more productive. These results suggest that management practices that are associated with improved productivity are also linked to lower greenhouse gas emissions.

A growing literature is pointing to differences in management practices as an important factor in explaining variations in productivity across firms and countries.[1] In this article, we examine how the quality of management relates to the energy intensity of firms, a key driver of greenhouse gas pollution (GHG). The theoretical relationship between management practices and energy intensity is *a priori* ambiguous.[2] On the one hand, better managed firms should be able to reduce energy use through more efficient production techniques. On the other hand, better management might achieve higher productivity through more intensive capital utilisation which may lead to higher energy usage. In this article we assemble the first data set on management practices and energy intensity to investigate this relationship.

We match firm-level information on management practices to production and energy usage data from the UK census for the establishments owned by these firms. The energy usage data from the census allows us to undertake the first evaluation of the firm level association between management practices and energy utilisation. We find a robust negative correlation between management practices and energy intensity, plotted in log deviations from 3-digit industry averages in Figure 1. In other words, better managed firms are less energy intensive and – as we discuss in Section 3 – this relationship is robust to a large number of additional controls like industry, location, technology, size and other factor inputs. Of course this does not necessarily imply that better management practices *cause* better energy use practices but it is an intriguing correlation whose causal mechanics should be explored in future research. And the magnitude of this negative cross-firm management correlation with energy intensity is

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[1] See, for example, Ichniowski *et al.* (1997), Black and Lynch (2001), Cappelli and Neumark (2001), Bertrand and Schoar (2003), Bartel *et al.* (2007), Bloom and Van Reenen (2007) and Bloom *et al.* (2007).

[2] See, for example, the survey in Rugman and Verbeke (1998).

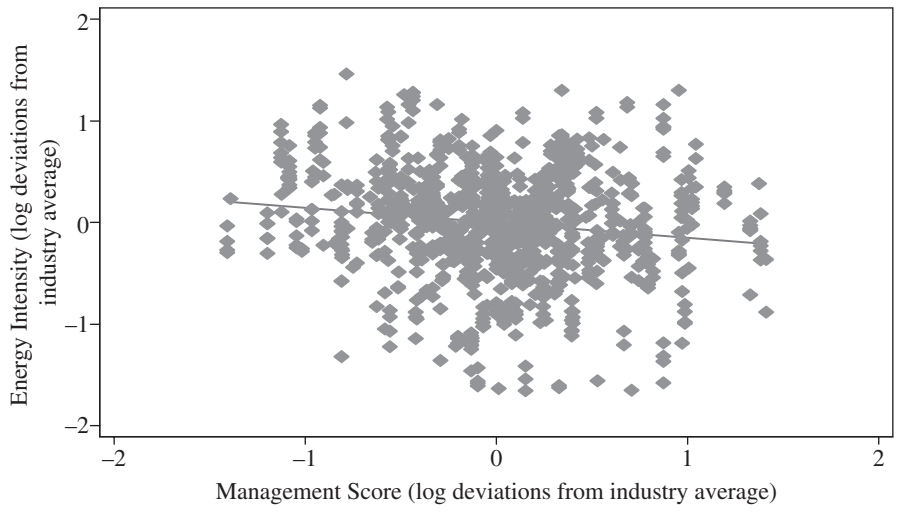

Fig. 1. *Energy Intensity and Management at the Firm Level* (*UK firms only*)
Notes. Data from census of production (ARD) and CEP management survey. The graph shows a scatter plot of the residuals of a regression of log(energy expenditure/sales) on 3-digit industry sector dummies against the residuals of a regression of the management score on the same 3-digit industry binary indicators.

quantitatively substantial: improving management practices from the 25th to the 75th percentile is associated with a 17.4% reduction in energy intensity.

We also investigate the link between management practices and productivity, finding a strong positive correlation: improving the quality of management from the 25th to 75th percentile is associated with a 3.7% increase in total-factor productivity. Therefore, overall these results suggest that management practices that are associated with improved productivity are not linked to worse environmental performance. Rather, our results are broadly supportive of the idea that well-run firms use energy inputs more efficiently, thereby increasing profitability and productivity, while at the same time reducing carbon emissions. We also find better managed firms use fewer materials in their production process, but more physical capital and labour.

A question that arises from our results is what could drive the negative correlation between energy intensity, management and economic performance in our firms? One explanation is that modern management involves production systems that minimise energy use. In particular, 'lean manufacturing', which is a widely adopted modern management technology developed by Toyota in the 1960s and 1970s, explicitly tries to reduce the waste of materials and energy.[3]

Another explanation is that good management practices enable firms to generate and implement a broad array of energy saving ideas (not just energy efficient production). A number of prior papers[4] have discussed evidence that US firms are not

[3] See, for example, Womack *et al.* (1990).
[4] See in particular DeCanio (1993), Howarth *et al.* (2000) and Anderson and Newell (2004).

using a range of energy efficient and cost effective technologies such as low energy lighting or thermal lagging. Interestingly, when firms are provided with assistance from Government programmes, such as the Environmental Protection Agency's Green Lights scheme, they frequently adopt these energy saving technologies, making substantial savings. This literature (Howarth *et al.*, 2000) has suggested that this lack of adoption of profitable initiatives without outside advice from the Government stems from a range of informational and principal–agent problems. For example, senior management may not be informed about best energy practices and junior managers performance incentives may be too narrow to cover energy efficiency. Another problem is that the budgets for energy improvement projects often fall across multiple departments – for example the costs arise in maintenance and the benefits in operations, so that incentives are not aligned. And the returns to energy saving projects can also be long run and risky, so that excessively short-term narrow targets can discourage managers pursuing these ideas.

It is clear that all of these informational and principal–agent problems, which can block the adoption of energy efficient technologies, would be much less severe in a firm with good management. In well-managed firms effective monitoring would mean energy saving ideas are picked up and analysed, appropriate targets would mean that managers are more focused on broader long-run goals, and aligned incentives would promote employees to operate across departments in the firm. Indeed, this is consistent with the results in De Canio and Watkins (1998) who report that more profitable and faster growing firms – those that we find to be better managed in our data – do indeed appear much more likely to adopt energy saving initiatives.

Our results also suggest that policies aimed at improving management practices – such as encouraging competition, reducing labour-market regulations and eliminating tax incentives for family ownership – could also be associated with improved environmental outcomes. [5] One example supporting this concept is the staggering energy inefficiency of the (old) Soviet block factories. These firms did not face product market competition, so had little incentive to economise on energy use. This could be particularly true in developing countries where management practices and energy efficiency are often particularly poor.[6]

The rest of the article is organised as follows. In the next Section we describe the two data sources used for this study. The second Section provides the results and counterfactual analysis, while the last Section concludes.

1. Data

The data used for the analysis are drawn from two different sources. The first source is the firm-level management survey conducted by the Centre for Economic Performance at the London School of Economics during the summer of 2006. This includes 18 questions from which the overall management source is computed plus additional information on firms' characteristics and the interview process. The second source is

[5] Of course the results might equally entail that environmental policies targeting firms lead to improvements in economic performance, as suggested for example in Berman and Bui (2001) and Shadbegian and Gray (2005).

[6] See for example Bloom *et al.* (2009).

the establishment-level Census of Production data from the UK Office of National Statistics, which provides detailed information on production inputs.

1.1. *Management Data*

Overall, we surveyed almost 4,000 firms across 12 countries. Although in this article we use only information on UK firms, in this Section we describe the three key steps in collecting informative management practice data from firms across all countries.

1.1.1. *Scoring management practices*

First, to measure management requires codifying the concept of 'good' or 'bad' management into a measure applicable to different firms across the manufacturing sector. This is a challenging task as good management is difficult to define and is often contingent on a firm's environment. Our initial hypothesis was that, while characterising every managerial practice as 'good' or 'bad' was extremely hard, there is a subset of practices that are common across manufacturing firms and for which such a characterisation is informative. Our survey questions focus on such practices, and is built from a practice evaluation tool developed by a leading international management consultancy firm.

Our survey evaluation tool defines 18 key management practices used by industrial firms and scores them from one (worst practice) to five (best practice). In Appendix A (Table A1) we detail these practices and the type of questions we asked in the same order as they appeared in the survey. Bloom and Van Reenen (2006) gives examples and more details on these practices.

These practices are grouped into four areas: *operations* (three practices), *monitoring* (five practices), *targets* (five practices) and *incentives* (five practices). The shop-floor operations section focuses on the introduction of lean manufacturing techniques, the documentation of processes improvements and the rationale behind the introduction of such improvements. The monitoring section focuses on the tracking of performance of individuals, reviewing performance (e.g. through regular appraisals and job plans) and consequence management (e.g. making sure that plans are kept and appropriate sanctions and rewards are in place). The targets section examines the type of targets (whether goals are simply financial or operational or more holistic), the realism of the targets (stretching, unrealistic or non-binding), the transparency of targets (simple or complex) and the range and interconnection of targets (e.g. whether they are given consistently throughout the organisation). Finally, the incentives section includes promotion criteria (e.g. purely tenure based or including an element linked to individual performance), pay and bonuses, and fixing or firing bad performers, where best practice is deemed the approach that gives strong rewards for those with both ability and effort. A subset of the practices has similarities with those used in studies on Human Resource Management practices literature such as Ichniowski *et al.* (1997), Black and Lynch (2001) and Cappelli and Neumark (2001).

In our main econometric specifications we take the unweighted average across the scores as our primary measure of overall managerial quality. We also experimented with other weighting schemes based on factor analytic approaches but none of our results changed in any fundamental way.

1.1.2. *Collecting accurate responses*

A second challenge is to obtain unbiased responses to these questions. The survey instrument was targeted at plant managers, who are typically senior enough to have an overview of management practices but not senior enough as to be detached from day-to-day operations of the enterprise. To obtain accurate information, we used a *double-blind* survey methodology. This consisted of two steps. First, the interviews were conducted by telephone without revealing to the managers that they were being scored. This enabled scoring to be based on the interviewer's evaluation of the firm's actual practices, rather than their aspirations, the manager's perceptions or the interviewer's impressions. Interviewers were specifically instructed to use open (i.e. 'can you tell me how you promote your employees?'), rather than closed questions (i.e. 'do you promote your employees on tenure [yes/no]?'). Furthermore, these questions targeted actual practices and examples, with the discussion continuing until the interviewer could make an accurate assessment of the firm's typical practices based on these examples. For each practice, the first question was broad and it was followed by detailed questions to fine-tune the scoring. For example, regarding the introduction of modern manufacturing practices, the initial question was: 'Can you tell me about your manufacturing process?' and was followed by the more specific question: 'How do you manage your inventory levels?'.

The second step of the *double-blind* scoring methodology was that the interviewers did not know anything about the firm's financial information or performance in advance of the interview. This was achieved by selecting medium-sized manufacturing firms and by providing only firm names and contact details to the interviewers (but no financial details). These smaller firms (the median size was 275 employees) would not be known by name and are rarely reported in the business media. The interviewers were specially trained graduate students from top European and US business schools. All interviews were conducted in the local language.

Since each interviewer ran 85 interviews, on average, we can remove interviewer fixed effects from all empirical specifications. This helps to address concerns over inconsistent interpretation of categorical responses (Manski, 2004), standardising the scoring system. As additional controls for any residual potential survey noise, we collected detailed information on the interview process itself (number and type of prior contacts before obtaining the interviews, duration, time-of-day, date and day-of-the week) and on the manager (gender, seniority, nationality, company and job tenure, internal and external employment experience and location). We refer to these variables as 'noise controls', since their inclusion should help us to control for measurement error.

1.1.3. *Obtaining interviews with managers*

Each interview took on average 45 minutes and was run during the summers of 2006 to 2008 from the Centre for Economic Performance at the London School of Economics. Overall, we obtained a relatively high response rate of 45%, which was achieved through four steps. First, the interview was introduced as 'a piece of work' without discussion of the firm's financial position or its company accounts, making it relatively uncontroversial for managers to participate. Interviewers did not discuss financials in the interviews, not only to maximise the participation of firms but also to ensure our interviewers were truly 'blind' on the firm's financial position. Also the fact that the

questions were focused on firms' managerial practices meant that many managers, besides the plant manager, could be contacted.[7] Second, practices were ordered to lead with the least controversial (shop-floor operations management) and finish with the most controversial (pay, promotions and firings). Third, interviewers' performance was closely monitored and explicitly incentivised. On the one hand, each team of interviewers (two or three persons) had a dedicated supervisor, providing on-the-spot training and advice but also double-scoring most of the interviews conducted. On the other hand, interviewers' compensation was per interview conducted and there were also bonus payments on reaching team goals. These efforts led interviewers to be persistent when chasing any particular firm. Fourth, the written endorsement of the Governments, Central Banks and Employer Federations across the countries interviewed helped to demonstrate to managers that this was an important exercise with official support.

We focused on medium-sized manufacturing firms, randomly selecting firms with between 100 and 5,000 employees. Comparing the responding firms with those in the sampling frame, we found no evidence that the responders were systematically different on any of the performance measures to the non-responders. The only exception was on size, where our firms were slightly larger on average than those in the sampling frame.

The average management scores for the 15 countries are highest for the US, Canada and the traditional manufacturing countries like Germany, Japan and Sweden, intermediate for Northern Europe (UK, France, Italy and Poland) and low for Southern Europe and developing countries (Portugal, Greece, India, Brazil and China).[8]

1.2. *Census of Production Data*

The UK Office of National Statistics (ONS) maintains a register of all businesses in Britain called the Interdepartmental Business Register (IDBR). On the basis of this register the ONS runs a mandatory survey of UK businesses at the establishment level, the Annual Business Inquiry (ABI).[9] Our establishment level production data, the Annual Respondents Database (ARD), is derived from this survey.[10] The ARD focuses mostly on the establishments of medium and large firms, whereas smaller businesses with less than 250 employees are not surveyed every year but included in the sample on a random basis. The ARD sample accounts for around 90% of total UK manufacturing employment.

1.2.1. *Matching the census of production data to the management survey data*

The CEP management survey provides data on 601 firms in Britain. Around 338 of these could be matched to the census production data. The match is not complete because the system of Company Register Numbers (CRN), which is the basis for the

[7] We found no significant correlation between the number, type and time-span of contacts before an interview is conducted and the management score. This suggests while different managers may respond differently to the interview proposition, this does not appear to be directly correlated with their responses or the average management practices of the firm.

[8] See, Bloom and Van Reenen (2010).

[9] Descriptions of the ABI can be found in Griffith (1999) and Criscuolo *et al.* (2003).

[10] This survey is the UK equivalent of the US Longitudinal Respondents Database (LRD).

Table 1
Descriptive Statistics

	(1)	(2)	(3)	(4)
			Percentiles	
	Mean	Standard Deviation	25th	75th
Management	3.061	0.641	2.655	3.495
Energy expenditure over gross output (*EE/GO*) %	1.744	2.026	0.748	2.045
Employment	407	456	161	480
Energy expenditure (£000s)	1,011	1,950	146	879

Notes. The Table provides summary statistics on some of the key variables of the matched census of production and management survey data. Management is the average score across the 18 questions on management practices from the CEP management survey.

management survey, is maintained independently from the businesses registry that the production census is based upon. Although the ONS provides a lookup table between the two registers, there are a number of firms surveyed on their managerial practices that could not be matched to the production census. This is typically the case for smaller, less established firms.

Table B1 in the Appendix reports descriptive statistics for the two samples of matched and un-matched firms. In terms of employment, matched firms have on average about 84 employees more than un-matched firms. They are also slightly older and have a higher management score. To the extent that this sample selection affects our results, we expect that it would introduce a downward bias by compressing the range of variation of firm performance (reducing the signal to noise ratio in the data). Appendix B provides further details of the matching process.

Because of stratified random sampling of smaller firms in the ARD,[11] we do not have production data for every firm in every year. Table 1 reports statistics for establishments of firms we can use for productivity and energy intensity analysis. In total we are able to use 1,046 observations corresponding to 272 establishments between 1999 (first year with energy expenditure data) and 2004 (last available wave of the ARD).

2. Results

Our results are discussed in three parts. First, as a basic check on the data we confirm that our firm-level management measure is significantly related to establishment level productivity, mirroring the results of Bloom and Van Reenen (2007). Second, we provide evidence showing that managerial quality is significantly related to lower levels of energy intensity. In other words, we demonstrate that the best managed firms are not only more productive but also more efficient consumers of energy. Finally, we examine how management is related to the intensity in other production factors.

[11] Establishments of firms with less than 250 employees are included on a random basis in the ARD whereas larger firms are sampled every year.

2.1. *Management Practices and Productivity*

Consider the basic establishment level production function:

$$go_{it} = \alpha_l l_{it} + \alpha_k k_{it} + \alpha_{in} in_{it} + \alpha_e e_{it} + \beta M_i + \boldsymbol{\gamma}' \mathbf{Z}_{it} + u_{it} \quad (1)$$

where GO = real gross output (sales and inventory changes deflated with a sectoral producer price index), L = labour, K = capital, IN = deflated expenditure on non-energy intermediate inputs (materials) and E = deflated energy expenditure of establishment i at time t. Lower case letters denote natural logarithms, e.g. $l = \ln(L)$. The matrix $\mathbf{Z}$ consists of a number of control variables that affect productivity, such as workforce characteristics[12] (the proportion of workers with a degree and the average hours worked), firm characteristics (firm age, whether the firm is listed) and a complete set of three digits industry binary indicators.

The crucial variable for us is management practices denoted by M, which is defined at the firm level. Our basic measure averages the 18 individual management practices as a proxy for M. We experimented with a number of other approaches, such as using the primary factor, and found very similar results. Below we also report separate regressions for each survey question that forms the overall measure.

The most straightforward approach to estimating (1) is to simply run OLS on the panel with standard errors clustered by firm and assume that all the correlated heterogeneity is captured by the control variables.[13] Of course these results reveal nothing about causality but the association between management and productivity is nevertheless still interesting. Table 2 investigates the association between firm performance and management practices. Column 1 reports an OLS regression of gross output (GO) controlling only for year and industry fixed effects. The management score is strongly positively and significantly associated with higher labour output (coefficient 0.490, standard error 0.093). In column 2 we introduce our additional 'noise controls', regional controls and firm characteristics. This has very little effect on the management coefficient which is still significant at the 1% level. In column 3 we examine the association between management and labour productivity by including (log) employment as additional control variable. In line with expectations – as more productive firms are also larger – this reduces the management coefficient greatly to a point estimate of 0.128. However it remains strongly significant at 5%. Finally, in columns 4 and 5, we examine the association between management and total factor productivity (TFP) by including further production factors (including worker skill in column 5). As with labour productivity, the point estimate on management falls while staying strongly significant, however. The economic magnitude of the effects found in Table 2 are equally substantial: improving the quality of management from the 25th to 75th percentile ($\Delta M = 0.840$ from Table 1) is associated with a 3.7% ($= 0.044 \times 0.840$) increase in total-factor productivity. These results parallel the findings of Bloom and Van Reenen (2007) indicating a positive and strong association between firm-level

[12] We experimented with a wide range of workforce characteristics such as gender, worker age, education and unionisation, finding our results to be robust to these additional controls.

[13] A large literature is concerned with endogeneity and biases in this kind of regression; see, Griliches and Mairesse (1995) for a summary. We examine the robustness of our main results with respect to issue by implementing a control function approach (Olley and Pakes, 1996; Levinsohn and Petrin, 2003; Martin, 2008). These results are available on request.

Table 2

Management Practices and Productivity

	log (Gross Output)				
	(1)	(2)	(3)	(4)	(5)
Management	0.490***	0.531***	0.128**	0.043**	0.044**
	(0.093)	(0.101)	(0.059)	(0.021)	(0.020)
Labour			1.035***	0.243***	0.247***
log (number workers)			(0.048)	(0.029)	(0.028)
Capital				0.084***	0.084***
log (capital stock)				(0.023)	(0.021)
Materials – Energy				0.654***	0.651***
log (material – energy expenditure)				(0.035)	(0.034)
Energy				0.029	0.027
log (energy expenditure)				(0.019)	(0.018)
Share of High Skilled					0.017**
log (share of employees with degree)					(0.008)
Three digit sector controls	yes	yes	yes	yes	yes
Age controls	no	yes	yes	yes	yes
Noise controls	no	yes	yes	yes	yes
Region controls	no	yes	yes	yes	yes
Observations	1,046	1,046	1,046	1,046	1,046
Firms	272	272	272	272	272

Source. Authors' calculations based on census production (ARD) and CEP management survey data.
Notes. The dependent variable in all regressions is the logarithm of gross output. All columns include a full set of year binary indicators. 'Management' is the average scores across the 18 questions on management practices from the CEP management survey; output and factor input variables (labour, capital, materials, energy) are from the census production data (ARD). Noise controls are a set of variables capturing interview characteristics: duration and time of the interview, the gender of the interviewee, the reliability and competence of the interviewee as perceived by the interviewer and binary indicators for each interviewer. Standard errors clustered at the firm level (i.e. robust to heteroscedasticity and autocorrelation of unknown form) are reported in parenthesis below coefficients: * significant at 10%; ** significant at 5%; *** significant at 1%.

management practices and establishment-level total factor productivity (TFP) across firms in four countries.

2.2. *Management Practices and Energy Intensity*

Before analysing econometrically the relationship between managerial quality and energy intensity, it is informative to look at the raw distribution non-parametrically. Figure 2 plots the kernel density of energy expenditure over gross output for the best managed (top quartile) versus the worst (bottom quartile) managed firms. Two key facts become evident from this graph. First, there are more well managed firms that consume energy less intensively ('fatter' left tail of the distribution) and, second, their whole distribution is to the left of that of the worst managed firms, indicating lower energy intensity overall. Of course this does not imply causality of better management practices on better energy practices, but it is interesting that well managed firms are substantially more energy efficient.

To investigate the relationship between management practices and energy intensity of production in more detail, we consider the following specification:

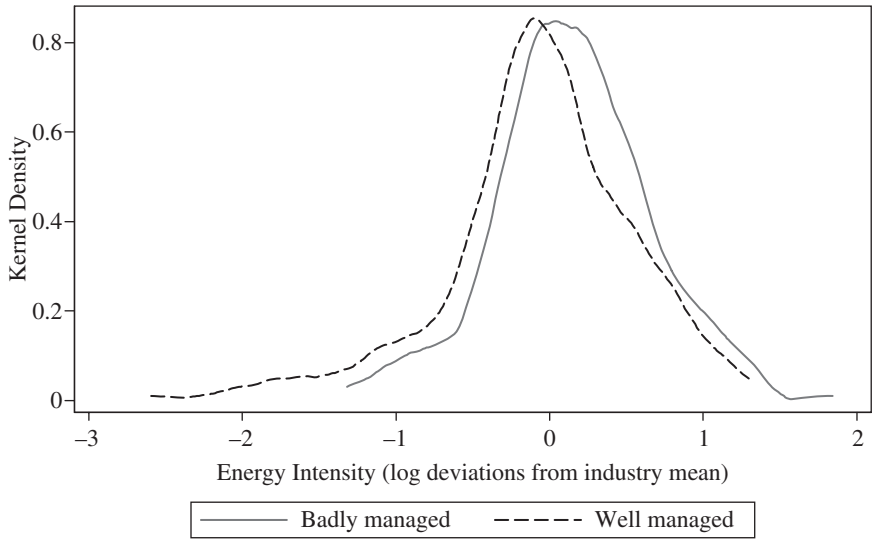

Fig. 2. *Management Practices and Energy Intensity*

Notes. Data from the Census production (ARD) and CEP management survey data. The graph shows kernel density plots of (the logarithmic transformation of) energy expenditure over gross output for the sample of firms with management score in the bottom quartile (badly managed) and the top quartile (well managed)

$$(EE/GO)_{it} \times 100 = \alpha_{in} go_{it} + \alpha_l l_{it} + \alpha_k k_{it} + \beta M_i + \boldsymbol{\gamma}' \mathbf{Z}_{it} + u_{it} \quad (2)$$

where $EE/GO \times 100$ = energy expenditure over gross output in percentage terms, GO = gross output (sales and inventory changes), L = labour, K = capital, and M = our management practices score for establishment i at time t. Lower case letters again denote natural logarithms, e.g. $l = \ln(L)$. The matrix $\mathbf{Z}$ consists of a number of control variables that affect productivity, such as workforce characteristics (the proportion of workers with a degree), firm characteristics (firm age), and a complete set of three digits industry binary indicators.

Table 3 reports the results from this specification. Column 1 simply regresses energy intensity – defined as the energy share of gross output – on management practices, controlling for year and industry differences. The management coefficient is strongly negative and significant, indicating that well managed firms consume energy more efficiently given their level of output. In column 2 the introduction of our 'noise controls' and firm characteristics renders the management coefficient stronger and more statistically significant. In column 3 we introduce (log) gross output to control for possible scale effects. The coefficient on gross output is negative which is consistent with scale effects – i.e. larger firms requiring less energy per unit of output – but not significant. The coefficient on management falls slightly from –0.394 to –0.326 but is still significant. In columns 4 to 6 we experiment with using labour and capital as proxies for size. The management coefficient is not significantly

Table 3

Management Practices and Energy Intensity

	Energy Expenditure over gross output ($EE/GO \times 100$)								
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Management	−0.225**	−0.394**	−0.326**	−0.351**	−0.375**	−0.365**	−0.361**	−0.362**	−0.370**
	(0.113)	(0.154)	(0.161)	(0.160)	(0.171)	(0.171)	(0.168)	(0.167)	(0.167)
Gross output			−0.127				−0.336**	−0.359*	−0.387**
log (gross output)			(0.109)				(0.164)	(0.197)	(0.193)
Labour				−0.110		−0.164		0.040	0.055
log (number workers)				(0.132)		(0.186)		(0.221)	(0.214)
Capital					−0.031	0.055	0.233	0.230	0.243
log (capital stock)					(0.122)	(0.172)	(0.196)	(0.199)	(0.194)
Share of High Skilled									0.023
log (share of employees with degree)									(0.072)
Three digit sector controls	yes	yes	yes	yes	yes	yes	yes	yes	yes
Age controls	no	yes	yes	yes	yes	yes	yes	yes	yes
Noise controls	no	yes	yes	yes	yes	yes	yes	yes	yes
Region controls	no	yes	yes	yes	yes	yes	yes	yes	yes
Observations	1,046	1,046	1,046	1,046	1,046	1,046	1,046	1,046	1,046
Firms	272	272	272	272	272	272	272	272	272

Source. Authors' calculations based on census production (ARD) and CEP management survey data.

Notes. The dependent variable in all regressions is energy expenditure over gross output. All columns include a full set of year binary indicators. 'Management' is the average scores across the 18 questions on management practices from the CEP management survey; output and factor input variables (labour, capital, materials, energy) are from the census production data (ARD). Column 3 introduces gross output to control for size. A potential issue is that instead of output in volume units, we only observe revenue. We therefore also include the other production factors in subsequent columns to correct for any possible scale effects. Noise controls are a set of variables capturing interview characteristics: duration and time of the interview, the gender of the interviewee, the reliability and competence of the interviewee as perceived by the interviewer and binary indicators for each interviewer. Standard errors clustered at the firm level (i.e. robust to heteroscedasticity and autocorrelation of unknown form) are reported in parenthesis below coefficients: * significant at 10%; ** significant at 5%; *** significant at 1%.

affected by their inclusion although its point estimate is somewhat larger than in column 3.

In columns 7 and 8 we re-introduce gross output. Once both gross output and employment or capital are introduced, the former becomes significantly negative, whereas capital and labour become positive, although not significant. This suggests that there are two opposing effects. On the one hand, there is a scale effect: larger output means that energy intensity reduces (there appear to be energy 'economies of scale'). On the other hand, more labour or capital intensive firms require more energy. However, irrespective of this heterogeneity, better managed firms are always significantly less energy intensive. The economic magnitude of these coefficients is large. For example, the coefficient of −0.362 in column 8 suggests that at the sample mean of *EE/GO* (1.744) improving managerial practices from the 25th to the 75th percentile (an increase in management of 0.840) is associated with a 17.4% reduction in energy intensity ($\beta_M \Delta M/(EE/GO) = -0.362 \times 0.840 / 1.744 = -0.174$). Finally, in column 9 we include controls for skills, as an additional proxy for firm type. The negative correlation between energy intensity and management practices persists and continues to be significant.

A number of concerns might arise with these results. First, our results imply nothing on the causality of the relationship between management and energy efficiency. It is quite possible this correlation is driven by other unobserved factors, for example that hiring management consultants helps to improve management practices and reduce energy usage. The evidence we have is merely suggestive, in that well managed firms appear to be robustly more energy efficient. As the first study of its kind to show this, we believe this is an interesting result in itself. We are also running field experiments in India to change the management practices of a randomly selected group of textiles firms to evaluate the causal impact of this on energy intensity.[14]

Second, because in our firm level data we do not have firm specific price information, our gross output measure captures both variations in actual output and variations in output price. Better managed firms might plausibly be able to charge higher prices for their products, increasing the mark-up and reducing factor cost-shares. In Appendix C (Table C1) (available online with the electronic version of the article) we therefore repeat the regressions from Table 3 using energy expenditure over variable costs (expenditure on labour and intermediates, *VCOST*) as our dependent variable. None of our results from Table 3 changes in any fundamental way. To ensure that our results are driven by variations in energy expenditure rather than variation in the denominator (*GO* or *VCOST*), in Table C2 we also report similar regressions where we use (log) energy expenditure (log *EE*) as the dependent variable. In column 1 and where we do not include any controls for firm size this leads to a positive and significant coefficient, because better managed firms are larger on average. With size controls from column 3 onward, the management coefficient turns significantly negative in line with our earlier results. Finally, we examine our results using log energy shares (Table C3). The main justification for using just energy shares in Tables 2 and 3 is that such an approach is consistent with

[14] See Bloom *et al.* (2009).

the popular translog factor estimation (Christensen *et al.* 1971; Christensen and Greene, 1976). However, as is evident from the Table 3, this choice is not essential for our basic correlation between managerial practices and energy intensity.

While we can not interpret our results as causal, it is nevertheless interesting to explore their economic magnitude. One experiment is to raise the managerial practices in a firm from the lowest to the top quartile and, assuming that its energy intensity changes in line, we would see a reduction of energy usage of 33%. Another exercise is to increase the management score of the average UK firm (which has a very similar average management score to the average firm in Europe[15]) to that of a US firm. Again making the strong assumption that the energy efficiency moved in parallel, we would see a reduction in energy used of 7.5%.

2.3. *Effect on Other Factors*

The analysis so far naturally raises questions about the factor intensity usage of other inputs: do better managed firms use all factor inputs less intensively, or substitute across different types of factor inputs? In summary, we find that better managed firms use less energy and materials but a higher level of capital and (skilled) labour inputs.

Table 4 examines this by reporting factor intensity results for materials, capital and labour. Columns 1 and 2 report regressions of the intensity in intermediate inputs including energy, whereas columns 3 and 4 exclude energy from intermediates. All materials input regressions yield significantly negative coefficient for management although the results without energy lead to somewhat lower (in absolute terms) and less significant point estimates. Better managed firms use less materials and less energy in their production process. Columns 5 and 6 report results for labour intensity (measured by the total wage bill) and 7 and 8 for capital intensity (measured by the stock of tangible fixed-assets).[16] The results from these last four columns strongly indicate that better managed firms are more labour and capital intensive even when controlling for size by including (log) gross output. This higher labour intensity appears to be due to a higher skill content of the workers, leading to a higher total wage bill.[17]

2.4. *Effect on CO_2 and Energy Quantity*

So far we implicitly assumed that energy prices do not vary systematically between firms after controlling for size, so that variations in energy expenditure intensity

[15] In the sample our UK average management score is 2.97 while the average across our firm sample from Europe (France, Germany, Greece, Ireland, Italy, Poland, Portugal and Sweden) is 2.98.

[16] To compute cost shares for capital we would have to make assumptions about depreciation and interest rates to derive the user cost of capital. To avoid that we simply examine the ratio between capital stocks and output or costs. As it is not bounded between zero and one, as the cost shares, we report results in log terms.

[17] Across the sample of all 601 UK firms covered by the CEP management survey the correlations (and their p-value) between management and the log(% of employees with a degree) is 0.127 (0.003) and between management and the log(average wage) is 0.171 (0.000). The same figures for the full sample of 5,198 firms from all 12 countries in the survey are 0.2607 (0.000) and 0.309 (0.000).

Table 4

Factor Intensities

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	ME/GO	*ME/VCOST*	(*ME-EE*)/*GO*	(*ME-EE*)/*VCOST*	*LE/GO*	*LE/VCOST*	ln(*K/GO*)	ln(*K/VCOST*)
	Materials expenditure over gross output	Materials expenditure over variable costs	Materials minus energy expenditure over gross output	Materials minus energy expenditure over variable costs	Labour expenditure over gross output	Labour expenditure over variable costs	Capital expenditure over gross output	Capital expenditure over variable costs
Management	−2.849**	−2.760**	−2.488*	−2.372*	1.642*	2.760**	0.147**	0.157***
	(1.447)	(1.243)	(1.454)	(1.292)	(0.973)	(1.243)	(0.058)	(0.056)
Gross output	2.703	6.871***	3.039*	7.203***	−7.267***	−6.871***	−0.102**	−0.087**
log (gross output)	(1.676)	(1.478)	(1.642)	(1.470)	(1.165)	(1.478)	(0.039)	(0.038)
Capital	1.250	−1.694	1.018	−1.912	2.563**	1.694		
log (capital stock)	(1.607)	(1.327)	(1.596)	(1.342)	(1.010)	(1.327)		
Three digit sector controls	yes	yes	yes	yes	yes	yes	yes	yes
Age controls	yes	yes	yes	yes	yes	yes	yes	yes
Noise controls	yes	yes	yes	yes	yes	yes	yes	yes
Region controls	yes	yes	yes	yes	yes	yes	yes	yes
Observations	1,046	1,046	1,046	1,046	1,046	1,046	1,046	1,046
Firms	272	272	272	272	272	272	272	272

Source. Authors' calculations based on census production (ARD) and CEP management survey data.

Notes. The Table reports regressions of materials, labour and capital factor intensities. The dependent variable in the first six columns is multiplied by 100. Note that material and labour intensities are reported without logs, which can be rationalised by a translog factor demand framework. For capital we only have a volume, but no expenditure index. Hence, capital over gross output is not bounded between zero and one and for that reason we report it in log terms. All columns include a full set of year binary indicators. 'Management' is the average scores across the 18 questions on management practices from the CEP management survey; output and factor input variables (labour, capital, materials, energy) are from the census production data (ARD). Noise controls are a set of variables capturing interview characteristics: duration and time of the interview, the gender of the interviewee, the reliability and competence of the interviewee as perceived by the interviewer and binary indicators for each interviewer. Standard errors clustered at the firm level (i.e. robust to heteroscedasticity and autocorrelation of unknown form) are reported in parenthesis below coefficients: * significant at 10%; ** significant at 5%; *** significant at 1%.

directly translate into variations in energy usage and pollution of the key greenhouse gas, CO_2. For a highly integrated energy market such as the UK this does not seem unreasonable. Nevertheless in this Section we provide some further evidence to support this assumption. Specifically, we confirm our key findings using quantity data on energy usage from the Quarterly Fuels Inquiry (QFI).[18] The QFI is a survey run by the UK Office of National Statistics, which inquires about the usage of a variety of different fuels at the firm level. However, its sample size is about a tenth of the ARD used for the results above. As a result, the overlap between QFI and management survey data sample is fairly small with less than 300 observations. For this reason we

Table 5
Quantity Measures

	(1)	(2)	(3)	(4)
	ln(kWh)	ln(kWh/*GO*)	ln(CO_2)	ln(CO_2/*GO*)
	log of kWh	log of kWh over gross output	log of carbon dioxide	log of carbon dioxide over gross output
Management	−0.332**	−0.332**	−0.288*	−0.288*
	(0.159)	(0.159)	(0.149)	(0.149)
Gross output	0.067	−0.933***	0.074	−0.926***
log (gross output)	(0.052)	(0.052)	(0.047)	(0.047)
Capital	0.919***	0.919***	0.913***	0.913***
log (capital stock)	(0.048)	(0.048)	(0.045)	(0.045)
Three digit sector controls	yes	yes	yes	yes
Age controls	yes	yes	yes	yes
Noise controls	yes	yes	yes	yes
Region controls	yes	yes	yes	yes
Observations	3,857	3,857	3,857	3,857
Firms	1,246	1,246	1,246	1,246
Observations with management data	286	286	286	286

Source. Authors' calculations based on census production (ARD), Quarterly Fuels Inquiry (QFI) and CEP management survey data.
Notes. The table reports regressions of kWh and carbon dioxide used in production. These variables are based on data from the Quarterly Fuels Inquiry (QFI). To compute CO_2 values on the basis of energy quantities we use the conversion factors reported in table D1 of the appendix (See the electronic version of the article on Wiley InterScience for access to supporting information). The QFI has a much smaller sample than the production census data (ARD). Hence, the intersection of all three datasets lead to a sample of only about 300 firms. To identify all control variables we run all regressions on the full sample of firms with QFI information and include a dummy equal to one when the management information is missing. All columns include a full set of year binary indicators. 'Management' is the average scores across the 18 questions on management practices from the CEP management survey; output and factor input variables (labour, capital, materials, energy) are from the census production data (ARD). Noise controls are a set of variables capturing interview characteristics: duration and time of the interview, the gender of the interviewee, the reliability and competence of the interviewee as perceived by the interviewer and binary indicators for each interviewer. Standard errors clustered at the firm level (i.e. robust to heteroscedasticity and autocorrelation of unknown form) are reported in parenthesis below coefficients: * significant at 10%; ** significant at 5%; *** significant at 1%.

[18] For more details on the QFI see Martin (2005).

did not use it for our main analysis but it nevertheless provides a useful cross-validation of our main results.

Table 5 contains the main QFI results. Column 1 looks simply at kWh of energy used and column 2 looks at the ratio between kWh and gross output. In either case we find a significantly negative relationship with management, i.e. better management firms use less kWh of energy. Columns 3 and 4 repeat the exercise with CO_2 (we compute CO_2 emissions on the basis of the quantity information on different fuel types and common conversion factors for the carbon content of fuels as reported in the Appendix, Table D1). Again we find a negative relationship, which is significant at the 10% level.

Table 6

Regressions of Energy Intensity on Each Management Practice
(separate regressions for each sub score)

	Energy Expenditure over gross output ($EE/GO \times 100$)			
	(1)	(2)	(3)	(4)
Lean	−0.040	0.024	0.008	0.021
Why lean?	−0.035	−0.014	−0.027	−0.013
Process documentation	−0.187**	−0.130	−0.156	−0.144
Performance tracking	−0.101	−0.050	−0.064	−0.072
Review of performance	−0.241***	−0.188*	−0.217**	−0.214*
Performance dialogue	−0.240**	−0.191**	−0.204**	−0.208**
Consequence management	−0.346***	−0.304***	−0.330***	−0.340***
Targets breadth	−0.194*	−0.123	−0.158	−0.149
Target interconnection	−0.264*	−0.205	−0.238	−0.219
Target time horizon	−0.002	0.050	0.029	0.046
Targets are stretching	−0.178*	−0.099	−0.140	−0.107
Performance clarity/comparability	0.010	0.053	0.036	0.049
Managing human capital	−0.179	−0.149	−0.159	−0.158
Rewarding high performance	−0.197*	−0.159	−0.176	−0.164
Removing poor performers	−0.217	−0.202	−0.208	−0.204
Promoting high performers	−0.265**	−0.232**	−0.249**	−0.248**
Attracting human capital	−0.269***	−0.210**	−0.236**	−0.210**
Retaining human capital	−0.168	−0.150	−0.158	−0.151
Capital stock controls	no	no	yes	yes
Gross output controls	no	yes	no	yes
Three digit sector controls	yes	yes	yes	yes
Age controls	yes	yes	yes	yes
Noise controls	yes	yes	yes	yes
Region controls	yes	yes	yes	yes
Observations	1,046	1,046	1,046	1,046
Firms	272	272	272	272

Notes. Every row represents a regression of energy intensity on a different management survey score (see Appendix A for detailed description of the various scores). Column 1 does not include any size controls, column 2 includes gross output, column 3 capital and column 4 both capital and gross output as size control. All columns include a full set of year binary indicators. Noise controls are a set of variables capturing interview characteristics: duration and time of the interview, the gender of the interviewee, the reliability and competence of the interviewee as perceived by the interviewer and binary indicators for each interviewer. Standard errors clustered at the firm level (i.e. robust to heteroscedasticity and autocorrelation of unknown form) are reported in parenthesis below coefficients: * significant at 10%; ** significant at 5%; *** significant at 1%.

2.5. *Which Aspect of Good Management?*

So far we have relied on an overall index of 'good management', *M*, obtained by averaging across all the management survey scores. However, it would be interesting to know whether certain management practices are more strongly correlated with energy savings than others. Thus, in Table 6 we report the coefficients of separate regressions of energy intensity on the various management scores; i.e. every row of Table 6 examines a different survey question. Moving through the columns, Table 6 examines the impact of different controls for size.

In Table 6 the first result is that almost all management practices are negatively correlated with energy intensity. This supports the idea that the subset of practices which we focus on in our survey are all highly complementary leading to better managed, more energy efficient firms. Interestingly though, some practices appear particularly strongly linked with lower energy intensity – the use and analysis of key performance indicators of production ('Review of Performance', 'Performance Dialogue', 'Consequence Management') and people management ('Rewarding high performance', 'Removing poor performers', 'Promoting High Performers', 'Attracting Human Capital'). Hence, it seems that the mere existence of performance measurement ('Performance Tracking') or of lean manufacturing practices ('Lean', 'Why Lean?') are not sufficient to generate a significant negative relation with energy intensity. Rather, it is the use and analysis of these performance indicators accompanied by some form of consequence management that leads firms to be less energy intensive.

3. Conclusions

In this article we match information that quantifies firm-level managerial quality, following the methodology developed by Bloom and Van Reenen (2007), to their establishment-level data in the UK census of production. Since the census data contain energy usage data, this allows us to undertake the first evaluation of the firm level association between management practices and energy intensity. We find a robust negative correlation between management practices and energy intensity. Better managed firms are more energy intensive, with the correlation substantial in magnitude – improving management levels from the 25th to the 75th percentile is associated with a 17.4% reduction in energy intensity. We also find a strong correlation between better management practices and establishment-level productivity, with a move from the 25th to 75th percentile of management associated with a 3.7% increase in total-factor productivity.

These results suggest that management practices that are associated with improved productivity are not linked to worse environmental performance. Rather, they are broadly supportive of the idea that well run firms use energy inputs more efficiently, thereby increasing profitability and productivity while at the same time reducing carbon emissions. Future research will seek to evaluate the causal nature of the relationship between management practices and energy intensity by using field experiments to randomly change management practices and evaluate its impact on energy intensity.

Appendix A: Details of the Survey Questionnaires

Table A1
Full List of Management Practices with Examples of the Questions Asked

Practice	Practice number	Practice type	Example of questions we asked
Modern manufacturing, introduction	1	Operations	a) Can you describe the production process for me? b) What kinds of lean (modern) manufacturing processes have you introduced? Can you give me specific examples? c) How do you manage inventory levels? What is done to balance the line?
Modern manufacturing, rationale	2	Operations	a) Can you take through the rationale to introduce these processes? b) What factors led to the adoption of these lean (modern) management practices?
Process documentation	3	Operations	a) How would you go about improving the manufacturing process itself? b) How do problems typically get exposed and fixed? c) Talk me through the process for a recent problem. d) Do the staff ever suggest process improvements?
Performance tracking	4	Monitoring	a) Tell me how you track production performance? b) What kind of Key Performance Indicators (KPIs) would you use for performance tracking? How frequently are these measured? Who gets to see this KPI data? c) If I were to walk through your factory could I tell how you were doing against your KPI's?
Performance review	5	Monitoring	a) How do you review your Key Performance Indicators (KPIs)? b) Tell me about a recent meeting. Who is involved in these meetings? c) Who gets to see the results of this review?
Performance dialogue	6	Monitoring	a) How are these meetings structured? Tell me about your most recent meeting. b) During these meeting, how much useful data do you have? c) How useful do you find problem solving meetings? d) What type of feedback occurs in these meetings?
Consequence management	7	Monitoring	a) What happens if there is a part of the business (or a manager) who isn't achieving agreed upon results? Can you give me a recent example? b) What kind of consequences would follow such an action? c) Are there are any parts of the business (or managers) that seem to repeatedly fail to carry out agreed actions?
Target breadth	8	Targets	a) What types of targets are set for the company? What are the goals for your plant? b) Tell me about the financial and non-financial goals? c)What do Company Head Quarters (CHQ) or their appropriate manager emphasise to you?
Target interconnection	9	Targets	a) What is the motivation behind your goals? b) How are these goals cascaded down to the individual workers? c) What are the goals of the top management team (do they even know what they are!)? d) How are your targets linked to company performance and their goals?

Table A1 *(Continued)*

Practice	Practice number	Practice type	Example of questions we asked
Target time horizon	10	Targets	a) What kind of time scale are you looking at with your targets? b) How are long term goals linked to short term goals? c) Could you meet all your short-run goals but miss your long-run goals?
Targets are stretching	11	Targets	a) How tough are your targets? Do you feel pushed by them? b) On average, how often would you say that you meet your targets? c) Are there any targets which are obviously too easy (will always be met) or too hard (will never be met)? d) Do you feel that all groups receive the same degree of difficulty in targets? Do some groups get easy targets?
Performance clarity and comparability	12	Monitoring	a) What are your targets (i.e. do they know them exactly)? Tell me about them in full. b) Does everyone know their targets? Does anyone complain that the targets are too complex? c) How do people know about their own performance compared to other people's performance?
Managing human capital	13	Targets	a) Do senior managers discuss attracting and developing talented people? b) Do senior managers get any rewards for bringing in and keeping talented people in the company? c) Can you tell me about the talented people you have developed within your team? Did you get any rewards for this?
Rewarding high performance	14	Incentives	a) How does you appraisal system work? Tell me about the most recent round? b) How does the bonus system work? c) Are there any non-financial rewards for top-performers?
Removing poor performers	15	Incentives	a) If you had a worker who could not do his job what would you do? Could you give me a recent example? b) How long would underperformance be tolerated? c) Do you find any workers who lead a sort of charmed life? Do some individuals always just manage to avoid being fixed/fired?
Promoting high performers	16	Incentives	a) Can you rise up the company rapidly if you are really good? Are there any examples you can think of? b) What about poor performers – do they get promoted more slowly? Are there any examples you can think of? c) How would you identify and develop (i.e. train) your star performers? d) If two people both joined the company 5 years ago and one was much better than the other would he/she be promoted faster?
Attracting human capital	17	Incentives	a) What makes it distinctive to work at your company as opposed to your competitors? b) If you were trying to sell your firm to me how would you do this (get them to try to do this)? c) What don't people like about working in your firm?
Retaining human capital	18	Incentives	a) If you had a star performer who wanted to leave what would the company do? b) Could you give me an example of a star performers being persuaded to stay after wanting to leave? c) Could you give me an example of a star performer who left the company without anyone trying to keep them?

Appendix B: Matching Census to Firm-Level Data

To combine the firm-level survey data with the UK Office of National Statistics (ONS) census data we rely on a lookup table provided by the ONS mapping from the Company House Register Number[19] (CRN) to the Interdepartmental Business Register (IDBR) – the UK government's company register. However, this lookup table is not complete for three reasons. First, for some records the ONS relied on name matching, which often does not lead to results if different names or spellings are used. Second, because the CRN and IDBR system are maintained independently the same businesses is sometimes represented differently in either register. The IDBR identifies business units according to functional units, which are relevant for the computing of government statistics. A CRN number is created whenever a company's management deems it necessary to register a new business name. Third, the lookup table is currently only provided for 2004. Hence, there is no match for businesses created after this date. Table B1 provides descriptive statistics comparing a number of key statistics between matched and non-matched companies. A plant is matched with higher probability if it is older, larger, better managed and also owned by a larger firm.

We also subjected the data to a number of cleaning steps. Our key variables of interest in this study are factor expenditure and revenue shares. For a small number of firms factor revenue shares are either negative or larger than one (often several orders of magnitude larger). This is not consistent with any standard models of firm behaviour and likely a consequence of misreporting and measurement error; e.g. revenue being reported in 1000s and expenditure just in pounds or vice versa. To avoid our results being driven by any of this we first, dropped establishments whose share of variable costs (materials plus labour cost) in gross output (VCOST/GO) was larger than one. We further dropped firms in the top and bottom percentile of the VCOST/GO distribution. Finally, we dropped establishments who had changes of more than 200% from year to year in VCOST/GO. Many of our results still go through even if we do not perform all of these steps. However, they ensure that things are more consistent; e.g. the dropping top and bottom percentiles is key for getting similar results when running either regressions of log factor shares or simply regression of factor shares.

Table B1
Descriptive Statistics of the Matched Sample

Variable	Sample	Obs	Mean
Employment at firm	unmatched	263	444.45
	matched	338	528.5***
Age	unmatched	255	41.24
	matched	337	45.53***
Employment at plant	unmatched	250	389.93
	matched	338	452.50***
Management Score	unmatched	263	2.93
	matched	338	3.04***

Source. Authors' calculations based on census production (ARD) and CEP management survey data.
Notes. The number of observations varies because of missing values for some variables for some firms.
* significant at 10%; ** significant at 5%; *** significant at 1%.

[19] The CEP management survey is conducted on the basis of this register which is used in the UK by commercial providers of business data such as Bureau van Dijk (http://www.bvdep.com/).

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Additional Supporting information may be found in the online version of this article:

Appendix C: Further results
Appendix D: Conversion Factors

Please note: The RES and Wiley-Blackwell are not responsible for the content or functionality of any supporting materials supplied by the authors. Any queries (other than missing material) should be directed to the authors of the article.

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