

SKILL-BIASED MANAGEMENT: EVIDENCE FROM MANUFACTURING FIRMS*

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This article investigates the link between management practices and workforce skills in manufacturing firms, exploiting geographical variation in the supply of human capital. Skills measures are constructed using newly compiled data on universities and regional labour markets across 19 countries. Consistent with management practices being complementary with skills, we show that firms further away from universities employ fewer skilled workers and are worse managed, even after controlling for a rich set of observables and fixed effects. Analysis using regional skill premia suggests that variation in the price of skill drives these relationships.

There have been major advances in the measurement and analysis of management practices in recent years. Survey data have established the importance of management practices in explaining differentials in productivity between and within countries and sectors (Bloom and Van Reenen, 2007; Bloom *et al.*, 2014b). Recent analysis has estimated that, across countries, management explains on average around 30% of the gap in total factor productivity with the United States (Bloom *et al.*, 2016), and experimental evidence from Indian textile plants has shown that management plays a causal role in this regard (Bloom *et al.*, 2013).¹ However, less is known about why firms adopt different management practices (Bloom *et al.*, 2019). Given that management practices are so important for firm performance, and can be measured and benchmarked across firms, why do we not see all firms adopting best practice?

Motivated by previously documented associations between plant-level management practices and skills (see, for example, Bloom and Van Reenen, 2007; Bloom *et al.*, 2014b), this article uses data from the World Management Survey (WMS) on manufacturing plants to test the hypothesis that human capital and management practices are complements. We construct a new data set across 19 countries related to plant- and region-level skill availability, and estimating ‘factor demand’ equations (Brynjolfsson and Milgrom, 2013), we find robust evidence that firms facing more abundant (and cheaper) skills have higher management scores, *ceteris paribus*.

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The authors requested a data exemption on the grounds that access to the data is restricted but provided a simulated or synthetic dataset for the purpose of checking that all relevant codes to reproduce the results have been provided. The codes and simulated or synthetic datasets are available on the Journal website.

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¹ Much of this literature is focused on interviewing middle managers to understand organisational structures and day-to-day processes within firms. There have also been major advances in the measurement of CEO behaviour (Bandiera *et al.*, 2020). While CEO behaviour and management practices are correlated with each other, they also appear to be independently correlated with firm performance.

This supports the hypothesis that modern management practices and a skilled workforce are complementary, consistent with a skilled workforce increasing the marginal benefit or lowering the marginal cost associated with good management practices, so that firms facing a skill-abundant workforce employ more skilled labour and have better management practices in equilibrium. In this sense, good management practices—adopted as a consequence of the channel studied here—are examples of ‘skill-biased management’.

Assuming that labour markets are local in nature (Moretti, 2011), we construct two main measures of local or regional skill supply. The first measure is the plant-specific distance to the nearest university. We calculate this as a drive time using geocoded information on WMS plants (across regions in 19 countries) and universities from the World Higher Education Database (WHED)—an international listing of higher education institutions. The second measure of skill supply is the regional skill premium. To calculate this we obtain labour force microdata in 13 countries, which allow us to run wage regressions and estimate the wage premium for university graduates at the subnational region level.

We hypothesise that universities increase the supply of skills, and hence reduce the price of skills; and that this is the mechanism through which we might expect the distance measure to be related to firm human capital and management practices. In support of this, we show that regions with higher university density (universities normalised by population) have a higher degree share and lower skill premium. This is a new finding that suggests that skill is expensive when it is relatively scarce in a location and cheap when it is abundant.

In the firm-level analysis, we find a robust relationship between distance (drive time), firm-level human capital and management practices: firms further from universities have fewer skilled workers and managers, and are on average worse managed. We control for firm and geographic characteristics, and country, time and industry fixed effects. We include region fixed effects to control for unobservable characteristics at the subnational level that are related to university presence and the management of firms. In the absence of an instrument for university location using this rich international data set, we cannot rule out the possibility that the results are driven by better-managed firms choosing locations close to universities, though we partially address this concern by showing that there is no differential effect for firms which are founded after their nearest university, and by considering within-firm variation as an extension to the skill premium analysis. We note, however, that if our results are driven by better-managed firms making such locational decisions, they are still suggestive of a complementarity between better management and skills.

Next, we replace distance to the nearest university with the regional skill premium in our regressions and show that firms facing higher skill premia in the region in which they are located employ significantly fewer skilled workers and are significantly worse managed. We find that these results are stronger when we exclude capital regions, where we might expect demand shocks or other unobservables that raise both the skill premium and management practices are more prevalent. Moreover, firms in capital cities are more likely to be able to recruit from wider areas (due to commuting patterns or inward migration).

We explore whether our results are heterogeneous by observable firm characteristics, noting that the assumption that labour markets are local may depend on firm type. We find that the relationships between management practices and both university distance and the regional skill premium are stronger for single-plant firms compared with plants that are part of multinationals or multi-plant domestic firms. This is intuitive, since these types of firms are likely to be less reliant on the local environment when recruiting staff and setting management practices. Plants that

are part of larger multinational enterprises may be able to attract workers from other regions or countries due to their stronger brand, and might also move staff between locations (Choudhury, 2017). Moreover, management practices in such firms might be set centrally at the company headquarters, which may be in a different region or even country. In contrast, in the distance analysis there is no evidence of heterogeneity with respect to observable university characteristics, including subject mix. In particular, the results are not driven by universities offering business-type courses. This suggests that the university effect is more likely to operate via their role as producers of general human capital, rather than as providers of consultancy services or training for local firms which we might expect to be more prevalent in business schools.

Our main regressions are estimated using surveyed firms as a cross-section. A subset of firms in the WMS were re-interviewed during the sample period, which allows us to estimate how changes in firm-level human capital and skill prices affect management practices (there is not enough variation in the number of universities over this short time frame to use the distance measure in the panel). While this specification is demanding on the data, there remains a robust positive relationship between firm-level changes in human capital and management practices, and a negative relationship between changes in regional skill premia and firm management practices.

The focus in this article is on testing for complementarities by estimating demand equations (Brynjolfsson and Milgrom, 2013). However, for a subsample of plants for which performance data are available we also examine whether there is evidence that a more highly skilled workforce increases the marginal benefit of adopting modern management practices. This is tested using interactions between workforce skills and management practices in performance equations (Brynjolfsson and Milgrom, 2013). We estimate simple production functions including firm degree share, and then the external skills measures (distance to university and regional skill premium) and their interaction with management practices. Here we find more tentative evidence of complementarities in the case of single plant firms only, consistent with the finding that plant-specific locational measures of skill supply appear more relevant in such cases.

In general, a complementarity between worker skills and management practices may seem intuitive. The surveyed management practices closely resemble the complementary characteristics of ‘modern manufacturing’ discussed by Milgrom and Roberts (1990) and Roberts (1995). Highly skilled, cross-trained workers are listed alongside (among other things) lean production techniques, performance tracking and communications as features of the modern firm (Roberts, 1995). A more educated workforce is more likely to show initiative and be able to effectively implement complex, flexible and more decentralised production practices. On the other hand, one could also argue that certain management practices and skilled workers could be substitutes. In the presence of a highly skilled workforce, there may be less need for constant performance tracking and communicating—more able workers could just be left to get on with their jobs. Of course, there may be heterogeneity in these relationships for different types of management practices, but our results show that skills and management are, on average, not substitute inputs to production. Shedding light on this issue empirically is therefore valuable for helping managers and policy makers understand best how to improve management practices and hence productivity.

This article contributes to the literature that seeks to explain the differences in management practices that are observed across firms. In a series of papers, Bloom, Sadun, Van Reenen and co-authors have shown that education of both managers and workers are strongly correlated with management scores (Bloom and Van Reenen, 2007; 2010; Bloom *et al.*, 2014b). Using

Census Bureau survey data on plants in the United States, Bloom *et al.* (2017) show that plants within counties with ‘quasi-random’ land grant colleges (Moretti, 2004) have significantly higher management scores, and the same can be said for counties with a higher college share in the working-age population.² Bender *et al.* (2018) use matched employer–employee data in Germany to show that better-managed firms recruit and retain skilled workers.³ We contribute to this literature by using newly collated international measures of skills that are external to the firm. Our empirical strategy of using distance to universities has been used widely in the labour economics and innovation literatures.⁴ This article is the first, to our knowledge, that relates distance to universities to firm management.⁵

More generally, we contribute to the evidence on organisational complementarities and skill-biased technology. A theoretical framework for thinking about organisational complementarities is set out by Milgrom and Roberts (1990), and Brynjolfsson and Milgrom (2013) give an overview of the theory and empirics of organisational complementarities.⁶ Much of the empirical literature has focused on testing whether different types of organisational practices are optimally implemented together (for example, Ichniowski *et al.*, 1997; Bresnahan *et al.*, 2002; Black and Lynch, 2001; 2004). Our work using regional skill premia uses a similar approach to that of Caroli and Van Reenen (2001), who find evidence of skill-biased organisational change. There is compelling evidence that management can be thought of as an organisational technology (Bloom *et al.*, 2016), creating a link to the skill-biased technical change literature. In models of endogenous technology adoption (Basu and Weil, 1998; Zeira, 1998; Caselli, 1999), which are tested using the time series data in Beaudry and Green (2003; 2005), when a major technology becomes available, it is not adopted immediately by all agents. Instead it is adopted in environments in which complementary factors are plentiful and cheap. Beaudry *et al.* (2010) find that US cities with low-skill premia adopted computers more intensively, and Garicano and Heaton (2010) find evidence of complementarity between IT and skilled workers in US police departments. Our contribution to this literature is to provide empirical evidence that management practices are complementary with human capital based on an international sample of manufacturing firms, and newly collated data on universities and labour markets.

This article is organised as follows. Section 1 describes the data. Section 2 sets out our conceptual framework and econometric strategy, and Section 3 our results. Section 4 provides some concluding comments.

² This is the working paper version of Bloom *et al.* (2019). Together with human capital, this article explores three other drivers of management practices—competition, business environment and learning spillovers—and finds that together they account for about a third of the variation in management practices.

³ Using administrative data from Portugal, Queiro (2016) finds that firms with educated managers have better performance, and suggests that the mechanism for this involves educated managers being more likely to introduce new technologies.

⁴ See, e.g., Card (1995), who relates distance to university to individual-level enrolment at university. Examples of papers that relate proximity to universities to firm innovation include Anselin *et al.* (1997), Henderson *et al.* (1998) and Belenzon and Schankerman (2013)

⁵ The WHED data in this article have also been employed by Bloom *et al.* (2019), who relate distance to university to hospital management practices. In contrast with our findings, they show that hospitals closer to universities with both business and medical schools are better managed, but that there are no effects for universities with only one of these departments, or neither. This suggests that specialist knowledge or training of managers (medical and MBA) is more important in the management of hospitals. Our results support a more of a general human capital effect, as university proximity is associated with a higher share of both managers and workers with a degree and better management practices, with no evidence of heterogeneity by broad university subject areas.

⁶ Ennen and Richter (2010) also give a review of the management, economics and other related literatures.

1. Data

1.1. Overview of Data Sources

We use data from three main sources, the key features of which are described in this section (for further details, see the Online Data Appendix). Survey data on management practices and skills in manufacturing plants are obtained from the World Management Survey (WMS). The unit of observation is the manufacturing plant (referred to interchangeably as the ‘firm’ in this article). WMS questions relate to the management practices at a particular plant surveyed (rather than the head office, which might differ in the case of multi-plant firms).⁷ Therefore the WMS gives a measure of management practices at a particular location, which makes the spatial approach taken in this article appropriate. The measure of management practices is the standardised WMS management score, which is based on the average score that a plant achieves across 18 practices (broadly relating to operations, monitoring, targets and people management). It has been shown that management scores are positively and robustly correlated with performance (e.g., Bloom and Van Reenen, 2007; Bloom *et al.*, 2014b, 2016), a relationship that holds across countries, sectors and types of firm. We therefore interpret a higher management score as ‘better’ management. The share of the workforce with a university degree is our measure of human capital—this is available for the total workforce, and managers/non-managers separately. In the distance analysis, we use data from surveys conducted between 2004 and 2010 across 19 countries, as a pooled cross-section.

Information on universities across countries is sourced from the World Higher Education Database (WHED), which provides data on university location and other characteristics (such as subjects or level of study offered, and founding date). See Valero and Van Reenen (2019) for a full description of the data. We geocode universities and plants, by mapping their postcodes to geographic coordinates. This enables us to calculate the main distance measure by estimating drive times between each plant and its nearest university. We favour drive time instead of a straight-line distance because it accounts for natural geographic features. Given that the analysis in this article is based on an international sample with differing geographies across countries, this helps to account for distance in a consistent manner. Alternative distance measures are explored in the robustness.

Analysis of the relationships between regional skill premia, firm human capital and management practices is conducted on a subsample of 13 countries in which we were able to access international labour force survey (or equivalent) data sources.⁸ Skill premia are estimated using wage regressions, where log wages are regressed on education, experience, experience squared and gender, by region. Our preferred specification includes a dummy variable to indicate whether or not an individual has a degree, and the estimated skill premium is the coefficient on this dummy. Available observations in regions are pooled over the years where data were available, and year fixed effects included in the regressions. We also compute the regional degree share and a raw wage ratio (the log ratio of skilled wages to unskilled wages)—measures that were available for additional countries as ready-made regional aggregates.⁹ Retrieving the skill premium from

⁷ The analysis in this article is at the plant level and we are clear when we explore heterogeneity across plants that are single-plant firms versus those that are part of multi-plant domestic or multinational enterprises.

⁸ For more details on the data sources and citations, see the Online Data Appendix.

⁹ Microdata were obtained for 14 countries, and ready-made regional aggregates for an additional four countries. Our main analysis sample is based on 13 countries in which reliable wage data were available, and the wider samples are included in robustness.

regional wage regressions is preferred as this controls for other factors that might differ across groups and regions.

The key geographic control is population density at the location of the plant (within 100 km), which is based on data from the Center for International Earth Science (CIESIN). Other regional data were obtained from Gennaioli *et al.* (2013). In addition to average years of education, and college share, which are used to sense-check the supply of skills data collected from surveys, there are also other covariates such as temperature, inverse distance to coast and oil per capita and population.

1.2. Descriptive Statistics

A summary of the key variables used in our analysis is provided in the Online Data Appendix. The mean management score in our sample is just under 3. In the average plant, 15% of the total workforce have a degree. This is closer to 60% looking only at managers, and 10% for non-managers. In our regressions we take the natural log of the degree share, and add one so that zero observations are kept in the sample. We control for plant and firm employment, plant age and multinational enterprise (MNE) status.¹⁰ Just under half of plants are part of an MNE, and 59% have more than one production site (multi-unit production). In our analysis, we consider multi-plant firms those that are either part of a multinational, or have multi-unit domestic production. Just over half of the plants are part of a large firm (which we define as having more than 300 employees), and 28% are listed. Some 40% of the workforce of the average plant is in a union.

The average distance (drive time) to the nearest university is 0.45 hours. Figure 1 plots the histogram of drive times in ten-minute bins, which is clearly skewed to the right. In the robustness tests, we experiment with using the natural log of the drive time, and exclude observations that are in the same postcode as universities (and hence have a drive time of zero). Locational features are controlled for by including longitude, latitude and average population density within a 100 km radius of the plant. The average plant in our sample is in a region where the skill premium is 0.57, 20% of the workforce has a degree and there are four universities per million people.

Country-level descriptive statistics on the sample on which we conduct our analysis are also reported in the Online Appendix. The United States has the highest management scores on average, though there is also substantial within-country variation. The highest degree share is in Japan, where 32% of the workforce of the average plant are university graduates. The skill premia appear of reasonable magnitude compared with estimates from the literature.¹¹ There is also variation in the mean distances and skill premia across countries.

In this article our focus is on finer-grained analysis based on variation within countries or regions. The region in this analysis is generally equivalent to a US state or NUTS1–2 regions in Europe, and our sample contains 314 such regions across the 19 countries listed.¹²

¹⁰ Missing values are imputed and a dummy to indicate missing status is included in regressions.

¹¹ For example, see Strauss and de la Maisonnette (2009) for OECD country estimates.

¹² In the Online Appendix we report the number of regions in each country and show that there is substantial within-region variation in the key variables of interest.

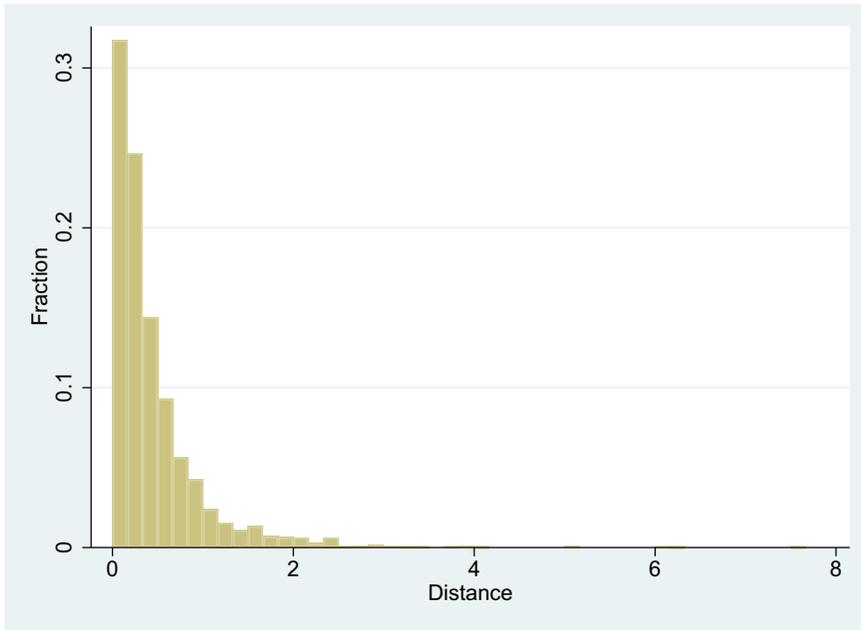


Fig. 1. *Histogram of Distance Measure.*

Notes: $N = 6,360$, observations split into ten-minute bins. Distance is measured as the drive time (in hours) between a plant and its nearest university.

2. Conceptual Framework and Empirical Strategy

2.1. Conceptual Framework

By their nature, it is reasonable to hypothesise that modern management practices and human capital are complements. Milgrom and Roberts (1990) and Roberts (1995) analysed ‘modern manufacturing’ and argued that, given that there are complementarities among organisational practices, a range of practices may need to be implemented together for a particular technological advance to raise efficiency. A highly skilled workforce with transferrable skills is listed as one of the features of modern manufacturing.

The management practices scores in the WMS closely resemble Roberts’ modern manufacturing. A well-managed firm is defined as one that has successfully implemented modern manufacturing techniques; and one that is ‘continuously monitoring and trying to improve its processes, setting comprehensive and stretching targets, and promoting high-performing employees and fixing (by training or exit) underperforming employees’ (Bloom *et al.*, 2012).

A simple framework helps to illustrate one path to our empirical strategy. We assume a neoclassical production function in a static environment. $Y = F(A, M, H)$ where output Y is some function of technology and human capital inputs H with $\partial Y / \partial H > 0$ and $\partial^2 Y / \partial H^2 < 0$.¹³ We distinguish between production technology A and management technology M (Lucas, 1978). It

¹³ We abstract from standard capital and labour for ease of notation.

is assumed that performance is increasing continuously in the level of management quality¹⁴, so $\partial Y/\partial M > 0$ and $\partial Y^2/\partial M^2 < 0$. Human capital–management complementarity, which we refer to as ‘skill-biased management’, implies a positive cross-derivative: $\partial Y^2/\partial M\partial H > 0$. It follows therefore that, in equilibrium, the firm’s managerial technology is an increasing function of human capital:

$$M = G(H, A, \eta). \quad (1)$$

We interpret (1) as a demand equation in a complementarity framework (see, e.g., Bresnahan *et al.*, 2002), but other interpretations are possible.¹⁵ This framework captures the fact that conditioning on firm-level human capital, there is variation across firms in management practices due to other technologies, information frictions, optimisation errors or other idiosyncratic factors (η).

While our core analysis is focused on ‘demand equations’ as represented in (1), we also estimate production functions including levels of H (or a shifter of this), M and their interaction. The levels reflect the extent to which the firm has successfully adopted modern management practices and the degree to which the firm uses more highly skilled labour; while the interaction term will reflect complementarity (a positive cross-derivative implies a positive coefficient on the interaction term).

2.2. Empirical Strategy

Suppose we estimated the following using OLS:

$$M_i = \beta_0 + \beta_1 H_i + X_i' \beta_2 + u_i, \quad (2)$$

where for firm i , M is the management score, H is the level of human capital, X are observable firm characteristics including size and industry, and u is an idiosyncratic error term. A number of endogeneity issues arise. First, there are issues of omitted variables bias, the sign of which will depend on the nature of the omitted technologies A . For example, if information technologies that facilitate better management practices are positively correlated with skills, the bias would be positive. But if communication technologies that facilitate better management practices lead to a reduction in worker skills, the bias would be negative.¹⁶ Intangible assets such as brand or firm culture may also be embodied in this unobserved technology, and such assets are also likely to be correlated with both management practices and worker skills. Second, observed correlations between management practices and skills might reflect reverse causality, if workers with higher human capital choose to work in better-managed firms. We therefore need to find exogenous variation in workforce skills to be able to make a causal claim about the relationship between skills and management practices.

¹⁴ See Bloom *et al.* (2016) for a full description of management as a technology, which is modelled as an intangible capital stock, and evidence to support this view.

¹⁵ If we interpret (1) as a production function, better management is ‘produced’ by higher-skilled managers or workers. An alternative interpretation (Nelson and Phelps, 1966) is that managers and workers of higher skill are able to draw and adapt random management technology from a better distribution. An interpretation closer to Lucas (1978) is that skilled managers are matched with better workers.

¹⁶ Bloom *et al.* (2014a) find that improvements in information technologies lead to decentralisation, while improvements in communication technologies have the opposite effect.

Our empirical strategy uses variation in the skill environments faced by firms, in a world with frictions that prevent the skill price equalising across space.¹⁷ It can be described schematically as follows:

$$Universities_k \rightarrow Skill\ Supply_k \rightarrow Skill\ Price_k \rightarrow H_{ik} \rightarrow M_{ik},$$

where the first arrow represents the relationship between the spatial presence of universities and supply of human capital (measured as the share of the workforce with a degree in a region k), which we hypothesise will be positive. This rests on the assumption that student mobility is imperfect after graduation, so that at least some graduates stay and contribute to the local labour market. This seems reasonable based on observations in the United States and the UK.¹⁸ The share of skilled labour in the region can be expected to affect the relative skill price (skill premium), which we hypothesise will affect the hiring decisions of firms. All else being equal, we would expect that a higher skill premium would result in a lower degree share in the firm (H_{ik}) since skilled labour is more expensive relative to unskilled labour. Finally, skill-biased management would imply that there is a positive relationship between firm-level human capital and the adoption of complementary management practices.

Our empirical approach to estimating these relationships is largely dictated by data availability and issues of aggregation. We begin by aggregating to the region level (equivalent to a US state), and linking university presence in a region with regional skills and prices ($Universities_k \rightarrow Skill\ Supply_k, Skill\ Price_k$). We then estimate the reduced form relationship between university presence and firm skills and management practices ($Universities_{ik} \rightarrow H_{ik}, M_{ik}$), calculating a firm-specific distance measure between each firm and its closest university. In this analysis we are able to examine within region variation, so that unobservable factors that affect regional skills and firm outcomes are controlled for. To get more information on the mechanism and explore the effects of relative skill prices, we estimate the associations between regional skill prices, firm skills and management practices ($Skill\ Price_k \rightarrow H_{ik}, M_{ik}$).

2.2.1. Distance to university, firm skills and management practices

Our reduced form analysis examines the relationships between firm skills and management practices and distance to closest university. We estimate:

$$Y_{ijkct} = \alpha_1 Dist_{ijkct} + X'_{ijkct} \alpha_2 + \phi_j + \xi_k + \tau_t + \varepsilon_{ijkct} \quad (3)$$

for firm i in sector j , region k , country c and survey year t . The outcome variable $Y \in \{M, H\}$. The distance variable, $Dist$, is measured as the drive time to the nearest university in hours. We expect α_1 to be negative, firms closer to universities should have a higher degree share and be better managed, due to their improved access to skills.

We include a number of firm controls, X , that have been shown to matter for management practices (see, e.g., Bloom and Van Reenen, 2007; Bloom *et al.*, 2016), and are likely to be related to skill share in the firm, too. These include firm size, age and ownership status—we also include industry fixed effects ϕ_j . To pick up any differences over the years in which the WMS surveys are conducted, we include year dummies τ_t . ε_{ijkct} is the error term, which we cluster at

¹⁷ In the absence of frictions, the price of skill would equalise (via the law of one price). In such a world, university presence should have no effect on skill shares in a local area. In reality, frictions and the inelastic supply of non-tradables such as land limit the extent of price equalisation—see, e.g., Roback (1988) and Glaeser and Gottlieb (2009).

¹⁸ For example, Kodrzycki (2001) looks at NSLY data in the United States and finds that over two-thirds of college graduates remain in the same state post graduation. Data from the UK Higher Education Statistics Authority shows that a high fraction of first degree graduates in a region remain in the same region for work. In 2004–5, this fraction was 61%.

the region level to allow for heteroscedasticity and correlation between firms in the same region. In the robustness tests we show that results are unchanged if we allow for more general spatial correlation.

To address concerns regarding location specific factors that might confound our estimates we do several things. First, we include regional fixed effects (ξ_k). We also control for geographic characteristics that might be correlated with both skills and the management of firms: in particular population density within 100 km of the plant (also, longitude and latitude).

There are two main concerns around this estimation strategy. First, we may worry that well-managed firms are endogenously located close to universities. To partially address this we examine universities founded after the firms were founded and show that our results are similar. It seems less likely that there would be issues of reverse causality (that universities choose locations close to medium-sized manufacturing firms—those surveyed in the WMS—with higher management scores), or firms endogenously choosing locations on the basis of future university openings.

Second, we may worry about the interpretation of a relationship between distance to universities and management practices. Such a relationship could be due to the diffusion of information or advice from universities to surrounding firms, for example, via consultancy services, managerial training or access to more specialised inputs—rather than through an effect on the supply of skills as our diagram suggests. In practice, both mechanisms are likely to be at play, but if non-human capital routes were more important we would expect that universities with certain subject mixes may have more of an effect—in particular, business, economics, finance or even engineering and sciences. We are able to filter such universities, and show that they do not drive our results.¹⁹

2.2.2. *Regional skill premia, firm skills and management practices*

We now turn to our analysis of how firm human capital and management practices respond to the relative price of skills that they face. The purpose of this part of the analysis is to provide evidence that firms respond to regional skill prices.

The regressions are similar to (3), but the distance term is replaced by the skill premium. In this spatial analysis, skill premia (the log ratio of skilled wages to unskilled wages) need to be calculated based on a locational unit, and in line with the literature (see, e.g., Caroli and Van Reenen, 2001; Gennaioli *et al.*, 2013) and what is feasible from a data perspective, we choose the subnational region, equivalent to a US state. We use the average skill premium over the period 2005–10. Our main measure is the coefficient on a degree dummy from wage regressions, which is an estimate of the skill premium having controlled for other factors (such as worker experience). We expect that the coefficient on the skill premium will be negative: firms facing a higher skill premium will have lower human capital and be worse managed if skill biased management holds.

Since the skill premium varies at the regional level, we are unable to include region fixed effects in these regressions, but we do include country dummies. These regressions are weighted using the population in a region divided by the population in the country to reduce the effects of outliers in low population regions (for which labour force data are likely to be less reliable), and standard errors are clustered at the region level as before.

¹⁹ Under the caveats above and the (strong) assumption that the exclusion restriction holds, i.e., that universities affect management only via their impact on the supply of skills, we also estimate the relationship between firm skills and management using the distance measure as an instrument for firm skills.

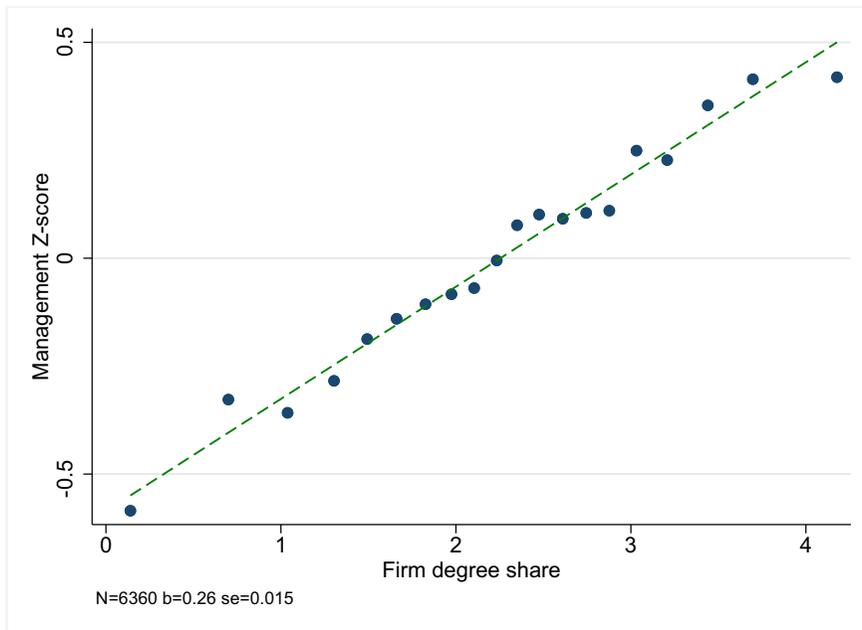


Fig. 2. *Firm Skills and Management Practices.*

Notes: Scatter plot of average firm management practices on average $\ln(1+\text{degree share})$ within 20 evenly sized bins. Variation is within country and wave dummies are also absorbed. Reported standard errors are clustered at the region level for consistency with regressions in tables. The dashed line represents the line of best fit.

3. Results

3.1. *Basic Relationships*

A number of correlations motivate the analysis in this article. The firm level correlation between degree share and management practices has been established in the literature (Bloom and Van Reenen, 2007; Bloom *et al.*, 2014b) and is the starting point for this study. Figure 2 plots the correlation between average management scores of firms within 20 equally sized bins in terms of degree share (absorbing country and survey wave fixed effects, though results are not sensitive to this), showing a positive and precise relationship.²⁰ This strong relationship exists for both managers and non-managers as shown in Table 1, which reports the regression equivalent.²¹ A Wald test on the coefficients on managers and workers in Column (4) shows that these are not significantly different from each other, and we keep our focus on total workforce skills in the analysis that will follow.

Figure 3 is a visualisation of the basic correlations between distance to nearest university, management practices and firm degree share, absorbing country and survey wave fixed effects.

²⁰ These relationships are as strong using the unlogged degree share, but we use the natural log since this provides a better fit to the data (the equivalent plot of the unlogged degree share reveals a non-linearity in the relationship).

²¹ Note that standard errors are clustered at the region level for consistency with later analysis. The relationship between firm skills and management practices remains highly significant, though coefficients are smaller in magnitude when a full set of controls is included.

Table 1. *Firm Skills and Management Practices, Basic Regressions.*

Dependent variable: management Z-score	(1)	(2)	(3)	(4)
Ln(1+degree share)	0.260*** (0.015)			
Ln(1+degree share), managers		0.206*** (0.013)		0.138*** (0.011)
Ln(1+degree share), non managers			0.196*** (0.010)	0.154*** (0.010)
Observations	6,360	6,360	6,360	6,360

Notes: *** denotes significance at the 1% level, ** 5% level and * 10% level. All columns estimated by OLS with standard errors clustered at the region level in parentheses (for consistency with later analysis). All columns include country and year dummies.

This shows that firms that are further from their closest university tend to have lower management scores and a lower degree share.²²

Finally, a key assumption in our regional skill premium analysis is that a higher price of skills in a region reflects lower supply and we therefore expect a negative correlation between the regional skill premium and degree share. We find that this is indeed the case (see Online Appendix Figure A1) and that the negative correlation is stronger when we omit capital regions. This seems intuitive, as demand shocks and other unobservables that raise both the skill premium and the supply of skilled workers may be considered more likely in hubs of economic activity.²³

3.2. Main Results

3.2.1. Universities, regional skills and skill premia

We begin with some region-level analysis to support the first causal link hypothesised in Section 2: the relationship between the location of universities, skill supply and skill premia. Table 2 shows that the correlations between regional university density (number of universities per million people), degree share and the estimated skill premium are significant and of the expected sign. Column (1) controls only for country dummies, and Column (2) adds geographic controls. This analysis suggests that a 1% rise in university density is associated with a 0.2% higher degree share and a 0.03% lower skill premium.²⁴

3.2.2. Distance to university, firm skills and management practices

Next we report the reduced from relationships between firm management practices, degree share and distance to university (Table 3). The dependent variable in Panel A is the standardised management score. Column (1) includes country and year dummies plus survey controls to reduce noise in the data. The relationship between management scores and distance is negative and significant. Column (2) adds region fixed effects that have little impact on the main coefficient.

²² These graphs show that there are some outlier observations in remote regions. These are spread across countries with larger landmass, including Argentina, Australia, Canada, Chile, China and India. We retain these in the analysis, even though dropping them strengthens the relationships. When we construct our distance measures, we winsorise the distances of very remote plants to the regional maximum: see the Online Data Appendix for more details. Our regression results are robust to dropping such cases.

²³ To reflect this, our regional regressions that follow include a dummy variable indicating regions that contain a capital city.

²⁴ In further analysis, not reported here, consistent relationships are found with alternative measures of skills including the simple log wage ratio and variables sourced from Gennaioli *et al.* (2013): their estimate of college share and average years of education.

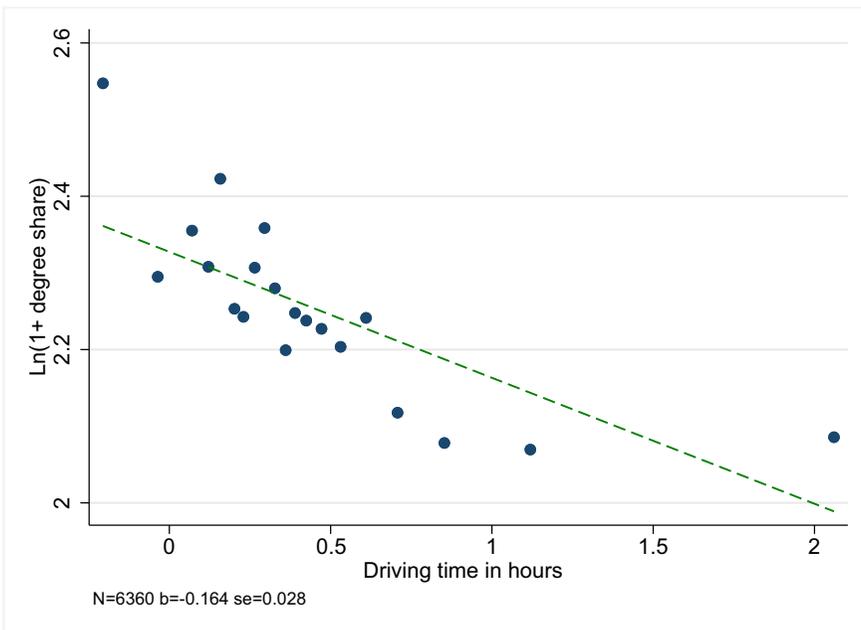
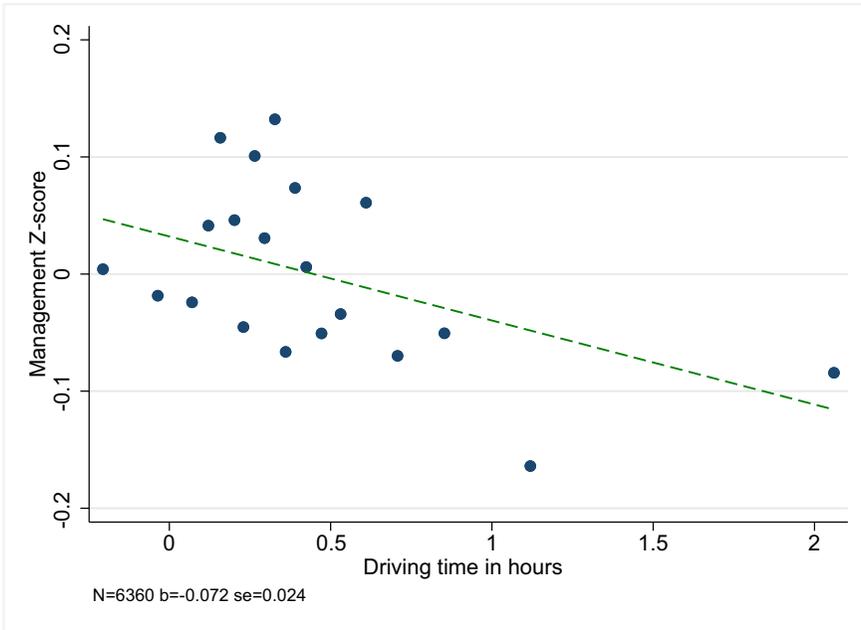


Fig. 3. *Distance to University, Management Scores and Degree Share, Basic Correlations.*
 Notes: Scatter plots of average management Z-score and degree share on average driving time within 20 evenly sized bins. Variation is within country and wave dummies are also absorbed. Reported standard errors are clustered at the region level for consistency with regressions in tables. The dashed line represents the line of best fit.

Table 2. *Regional Skills and Universities.*

	(1)	(2)
<i>Panel A: Dependent variable is Ln(region degree share)</i>		
Ln(1+universities per million)	0.176*** (0.036)	0.162*** (0.026)
<i>Panel B: Dependent variable is skill premium in region</i>		
Ln(1+universities per million)	-0.027* (0.015)	-0.030** (0.013)
Observations	208	208
Country dummies	Yes	Yes
Geographic controls	No	Yes

Notes: *** denotes significance at the 1% level, ** 5% level and * 10% level. All columns estimated by OLS with robust standard errors in parentheses. All columns contain country dummies. The unit of observation is a region. *Skill premium* is the coefficient on a degree dummy, recovered from regional wage regressions. Geographic controls include the regional average of the plant level geographic controls: population density within 100 km, longitude and latitude, and region level variables: capital region dummy, temperature, inverse distance to the coast, Ln(oil production) and Ln(population).

Table 3. *Distance to University, Plant Management and Skills.*

	(1)	(2)	(3)	(4)
<i>Panel A: Dependent variable is Management Z-score</i>				
Distance	-0.067*** (0.018)	-0.068*** (0.020)	-0.047** (0.018)	-0.048** (0.019)
Ln(employment, plant)			0.202*** (0.017)	0.201*** (0.017)
Ln(employment, firm)			0.069*** (0.012)	0.069*** (0.012)
Ln(plant age)			-0.031** (0.014)	-0.031** (0.014)
MNE			0.389*** (0.031)	0.389*** (0.031)
<i>Panel B: Dependent variable is Ln(1+degree share)</i>				
Distance	-0.161*** (0.030)	-0.143*** (0.029)	-0.112*** (0.027)	-0.118*** (0.027)
Ln(employment, plant)			0.062*** (0.019)	0.061*** (0.019)
Ln(employment, firm)			0.018 (0.017)	0.018 (0.017)
Ln(plant age)			-0.011 (0.018)	-0.011 (0.018)
MNE			0.234*** (0.031)	0.235*** (0.031)
Observations	6,360	6,360	6,360	6,360
Number of clusters	314	314	314	314
Region dummies	No	Yes	Yes	Yes
Industry dummies	No	No	Yes	Yes
Geography controls	No	No	No	Yes

Notes: *** denotes significance at the 1% level, ** 5% level and * 10% level. All columns estimated by OLS with standard errors clustered at the region level in parentheses. *Distance* is the driving time in hours from the plant to the nearest university. All columns include country dummies, year dummies, and survey controls for interviewer gender, interviewee job tenure, interviewee seniority, interview reliability, interview day of week, time and duration, and dummy variables for the analyst conducting the interview. Missing values are mean-coded, and dummies included to indicate where this is the case. Geography controls include population density, longitude and latitude. See the Online Data Appendix for a description of the key variables.

In Column (3), industry dummies and firm controls (as reported) are added and these reduce the magnitude of the coefficient slightly to -0.047 . Column (4) adds geographic controls (population density, longitude and latitude, not reported here) none of which is significant, and the our coefficient is unchanged. Column (4) is the core specification, and implies that plants that are an extra hour of drive time away from their closest university (which is roughly two standard deviations) have on average 0.05 standard deviations worse management practices. In the next section we show that this result is robust to alternative specifications and sample selection.

Panel B reports regressions of firm-level degree share on distance to university. Again, there is a significant and negative correlation between distance and degree share of -0.16 (Column (1)). This decreases slightly in magnitude as we add controls in the order discussed previously. The result in Column (4) implies that an extra hour of driving time reduces the log degree share by 0.12, representing over a tenth of the standard deviation across firms.²⁵

The results of the core specifications (Table 3, Column (4)) are depicted in Figure 4. This analysis suggests that, within regions, firms located close to universities have both higher human capital and higher management scores. While we cannot rule out the possibility that better managed firms are locating near to universities, or universities are providing other support that raises management practices, we go some way towards addressing these concerns in the analysis that follows.

3.2.3. *Regional skill premia, firm skills and management practices*

We have seen that regions with higher university density tend to have lower skill premia. In this section we provide evidence to suggest that the mechanism underlying the relationship between distance to university, skills and management practices is, at least in part, via the role of universities in increasing the supply and reducing the price of skills in their local area.

The relationships between regional skill premia and firm management practices and human capital are reported in Table 4 on the subsample of countries in which labour force microdata were collected. The dependent variable in Panel A is the standardised management score. Column (1) controls only for country and year fixed effects, and shows that management scores are negatively and significantly related to regional skill premia. Column (2) adds two-digit industry dummies and firm controls (consistent with the previous analysis), which reduces the coefficient. The addition of plant-level geographic controls (longitude, latitude and population density) in Column (3) increases significance.²⁶ Column (4) adds survey controls and our coefficient is slightly reduced.²⁷ The coefficient of -0.82 implies that a 1% rise in the degree premium leads to a 0.0082 standard deviation reduction in management scores. To assess the magnitude of this effect, we apply it to the variation between US states. It implies that a one standard deviation rise in the skill premium reduces management scores by -0.048 standard deviations, representing 18% of the cross-state variation.²⁸ Column (5) reports the result when capital regions are dropped: the relationship is now stronger and significant at the 1% level, suggesting that unobservables

²⁵ We also estimated Column (4) for managers and non-managers separately and found that the effect is negative and highly significant for both (the coefficient on distance for degree share of managers is -0.09 , and the coefficient for non-managers is -0.12 , both are significant at the 1% level).

²⁶ We show that the core specification, Column (4), is robust also to the addition of regional geographic controls in the robustness tests (see Online Appendix, Table A11).

²⁷ Here we exclude the analyst dummies. This model using region-level variation has fewer effective degrees of freedom and we find that the analyst dummies have a large effect, reducing the magnitude of the coefficient and raising the standard errors (see Online Appendix, Table A11). We therefore leave them out of this core specification.

²⁸ The cross-state standard deviation of the degree premium in the United States is 0.058. $-0.82 \times 0.058 = -0.048$, which is 18% of the cross-region standard deviation in management scores (0.27).

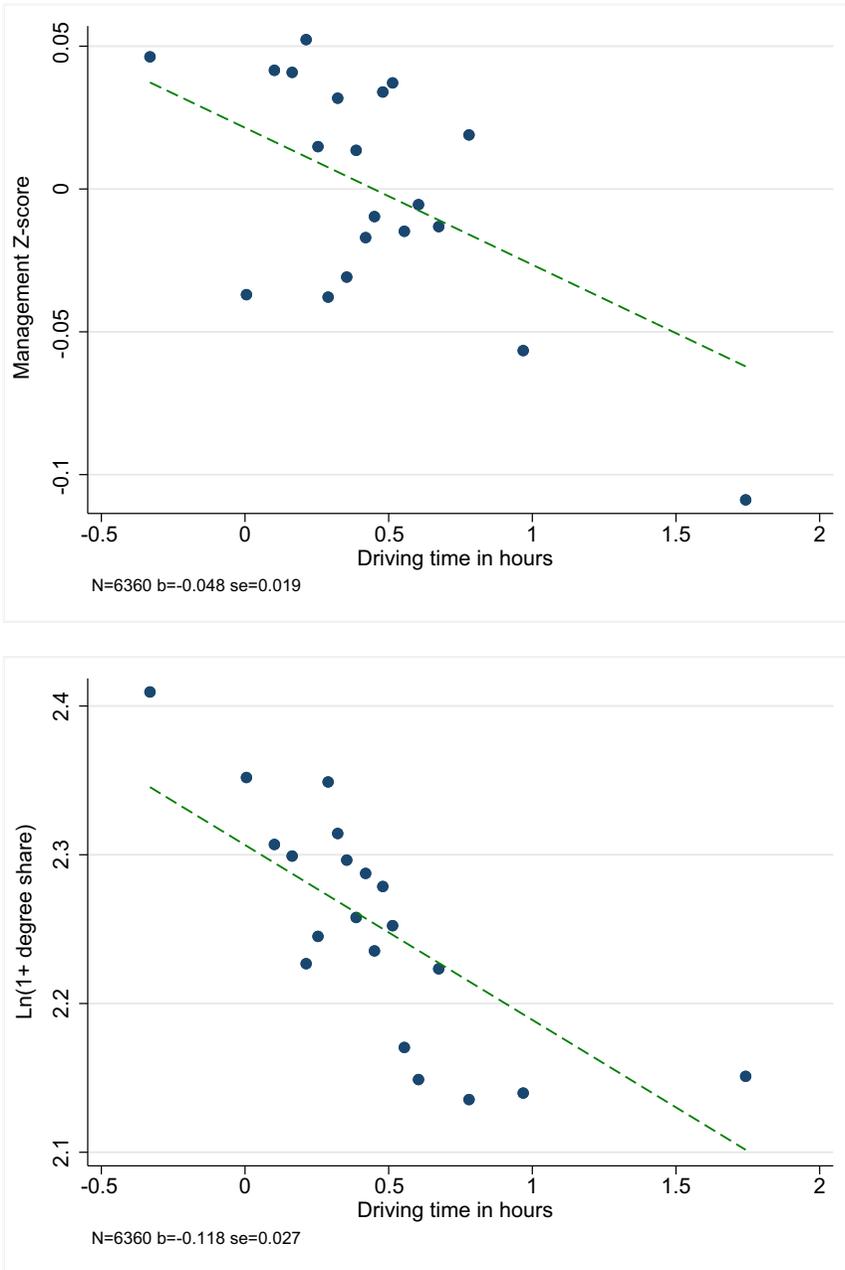


Fig. 4. *Distance to University, Management Scores and Degree Share, Main Results.*

Notes: Scatter plots of average management Z-score and degree share on average driving time within 20 evenly sized bins. Controls and fixed effects are absorbed as per Table 3, Column (4). Reported standard errors are clustered at the region level for consistency with regressions in tables. The dashed line represents the line of best fit.

Table 4. *Regional Skill Premia, Plant Management and Skills.*

	(1)	(2)	(3)	(4)	(5)
<i>Panel A: Dependent variable is Management Z-score</i>					
Skill premium	-1.104** (0.463)	-0.727** (0.349)	-0.863** (0.347)	-0.824** (0.334)	-0.940*** (0.255)
Ln(employment, plant)		0.274*** (0.030)	0.275*** (0.031)	0.241*** (0.030)	0.255*** (0.033)
Ln(employment, firm)		0.071*** (0.015)	0.072*** (0.015)	0.053*** (0.016)	0.048** (0.020)
Ln(plant age)		-0.024 (0.019)	-0.025 (0.019)	-0.032 (0.020)	-0.030 (0.019)
MNE		0.529*** (0.050)	0.525*** (0.050)	0.477*** (0.050)	0.402*** (0.052)
Capital			0.055 (0.053)	0.055 (0.047)	
<i>Panel B: Dependent variable is Ln(1+degree share)</i>					
Skill premium	-0.692 (0.491)	-0.593 (0.403)	-0.822** (0.364)	-0.855** (0.353)	-0.945*** (0.279)
Ln(employment, plant)		0.078** (0.033)	0.081** (0.034)	0.077** (0.035)	0.064*** (0.023)
Ln(employment, firm)		0.010 (0.019)	0.011 (0.019)	0.006 (0.018)	0.011 (0.020)
Ln(plant age)		0.007 (0.025)	0.005 (0.024)	0.007 (0.024)	0.020 (0.021)
MNE		0.355*** (0.039)	0.350*** (0.040)	0.340*** (0.041)	0.317*** (0.047)
Capital			0.135** (0.053)	0.142*** (0.050)	
Observations	4,553	4,553	4,553	4,553	3,879
Number of clusters	208	208	208	208	198
Industry dummies	No	Yes	Yes	Yes	Yes
Geographic controls	No	No	Yes	Yes	Yes
Survey controls	No	No	No	Yes	Yes
Capital regions	Yes	Yes	Yes	Yes	No

Notes: *** denotes significance at the 1% level, ** 5% level and * 10% level. All columns estimated by OLS with standard errors clustered at the region level in parentheses. *Skill premium* is the coefficient on a degree dummy, recovered from regional wage regressions. Regressions are weighted using population in the region as a share of country population. All columns include country and year dummies. Industry dummies are 2 digit SIC code, geography and survey controls as before (but excluding the analyst dummies). See the Online Data Appendix for a description of the key variables.

that raise management practices and also raise the skill premium are more prevalent in capital regions.

The relationship between the skill premium and degree share is less precisely estimated (Panel B), but still negative. In fact our coefficient gets stronger and more precise as geographic controls are added, in particular the capital region dummy. In Column (4), the coefficient is -0.86 , and significant at the 5% level. As in Panel (A), excluding capital regions altogether increases the magnitude of the effect and its significance.

3.3. Robustness and Heterogeneity

3.3.1. Summary of robustness tests

The results so far provide strong evidence that distance to university and regional skill premia matter for firm management practices. We test the robustness of the relationships between

management practices and both the distance and skill premium measures, and the results are detailed in Online Appendix B. First, we show that the distance results are robust to different specification assumptions with respect to the clustering of standard errors, allowing non-linearities in the distance measure, including additional geographic controls (in particular, local population density), or more detailed fixed effects. We experiment with different distance measures that do not take geographical features into account (driving distance, straight-line distance and the number of universities within a 100 km radius). With driving and straight-line distance, the coefficient takes the expected sign but precision is lost, while there is a positive relationship between management practices and the quantity of universities. Results are robust to different sample choices. We also add more granular fixed effects to the regressions. The distance coefficient remains negative and significant on the inclusion of country–year dummies, and region–industry dummies, but significance is lost in some of the more demanding specifications, for example using county or city-level fixed effects.

Analogue robustness tests are carried out on our regional skill premium regressions (using the full sample that includes capital regions). These show that the sign of the relationship between skill premia and management practices is robust to different assumptions on specification and sample, but precision is lost in some cases. In particular, when standard errors are clustered at the country level, or when the regressions are unweighted (more noise is expected as skill premia are likely to be worse measured in less populous regions where sample sizes are smaller). In addition, we explore whether the expected relationships exist for alternative measures of regional skills such as a raw regional wage ratio or various quantity measures (such as degree share or regional years of education). In general, the coefficients on these measures are of the expected sign but they tend not to be significant at conventional levels. These measures are likely to provide a more noisy measure of the supply of skills in the labour market: the raw wage ratio does not correct for years of experience and gender; quantity-based measures such as college share do not reflect how the market values skills; and an additional year of education means different things in different contexts or stages of education.²⁹

3.3.2. *Heterogeneity across firm or university type*

We explore whether there is heterogeneity across observable characteristics of firms and universities to gain a better understanding of the mechanisms driving our results. We find evidence of heterogeneity in effects between plants that belong to multi-plant enterprises (defined as either being part of multinational firms or firms that have more than one production site domestically) and those that are single-plant firms. This appears to be the case in both the distance and skill premium specifications (Table 5). Column (1) shows our distance regression with a dummy for multi-plant firms.³⁰ In Column (2) we add an interaction term between distance and the multi-plant dummy. This is positive but not significant, but the effect for single-plant firms is slightly larger. In Columns (3) and (4) we replicate Columns (1) and (2) on the sample for which skill premia are available. The average effect across all plants on the reduced sample is similar in this sample (0.056 compared with 0.049 in the full sample), but the effect of distance in single-plant firms is double the size (−0.11) and significant at the 1% level, and the interaction term is larger and more significant (the *p*-value is 0.11). Columns (5) and (6) show that, similarly, the skill

²⁹ Indeed, the fact that our management regressions are not robust to quantity measures is consistent with Caroli and Van Reenen (2001), where the main measure of skills supply is the skill premium.

³⁰ We vary our previous regressions here slightly by including a multi-plant dummy rather than only the MNE dummy from before.

Table 5. *Heterogeneity by Multi-plant Status.*

Dependent variable: Management Z-score	(1)	(2)	(3)	(4)	(5)	(6)
Distance	-0.049** (0.019)	-0.056* (0.033)	-0.056** (0.022)	-0.107*** (0.037)		
Distance × multi-plant		0.012 (0.042)		0.076 (0.048)		
Skill premium					-0.802** (0.363)	-1.095*** (0.386)
Skill premium × multi-plant						0.381** (0.157)
Multi-plant	0.267*** (0.032)	0.262*** (0.037)	0.319*** (0.039)	0.284*** (0.047)	0.411*** (0.046)	0.180 (0.124)
Observations	6,360	6,360	4,553	4,553	4,553	4,553
Number of clusters	314	314	208	208	208	208

Notes: *** denotes significance at the 1% level, ** 5% level and * 10% level. All columns estimated by OLS with standard errors clustered at the region level in parentheses. *Distance* is the driving time in hours from the plant to the nearest university. *Skill premium* is the coefficient on a degree dummy, recovered from regional wage regressions. *Multi-plant* is a dummy denoting multi-plant status, which we define as a plant that either belongs to a multinational enterprise, or a domestic multi-plant firm.

premium has a stronger relationship with management practices in single-plant firms, now the interaction term is positive and significant at the 5% level.

The finding that these relationships appear to be stronger in single-plant firms is intuitive as we might expect such firms to be more sensitive to their local labour markets. Plants that are part of a domestic multi-plant or multi-national firms are likely to have access to wider national or even international labour markets due to their ability to transfer staff internally or recruit staff from further afield, perhaps benefitting from a stronger or better known 'brand'. The relevant skills price for such firms is therefore not necessarily the regional skill premium; or at least we might expect that the regional skill premium is a worse-measured estimate of the effective skills price in such cases. A separate but related point is that in larger, multi-unit firms, management practices and processes might be set centrally at their headquarters. This could imply that managers in constituent plants are constrained in choosing the optimal management practices for their particular setting based on the availability of a complementary skilled workforce, i.e., that optimisation errors are more likely in these plants.³¹

Second, in the university distance analysis, we investigate whether specific types of university are driving the results. Heterogeneity across universities may tell us something about the mechanism through which universities impact on local firms. If we find stronger effects for universities with business departments, this could imply that it is managerial education that is important for the management of firms rather than general human capital. Furthermore, we might worry that the effects we have found are due to universities providing consulting services or other support to local firms rather than the provision of human capital, and stronger effects for universities with business departments could suggest this type of mechanism is at work. The results show that there is no evidence of heterogeneity for universities offering business type courses or any other subject type (law and social sciences, medicine and science or arts and

³¹ We explore heterogeneity across other firm characteristics including ownership, size and union representation, and in general there is no evidence of this in the distance specifications. On the other hand, consistent with the multi-unit results in the skill premium analysis, there are positive and significant interaction terms with a large firm dummy and listed status.

humanities), suggesting that universities affect firm management via their effect on general human capital rather than through the teaching of any particular discipline (see Table A5 in the Online Appendix).

We also examine whether the distance effect is stronger where the nearest university was founded before the plant. If better-managed firms have based location decisions on the proximity to existing universities, then we may expect a stronger coefficient when we look at observations where the nearest university was founded before the plant. In fact, we find that there is no differential effect in such cases.

Finally, we check whether the relationships between management practices and skills measures that we have found exist for all the types of management practices scored in the WMS, or whether skills are more important for a subset of these. We run our distance and skill premium regressions with the standardised scores for each of the four different management practice groupings as dependent variables: Operations, Monitoring, Targeting and People Management (see Online Appendix Table A6). We find that the negative relationships with both the distance and skill premia measures apply across all practice groupings. This is consistent with the empirical fact that management practices within firms are correlated: a firm that scores highly on one managerial question will tend to score highly on all of them (Bloom *et al.*, 2014b). The coefficients vary in magnitude and significance across the two specifications and this is not driven by the different samples. In particular, distance to university appears to have the strongest relationship with targeting, while the skill premium appears to be more strongly related to people management and monitoring. The stronger relationship between the skill premium and people management, in particular, is intuitive as when skills are relatively more expensive, it is optimal for firms to do more to recruit and retain talent.

3.3.3. *Distance to university as an instrument*

Based on the reduced form analysis we have presented, showing a robust relationship between management practices and distance to nearest university, we revisit the endogenous relationship between firm-level degree share and management practices and estimate IV regressions using distance to nearest university as an instrument. The first stage therefore is equivalent to the specification in Panel B, Column (4) from Table 3. The results are in the Online Appendix. Overall, this analysis does not suggest that OLS overestimates the relationship between firm skills and management practices, as we might expect.³² However, we treat these results with caution, as they rely not only on the exogeneity of university location, but also on the assumption that universities affect the management of firms only via their impact on firm degree share (rather than through direct consultancy, training services or other externalities), which is unlikely to hold in practice.

³² In fact the IV results suggest that OLS estimates are biased downwards. In general, we anticipate an upward bias due to unobservables such as effective strategy or leadership that are likely to be positively correlated with both a higher-skilled workforce and better management practices. However, a negative bias could occur if, for example, communication technologies that are complementary with management practices, and raise management scores when employed, also reduced the requirement for skilled workers. It could also be the case that OLS results are attenuated due to measurement error in firm human capital which is a survey response, or reflect LATE effects whereby the relationships between firm level human capital and management practices are stronger for firms for whom distance to university is an important determinant of skilled workforce composition.

Table 6. *Panel Regressions.*

	(1)	(2)	(3)	(4)
Dependent variable	Management Z-score	Management Z-score	d Management Z-score	d Management Z-score
<i>Panel A: Firm human capital</i>				
Ln(1+degree share)	0.201*** (0.0233)	0.126*** (0.0261)		
d Ln(1+degree share)			0.0569** (0.0241)	0.0730*** (0.0246)
Observations	1,437	1,437	1,437	1,437
Number of clusters	216	216	216	216
<i>Panel B: Regional wage ratio</i>				
ln(wage ratio)	-0.245 (0.504)	-0.809** (0.409)		
d ln(wage ratio)			-0.521 (0.346)	-0.825** (0.401)
Observations	1,017	1,017	1,017	1,017
Number of clusters	162	162	162	162
Year dummies	Yes	Yes	Yes	Yes
Country dummies	Yes	Yes	Yes	Yes
Controls	No	Yes	No	Yes

Notes: *** denotes significance at the 1% level, ** 5% level and * 10% level. All columns estimated by OLS with standard errors clustered at the region level in parentheses. *Ln(wage ratio)* is based on calculation from microdata or ready-made data as set out in the Online Data Appendix. Sample includes all firms that were interviewed in more than one wave over the period 2005–10, in their latest observation. Differenced variables are calculated as average annual differences. All columns include country and year dummies. Controls include industry, firm, geography and noise controls as in core specifications. The regressions in Panel A, Columns (2) and (4) include region fixed effects.

3.4. Extensions

3.4.1. Panel estimates

The core results in this article are based on cross-sectional analysis, and while we have addressed concerns regarding identification to the extent possible, we cannot entirely rule out the possibility that the results are driven by other omitted variables or endogenous plant location. Therefore it is valuable to examine whether our relationships survive when variation is within firm. A subset of firms in a subset of countries (12 of our sample of 19) were re-interviewed during the sample period (2005–10).

We begin by examining whether the firm-level relationship between degree share and management practices survives when we estimate a differenced regression (Table 6). Column (1) is the same specification as in the basic correlations reported in Table 1, Column (1) where only country and year fixed effects are controlled for, estimated on the more recent observation in the panel sample for comparison. Column (2) includes firm, industry, geography and noise controls. Columns (3) and (4) then replicate the first two columns but include the average annual change in management practices and degree share between survey waves instead of the levels. These results suggest that there is a positive bias in OLS estimates, and that plant specific unobservables are likely to be positively correlated with both skills and management practices.

Moving now to the regional skill premium analysis in Panel B, we also find evidence that the effects that we found in the main analysis (Table 4) are not driven entirely by unobserved factors. Here Columns (1) and (2) follow the cross-sectional analysis on the reduced panel sample, but

use a simple wage ratio as our time-varying measure of the skill premium,³³ for the nine countries in the panel in which annual wage ratio data were available.³⁴ We find a negative relationship between changes in management scores and the skill premium which becomes stronger once controls are added.³⁵

3.4.2. *Performance equations*

On the subsample of firms where financial data are available, we estimate simple production functions including firm degree share, and then separately in a reduced form approach, the external skills measures (distance to university and regional skill premium); and their interaction with management practices. Interacting the external measures that are proxies for the price of skills faced by the plants allows us to examine whether the marginal benefit of adopting modern management practices is higher when skills are cheaper. The results of this analysis are in the Online Appendix. In summary, we find more tentative evidence of complementarities in the case of single-plant firms only, consistent with the finding that plant-specific locational measures of skill supply appear more relevant for such firms. These results provide additional suggestive evidence for complementarities to support our core analysis.

4. Conclusions

We have presented robust evidence that skills and management practices are complements using a newly analysed data set on international universities and newly collated data on international subnational skill prices. Our proxy for skills access at the firm level is a measure of distance to closest university. Firms closer to universities have both higher degree share and management scores. These results can help us to understand one of the channels through which universities affect regional economic performance (Valero and Van Reenen, 2019). Using our estimates of regional skill premia, we provide evidence that universities might shift the supply and relative price of skills, which we then show are related to firm human capital and management scores. In extensions to our main analysis we also show that our results survive when variation is within plant, and provide some more tentative evidence of complementarities using the performance equations approach.

Complementarity between productivity enhancing management practices and general human capital is relevant for policymakers seeking ways to improve management in lagging firms, and productivity in general for two main reasons. First, complementarity implies that policies to raise human capital do not only raise productivity via a direct impact on worker skills, but also via an indirect effect as firms with a skilled workforce are more likely to adopt better management practices. Second, it implies that the payoffs from implementing policies to raise general human capital and policies specifically aimed at improving management practices (such as managerial training) are higher when such policies are implemented together. Similarly, the

³³ We use this measure rather than the degree dummy coefficient from regional regressions on micro labour force data used in the cross-section, as there were insufficient observations in some region-year cells to calculate the latter measure robustly on an annual basis.

³⁴ These are France, Germany, Greece, Italy, Japan, Poland, Sweden, the UK and the United States. Japan and Poland were not included in our core cross-section analysis, as we were not able to obtain the microdata to run wage regressions. However, ready-made regional average wages (for skilled and unskilled workers respectively) were obtained from the statistical agencies in these countries. We note that the results in this table are very similar when Japan and Poland are excluded.

³⁵ Consistent with the cross-sectional analysis, the coefficients are more negative when capital regions are excluded. Some additional robustness tests on these specifications are described in the Online Appendix.

evidence presented in this article suggests that managers seeking to implement or maximise the effectiveness of modern management practices should ensure that they recruit sufficiently skilled workers and managers.

There are a number of directions for future work. First, the measure of firm level human capital used in this article (degree share) does not account for skills acquired from vocational education or on-the-job training. It would be valuable to understand better the specific types of skill that are relevant with respect to modern management practices, and how these can best be acquired. Second, the analysis in this article is based on the manufacturing sector and similar work could be carried out to explore whether there is evidence of complementarities in the service sectors which dominate as a share of GDP in advanced economies like the United States and the UK. Finally, it would be interesting to consider how workforce skills might complement different manager types (Bandiera *et al.*, 2020), and how these interact with management practices as determinants of firm performance.

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

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