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PhD CEOs and firm performance

Andrew Urquhart[1] | **Hanxiong Zhang**[2]

[1]ICMA Centre, Henley Business School, University of Reading, Reading, UK

[2]Surrey Business School, University of Surrey, Guilford, Surrey, UK

Correspondence
Andrew Urquhart, ICMA Centre, Henley Business School, University of Reading, Reading RG6 6UR, UK.
Email: a.j.urquhart@icmacentre.ac.uk

Abstract

This paper investigates the relationship between the education of a Chief Executive Officer (CEO) and firm performance and provides robust evidence that firms led by CEOs with PhDs outperform their peers. We find that CEOs with PhDs increase firm performance by 3.03% while CEOs with a PhD from a highly ranked university increase firm performance by 4.65%. Our results are robust to endogenous CEO selection, transition firms, alternative rankings, unobserved firm characteristics and the network of the CEO. We also show that the increase in firm performance is due to a tighter control of costs and superior cash flow management.

KEYWORDS
CEO characteristics, education, firm performance, PhD

JEL CLASSIFICATION
G00, G03

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1 | INTRODUCTION

The corporate governance literature is abound with studies examining the personal characteristics of Chief Executive Officers (CEOs) and which of them drive the decision making of the CEO and influence firm performance. The idea that the experience, demographic and psychological characteristics of managers' shape their cognitive and values and thus their strategic decision making comes from upper echelons research by Hambrick and Mason (1984). One life experience that has received limited attention in the literature is the education of a CEO. We add to this literature and provide a thorough investigation on the relationship between the CEO education and firm performance and find that CEOs with a PhD increase firm performance by 3.03% while CEOs with a PhD from a highly ranked institution increase firm performance by 4.65%.

The higher education received by a CEO is an important determining factor on the personality and skills of an individual as this may be the last formal education they receive before they enter the work place. Chevalier and Ellison (1999) document a positive relationship between managers' education and mutual fund performance, where managers with undergraduate degrees from Ivy League universities generate higher risk-adjusted returns. However they also show that managers with Ivy League MBA degrees achieve higher returns also entirely by shifting towards greater systematic risk. Bhagat et al. (2010) show that education is a very important factor in the hiring process of CEOs, however they show no significant relationship with their education and long-term firm performance. Recently, King et al. (2016) examine bank performance and show that CEOs with MBAs outperform their peers by arguing that management education delivers the skills required to manage large banks and achieve successful performance.

Education has two broad dimensions, namely the level of education attained, and the quality of the education received. There are four main levels of education an individual can receive at university, namely an Undergraduate (UG) degree, a Postgraduate (PG) degree, a Masters of Business Administration (MBA) degree as well as a Doctor of Philosophy (PhD) degree. These differing levels of degrees have different focuses and qualities, and therefore will impart different skills and knowledge onto the individual. Higher levels of CEO education have been linked to superior levels of cognitive complexity (Wally & Baum, 1994), more innovation (Wiersema & Bantel, 1992), more sustained investment in a firm (Bertrand & Schoar, 2003), and a facility to make valuable alliances (Palmer & Barber, 2001). All of these outcomes may lead to sustainable superior firm performance. The second dimension of an education is the quality of the education received. Universities accept students based on their grades from school or college and therefore higher ranked universities will only accept students with excellent grades. We would expect that at higher ranked universities students will be more capable and therefore will be exposed to more challenging and a more advanced level of content than students who go to lower ranked universities which accept students with lower grades. It stands to reason therefore, that admission to a highly ranked university may signal a human resource that is particularly likely to promote superior sustained performance, as those selected are, in effect, winners of a tournament of talent (Lazear & Rosen, 1981). Also, selection by a top university may indicate a variety of talents as Rogers (2010) finds that education is associated with more creativity and innovation, and greater receptiveness to new ideas.

Nevertheless, there are two competing channels in which education can influence the performance of a CEO. The first channel is that more capable individuals do well at school and therefore attend a high-quality institution where they go on to study a PhD. In this respect, the

education received had little effect on the individual but the level and quality of education is a signal of the cognitive ability of the individual. The alternative channel is that individuals gain skills and knowledge during their studies that increase their decision-making ability, and this is very important for individuals who complete a PhD. As noted by He and Hirshleifer (2021), studying for a PhD shows a commitment to invest in costly human capital and requires considerable patience, problem solving and an explanatory mindset. Therefore by pursing and completing a PhD, individuals will gain certain skills that they would have otherwise not gained by only studying for an undergraduate or postgraduate taught programme. However we do accept that it is impossible in our current study to disentangle these two channels as we lack data on the cognitive ability of CEOs before their education and after they finish their studies.

We construct a data set that captures CEO educational qualifications for FTSE 350 firms for the period 1999–2017. We collect data on the types of degrees held by all CEOs and also identify whether the awarding institution is among the top 100 ranked universities in the world, according to the highly respected QS-ranking system. This is very important since the quality of the university attended is a signal to the cognitive ability of the CEO, and therefore the quality of education they receive at university. Therefore students graduating from highly ranked institutions should have a higher cognitive ability and have been subjected to a quality level of education than students that go to lower ranked institutions. Our paper offers several important contributions to the existing literature. We extend and complement the existing literature by examining the link between CEO characteristics and firm performance. Previous studies have mainly focused on the banking industry or a small sample size, while we study all types of firms listed on the FTSE 350, including banks. We find that CEOs with undergraduate, postgraduate or MBA level education offer little explanatory power when explaining firm performance. We do find however that CEOs with PhDs exhibit significantly higher firm performance compared with their peers without a PhD education. This suggests that CEOs who conduct a lengthy research-based degree acquire skills and knowledge that enables them to perform better as a CEO compared with their peers.

We capture the level and quality of CEO education by employing factor analysis, which has been very popular since the seminal work by Tetlock (2007). Using factor analysis allows us to extract the key factors in the CEO education index and this method is preferred since it avoids the issue of including a large number of inter-correlated variables, subjectively choosing education variables and it also enables the inclusion of broader dimensions than other methods allow. Through this factor analysis, we find that the combination of the level and quality of PhD education is the largest factor, followed by the combination of the level and quality of a PG education and then the combination of the level and quality of a MBA education.

We probe the validity of our results through propensity score matching based difference-in-difference since it could be that only large and wealthier firms are able to attract CEOs with excellent education credentials. Nevertheless, our results are robust and show the added value of a CEO with a PhD from a highly ranked institution. We also find that CEOs with a PhD increase firm performance by controlling costs and superior cash flow management. Finally we show that our results are robust to alternative quality ratings, alternative university rankings, CEO networks and to the exclusion of financial and utility firms.

Our paper also adds to the literature of CEO cognitive ability. Recently, Adams et al. (2018) show that the median large-company CEO belongs to the top 17% of the population in cognitive ability. While we cannot explicitly capture the cognitive ability of our CEOs, it is reasonable to assume that CEOs who attend highly ranked institutions performed well at school and therefore are towards the top of the population based on cognitive ability. We find that CEOs

with a PhD from a top 100 university increase industry-adjusted ROA by 4.65% while a CEO with a PhD in general increases ROA by 3.03%. This suggests that although a CEO with a PhD does significantly improve firm performance, a CEO from a top 100 university is more valuable for a firm. Only CEOs with high cognitive ability are admitted to top 100 universities and therefore our results support idea that CEOs with higher cognitive ability perform better than their peers.

Our paper also adds to the literature exploring the relationship between managers' psychological traits and firm decisions. Existing research has found that risk-seeking of CEOs affect their policies within the firm, where Grinblatt and Keloharju (2009) use speeding tickets to identify sensation seekers and find that individuals who speed while driving trade more in their personal stock portfolios. Cain and McKeon (2016) use CEOs' pilot certification to capture risk taking and show that personal flying is linked to high fatality rate and list examples of CEOs who lost their lives operating small aircraft, while Sunder et al. (2017) study the relationship between sensation seeking from holding a pilots license to innovation. In a recent paper, He and Hirshleifer (2021) argue that PhD CEOs are likely to be low on sensation seeking, since obtaining a doctorate requires years of quiet study rather than brief episodes of exciting physical activity.

Finally, our paper adds to the literature on academics in the boardroom where studies have found that academics offer a different dimension to boards. For instance, directors with academic backgrounds can enhance the competitive advantage of firms by facilitating access to and the absorption of external knowledge spillover (Audretsch & Lehmann, 2006). Also, in most academic appointment announcements of nonexecutive directors, CEOs often note that a professor's academic expertise will be of great benefit to the company.[1] Francis et al. (2015) finds that directors from academia are associated with higher firm performance since academics tend to look at problems differently than non-academics. We find that PhD CEOs outperform other firms which could be a reflection of the problem solving skills these CEOs have acquired during their PhD studies.

The rest of this paper proceeds as follows. Section 2 develops the hypotheses regarding the influence of CEO education on firm performance while Section 3 introduces the data set, explains the construction of the CEO Education index, provides variable definitions and the baseline methodology. Section 4 investigates the impact of CEO education on firm performance, which includes various robustness checks as well as the mechanism in which the CEO may improve firm performance. Section 5 provides thorough robustness analysis of our results while 6 summarizes the findings and provides conclusions.

2 | LITERATURE REVIEW AND HYPOTHESIS DEVELOPMENT

"Upper Echelons Theory", proposed by Hambrick and Mason (1984), argues that managers' experiences, values and cognitive ability affect their strategic choices and in turn are reflected in firm outcomes. Research has focused on the career experiences (Custódio & Metzger, 2014; Li & Patel, 2019), overconfidence (Chen et al., 2019; Galasso & Simcoe, 2011; Hirshleifer et al., 2012; Malmendier & Tate, 2005, 2008), age (Cline & Yore, 2016; Panayiotis et al., 2017;

[1]An article in Directors and Boards (January 1, 1997) points out that US companies recruit directors from academia to benefit from their special expertise and to enrich board diversity.

Serfling, 2014; Yim, 2013), gender (Brinkhuis & Scholtens, 2018; Faccio et al., 2016; Huang & Kisgen, 2013), masculinity (Jia et al., 2014; Kamiya et al., 2019; Wong et al., 2011), emotional traits (Delgado-García et al., 2010), materialism (Bushman et al., 2018) and hobbies (Brown et al., 2018; Cain & McKeon, 2016; Sunder et al., 2017) of CEOs, and have shown that these are determining factors on the decision making and performance of CEOs.

The education of CEOs has been found to influence career outcomes in terms of pay and career trajectory as well as firm investments and general decision-making (Donkers et al., 2001; Laderman, 1994). Chevalier and Ellison (1999) show a positive relationship between managers' education and mutual fund performance, where managers with undergraduate degrees from Ivy League universities generate higher risk-adjusted returns. However they also show that managers with Ivy League MBA degrees achieve higher returns also entirely by shifting towards greater systematic risk. Barker and Mueller (2002) show that CEOs with a college degree increase spending in R&D, however education generally has a diminishing association with spending in R&D once a CEO has a college degree. Educational attainment contains expectations on the latent ability of CEOs, with Bhagat et al. (2010) reporting the market reaction to announcements of appointments of CEOs with stronger education credentials generates significant abnormal returns although this is not a long-term relationship. Beber and Fabbri (2012) show that CEOs with MBA degrees are riskier, and therefore speculate more in the foreign exchange market than CEOs without a MBA degree. Although Falato et al. (2015) find that firms pay a premium for CEOs with superior educational credentials, not all forms of education produce a homogeneous effect on firm performance due to selection effects. As Miller et al. (2015) point out, academic qualifications differ by quality of education and levels of education and therefore different CEO skill-sets and results in performance differentials. King et al. (2016) examine bank performance and show that CEOs with MBAs outperform their peers by arguing that management education delivers the skills required to manage large banks and achieve successful performance. Recently, Adams and Jiang (2017) show that CEOs in the UK insurance industry with insurance and financial expertise enhance the financial performance of the firm while Fedaseyeu et al. (2018) show that more qualified directors handle more board functions, resulting in higher pay.

Therefore the literature shows a strong link between the education of the CEO and firm performance. One dimension of education is the level of education received. There are four main levels of education an individual can receive at university, namely an Undergraduate (UG) degree (constituting a basic UG level of training that aids development of transferable skills), a Postgraduate (PG) degree (PG level training), a Masters of Business Administration (MBA) degree (representing the level of management training and knowledge acquired through an MBA programme) as well as a Doctor of Philosophy (PhD) degree (showing the level of technical expertise obtained through an advanced degree or doctorate). These differing levels of degrees have different focuses and qualities, and therefore will impart different skills and knowledge onto the individual. Higher levels of CEO education have also been linked to superior levels of cognitive complexity (Wally & Baum, 1994), more innovation (Wiersema & Bantel, 1992), more sustained investment in a firm (Bertrand & Schoar, 2003), and a facility to make valuable alliances (Palmer & Barber, 2001) thereby suggesting that higher levels of education are linked to better performance by the CEO. Consequently:

H1: *Ceteris paribus*, a CEO with a higher level of education will be positively related to superior firm performance

Linked to the level of education received is the quality of the education. Universities accept students based on their grades from school or college and therefore higher ranked universities will only accept students with excellent grades. We would expect that at higher ranked universities students will be more capable and therefore will be exposed to more challenging and a more advanced level of content than students who go to lower ranked universities which accept students with lower grades. It stands to reason therefore, that admission to a highly ranked university may signal a human resource that is particularly likely to promote superior sustained performance, as those selected are, in effect, winners of a tournament of talent (Lazear & Rosen, 1981). Also, selection by a top university may indicate a variety of talents as Rogers (2010) finds that education is associated with more creativity and innovation, and greater receptiveness to new ideas. Consequently:

H2: *Ceteris paribus*, the quality of the CEO education will be positively related to superior firm performance

3 | DATA AND METHODOLOGY

3.1 | Education sample

The analysis is based on a sample of CEOs at publicly-listed FTSE 350 firms. Our sample period is from 1999 to 2017 where we begin by extracting data on CEOs from the BoardEx database which provides detailed data on the CEOs of firms and their education, which includes the level as well as the institution in which they received their degree from.[2] We restrict our definition of CEO to "CEO" and "Chief Executive" in the individual role column in BoardEx so as to avoid issues with CEOs with other roles in the firm and acting-CEOs. From the initial sample, we retain only those CEOs from which we could collect detailed data on their CEO educational backgrounds that captures information on the different types of degrees held and on the awarding institutions. We collect firm characteristic data from Datastream and merge both datasets where we have 3,902 firm year observations, with 435 unique firms and 764 unique CEOs.

An important consideration, as well as the type of degree, is the quality of the degree attained and therefore we collect rankings of universities from the QS world-wide university rankings 2017.[3,4] Table 1 reports the QS 100 university we use in our sample. We can see that the most represented country is the USA with 31 institutions in the top 100, while the UK has 16. Australia has 7 institutions while mainland China has 6. Japan and Hong Kong have 5 institutions in the top 100 while Canada and South Korea has 4 representatives. France, Germany and Switzerland have 3 each and the Netherlands, Singapore and Sweden have 2 each. Finally, Argentina, Belgium, Denmark, Ireland, New Zealand, Russia and Taiwan have 1 representative each.[5] Table A1 in the appendix shows the distribution of CEO education by year and shows that there is no clear trend in the number of CEOs with a certain education

[2]BoardEx is popular source for data on CEOs and have been used in recent papers such as Wang and Yin (2018) and Conyon et al. (2018) for example.

[3]We use the 2017 QS rankings and also examine previous years rankings where we find that the correlation is very high and therefore there is not much change in the world top 100 institutions.

[4]The QS University rankings can be found at https://www.topuniversities.com/university-rankings/world-university-rankings/2018

[5]We do not report the exact number CEOs with degrees awarded by each institution to conserve space but is available upon request from the corresponding author.

TABLE 1 List of QS top 100 universities

This table reports the QS 100 Universities that we use to signify a quality education, along with the country they are located.

Ranking	Institution	Country	Ranking	Institution	Country
1	Massachusetts Institute of Technology (MIT)	USA	51	University of British Columbia	Canada
2	Stanford University	USA	52	New York University (NYU)	USA
3	Harvard University	USA	53	Brown University	USA
4	California Institute of Technology (Caltech)	USA	54	Delft University of Technology	The Netherlands
5	University of Cambridge	UK	55	University of Wisconsin-Madison	USA
6	University of Oxford	UK	56	Tokyo Institute of Technology	Japan
7	University College London (UCL)	UK	57	University of Warwick	UK
8	Imperial College London	UK	58	University of Amsterdam	The Netherlands
9	University of Chicago	USA	59	Ecole Polytechnique	France
10	ETH Zurich - Swiss Federal Institute of Technology	Switzerland	60	Monash University	Australia
11	Nanyang Technological University (NTU)	Singapore	61	University of Washington	USA
12	Ecole Polytechnique Federale de Lausanne (EPFL)	France	62	Shanghai Jiao Tong University	China
13	Princeton University	USA	63	Osaka University	Japan
14	Cornell University	USA	64	Technical University of Munich	Germany
15	National University of Singapore (NUS)	Singapore	65	University of Glasgow	UK
16	Yale University	USA	66	Ludwig-Maximilians-Universität München	Germany
17	John Hopkins University	USA	67	University of Texas	USA
18	Columbia University	USA	68	Reprecht-Karls-Universität Heidelberg	Germany
19	University of Pennsylvania	USA	69	University of Illinois at Urbana-Champaign	USA

(Continues)

TABLE 1 (Continued)

Ranking	Institution	Country	Ranking	Institution	Country
20	The Australia National University (ANU)	Australia	70	Georgia Institute of Technology	USA
21	Duke University	USA	71=	KU Leuven	Belgium
22	University of Michigan	USA	71=	Pohang University of Science and Technology (POSTECH)	South Korea
23	University of Edinburgh	UK	73=	University of Copenhagen	Denmark
24	King's College London	UK	73=	University of Zurich	Switzerland
25	Tsinghua University	China	75	Universidad de Buenos Aires (UBA)	Argentina
26	The University of Hong Kong	Hong Kong	76=	National Taiwan University (NTU)	Taiwan
27	University of California, Berkeley (UCB)	USA	76=	Tohoku University	Japan
28	University of Tokyo	Japan	78=	Durham University	UK
29	Northwestern University	USA	78=	Lund University	Sweden
30	The Hong Kong University of Science and Technology	Hong Kong	80	University of North Carolina, Chapel Hill	USA
31	University of Toronto	Canada	81	Boston University	USA
32	McGill University	Canada	82=	University of Auckland	New Zealand
33	University of California, Los Angeles (UCLA)	USA	82=	University of Sheffield	UK
34	University of Manchester	UK	84=	University of Birmingham	UK
35	London School of Economics and Political Science (LSE)	UK	84=	University of Nottingham	UK
36	Kyoto University	Japan	86	The Ohio State University	USA
37	Seoul National University	South Korea	87	Zhejang University	China
38	Peking University	China	88	Trinity College Dublin, University of Dublin	Ireland

TABLE 1 (Continued)

Ranking	Institution	Country	Ranking	Institution	Country
39	University of California, San Diego (UCSD)	USA	89	Rice University	USA
40	Fudan University	China	90=	Korea University	South Korea
41	KAIST—Korea Advanced Institute of Science and Technology	South Korea	90=	University of Alberta	Canada
42	University of Melbourne	Australia	92	University of St Andrews	UK
43	Ecole Normale Superieure, Paris	France	93=	Pennsylvania State University	USA
44	University of Bristol	UK	93=	University of Western Australia	Australia
45	University of New South Wales (UNSW)	Australia	95=	Lomonosov Moscow University	Russia
46	Chinese University of Hong Kong (CUHK)	Hong Kong	95=	The Hong Kong Polutechnic University	Hong Kong
47	University of Queensland	Australia	98=	University of Science and Technology of China	China
48	Carnegie Mellon University	USA	98=	KTH Royal Institute of Technology	Sweden
49	City University of Hong Kong	Hong Kong	98=	University of Geneva	Switzerland
50	University of Sydney	Australia	100	Washington University in St. Louis	USA

TABLE 2 Descriptive statistics of the CEO education variables

This table presents descriptive statistics for our education variables that denote the level and quality of CEO education for our sample. The four variables denoting level of CEO education (UG/PG/MBA/PhD degree) are dummy variables that take a value of 1 if a CEO holds the corresponding degree, and 0 otherwise. Similarly, the four variables that capture the quality of CEO education (Top 100 UG/PG/MBA/PhD) take a value of 1 if a CEO obtained their degree from the QS Top 100 institution, according to the QS 2018 rankings.

	Percentile
Panel A: Level of education	
UG degree	0.969
PG degree	0.295
MBA degree	0.199
PhD degree	0.105
Panel B: Quality of education by overall ranking	
Top 100 UG	0.323
Top 100 PG	0.141
Top 100 MBA	0.073
Top 100 PhD	0.041
Panel C: Gender, nationality and location of education	
Male CEO	0.972
British CEO	0.786
CEO Educated in Britain	0.723
British CEO Educated in Britain	0.686
British CEO Educated outside of Britain	0.218
Non-British CEO Educated in Britain	0.037

attainment throughout our sample while Table A2 reports the percentage of CEOs with certain qualification by industry. We can see that fairly consistent numbers across undergraduate degrees but some variation across industry for PG, MBA and PhD level education, which supports our reasoning for including industry fixed effects in the high-dimensional fixed effects.

Table 2 reports the summary statistics for our education variables where nearly 97% of CEOs have an undergraduate degree, while almost 30% of them have a postgraduate degree. This indicates that the vast majority of CEOs have some sort of higher level education. We also find that nearly 20% of CEOs have a MBA degree whilst only 10% have a PhD. We also distinguish the quality of the education received by CEOs in Panel B and show that 32.3% of CEOs have an undergraduate degree from a top 100 institution, which shows that about a third of our CEOs have an undergraduate degree from an institution ranked in the top 100 institutions in the world. We also find that 14.1% of CEOs have a postgraduate degree from a top 100 institution while only 7.3% have a MBA from a top 100 institution. Finally we show that 4.1% of our CEOs have a PhD from from a top 100 institution, just under half the total number of CEOs who have a PhD. Finally in Panel C, we report some more descriptive statistics for the CEOs in our sample, and find that 97.2% of them are male, while 78.6% of the CEOs are British

by nationality. 72.3% of CEOs are educated in the UK, while 68.6% of CEOs are British and also educated in the UK.[6] We find that 21.8% of CEOs are British CEOs educated outside of the UK and only 3.7% of CEOs are non-British that are educated in the UK, indicating that very few CEOs are of non-British nationality and educated in the UK.

3.2 | Education variable construction

Although we have clear variables for the level and quality of education attained by CEOs, these variables represent an underlying fundamental construct (or latent variable), and therefore we follow the influential work by Tetlock (2007) and use factor analysis to form our education factors. Factor analysis has become popular in the recent corporate finance literature, where Kaplan et al. (2012) use it when analysing interview transcripts of CEOs and Ellul and Yerramilli (2013) use it to form a risk management index. We employ factor analysis to extract the underlying structure from the variance-covariance matrix of our education categories, which will enable us to determine the key factors in the CEO education index. The benefit of this method is that it takes into account the total variance of each variable and groups of variables that have high levels of shared or common variance into broader factors. Therefore these factors share a common core and represent the overall relationship between these variables and has a number of advantages. First, factor analysis avoids the issue of including a large number of inter-correlated variables, as well as other issues associated with multivariate analyses (Custódio & Metzger, 2014) since the factor analysis consists of composite measures for variables that share a common core and these factors are orthogonal to each other. Second, this method avoids the need to arbitrarily include factors that the authors believe are important, and therefore makes this method objective, rather than subjective. Finally, this method enables the inclusion of broader dimensions than other methods, as it first establishes the dimensionality of the construct, and then extracts the structure and composition of its dimension for use in subsequent analyses.

The factor analysis results are reported in Table 3 where each factor represents a linear combination of variables that accounts for more variance than any other possible combination, and the factor loadings for each variable on the three factors indicate the correlation of each variable with the broader factor, as well as indicate the contribution of each variable in defining that factor. The first factor we find is a combination of PhD degree and top 100 PhD, which explains 24.7% of the covariance amongst the variables. This suggests that the level and quality of a PhD is an important factor among our education variables and we interpret it as showing CEOs technical expertise acquired through a doctorate degree. Our second factor is a combination between top 100 PG and PG education, which represents the quality and level of PG education. This factor represents 21.6% of the variation and with the first factor, represents 46.3% of the total variation. Finally, the third factor represents 15.8% of the variance and is a combination of the level and quality of the MBA received by the CEO.

Ceteris paribus, a CEO in our sample awarded a PhD by Massachusetts Institute of Technology (MIT) has a PhD Education factor score of 3.506, reflecting that she is 3.506 standard deviations above the sample mean. However, a CEO who has no PhD has the corresponding factor score of -0.448.

[6]This is potentially quite important since in many countries, especially the USA, one's social class is a determining factor on the institution that they attend. However in the UK, University fees are set across the sector and as of July 2019, is set at £9250 while in the US, fees vary across institution which reflect their prestige and demand. Therefore we argue that social class is not a determining factor in the choice of University in our study since nearly two-thirds of our CEOs attend UK Universities.

TABLE 3 CEO education index

This table presents factor loadings on the first three factors based on eight education characteristics for 3902 firm-year observations in our sample from 1999 to 2017. Factor loadings are presented after a normalized orthogonal varimax rotation. Factor loadings with absolute value less than 0.40 are blank consistent with King et al. (2016). The factors have been sorted by the percentage of variance explained.

	Factor 1	**Factor 2**	**Factor 3**
	PhD education	**PG education**	**MBA education**
Panel A: Factor loadings			
Level of education			
UG degree			
PG degree		0.726	
MBA degree			0.657
PhD degree	0.805		
Quality of education			
QS top 100 UG			
QS top 100 PG		0.713	
QS top 100 MBA			0.658
QS top 100 PhD	0.656		
Panel B: Model statistics			
Eigenvalue	1.276	1.130	0.976
% variance explained	0.247	0.216	0.158
Cumulative % variance explained	0.247	0.463	0.621

Similarly, a CEO who has an MBA degree from Stanford University has a MBA Education factor score of 2.533, while a CEO with an MBA degree from non-QS top 100 institution has a factor score of −0.446. Consistent with previous usage factor analysis, we use these loadings to predict factor scores for each of our three factors. Factor score is standardized value that is computed using all of the variables, with their influence based on the factor loadings. We use these factor solutions to estimate the relationship between CEO education and firm performance in the following section.

3.3 | Firm performance measure

We do not make lightly the specific choice of dependent variables for our empirical estimations. While accounting-based measures like return on assets (ROA) are popular for their simplicity and ease of understanding, and the fact that they are precisely estimated based on audited figures, they are also based on historical numbers and therefore backward looking. Therefore they may be difficult to use as a way to compare across companies due to potentially different accounting policies prevalent in different companies within our data. Further, accounting-based measures can be successful in measuring the impact of corporate decisions made in the immediate past including the present. In contrast, the most commonly used market-based

performance measures include Tobin's *Q*, the market to book (MTB) ratio amongst others. The advantage of using market performance-based measures is that they reflect the fundamental value of a corporation given by share prices. However, since the share price reflects both market expectations (forward looking) in addition to true performance (backward looking), using performance-based measures may subtly introduce the anticipation effect where one is not needed as per the specific research question.[7] Consistent with the above, we choose to use the accounting-based measure, industry adjusted ROA, defined as the ratio of net income to total assets, as our main dependent variable (consistent with Bhagat & Bolton, 2013; Fauver et al., 2018; Frijns et al., 2018). This measure ensures that our results are not industry specific.

3.4 | Control variables

The models employed in our analysis include a number of firm-level control variables as these have been shown to have a potentially important effect on firm performance. With regard to firm-specific control variables, volatility is the standard deviation of annualized monthly stock price returns over the calendar year, leverage is the total debt divided by total assets, natural log of market to book value, while firm size is the natural log of total assets. As well as firm control variables, we also include controls for CEO characteristics, such as age, tenure, and bonus fraction, equity fraction, natural log of CEO total wealth, gender and whether the CEO is British. The inclusion of these are important, since earlier evidence suggests that younger CEOs (Kovalchik et al., 2005; Li et al., 2017) and wealthier CEOs (Calvet & Sodini, 2014; Paravisini et al., 2017) behave differently. Finally, we also include a control variable for governance characteristics whether the CEO is chairman of the board. More information on the exact nature of these control variables is available from Table B1 in Appendix B of this paper while the summary statistics of all the control variables employed in this study are reported in Table 4 and the correlation matrix is reported in Table B2.

3.5 | Methodology

To test our hypothesis, the following panel data regression model is estimated:

$$\begin{aligned} Firm.\ Performance_{i,t+1} = {} & \alpha + \beta_1(PhD.\ Education_{i,t}) + \beta_2(PG.\ Education_{i,t}) \\ & + \beta_3(MBA.\ Education_{i,t}) + \beta_4(Control\ \ Variables_{i,t}) + YearFE_t \\ & + FirmFE_{i,j} + \epsilon_t, \end{aligned} \tag{1}$$

where *PhD. Education* refers to the first factor we calculate through the factor analysis, namely the combination of the level and quality of the PhD education, *PG. Education* is the factor that is the combination of the level and quality of the PG education while *MBA. Education* refers to combination of the level and quality of the MBA education. *ControlVariables* refer to our vector of controls discussed in the previous section, while we also include *Year* and *Firm* fixed effects. All independent variables are lags of the dependent

[7] See Aliabadi et al. (2013) for a review of the issues between accounting-based and market-based measures.

TABLE 4 Descriptive statistics for the control variables

This table shows summary statistics for various CEO and firm control variables for 3902 firm-year observations from 1999 to 2017. Following Conyon et al. (2018) and Florackis and Sainani (2018), all continuous variables are winsorized at their 1st and 99th percentiles to alleviate the influence of outliers. The definition of the variables are available in Table B1 in the Appendix.

	Observations	Mean	*SD*	Min	Max
Leverage	3902	0.334	0.241	0	0.924
ROA	3902	0.045	0.102	−0.432	0.317
Industry adjusted ROA	3902	0.008	0.123	−0.623	0.43
Ln(CEO age)	3902	3.927	0.12	3.611	4.174
Ln(CEO tenure)	3902	1.215	1.062	−1.609	3.219
Female CEO	3902	0.028	0.164	0	1
British CEO	3902	0.786	0.411	0	1
Ln(CEO Wealth)	3902	8.204	1.596	4.060	12.992
Bonus fraction	3902	0.179	0.149	0	0.74
Equity fraction	3902	0.365	0.000	0.248	0.892
Stock volatility	3902	10.344	47.15	0.402	419.959
Ln(Market-to-book value)	3902	0.833	0.865	−1.079	3.443
Ln(Firm size)	3902	13.859	1.729	9.887	18.528
CEO is Chairman	3902	0.122	0.327	0	1

variable hence from our original 3,902 observations reported in Table 4, our estimation has 3294 observations.

4 | EMPIRICAL FINDINGS

In this section, we present our empirical results from the data and methodology previously described in Section 3.

4.1 | Education factor analysis

Table 5 reports the baseline regression results, where we introduce the CEO Education factors sequentially in columns (1)–(3) and present the full model in column (4). We can see that our PhD factor is a strong determinant on firm performance, with the coefficient positive and statistically significant at the 5% level indicating that PhD CEOs significantly improve firm performance. The magnitude of the coefficient is also economically meaningful. The standard deviation of the sample of the PhD factor is 0.84, therefore the coefficient for the PhD factor suggests that a one standard deviation increase in PhD education is associated with a 1.2% increase in industry-adjusted ROA. However in columns (2) and

TABLE 5 CEO education and firm performance

This table reports the impact of our three-factor CEO education index on firm performance. All models include year fixed effects and firm fixed effects. All the independent variables are one order lagged, t-statistics (adjusted for heteroskedasticity and clustering at the firm level), are in parentheses.***, ** and * indicate significance at the 1%, 5% and 10% levels, respectively.

	1	2	3	4
PhD Education	0.0120**			0.0130**
	(2.07)			(2.26)
PG Education		−0.0027		−0.0049
		(−0.62)		(−1.09)
MBA Education			0.0016	0.0034
			(0.34)	(0.71)
Ln(CEO age)	0.0477	0.0589*	0.0615*	0.0493
	(1.46)	(1.82)	(1.88)	(1.53)
Ln(CEO tenure)	−0.0052	−0.0054	−0.0056	−0.0051
	(−1.43)	(−1.49)	(−1.53)	(−1.40)
Female_CEO	0.0537***	0.0565**	0.0565**	0.0540***
	(2.66)	(2.51)	(2.50)	(2.71)
British_CEO	−0.001	−0.0053	−0.003	−0.0005
	(−0.10)	(−0.46)	(−0.29)	(−0.05)
Bonus fraction	0.0467**	0.0475**	0.0473**	0.0470**
	(2.39)	(2.43)	(2.42)	(2.41)
Equity fraction	0.0167	0.0183	0.0180	0.0173
	(1.40)	(1.53)	(1.51)	(1.45)
Ln(CEO wealth)	0.0041	0.0044	0.0044	0.0042
	(1.10)	(1.18)	(1.17)	(1.12)
Stock volatility	0.0001	0.0001	0.0001	0.0001
	(0.92)	(0.94)	(0.93)	(0.91)
Leverage	−0.0415*	−0.0433*	−0.0431*	−0.0408*
	(−1.71)	(−1.78)	(−1.77)	(−1.68)
Ln(Market-to-book value)	0.0338***	0.0334***	0.0333***	0.0332***
	(4.19)	(4.11)	(4.07)	(4.10)
Ln(Firm size)	−0.0171***	−0.0172***	−0.0171***	−0.0175***
	(−2.72)	(−2.71)	(−2.68)	(−2.78)
CEOisChairman	0.0135	0.0145	0.0142	0.0147
	(1.28)	(1.37)	(1.35)	(1.39)

(Continues)

TABLE 5 (Continued)

	1	2	3	4
Constant	0.0029	−0.0376	−0.0499	0.0002
	(0.02)	(−0.24)	(−0.32)	(0.00)
Year FE	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes
Adj R^2	0.1113	0.1084	0.1083	0.1114
Observations	3294	3294	3294	3294

(3), we find no significant evidence that our remaining two factors are significant determinants of firm performance. The coefficients for the PG and MBA factors are very small and statistically insignificant suggesting that the level and quality of the PG and MBA education has very little determining power on the performance of the firm. The full model results in column (4) confirms our findings in that the PhD factor have significant explanatory power in improving firm performance, while the other factors offer very little explanatory power. Regarding the coefficients of our control variables, we find that female CEOs are an important factor in determining firm performance, while firm size has a statistically negative relationship with firm performance. Therefore, our factor analysis supports *Hypothesis 1* and *Hypothesis 2* in that higher and better educated CEOs significantly improve firm performance above their peers.

4.2 | Education as dummy variables

The education factors generated are not straightforward, since the aim of factor analysis is to capture the total variance of each variable and group them together into broader factors. Therefore we also estimate dummy variable analysis to add robustness to the factor analysis results. Table 6 reports the dummy variable results where we examine individually each dummy variable for the level of qualification. We find that CEOs with UG, PG and MBA qualifications do not significantly improve the performance of the firm, with each of the education variables generating insignificant coefficients. However we find that CEOs with a PhD education significantly improves the industry-adjusted ROA by 3.03% indicating that PhD CEOs offer value to firms. We also find quality UG, PG and MBA degrees also offer no significant improvement in firm performance, although each of them do offer positive coefficients indicating that they do increase firm performance at a certain level. In column (9) we find that a top 100 PhD CEO significantly improves firm performance, where industry-adjusted ROA increases by 4.65%, suggesting that while a PhD CEO significantly improves firm performance, a quality PhD from a highly ranked institution improves firm performance by a higher magnitude. Therefore our findings in Table 6 shows that a PhD from a top 100 institutions increases industry-adjusted ROA by 4.65%, while any PhD increases firm performance by 3.03%, indicating that there is a 1.62% industry-adjusted ROA premium for firms with a CEO from a top 100 institution. Our findings are consistent when we control for the quality of the UG, PG and MBA education as well. This is consistent with our factor analysis finding and again supports *Hypothesis 1* and *Hypothesis 2*.

TABLE 6 CEO education proxied by dummy variables and firm performance

All models include year fixed effects and firm fixed effects. All the independent variables are one order lagged. t-statistics, adjusted for heteroskedasticity and clustering at the firm level, are in parentheses. ***, ** and * indicate significance at the 1%, 5% and 10% respectively.

	1	2	3	4	5	6	7	8	9	10
UG level	0.0266				0.0238					
	(1.12)				(1.04)					
PG level		0.00249			−0.0120					
		(0.28)			(−1.23)					
MBA level			0.00745		0.00894					
			(0.76)		(0.93)					
PhD level				0.0303**	0.0400**					
				(2.03)	(2.43)					
Top 100 UG						−0.00203				−0.00194
						(−0.27)				(−0.26)
Top 100 PG							−0.00486			−0.00695
							(−0.46)			(−0.67)
Top 100 MBA								−0.00128		0.00310
								(−0.11)		(0.25)
Top 100 PhD									0.0465*	0.0478*
									(1.87)	(1.93)
Ln (CEO age)	0.0621*	0.0594*	0.0620*	0.0487	0.0514	0.0584*	0.0589*	0.0590*	0.0518	0.0509
	(1.91)	(1.82)	(1.89)	(1.50)	(1.58)	(1.75)	(1.81)	(1.82)	(1.59)	(1.55)

(Continues)

TABLE 6 (Continued)

	1	2	3	4	5	6	7	8	9	10
Ln(CEO tenure)	−0.00549	−0.00552	−0.00547	−0.00528	−0.00508	−0.00543	−0.00541	−0.00547	−0.00524	−0.00511
	(−1.52)	(−1.52)	(−1.51)	(−1.45)	(−1.40)	(−1.49)	(−1.49)	(−1.51)	(−1.45)	(−1.41)
Female_CEO	0.0567**	0.0561**	0.0567**	0.0567**	0.0586***	0.0567**	0.0563**	0.0563**	0.0496***	0.0496***
	(2.51)	(2.48)	(2.51)	(2.56)	(2.64)	(2.52)	(2.50)	(2.50)	(2.96)	(2.98)
British_CEO	−0.00357	−0.00373	−0.00234	0.00000323	0.00155	−0.00380	−0.00492	−0.00460	−0.00483	−0.00454
	(−0.31)	(−0.32)	(−0.21)	(0.00)	(0.14)	(−0.32)	(−0.43)	(−0.40)	(−0.42)	(−0.37)
Bonus fraction	0.0465**	0.0471**	0.0472**	0.0463**	0.0459**	0.0472**	0.0474**	0.0473**	0.0479**	0.0479**
	(2.38)	(2.40)	(2.42)	(2.37)	(2.35)	(2.42)	(2.42)	(2.42)	(2.46)	(2.47)
Equity fraction	0.0179	0.0178	0.0181	0.0169	0.0176	0.0180	0.0181	0.0179	0.0172	0.0174
	(1.49)	(1.48)	(1.51)	(1.41)	(1.47)	(1.50)	(1.51)	(1.50)	(1.45)	(1.47)
Ln(CEO wealth)	0.00451	0.00438	0.00443	0.00413	0.00426	0.00434	0.00443	0.00439	0.00421	0.00419
	(1.20)	(1.16)	(1.18)	(1.10)	(1.14)	(1.14)	(1.18)	(1.17)	(1.12)	(1.10)
Stock volatility	0.0000531	0.0000537	0.0000534	0.0000516	0.0000505	0.0000542	0.0000545	0.0000540	0.0000549	0.0000557
	(0.92)	(0.93)	(0.92)	(0.90)	(0.87)	(0.94)	(0.94)	(0.93)	(0.95)	(0.96)
Leverage	−0.0436*	−0.0433*	−0.0427*	−0.0413*	−0.0403*	−0.0432*	−0.0434*	−0.0434*	−0.0426*	−0.0424*
	(−1.79)	(−1.78)	(−1.75)	(−1.70)	(−1.68)	(−1.77)	(−1.78)	(−1.78)	(−1.74)	(−1.73)
Ln(Market−to−book value)	0.0336***	0.0336***	0.0330***	0.0337***	0.0330***	0.0336***	0.0335***	0.0336***	0.0339***	0.0337***
	(4.13)	(4.13)	(4.06)	(4.18)	(4.09)	(4.13)	(4.12)	(4.11)	(4.17)	(4.15)
Ln(Firm size)	−0.0171***	−0.0170***	−0.0172***	−0.0169***	−0.0173***	−0.0170***	−0.0172***	−0.0170***	−0.0175***	−0.0176***
	(−2.70)	(−2.69)	(−2.71)	(−2.68)	(−2.74)	(−2.67)	(−2.71)	(−2.67)	(−2.77)	(−2.78)

TABLE 6 (Continued)

	1	2	3	4	5	6	7	8	9	10
CEOisChairman	0.0142	0.0138	0.0143	0.0139	0.0155	0.0139	0.0143	0.0140	0.0128	0.0132
	(1.35)	(1.29)	(1.35)	(1.32)	(1.47)	(1.32)	(1.35)	(1.33)	(1.20)	(1.25)
Constant	−0.0774	−0.0432	−0.0523	−0.00889	−0.0379	−0.0383	−0.0371	−0.0398	−0.00711	−0.000992
	(−0.48)	(−0.27)	(−0.33)	(−0.06)	(−0.24)	(−0.24)	(−0.23)	(−0.26)	(−0.04)	(−0.01)
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Adj R^2	0.1086	0.1083	0.1085	0.1107	0.1111	0.1082	0.1083	0.1082	0.1111	0.1105
No. of obs	3294	3294	3294	3294	3294	3294	3294	3294	3294	3294

4.3 | Transition firms

So far, our analysis has studied the impact of the education of CEOs on the performance of firms in the UK. But what impact does a the higher education CEO have on a firm? For instance, if a firm had a CEO with a UG education, but then hire one who has a PhD, what impact does this higher education CEO have on firm performance? Therefore we re-estimate our analysis and include only those firms that experience a change in CEO to a different level or quality of education, as only those firms contribute to the identification.[8] Table 7 reports the regression results where we only include that experience moving from one CEO to another, with the new CEO having a certain level of education.[9] We find that, consistent with our previous findings, that CEOs with a PhD have a positive impact on firm performance. Specifically, firms that transition from a non-PhD CEO to a CEO with a PhD have significantly higher firm performance in the following year.

4.4 | How do CEOs improve performance?

So far, we have shown the potential value of CEOs with a PhD qualification and now we explore the potential channels through which CEOs are able to improve firm performance. This helps in identifying which CEO actions and decisions realize improvements in firm performance.

Firstly we examine the profit margin where we follow Fairfield and Yohn (2001) and define profit margin as the fraction of net income over sales. This measure indicates whether the increase in firm performance is due the firm's ability to control the costs incurred to generate revenues. We find in Table 8 that firms with a PhD CEO significant improve the profit margin of firms, given the interaction term (PhD Education # Profit Margin) is statistically significant and positive at 5% significance level. In addition, the F-test suggests the incremental impact of Profit Margin. We also examine the cash flow on total assets ratio, as this shows how a business uses its assets to generate cash flow, so one can determine its profitability and efficiency. We also find that PhD CEOs significantly improve the cash flow to total assets ratio indicating how PhD CEOs again improve the efficiency of the firm.[10]

4.5 | Is the effect persistent?

We find that CEOs with a PhD education significantly improve firm performance over the next year, but does this increase in performance continue over the next few years? To examine this, we re-estimate our panel regressions but instead of using the next year industry-adjusted ROA as the dependent variable, we use the average of industry-adjusted ROA over the next 3 years to

[8]To mitigate against the concern that CEO transitions are likely to be accompanied by changes in CEO characteristics other than education, we also include a number of noneducation related CEO characteristics as in the previous analysis.

[9]We have conducted difference-in-difference estimates for transition firms but the sample size is quite small for certain levels of educations. Hence we present the full regression results instead, however the difference-in-difference estimation results are available upon request from the corresponding author.

[10]As suggested by the reviewer, we also examine how PhD CEOs' improve performance over time. We find PhD CEOs improve industry-adjusted ROA in the sub-samples 1999-2007 and 2008-2010, which indicate PhD CEOs' superior cash flow management played important role in steering firms out of the global financial crisis.

TABLE 7 CEO education of transition firms only

All models include year fixed effects and firm fixed effects. All the independent variables are one order lagged. t-statistics, adjusted for heteroskedasticity and clustering at the firm level, are in parentheses. ***, ** and * indicate significance at the 1%, 5% and 10% respectively.

	1	2	3	4	5	6	7	8
UG level	0.0165							
	(0.54)							
PG level		0.00141						
		(0.16)						
MBA level			0.0131					
			(1.38)					
PhD level				0.0306*				
				(1.94)				
Top 100 UG					0.00323			
					(0.40)			
Top 100 PG						−0.00258		
						(−0.25)		
Top 100 MBA							−0.00107	
							(−0.09)	
Top 100 PhD								0.0420*
								(1.72)
Ln(CEO age)	−0.0270	0.128**	0.114*	0.0129	0.151***	0.129	0.175**	−0.0451
	(−0.26)	(2.45)	(1.99)	(0.16)	(3.09)	(1.61)	(2.66)	(−0.44)

(Continues)

TABLE 7 (Continued)

	1	2	3	4	5	6	7	8
Ln(CEO tenure)	0.00633	−0.00615	−0.00244	0.0000858	−0.0103**	−0.00467	−0.0184**	−0.00235
	(0.85)	(−1.08)	(−0.33)	(0.01)	(−2.02)	(−0.68)	(−2.26)	(−0.14)
Female_CEO	–	0.0351**	0.0297*	0.0337	0.00926	0.0229	0.00333	0.157***
	–	(2.52)	(1.96)	(1.40)	(0.76)	(1.44)	(0.16)	(2.96)
British_CEO	−0.0506	−0.0139	−0.00402	−0.00751	0.000797	−0.0219	−0.0226	−0.00137
	(−1.30)	(−0.86)	(−0.34)	(−0.42)	(0.05)	(−0.80)	(−1.29)	(−0.04)
Bonus fraction	0.0659	0.0402	0.0458	0.0644	0.0481	0.0638	−0.0250	0.0147
	(1.29)	(1.08)	(1.24)	(1.00)	(1.57)	(1.31)	(−0.40)	(0.14)
Equity fraction	0.0125	0.0365	0.0180	0.0544	0.0223	0.0499*	−0.0107	−0.00725
	(0.27)	(1.57)	(0.94)	(1.64)	(1.06)	(1.74)	(−0.36)	(−0.11)
Ln(CEO wealth)	−0.00255	−0.00237	−0.00399	−0.00628	0.00877*	−0.00456	0.00663	−0.00502
	(−0.19)	(−0.46)	(−0.71)	(−0.80)	(1.83)	(−0.72)	(1.07)	(−0.36)
Stock volatility	−0.0000257	−0.0000364	0.000126	−0.000339	0.000170	−0.0000165	0.000237	−0.000365
	(−0.49)	(−0.39)	(0.94)	(−1.15)	(1.37)	(−0.22)	(0.98)	(−1.42)
Leverage	−0.0305	−0.0886*	−0.0326	−0.0837	−0.0789*	−0.00759	−0.0755	−0.0946
	(−0.61)	(−1.91)	(−0.70)	(−1.64)	(−1.90)	(−0.14)	(−1.05)	(−1.21)
Ln(Market-to-book value)	0.0432**	0.0484***	0.0507***	0.0588***	0.0421***	0.0570***	0.0482***	0.0713**
	(2.70)	(4.18)	(4.02)	(2.91)	(4.23)	(4.20)	(3.12)	(2.61)
Ln(Firm size)	0.0369	−0.0190*	−0.0208	−0.00524	−0.0211**	−0.0258	−0.0335**	−0.00924
	(1.71)	(−1.74)	(−1.65)	(−0.25)	(−2.54)	(−1.56)	(−2.31)	(−0.40)

TABLE 7 (Continued)

	1	2	3	4	5	6	7	8
CEOisChairman	0.0310	0.0147	0.0462	−0.0198	0.0233	0.0339**	0.0560	−0.0387
	(1.01)	(1.09)	(1.53)	(−1.15)	(1.14)	(2.08)	(1.42)	(−1.15)
Constant	−0.382	−0.250	−0.171	0.0213	−0.370	−0.206	−0.272	0.286
	(−0.77)	(−0.89)	(−0.50)	(0.05)	(−1.46)	(−0.46)	(−0.76)	(0.50)
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Adj R2	0.2225	0.1132	0.1227	0.1554	0.1518	0.1019	0.1559	0.1451
No. of Obs	118	1,151	869	499	1,196	685	446	218
No. of CEO_Year obs with X degree for the regression	77	559	386	208	598	295	186	94
No. of CEOs transitions from none to certain education for this regression	5	40	36	13	49	20	16	7
No. of CEOs transitions from none to certain education throughout the sample	10	69	63	21	77	36	29	11
No. of CEOs transitions from certain education to none for this regression	5	50	27	19	45	33	17	8
No. of CEOs transitions from certain education to none throughout the sample	6	81	48	31	72	46	25	11

TABLE 8 CEO education and channels to improve firm performance

This table presents the channels that CEO education improves firm performance. Panel A focuses on profit margin, measured by the fraction of net income over sales while Panel B focuses on the ratio of net cash flow to total assets. All the independent variables are one order lagged. t-statistics, adjusted for heteroskedasticity and clustering at the firm level, are in parentheses. ***, ** and * indicate significance at the 1%, 5% and 10% respectively.

	1	2	3	4
Panel A: Profit Margin				
Profit Margin	0.00852***	0.00352	0.00385*	0.00865***
	(3.01)	(1.55)	(1.88)	(3.11)
PhD Education # Profit Margin	0.0179**			0.0185**
	(2.35)			(2.42)
PG Education # Profit Margin		−0.00154		−0.00194
		(−0.42)		(−0.54)
MBA Education # Profit Margin			−0.000902	−0.00176
			(−0.21)	(−0.43)
PhD Education	0.0112*			0.0123**
	(1.81)			(1.97)
PG Education		−0.00238		−0.00497
		(−0.55)		(−1.09)
MBA Education			0.00201	0.00398
			(0.42)	(0.82)
Controls	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes
Adj R^2	0.1154	0.1100	0.1098	0.1155
Observations	3294	3294	3294	3294
F-stat: incremental impact of Profit Margin				
PhD Education # (1 + Profit Margin)	12.90***			13.49***
PG Education # (1 + Profit Margin)		0.60		1.66
MBA Education # (1 + Profit Margin)			0.02	0.09
Panel B: CashFlow/L.TotalAssets				
Net Cash Flow/L.Average Total Assets	0.0670***	0.0434	0.0449	0.0378
	(3.49)	(0.92)	(0.39)	(0.31)
PhD Education # CashFlow/L.TotalAssets	0.1180*			0.1330
	(1.86)			(1.59)

TABLE 8 (Continued)

	1	2	3	4
PG Education # CashFlow/L.TotalAssets		0.0251		−0.0036
		(0.24)		(−0.04)
MBA Education # CashFlow/L.TotalAssets			0.0409	−0.1020
			(0.11)	(−0.24)
PhD Education	0.0148**			0.0155*
	(12.05)			(2.10)
PG Education		−0.0027		−0.0052
		(-0.57)		(−1.06)
MBA Education			−0.0015	0.0006
			(−0.27)	(0.10)
Controls	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes
Adj R^2	0.1207	0.1149	0.1147	0.1200
Observations	2729	2729	2729	2729
F-stat: incremental impact of CashFlow/L.TotalAssets				
PhD Education # (1 + CashFlow/L.TotalAssets)	4.73**			3.32*
PG Education # (1 + CashFlow/L.TotalAssets)		0.05		0.01
MBA Education # (1 + CashFlow/L.TotalAssets)			0.01	0.06

determine whether the increase in performance continued over the next 3 years.[11] We show in Table 9 that both PhD level dummy and top 100 PhD dummy variables significantly improve the moving average industry adjusted ROA over the next 3 years indicating that the effect of CEOs with a PhD education is persistent over the next 3 years.

4.6 | Alternative performance measures

So far in our analysis, we have used industry adjusted-ROA to determine the performance but there are other accounting-based measures we could utilize. Therefore we also include the net sales over lagged total asset as an alternative measure of the performance of a firm. we find the Table 10 that PhD education does improve firm performance, although the significance is somewhat reduced.

So far in the analysis, we have used accounting-based measures and we could have used market-based measures of firm performance. As García-Meca et al. (2015) notes, many studies have used both accounting and market-based measures of firm performance and found a significant relationship with one measure but no relationship with the other measure since

[11]The total number of observations in the regression now drop to 2327 given the nature of the specification.

TABLE 9 Long-term impact

This table presents the panel fixed effect regression where we examine the influence of a certain CEO education on the 3-year weighted industry adjusted ROA. All the independent variables are one order lagged. All models include year fixed effects and firm fixed effects. *t* Statistics, adjusted for heteroskedasticity and clustering at the firm level, are in parentheses. ***, ** and * indicate significance at the 1%, 5% and 10% respectively.

	1	2	3	4	5	6	7	8
UG level	0.0184							
	(0.85)							
PG level		0.00480						
		(0.56)						
MBA level			0.00618					
			(0.58)					
PhD level				0.0313**				
				(2.42)				
Top 100 UG					−0.00655			
					(−0.80)			
Top 100 PG						−0.0160		
						(−1.63)		
Top 100 MBA							−0.0109	
							(−0.71)	
Top 100 PhD								0.0427**
								(2.35)
Ln(CEO age)	0.0000821	−0.00183	0.000831	−0.0124	−0.00656	−0.00151	−0.00561	−0.00805
	(0.00)	(−0.06)	(0.03)	(−0.41)	(−0.20)	(−0.05)	(−0.17)	(−0.25)

TABLE 9 (Continued)

	1	2	3	4	5	6	7	8
Ln(CEO tenure)	0.000145	0.000103	0.000155	0.000336	0.000391	0.000206	0.000394	0.000416
	(0.05)	(0.04)	(0.05)	(0.12)	(0.14)	(0.07)	(0.14)	(0.14)
Female_CEO	0.0604***	0.0598**	0.0603***	0.0625***	0.0611***	0.0595**	0.0611***	0.0515***
	(2.59)	(2.57)	(2.59)	(2.68)	(2.66)	(2.55)	(2.60)	(3.29)
British_CEO	0.00142	0.00293	0.00259	0.00691	0.00330	−0.00282	−0.00159	0.000579
	(0.11)	(0.24)	(0.21)	(0.63)	(0.28)	(−0.22)	(−0.12)	(0.05)
Bonus fraction	−0.00852	−0.00814	−0.00831	−0.00806	−0.00850	−0.00764	−0.00798	−0.00744
	(−0.56)	(−0.53)	(−0.54)	(−0.53)	(−0.56)	(−0.50)	(−0.52)	(−0.49)
Equity fraction	−0.00510	−0.00508	−0.00511	−0.00583	−0.00507	−0.00499	−0.00494	−0.00527
	(−0.56)	(−0.56)	(−0.56)	(−0.65)	(−0.56)	(−0.55)	(−0.54)	(−0.59)
Ln(CEO wealth)	0.00346	0.00334	0.00346	0.00293	0.00327	0.00354	0.00330	0.00310
	(1.31)	(1.26)	(1.31)	(1.15)	(1.24)	(1.36)	(1.24)	(1.19)
Stock volatility	0.0000143	0.0000123	0.0000125	0.00000929	0.0000147	0.0000187	0.0000174	0.0000158
	(0.37)	(0.32)	(0.32)	(0.24)	(0.38)	(0.48)	(0.45)	(0.40)
Leverage	−0.0245	−0.0243	−0.0239	−0.0205	−0.0245	−0.0253	−0.0251	−0.0225
	(−1.37)	(−1.38)	(−1.35)	(−1.20)	(−1.36)	(−1.39)	(−1.41)	(−1.29)
Ln(Market-to-book value)	0.0238***	0.0239***	0.0236***	0.0241***	0.0241***	0.0236***	0.0242***	0.0240***
	(4.74)	(4.74)	(4.74)	(4.94)	(4.84)	(4.75)	(4.81)	(4.91)
Ln(Firm size)	−0.0212***	−0.0211***	−0.0211***	−0.0209***	−0.0208***	−0.0216***	−0.0208***	−0.0214***
	(−3.13)	(−3.14)	(−3.12)	(−3.12)	(−3.06)	(−3.15)	(−3.08)	(−3.16)

(Continues)

TABLE 9 (Continued)

	1	2	3	4	5	6	7	8
CEOisChairman	0.00260	0.00223	0.00275	0.00195	0.00208	0.00316	0.00216	0.000973
	(0.31)	(0.26)	(0.33)	(0.24)	(0.25)	(0.38)	(0.26)	(0.11)
Constant	0.263*	0.285*	0.275*	0.320**	0.303*	0.297*	0.303*	0.316**
	(1.66)	(1.80)	(1.74)	(2.06)	(1.91)	(1.89)	(1.86)	(1.99)
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Adj R^2	0.1443	0.1445	0.1446	0.1521	0.1449	0.1471	0.1449	0.1518
No. of Obs	2327	2327	2327	2327	2327	2327	2327	2327
No. of CEO_Year obs with X degree for the regression	2249	696	458	271	774	345	173	112

TABLE 10 Alternative performance measures

This table presents the panel fixed effect regression where we examine the influence of a certain CEO education on two alternative performance measures, namely net sales over total assets and market-to-book ratio. All the independent variables are one order lagged. All models include year fixed effects and firm fixed effects. t-statistics, adjusted for heteroskedasticity and clustering at the firm level, are in parentheses. ***, ** and * indicate significance at the 1%, 5% and 10% respectively.

	NetSales/L.TA	NetSales/L.TA	NetSales/L.TA	NetSales/L.TA	L.MTB	LnMTB	LnMTB	LnMTB
PhD Education	0.0199			0.0259*	−0.0214			−0.00465
	(1.47)			(1.94)	(−0.77)			(−0.18)
PG Education		−0.0236*		−0.0284**		−0.0446		−0.0486*
		(−1.67)		(−1.99)		(−1.62)		(−1.79)
MBA Education			0.0133	0.0181			0.1000***	0.102***
			(0.80)	(1.05)			(3.11)	(3.16)
Ln(CEO age)	−0.00140	0.0123	0.0340	0.00644	0.0179	−0.0150	0.112	0.107
	(−0.01)	(0.08)	(0.21)	(0.04)	(0.09)	(−0.08)	(0.61)	(0.58)
Ln(CEO tenure)	0.0111	0.0114	0.0101	0.0116	−0.0201	−0.0179	−0.0216	−0.0200
	(0.91)	(0.94)	(0.83)	(0.96)	(−1.02)	(−0.91)	(−1.14)	(−1.06)
Female_CEO	0.0259	0.0318	0.0315	0.0279	0.00737	0.00532	0.0116	0.0159
	(0.28)	(0.33)	(0.34)	(0.31)	(0.07)	(0.05)	(0.13)	(0.17)
British_CEO	0.0769*	0.0631	0.0801**	0.0796**	0.121*	0.110*	0.187***	0.169***
	(1.96)	(1.64)	(2.03)	(1.98)	(1.89)	(1.70)	(3.03)	(2.59)
Bonus fraction	0.159*	0.161*	0.159*	0.160*	0.523***	0.525***	0.515***	0.517***
	(1.81)	(1.84)	(1.82)	(1.84)	(5.72)	(5.76)	(5.65)	(5.71)
Equity fraction	0.0238	0.0284	0.0263	0.0270	0.236***	0.239***	0.235***	0.241***
	(0.60)	(0.71)	(0.66)	(0.68)	(4.20)	(4.23)	(4.22)	(4.32)

(Continues)

TABLE 10 (Continued)

	NetSales/L.TA	NetSales/L.TA	NetSales/L.TA	NetSales/L.TA	L.MTB	LnMTB	LnMTB	LnMTB
Ln(CEO wealth)	−0.00949	−0.00878	−0.00884	−0.00907	0.0962***	0.0959***	0.0943***	0.0944***
	(−0.55)	(−0.51)	(−0.51)	(−0.53)	(6.15)	(6.10)	(5.96)	(5.94)
Stock volatility	−0.0000285	−0.0000220	−0.0000298	−0.0000278	0.000434	0.000441	0.000409	0.000419
	(−0.22)	(−0.17)	(−0.23)	(−0.21)	(1.24)	(1.28)	(1.17)	(1.22)
Leverage	−0.338***	−0.340***	−0.339***	−0.334***	0.579***	0.581***	0.582***	0.580***
	(−3.40)	(−3.46)	(−3.42)	(−3.38)	(4.55)	(4.59)	(4.71)	(4.69)
Ln(Market-to-book value)	0.168***	0.166***	0.165***	0.164***	–	–	–	–
	(5.17)	(5.10)	(5.08)	(5.02)				
Ln(Firm size)	−0.219***	−0.220***	−0.219***	−0.221***	−0.223***	−0.226***	−0.223***	−0.225***
	(−6.67)	(−6.56)	(−6.72)	(−6.72)	(−6.66)	(−6.66)	(−6.82)	(−6.88)
CEOisChairman	0.0326	0.0379	0.0350	0.0396	0.0381	0.0453	0.0470	0.0564
	(0.77)	(0.89)	(0.81)	(0.93)	(0.71)	(0.84)	(0.88)	(1.05)
Constant	3.974***	3.941***	3.837***	3.965***	2.701***	2.859***	2.294***	2.347***
	(5.73)	(5.63)	(5.41)	(5.55)	(3.13)	(3.34)	(2.76)	(2.82)
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Adj R^2	0.1818	0.1821	0.1814	0.1830	0.2466	0.2483	0.2543	0.2565
Observations	3294	3294	3294	3294	3294	3294	3294	329

these variables use different types of numerators and denominators to calculate firm performance. Market-based measures have the advantage of incorporating the value of the company according to the market, however this then allows the possibility of market anomalies that may impede all available information being reflected in the stock price. Also market-based measures are backward looking as well as forward looking, thereby the anticipation of future price moves may already been reflected in the price and we may not fully measure the impact of a CEO on the performance of the firm in the previous year.

Nevertheless, we employ the market-to-book ratio (Chakravarty & Hegde, 2019). Table 10 reports our findings and shows that the PhD does not offer any explanatory power. This may be due to the forward looking component of these market-based measures or could be that hiring of CEO with a PhD had a shorter-term impact in the market price of the firm and this has been diluted over time. Further, the finding that the market does not price PhD CEOs supports the recent findings of He and Hirshleifer (2021) in that firms run by PhD CEOs are on average undervalued but generate superior long-run operating performance.[12]

5 | ROBUSTNESS

So far, the results have shown that CEOs with a PhD education significantly improve firm performance while other education levels offer very little explanatory power. In this section, we present some additional robustness checks to add confidence to our findings. First, instead of classifying education from top 100 institutions as higher quality, we now examine the top 50 institutions since these institutions are unlikely to fall in and out of the top 100. Second, we examine alternative rankings to ensure our results are not specific to the QS rankings. Third, we control for CEO networks. Fourth, we implement a fixed effects model to mitigate the potential endogeneity concern due to unobserved heterogeneity across firms and time-varying heterogeneity across industries. Finally, we re-estimate our analysis but we exclude financial and utility firms since they have different corporate structures. All tables in this robustness section are reported in Table F1 in a condensed manner to conserve space.

5.1 | Alternative quality ratings

So far, we have measured the quality of the education of CEOs through the QS rankings, where we have chosen the top 100 as a measure of quality. However it can be argued that this is quite arbitrary and may be too wide a measure for quality institutions as the top institutions in the world are at least in the top 50. Therefore we re-estimate our analysis but employ the QS top 50 as the cut-off point for quality of the education. We find that only 20.1%, 11.3% and 6.6% of our CEOs have a UG, PG and MBA education from top 50 institutions, while only 2.9% have a PhD from a top 50 institution. The factor analysis generates the same factors as early and Table C1 confirms our earlier findings that the PhD factor significantly improves firm performance.

[12]In a recent paper, Bennouri et al. (2018) show that female directorships increase accounting-based measures of firm performance but not market-based measures. They attribute this to the different attributes female's bring to the role and that the impact is not uniform across all measures of performance.

5.2 | Alternative university rankings

Our analysis so far has employed the well-respected QS rankings, however many other rankings are available. To ensure that our results are not specific to the ranking criteria of QS, we re-run our regressions with alternate measures of CEO educational attainment, namely the top 100 institutions according to the Times Higher Education World University rankings.[13] There are 28 universities in the Times Higher World university top 100 that are not in the QS top 100 rankings. Some exclusions from the times higher education top 100 compared that are in the QS top 100 are KAIST, Ecole Normale Superieure Paris, Osaka University, Durham University and Trinity College Dublin.[14]

Table E1 reports the factor analysis results and shows that the PhD factor is positive and statistically significant at the 10% level and that both the PG education factor and MBA education factor are insignificant. When we put all three factors together, we find that the PhD factor is positive and significant, confirming our earlier findings. Therefore our results are robust to an alternative University rankings.

5.3 | CEO networks

There is growing evidence documenting the importance of CEOs network, where better connected firms are more active bidders in takeovers (Renneboog & Zhao, 2014), better connected CEOs are more likely to move firms (Liu, 2014) and that highly networked CEOs conduct more M&A activities (El-Khatib et al., 2015). Therefore to ensure that our results are not due to the network of a CEO but rather their education, we re-estimate our baseline regression with the network size control variable from BoardEx. The results in Table F1 show that the network is consistently negative and insignificant, indicating that the network size is not a determining factor on firm performance, while our CEO education factor remains statistically significant. Therefore our results are robust to the network size of the CEO.[15]

5.4 | High-dimensional fixed effects

One potential weakness of our previous analysis is that we only control for observed firm characteristics. If the correlation between CEO education and firm performance is affected by unobservable firm characteristics that cannot be accounted for in our analysis, then any hidden bias due to latent variables may still remain after matching. Therefore we follow the recommendation of Gormley and Matsa (2014) and implement a fixed effects model to mitigate the potential endogeneity concern due to unobserved heterogeneity across firms and time-varying heterogeneity across industries. Specifically, we control for the firm and interacted industry-year fixed effects in our baseline regression.[16] Table F1 reports the findings and they are consistent with our previous results in that firms with a PhD CEO significantly outperform firms without a PhD CEO. Therefore our main results are robust after controlling for unobserved firm characteristics.

[13] See www.timeshighereducation.com/world-university-rankings/.

[14] The list of Universities in the THE top 100 rankings are in Table D1.

[15] We do not report the results to conserve space but are available upon request from the corresponding author.

[16] Similar to Li and Zeng (2019).

5.5 | Removal of financial and utility firms

It is common practice in the corporate finance literature to remove financial and utility companies from the sample as they have different corporate structures to other firms. Therefore we follow this lead and re-estimate our analysis and remove all financial and utility firms in the FTSE 350. In Table F1 we re-estimate our factor analysis and consistent with our previous results, the significant factors are quality PhD, quality PG and quality MBA education. These findings are similar to our previously findings in that a PhD education significantly improves firm performance while other factors have very little explanatory power.

5.6 | Industry-specific analysis

In Table A2, we show that there is quite a lot of variation across industry in terms of the number of CEOs that hold a PhD. This suggests that there may be some cross-industry variation in our results. Specifically, it could be the case that our results are driven by a small number of PhD CEOs in industries without many CEOs with such a high-level qualification.[17] To ensure this is not the case, we re-estimate our baseline analysis but include only the top three sectors in terms of the number of CEOs with PhDs, namely the Oil and Gas, Health care and Technology industries. Table F1 reports our findings which are qualitatively very similar in that a PhD education does improve firm performance and that CEOs with a top-100 PhD significantly improves firm performance.

5.7 | CEO turnover over 3 years

We further examine the robustness of our results by following the method of Huang and Kisgen (2013) and utilize our diff-in-diff framework to study how firms perform over a 3-year window surrounding CEO turnover.[18] This is an interesting aspect to study since the turnover of the CEO can be an exogenous event that effects the performance of a firm although his impact may not be immediate but take a few years to reflect in the performance of the firm. Our findings, reported in Table F1 are consistent with our previous in that a day from a CEO without a PhD to CEO with a PhD significantly improves firm performance over a 3-year period indicating that the effect of PhD CEOs is long lasting.

5.8 | Foreign educated CEOs

There is recent evidence that CEOs with foreign working experience demand a significantly higher compensation than those without such an experience (Conyon et al., 2018). This paper shows that pay premiums are attributable to the specialized foreign expertise and foreign networks of CEOs, which stem from foreign experience rather than broader general managerial skills. To ensure that our results are driven by this fact, we re-estimate the factor analysis but

[17]We thank the anonymous referee for suggesting this analysis.
[18]We thank the anonymous referee for suggesting this analysis.

include a dummy variable for foreign educated CEOs. Table F1 reports our findings and we show consistency with our baseline results in that PhD CEOs significantly improve firm performance.

6 | CONCLUSION

This study investigates the relationship between the education level and quality of a CEO and firm performance. To do this, we utilize a data set of the university degrees of CEOs from FTSE 350 firms from 1999 to 2017 and determine whether these education variables are determinants of firm performance.

We employ factor analysis to form education factors from different levels and different qualities of education received and we find that the factor that captures most of the covariance of the variables is a quality PhD education. Following from this, our robust set of results show that firms led by CEOs with a PhD education achieve higher firm performance that is statistically higher than firms headed by non-PhD CEOs. Specifically, our factor analysis shows that a one standard deviation increase in PhD education is associated with a 1.20% increase in industry-adjusted ROA. We also use dummy variable analysis and show that a CEO with a PhD significantly improves improve performance by 3.03%, while a CEO with a PhD degree from a top 100 university significantly improves firm performance by 4.65%, indicating the value-added of a CEO who attends a top 100 institution. We also show that this result is also present in transition firms, where firms that hire a CEO with a quality PhD improve performance by 4.20%. Moreover, we find that CEOs with better PhD education improve the performance of the firm through controlling costs and superior cash flow management. Our results are robust to alternative education ratings, alternative university rankings, CEO networks and the removal of financial and utility firms. Therefore our findings suggest that CEOs who have completed a research degree acquire skills and knowledge that enables them to perform better as a CEO.

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APPENDIX A: DISTRIBUTION OF CEO EDUCATION

TABLE A1 Distribution of CEO education by year

This table shows the distribution of CEO education attainment by year.

Year	UG	PG	MBA	PhD	QS Top100 UG	QS Top100 PG	QS Top100 MBA	QS Top100 PhD
1999	90.91%	26.26%	18.18%	14.14%	34.34%	10.10%	8.08%	3.03%
2000	92.54%	27.61%	14.93%	11.19%	28.36%	13.43%	5.97%	3.73%
2001	95.12%	28.66%	14.02%	11.59%	30.49%	14.63%	6.10%	4.27%
2002	95.53%	26.82%	13.41%	11.17%	30.17%	13.97%	5.03%	4.47%
2003	96.43%	28.06%	15.82%	10.71%	31.63%	13.78%	5.61%	5.10%
2004	97.74%	31.22%	15.38%	9.50%	33.48%	16.29%	5.88%	4.07%
2005	97.40%	31.60%	15.15%	10.82%	34.63%	17.75%	6.06%	4.33%
2006	97.11%	30.99%	16.53%	9.92%	33.47%	17.77%	6.61%	3.31%
2007	97.23%	32.02%	17.39%	9.09%	30.43%	17.79%	6.32%	3.16%
2008	96.73%	31.02%	17.14%	9.80%	32.65%	16.33%	6.12%	4.49%
2009	97.15%	30.89%	20.33%	9.35%	33.33%	15.85%	6.50%	4.47%
2010	97.10%	31.95%	21.99%	10.37%	33.61%	15.35%	8.30%	4.98%
2011	96.96%	29.13%	23.48%	10.00%	36.09%	13.04%	9.13%	4.35%
2012	97.29%	27.15%	25.34%	11.31%	34.84%	11.31%	9.05%	4.07%
2013	97.84%	25.00%	25.00%	9.48%	31.03%	10.34%	9.05%	3.88%
2014	97.83%	27.39%	25.22%	9.57%	30.00%	11.30%	9.13%	3.48%
2015	97.92%	30.00%	24.17%	12.08%	31.67%	11.67%	8.75%	4.17%
2016	98.20%	29.28%	25.23%	10.36%	30.18%	9.91%	9.01%	3.15%
2017	97.37%	34.21%	30.26%	14.47%	31.58%	13.16%	3.95%	6.58%

TABLE A2 Distribution of CEO education by industry

This table shows the distribution of CEO education attainment by industry

ICB industry	Frequency	% of CEOs with UG level	% of CEOs with PG level	% of CEOs with MBA level	% of CEOs with PhD level
Basic materials	255	100.00%	32.94%	19.61%	16.08%
Consumer goods	376	97.87%	24.73%	19.15%	7.98%
Consumer services	690	95.07%	16.38%	26.09%	2.75%
Financials	732	96.17%	30.46%	12.30%	3.83%
Health care	225	100.00%	57.33%	37.33%	37.78%
Industrials	999	100.00%	26.33%	20.02%	9.31%
Oil and gas	204	100.00%	50.00%	13.73%	29.41%
Technology	283	100.00%	27.21%	14.49%	14.49%
Telecommunications	59	100.00%	69.49%	30.51%	16.95%
Utilities	79	100.00%	32.91%	17.72%	2.53%
ICB Industry	**Frequency**	**% of CEOs with Top 100 UG**	**% of CEOs with Top 100 PG**	**% of CEOs with Top 100 MBA**	**% of CEOs with Top 100 PhD**
Basic materials	255	25.10%	7.45%	9.80%	4.31%
Consumer goods	376	28.19%	6.65%	10.64%	2.39%
Consumer services	690	33.04%	11.16%	10.58%	0.87%
Financials	732	32.38%	19.40%	2.19%	1.37%
Health care	225	32.89%	22.22%	13.33%	17.33%
Industrials	999	36.04%	13.61%	5.91%	3.00%
Oil and gas	204	39.22%	25.00%	4.41%	14.22%
Technology	283	22.26%	4.24%	4.95%	9.19%
Telecommunications	59	13.56%	32.20%	27.12%	0.00%
Utilities	79	51.90%	24.05%	1.27%	0.00%

APPENDIX B: CONTROL VARIABLES

TABLE B1 The main variables employed in this paper

This table reports the control variables in our study, how they are calculated and their respective sources.

Variable	Definition
CEO characteristics	
Female CEO	A dummy variable equal to one if the CEO is female (BoardEx: Gender)
Log of CEO age	The log of CEO age (BoardEx: Age (Years))
British CEO	A dummy variable equal to 1 if the CEO is British (BoardEx: Nationality Mix)
Log of CEO tenure	The log of the number of years the CEO has held the role at the firm (BoardEx: Time in Role (Years))
Level of Education	A dummy variable equal to 1 if the CEO has a UG, PG, MBA or PhD qualification (BoardEx: Qualification)
Quality of Education	A dummy variable equal to 1 if the CEO has a qualification from a top-100 QS institution (BoardEx: Institution)
CEO compensation	
Equity fraction	Equity as a proportion of total compensation (BoardEx: Salary/Total Compensation (GBP))
Bonus fraction	Bonus as a proportion of total compensation (Boardex: Bonus/Total Compensation (GBP))
CEO Wealth	The log of the CEO wealth (BoardEx: Total Wealth)
Firm characteristics	
Return on assets	Net income before preferred dividends divided by total assets (Datastream ((DPL#(X(WC01651)/X(02999),6)))
Stock volatility	The standard deviation of annualized monthly returns over the calendar year. (Datastream: Calculated by authors where the stock price is proxied by the Total Return Index (RI))
Leverage	Total debt divided by total assets (Datastream: Total Debt % Total Capital (Datastream: WC08221))
Market to book value	The log of market value of the ordinary equity divided by the balance sheet value of the ordinary equity in the firm (Datastream: Market to Book Value (MTBV))
Firm Size	Sum of total current assets, long-term receivables, investment in unconsolidated subsidiaries, other investments, net property plant and equipment and other (Datastream: WC02999)
Governance characteristics	
CEO is Chairman	An indicator variable that equals one if the CEO is also the chairman (BoardEx: Combined role of CEO and Chairman is present)

TABLE B2 Correlation matrix of the variables of interest in this paper

	Industry adjusted ROA	Ln (CEO age)	Ln(CEO tenure)	Female_ CEO	British_ CEO	Bonus fraction	Equity fraction	Ln (CEO wealth)	Stock vola-tility	Leverage	Ln (Market-to-book value)	Ln (Firm size)	CEOi-sChai-rman
Industry adjusted ROA	1												
Ln(CEO age)	−0.04	1											
Ln(CEO tenure)	0.04	0.26	1										
Female_CEO	0	−0.03	−0.04	1									
British_CEO	−0.02	−0.05	0.06	−0.04	1								
Bonus fraction	0.13	−0.01	0.03	0.02	0.01	1							
Equity fraction	0.04	−0.02	−0.07	0.04	−0.06	−0.34	1						
Ln(CEO wealth)	0.16	0.1	0.32	−0.03	−0.16	0.09	0.29	1					
Stock volatility	−0.12	−0.03	−0.03	−0.02	0.02	−0.08	−0.03	−0.12	1				
Leverage	−0.12	0.03	−0.04	−0.03	0.04	−0.08	0.12	0.01	0.02	1			
Ln(Market-to-book value)	0.23	−0.11	−0.02	0.02	−0.06	0.02	0.13	0.26	−0.05	0.14	1		
Ln(Firm size)	0.01	0.21	−0.01	0.05	−0.2	0.07	0.32	0.39	−0.12	0.38	−0.1	1	
CEOisChairman	0.02	−0.1	−0.09	−0.05	0.02	0.03	−0.1	−0.09	0.02	0	0.02	−0.11	1

APPENDIX C: QS TOP 50 RANKINGS

TABLE C1 CEO education and firm performance for QS top 50 rankings

This table reports the impact of our three-factor CEO index on firm performance. All models include year fixed effects and firm fixed effects. All the independent variables are one order lagged, t-statistics (adjusted for heteroskedasticity and clustering at the firm level), are in parentheses. ***, ** and * indicate significance at the 1%, 5% and 10% levels, respectively.

	1	2	3	4
PhD Education	0.0104*			0.0113*
	(1.75)			(1.89)
PG Education		−0.00130		−0.00367
		(−0.29)		(−0.79)
MBA Education			0.00124	0.00249
			(0.25)	(0.50)
Ln(CEO age)	0.0501	0.0593*	0.0611*	0.0514
	(1.54)	(1.83)	(1.86)	(1.59)
Ln(CEO tenure)	−0.00518	−0.00545	−0.00554	−0.00510
	(−1.43)	(−1.50)	(−1.53)	(−1.40)
Female_CEO	0.0538***	0.0564**	0.0564**	0.0539***
	(2.65)	(2.50)	(2.50)	(2.68)
British_CEO	−0.000840	−0.00466	−0.00354	0.0000769
	(−0.07)	(−0.41)	(−0.31)	(0.01)
Bonus fraction	0.0467**	0.0474**	0.0473**	0.0471**
	(2.39)	(2.42)	(2.42)	(2.41)
Equity fraction	0.0168	0.0181	0.0180	0.0172
	(1.40)	(1.52)	(1.50)	(1.44)
Ln(CEO wealth)	0.00401	0.00440	0.00441	0.00399
	(1.06)	(1.17)	(1.17)	(1.06)
Stock volatility	0.0000526	0.0000541	0.0000537	0.0000526
	(0.91)	(0.93)	(0.93)	(0.91)
Leverage	−0.0424*	−0.0432*	−0.0432*	−0.0418*
	(−1.74)	(−1.78)	(−1.77)	(−1.72)
Ln(Market-to-book value)	0.0340***	0.0335***	0.0334***	0.0336***
	(4.19)	(4.12)	(4.08)	(4.13)

(Continues)

TABLE C1 (Continued)

	1	2	3	4
Ln(Firm size)	−0.0169***	−0.0171***	−0.0171***	−0.0171***
	(−2.67)	(−2.70)	(−2.68)	(−2.69)
CEOisChairman	0.0134	0.0142	0.0141	0.0142
	(1.26)	(1.34)	(1.34)	(1.35)
Constant	−0.00820	−0.0407	−0.0481	−0.0116
	(−0.05)	(−0.26)	(−0.30)	(−0.07)
Year FE	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes
$AdjR^2$	0.1103	0.1083	0.1082	0.1101
Observations	3294	3294	3294	3294

APPENDIX D: THE TIMES HIGHER UNIVERSITY RANKINGS

TABLE D1 List of the top 100 universities in the Times Higher Education World Rankings

This table reports the Times Higher Education World Rankings top 100 universities, along with the country they are located.

Ranking	Institute	Country	Ranking	Institute	Country
1	University of Oxford	UK	51	Nanyang Technological University (NTU)	Singapore
2	University of Cambridge	UK	52	University of California, Santa Barbara	USA
3	Stanford University	USA	53	Brown University	USA
4	Massachuetts Institute of Technology (MIT)	USA	54	Washington University in St. Louis	USA
5	California Institute of Technology (Caltech)	USA	55	Chinese University of Hong Kond (CUHK)	Hong Kong
6	Harvard University	USA	56	University of North Carolina, Chapel Hill	USA
7	Princeton University	USA	57	University of Manchester	UK
8	Yale University	USA	58	Delft University of Technology	The Netherlands
9	Imperial College London	UK	59	University of California, Davis	USA
10	University of Chicago	USA	60	University of Sydney	Australia
11	ETH Zurich - Swiss Federal Institute of Technology	Switzerland	61	Wageningen University & Research	The Netherlands
12	John Hopkins University	USA	62	University of Amsterdam	The Netherlands
13	University of Pennsylvania	USA	63	Seoul National University	South Korea
14	University College London (UCL)	UK	64	Purdue University	USA
15	University of California, Berkeley (UCB)	USA	65	Kyoto University	Japan
16	Columbia University	USA	66	University of Southern California	USA

(Continues)

TABLE D1 (Continued)

Ranking	Institute	Country	Ranking	Institute	Country
17	University of California, Los Angeles (UCLA)	USA	67	Humboldt University of Berlin	Germany
18	Duke University	USA	68	Leiden University	The Netherlands
19	Cornell University	USA	69	University of Queensland	Australia
20	University of Michigan	USA	70	Erasmus University Rotterdam	The Netherlands
21	University of Toronto	Canada	71=	University of Minnesota Twin Cities	USA
22	Tsinghua University	China	71=	The Ohio State University	USA
23	National University of Singapore (NUS)	Singapore	73=	Sorbonne University	France
24	Carnegie Mellon University	USA	73=	Boston University	USA
25	Northwestern University	USA	75	Utrecht University	The Netherlands
26	London School of Economics and Political Science (LSE)	UK	76=	University of Freiburg	Germany
27	New York University (NYU)	USA	76=	McMaster University	Canada
28	University of Washington	USA	78=	University of Bristol	UK
29	University of Edinburgh	UK	78=	University of Groningen	The Netherlands
30	University of California, San Diego (UCSD)	USA	80	University of Warwick	UK
31	Peking University	China	81	Pennsylvania State University	USA
32	LMU Munich	Germany	82=	University of Maryland	USA
33	University of Melbourne	Australia	82=	Sungkyunkwan University (SKKU)	South Korea
34	Georgia Institute of Technology	USA	84=	Emory University	USA
35	Ecole Polytechnique Federale de Lausanne (EPFL)	France	84=	Monash University	Australia
36	The University of Hong Kong	Hong Kong	86	Rice University	USA
37	University of British Columbia	Canada	87	RWTH Aachen University	Germany

TABLE D1 (Continued)

Ranking	Institute	Country	Ranking	Institute	Country
38	King's College London	UK	88	Uppsala University	Sweden
39	University of Texas	USA	89	University of Tubingen	Germany
40	Karolinska Institute	Sweden	90=	Cahrtie - Universitatsmedizin Berlin	Germany
41	Paris Sciences et Lettres - PSL	France	90=	University of Montreal	Canada
42	University of Tokyo	Japan	92	University of Zurich	Switzerland
43	University of Wisconsin-Madison	USA	93=	University of Glasgow	UK
44	McGill University	Canada	93=	Michigan State University	USA
45	Technical University of Munich	Germany	95=	University of Science and Technology China	China
46	The Hong Kong University of Science and Technology	Hong Kong	95=	University of California, Irvine	USA
47	Heidelberg University	Germany	98=	University of New South Wales (UNSW)	Australia
48	KU Leuven	Belgium	98=	Lund University	Sweden
49	The Australia National University (ANU)	Australia	98=	Dartmouth College	USA
50	University of Illinois at Urbana-Champaign	USA	100	University of Helsinki	Finland

APPENDIX E: THE TIMES HIGHER EDUCATION RANKINGS RESULTS

TABLE E1 CEO education and firm performance employing the times higher education world rankings

This table reports the impact of our three-factor CEO education index on firm performance. All models include year fixed effects and firm fixed effects. All the independent variables are one order lagged, t-statistics (adjusted for heteroskedasticity and clustering at the firm level), are in parentheses. ***, ** and * indicate significance at the 1%, 5% and 10% respectively.

	1	2	3	4
PhD Education	0.0102*			0.0108*
	(1.77)			(1.89)
PG Education		−0.000986		−0.00302
		(−0.23)		(−0.69)
MBA Education			0.00137	0.00226
			(0.28)	(0.46)
Ln(CEO age)	0.0500	0.0595*	0.0612*	0.0517
	(1.54)	(1.83)	(1.87)	(1.60)
Ln(CEO tenure)	−0.00523	−0.00547	−0.00554	−0.00518
	(−1.44)	(−1.50)	(−1.53)	(−1.42)
Female_CEO	0.0539***	0.0564**	0.0565**	0.0542***
	(2.64)	(2.50)	(2.50)	(2.68)
British_CEO	−0.00160	−0.00465	−0.00343	−0.000941
	(−0.14)	(−0.41)	(−0.29)	(−0.08)
Bonus fraction	0.0465**	0.0474**	0.0473**	0.0468**
	(2.38)	(2.42)	(2.42)	(2.40)
Equity fraction	0.0169	0.0181	0.0180	0.0173
	(1.41)	(1.51)	(1.50)	(1.45)
Ln(CEO wealth)	0.00410	0.00441	0.00441	0.00411
	(1.09)	(1.17)	(1.17)	(1.09)
Stock volatility	0.0000528	0.0000541	0.0000536	0.0000530
	(0.92)	(0.93)	(0.93)	(0.92)
Leverage	−0.0417*	−0.0433*	−0.0432*	−0.0412*
	(−1.72)	(−1.78)	(−1.77)	(−1.70)
Ln(Market-to-book value)	0.0339***	0.0335***	0.0334***	0.0334***
	(4.18)	(4.12)	(4.08)	(4.12)

TABLE E1 (Continued)

	1	2	3	4
Ln(Firm size)	−0.0169***	−0.0171***	−0.0171***	−0.0171***
	(−2.68)	(−2.70)	(−2.68)	(−2.70)
CEOisChairman	0.0136	0.0142	0.0142	0.0143
	(1.28)	(1.34)	(1.34)	(1.36)
Constant	−0.00751	−0.0415	−0.0487	−0.0125
	(−0.05)	(−0.26)	(−0.31)	(−0.08)
Year FE	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes
Adj R^2	0.1103	0.1082	0.1083	0.1100
Observations	3294	3294	3294	3294

APPENDIX F: ROBUSTNESS RESULTS

TABLE F1 Robustness results

This table provides the results of our robustness section. All the independent variables are one order lagged, *t* statistics (adjusted for heteroskedasticity and clustering at the firm level) are in parentheses. ***, ** and * indicate significance at the 1%, 5% and 10% respectively.

	Inclusion of CEO network				**High-dimensional fixed effects**				**Removal of financial and utility firms**			
PhD Education	0.0129**			0.0142**	0.0109*			0.0121**	0.0160*			0.0160*
	(2.08)			(2.32)	(2.01)			(2.26)	(1.79)			(1.80)
PG Education		−0.0029		−0.0048		−0.0032		−0.0052		0.0012		−0.0012
		(−0.66)		(−1.08)		(−0.82)		(−1.30)		(0.15)		(−0.17)
MBA Education			0.0037	0.0058			0.0025	0.0044			−0.0040	−0.0023
			(0.82)	(1.33)			(0.57)	(1.03)			(−0.46)	(−0.27)
Network Size	−0.0028	−0.0009	−0.0012	−0.0030								
	(−0.83)	(−0.28)	(−0.37)	(−0.88)								
Control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	No	No	No	No	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year # Industry FE	No	No	No	No	Yes	Yes	Yes	Yes	No	No	No	No
Adj R^2	0.1158	0.1128	0.1128	0.1162	0.6259	0.6242	0.6241	0.6262	0.1216	0.1193	0.1194	0.1209
Observations	3212	3212	3212	3212	3261	3261	3261	3261	2602	2602	2602	2602

	Oil and gas, health care and technology sectors only				CEO turnover over 3 years				Foreign educated CEOs			
PhD Education	0.0357**			0.0324**	0.0126***			0.0135***	0.0120**			0.0130**
	(2.09)			(1.97)	(2.74)			(2.92)	(2.06)			(2.25)
PG Education		0.0135		0.0092		−0.0044		−0.0064		−0.0028		−0.0047
		(0.83)		(0.56)		(−1.02)		(−1.45)		(−0.64)		(−1.07)
MBA Education			0.0207	0.0063			−0.0011	0.0009			0.0018	0.0035
			(1.05)	(0.30)			(−0.19)	(0.15)			(0.37)	(0.74)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year # Industry FE	No	No	No	No	No	No	No	No	No	No	No	No
Adj R^2	0.1627	0.1486	0.1500	0.1611	0.1545	0.1453	0.1442	0.1563	0.1113	0.1084	0.1083	0.1114
Observations	596	596	596	596	2327	2327	2327	2327	3294	3294	3294	3294