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Abstract

Purpose: We aim to provide early evidence on corporate transformation towards Industry 4.0 in the UK, particularly by examining the effect of corporate governance on the narrative reporting of corporate transformation towards Industry 4.0 (CTTI4).

Methodology: We analyse all UK FTSE All-share non-financial firms that have published their annual reports for the period of 2013- 2018. We use computerised textual analysis to measure the level of corporate reporting on Industry 4.0 for 1001 firm-year observations. We used different regression models to test our research hypotheses.

Findings: Our findings contribute to the growing literature on business model transformation in UK companies towards the I4.0 strategy. The findings show that the level of reporting on CTTI4 is improving over the sample period and varies between industries. We also find that better governance quality enhances the level of reporting on CTTI4.

Implications: The findings of this study inform decision-makers and regulators about factors driving UK companies to report information about their actionable strategies to direct I4.0 endeavours.

Originality: Our paper makes an important and novel contribution to corporate disclosure literature. So far as we know, it is the only paper to examine the impact of corporate governance on corporate narrative reporting on industry 4.0 technologies. Moreover, it is the first paper to show that the quality of corporate governance adds value to this strategic type of corporate disclosure.

Keywords: Industry 4.0, business model transformation, governance quality, narrative reporting, content analysis, UK.

Introduction

Manufacturing in 2050 will look very different from today. Successful companies will be capable of rapidly adapting their physical and intellectual infrastructures to exploit changes in technology as manufacturing becomes faster, more responsive to changing global markets and closer to customers (Foresight, 2013; Alkaraan et al., 2022). Successful companies are led by effective boards, whose roles are to promote the long-term sustainable success of the company, generate value for shareholders and contribute to wider society. The revised UK corporate governance code (2018) has reinforced and expanded on the long-standing requirements of the UK Companies Act for directors to remain mindful of their duties to consider the interests of key stakeholders. The objective is to create a shift in focus from

meeting short-term financial goals towards a long-term, future-oriented, business-model and value-based approach to running a company (Alkaraan, 2022).

I4.0 strategy is concerned with the fourth industrial revolution in manufacturing, in which technological trends created new business models. Since the I4.0's introduction at the Hannover Fair in Germany in 2011. I4.0 has enjoyed a meteoric rise in popularity and is currently high on the agenda of companies and governments and researchers (Madsen, 2019). I4.0 strategy enables autonomous decision-making processes, monitors assets and processes in real-time, and enables equally real-time connected value creation networks through the early involvement of stakeholders. Companies Business Model Transformation practices towards I4.0 strategy is based on strategic choices in boardrooms. Such strategic transition required investment in I4.0 strategy components such as industrial internet of things, smart manufacturing, digitalization, cloud computing, artificial intelligence, big data, simulation, augmented reality, horizontal and vertical systems integration, autonomous robots, cyber-physical systems and cybersecurity (Alcácer and Cruz-Machado, 2019; Alkaraan, 2021).

In 2013, a long-term action plan for the manufacturing industry in the UK called the 'Future of Manufacturing' was implemented (Foresight, 2013). In its various guises the UK manufacturing industry employs almost three million people, contributes approximately half of UK exports. While there is much evidence that clearly shows that the concept of I4.0 has had a wide-ranging impact at the discursive level, the currently available research is less clear about what impact the concept has had so far on industries (Madsen, 2019).

The conventional manufacturing business model is changing, and new models are emerging. I4.0 mechanisms associate with efficiency, cost-cutting and profit maximisations. Yet, little conceptual or empirical research examines the reporting of corporate transformation towards Industry 4.0 (CTTI4). Rogers (2016, p.308) argues that "digital transformation is fundamentally not about technology, but about strategy," meaning that senior leadership teams must find ways to capitalize on new and unexpected business model innovations that optimize customer needs and experiences.

Further, the determinants of non-financial reporting have become an established part of mainstream accounting research and attracted major interest in accounting journals over the last decade (for example, Skoiloudis, et al, 2014; Elshandidy et al, 2013 and Moumen et al, 2020; Al Lawati and Hussainey, 2020 and Karim et al., 2021). In addition, corporate governance has attracted major interest in disclosure studies since a remarkable paper by Eng and Mak (2003). The reason behind the increased attention to governance-disclosure areas is that this research carries implications for policy-makers, so this can offer guidance on

encouraging companies to improve their disclosure. Further, specific corporate governance mechanisms may lead to particular disclosure on CTTI4 because strong corporate governance can affect decision-making on the company policies related to the disclosure on CTTI4.

This study responds to the above calls, we examine whether corporate governance affects corporate transformation towards Industry 4.0 from a disclosure perspective. We devise four proxies to examine the narrative disclosure related to CBMT towards I4.0 strategy. We examine the CBMT trends towards I4.0 strategy disclosure through the analysis of corporate narrative reports for the period (2013-2018) for a number of FTSE All share non-financial companies.

In contrast to majority of mainstream research on I4.0, findings of this study offer a better understanding of the disclosure of CBMT practices towards I4.0 strategy and contribute to the growing literature on I4.0 within the UK context. Our analysis provides new empirical evidence that the quality of corporate governance improves the disclosure levels of CTTI4. This study contributes to the narrative disclosure literature through the devised analytical framework and four proxies towards a unified disclosure index regarding narrative disclosure measurements of CTTI4.

Section two outlines the I4.0 strategy literature and highlights the rationale underlying of the study. Section three outlines the research methodology employed for this study. Section four presents the findings of this study and is followed by conclusions in section five.

2. Literature review: I4.0- strategic organisational perspective

I4.0 can be viewed as a combination of managerial and technological mechanisms (McKinsey, Boston Consulting Group). It is an umbrella that provides prescriptions about how production processes can be controlled using new technological innovations to improve areas of performance such as flexibility, productivity and quality (Hofmann and Rüsch, 2017; Sarbu, 2021). I4.0 can be defined as cyber-physical systems production, based on heterogeneous data and knowledge integration, and as interoperable manufacturing process, integrated, adapted, optimized, service-oriented which is correlated with algorithms, big data and high technologies such as the internet of things, industrial automation, cloud computing, 3D printing, robotics and cybersecurity. 3D printing makes the fabrication of components much more flexible, cost-effective, distributed, and on-demand, while augmented reality helps to speed up the production chain and has a significant impact on maintenance costs (Leyh et al, 2017).

I4.0 strategy is not only about creating a technology roadmap, but also a strategic investment roadmap for the long-term. Thus, CTTI4 processes can be viewed as strategic investment decision- making practices, reflecting the art and science of steering and controlling organisational resources to achieve the desired strategy. Strategic investment projects are extensive, multifaceted, and competitively oriented, involve high levels of risk, produce intangible outcomes and have a significant long-term impact on corporate performance. Typical examples include company acquisitions and mergers, the introduction of major new product lines, the installation of new manufacturing processes, the introduction of advanced manufacturing and business technologies and substantial shifts in production capability (see Alkaraan and Northcott, 2006; Northcott and Alkaraan, 2007; Alkaraan and Northcott, 2007; Alkaraan and Northcott, 2013; Adel and Alkaraan, 2019). Successful CTTI4 lead to increase profit, decrease costs, enhance customer experience, optimisation, customization and innovation. Successful strategic investment decision-making processes require reliable, accessible, accurate, consistent, timely and contextual information (Alkaraan, 2020).

Recent studies have examined what causes technological changes and how companies respond to technological change (see Adner and Kapoor, 2016; Aggarwal, Posen, Workiewicz, 2016; Triulzi, Alstott, and Magee, 2018). Singh and Hess (2017, p. 124) suggest the term "transformation" rather than "change" emphasizes that an organization's digital transformation goes far beyond functional thinking and holistically considers the "comprehensiveness of actions" that must be taken to exploit the opportunities or avoid the threats that stem from digital technologies. Through CTTI4 processes, it becomes possible to gather and analyze data across machines, enabling faster, more flexible, and more efficient processes to produce higher-quality goods at reduced costs. This will increase productivity, shift economics, foster industrial growth, and the competitiveness of companies and countries. However, organisations differ greatly regarding the adoption of I4.0 mechanisms due to lack a detailed understanding of the I4.0 concept as well as mangers attributes (Frank et al., 2019; Sony and Naik, 2019; Hamada 2019).

Based on a thematic analysis of I4.0 literature, Sony and Naik (2019) argue that most organisations lack a detailed understanding of the I4.0 concept. Further, there are still attitudinal and decision-making issues which makes some managers less inclined to adopt I4.0 (Hamada 2019). Frank, Dalenogare, and Ayala (2019) shows that organisations differ significantly in terms of what types and the number of technologies they adopt and how advanced their level of I4.0 implementation is. Companies are now facing increased pressure from their national governments (e.g. UK, USA, Germany) to take part in the transition. Thus,

it is important to understand boardrooms practices in UK companies regarding this strategic domain.

In contrast to majority of mainstream research on I4.0, this study offers a better understanding of the drivers of the disclosure of CTTI4 practices. It contributes to the growing literature on I4.0 within the UK context.

The research question underpinning this study is: *To what extent does the quality of corporate governance affect the levels of narrative reporting related to corporate transformation towards Industry 4.0.*

Narrative disclosure has become longer and more sophisticated over the recent decade. The growing importance of narrative disclosures in corporate documents allows companies to overcome information asymmetries by presenting more detailed information and explanation, thereby increasing their strategic choices usefulness.

Previous reporting literature has focused on the relationship between corporate governance mechanisms and risk disclosure (Allini et al., 2016; Salem et al. 2019) or governance mechanisms and forward-looking disclosures (Wang and Hussainey, 2013), corporate environmental reasonability (CER) engagement (Li et al., 2020; Chen et al., 2021; Albitar et al., 2021a), Carbon reporting (Karim et al 2021) and Covid related disclosure (Elmarzouky et al., 2021; Albitar et al 2021b). However, to the best of our knowledge, this is the first study exploring governance quality's effect on CTTI4 disclosure.

The predominant perspective on impression management in a corporate reporting context is informed by economics-based theories, particularly agency theory (Merkl-Davies and Brennan 2007). Grounded on the contribution related to the relationship between board characteristics and disclosure, this study's conceptual framework is based on agency theory. Disclosure represents an appropriate approach that could mitigate agency problems by reducing information asymmetry through balancing the interest of managers and shareholders and reducing agency cost. Accordingly, companies reporting on strategic choices, such as CTTI4, are taken on the basis of cost-benefit analysis. Prior literature provides evidence gender diversity (Allini et al, 2016), board size (Elshandidy et al, 2013) and board independence (Elshandidy et al, 2013) affect levels of non-financial disclosure. We test if these governance mechanisms affect CTTI4 reporting. We also test to see if the overall quality of corporate governance as a measurement of company's system and process which ensure that board members act into best interest of long-term shareholders has an impact on CTTI4 reporting. This reflects company's capacity through its use of best management practice. As the literature

on the impact of corporate governance mechanisms on CTTI4 reporting does not exist, to the best of our knowledge, we formulate the following non-directional hypotheses:

H1: Board size affects corporate transformation towards Industry 4.0 from reporting perspective.

H2: Board independence affects corporate transformation towards Industry 4.0 from reporting perspective.

H3: Board's gender diversity affects corporate transformation towards Industry 4.0 from reporting perspective.

H4: Corporate governance quality affects corporate transformation towards Industry 4.0 from reporting perspective.

3. Research method

3.1 Sample and data collection

The initial sample of this study includes all UK FTSE All-share non-financial firms that have published their annual reports for the period of 2013- 2018 at a total of 1001 firm-year observations. We exclude financial firms due to the differences in the disclosure regulations. We exclude firms that are missing the necessary data for the variables used in our analysis. The use of the narrative section of the annual reports has been a trend in the past few years and has been used in several studies (Fisher et al., 2019; Albitar et al., 2021a; Karim et al., 2021). We use computerised textual analysis to score the total disclosure on CTTI4 reporting as well as to measure the sub categories, corporate business model transformation reporting (CBMT); I4.0 components; benefits of CTTI4 reporting; and challenges of CTTI4 reporting. Other data has been collected from the Eikon database.

3.2 Selection of disclosure items

Researchers used different proxies for disclosure quality (e.g. self-constructed measures, subjective measures), employing techniques in natural language processing from fields like computer science, linguistics and artificial intelligence to construct their disclosure scores. Following Alkaraan et al., 2022, the selection of disclosure topics is carried out in three stages. *First*, we create I4.0 strategy components through a comprehensive review of I4.0 strategy frameworks adopted by top professional organisations: Boston Consulting Group; McKinsey & Company; Deloitte; KPMG; i-SCOOP Organisation. This process produces a preliminary list of I4.0 strategy components keywords. Findings of this review reveal inconsistencies regarding I4.0 terminologies underpinning each framework proposed by these professional organisations as shown in Table 1.

Table 1: I4.0 terminologies proposed professional organisations

Boston Consulting Group (BCG)	Big data and analytics, artificial intelligence (AI), simulation, *robotic process automation,* advanced robotics, additive manufacturing, augmented reality, horizontal/vertical integration, 3D printing, the industrial IoT, cloud, cybersecurity. Security is also an inherent part of the I4.0 strategy and vision.
McKinsey & Company (2015)	Augmented reality, human-robot collaboration, remote monitoring and control, digital performance management, 3D printing, real time supply-chain optimisation, advanced process control, digital quality management, data-driven demand prediction, data-driven design to value, simulation, predictive maintenance, smart energy consumption, remote maintenance, virtually guided self-services, remote monitoring and control, real-time yield optimisation.
Deloitte (2020)	Internet of things (IoT), artificial intelligence (AI), cloud infrastructure, big data analysis, nano-technology, advanced robotics, sensors, blockchain, 3D printing, augmented reality, quantum computing, edge computing.
KPMG (2017)	Big data, cloud, cyber security, additive manufacturing, robotics, machine to machine comm, internet of things (IoT), augmented decision support, digital twin, demand driven supply chain.
i-SCOOP Organisation	I4.0 strategy components include; digital transformation; digital transformation strategy; industrial IoT; internet of things (IoT); big data; edge computing; cloud computing; IoT platforms; cybersecurity; additive manufacturing; artificial intelligence; digitization; smart factory.

Second, we add synonyms and amend the preliminary I4.0 strategy index: In this sage, synonyms have been identified and added to the preliminary index. This stage resulted in another version of the preliminary index (see Appendix 1) that can be classified into four proxies: CBMT mechanisms, I4.0 components, benefits and challenges.

Third, we apply computerised content analysis to measure CTTI4 and score the annual reports. Using content analysis is an appropriate method of measuring levels of narrative disclosure. These processes applied by many studies (e.g. Hussainey et al, 2003; Hassanein and Hussainey, 2015 and Albitar et al., 2021a; Karim et al., 2021; Alkaraan et al., 2022).

3.3 Variables Measurement

Company disclosure on transformation towards Industry 4.0 (Tscore)

We use the textual analysis method by using a computerised software to develop a measurement based on conducted wordlist (see Appendix 1) to measure the level of CTTI4 reporting in the narrative sections of the annual reports.

Research model

We apply OLS with random effect, 2SLS models to investigate the relationship between corporate governance and CCTI4 reporting in the annual reports. We have used the Hausman test and we find that the P-value was insignificant which suggested us to use the random effects instead of the fixed effects. The model is as follows:

Tscore = $\beta 0 + \beta 1$ BS+ $\beta 2$ Ind+$\beta 3$ GD+ $\beta 4$ ROA + $\beta 5$ LEV + $\beta 6$ FA + $\beta 7$ FS + Industry Fixed

Effects+ Year Fixed Effects +ε   (Equation.1)

where:

Tscore: The authors' self-constructed CTTI4 reporting index (see appendix 1).

Board Size (BS): The number of directors on the firm's board is used to measure board size (Allini et al, 2016; Albitar et al., 2020).

Independent directors (Ind): The percentage of independent non-executive directors (Allini et al, 2016).

Gender diversity (GD): The percentage of women on the board of directors has been used as a measurement for women on the board (Allini et al, 2016).

Control variables: Return on assets (ROA), Leverage (LEV), firm age (FA), firm size (FS) are used as control variables following non-financial disclosure studies (Allini et al, 2016). Appendix 2 shows the definitions of our variables.

4. Empirical results

4.1 Descriptive Statistics

Table 2 shows the mean total score for CTTI4 reporting over time and across industries. Overall, UK non-financial companies are aware of the value that I4.0 strategy could deliver to their long-term business performance. The total score for CTTI4 disclosure varies across industries. Some industries have been more willing to provide information about I4.0 strategy while others show a less response. We found that industries such as Health Care, and information technology are likely to provide more disclosure about transformation towards I4.0 strategy in the annual report. This is evident that the Health Care and information technology sectors have taken the initiative and advantage towards I4.0 strategy. Table 2 also shows that disclosure level of the transformation towards I4.0 strategy is increasing over time and that disclosure scores are increased approximately by twofold in 2018 compared to 2013 regarding CBMT mechanisms, I4.0 strategy components including benefits and challenges associated with this strategic transition which is a significant signalling that UK companies are entering a dynamic new phase since 2013 which accelerated over time 2013-2018. Table 2 also reveals

that UK companies are aware of the value that I4.0 strategy could deliver to their long-term business performance.

Total 2: Tscore by Industry Year

Industry	Year						
	2013	2014	2015	2016	2017	2018	Total
Communication Services	158.182	137.333	147.333	159.5	174.429	183.643	161.065
Consumer Discretionary	79.343	87.333	92.62	111.407	123.4	152.352	110.925
Consumer Staples	131.333	136.667	170.789	169.778	192	229.471	173.495
Energy	112.111	120	176	176.8	159.667	161.727	151.446
Health Care	181.778	206.636	210.167	215	244.071	296.538	229.139
Industrials	117.931	126.371	144.969	152.522	170.456	214.5	155.302
Information Technology	133.727	129.769	167.714	193.688	231.75	206.941	181.966
Materials	121.455	158.522	172.923	183.2	179.793	220.593	174.763
Real Estate	73.692	74.303	74.2	84.316	101.95	111.977	88.66
Utilities	126.2	136	108.833	157.333	157.667	233.2	152.121
Total	1235.752	1312.935	1465.549	1603.544	1735.182	2010.942	1578.883

Table 3 presents descriptive statistics for the variable included in the research model, including the total disclosure on CTTI4 reporting and measures the subcategories, CBMT mechanisms, I4.0 components, benefits, and challenges. As it can be seen the mean of the total disclosure on CTTI4 reporting is 145.916 with a minimum of 0 and a maximum of 635, which reflect that some companies do not provide any information about CBMT towards I4.0 strategy. We can see that the mean governance pillar score is 54.5% and varies from 3.177% to 95.9%.

Table 3: Descriptive Statistics

Variable	Mean	Std. Dev.	Min	Max
Tscore	145.916	95.557	0	635
Benscore	75.607	56.749	0	537
Chalscore	14.272	11.021	0	83
I4score	27.876	32.99	0	224
Transformscore	28.16	24.711	0	261
gscore	54.525	21.491	3.177	95.96
BS	8.646	2.129	3	16
Ind	57.081	13.892	18.18	85.7
GD	19.99	10.71	0	60
ROA	6.311	5.021	-1.606	15.071
LEV	68.115	64.751	.076	207.071
FA	65.47	54.054	4	217
FS	20.467	1.598	14.681	26.410

Table 4 shows the correlation matrix for the dependent and independent variables. It shows the correlation between the total disclosure on CTTI4 reporting with the sub categories including, benefits disclosure score, challenges score, I4.0 components disclosure, CBMT mechanisms disclosure, governance pillar and other control variables. Following the correlation matrix, we found that governance pillar as a measurement of company's system that board members act into best interest of long-term shareholders is positively correlated with

the total disclosure on CBMT towards I4.0 strategy disclosure. This also will help checking the statistical relationship between the dependent and the independent variables, and whether there is any potential sign of Collinearity. It can be decided that multicollinearity does not appear to be a concern in explaining the regression results.

Table 4: Pairwise correlations

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
(1) Tscore	1.000							
(2) BS	0.326	1.000						
(3) Ind	0.200	0.069	1.000					
(4) GD	0.182	0.083	0.282	1.000				
(5) ROA	-0.043	-0.078	0.019	0.097	1.000			
(6) Lev	0.113	0.194	0.062	0.060	-0.241	1.000		
(7) FA	0.207	0.101	0.198	0.131	0.007	0.054	1.000	
(8) FS	0.253	0.337	0.275	0.072	-0.091	0.092	0.126	1.000

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

4.2 Regression results

Tables 5, 6 and 8 show the regression results for the constructed models, different regressions (OLS and random effect) have been used. The random effect regression was used based on the results of the Hausman test. The results show that we can see that board size is significantly associated with the total CTTI4 reporting. Board size is one of the main factors for corporate governance mechanism. More members on the board of directors mean more expert within the board, which lead to pressure to take the initiative in moving towards the I4.0 strategy as well as to provide more information on CTTI4 strategy. Further, we also find that board size has a significant positive relationship with all subcategories. The analysis also shows that the percentages of independent directors on the board is positively related with the total disclosure of CTTI4 reporting and also with the sub categories, except for the level of benefit of I4.0 strategy disclosure and for I4.0 strategy's components disclosure. We can also see that the percentage of women on board is positively associated with each of the total score of disclosure of CTTI4 reporting, I4.0 strategy's components disclosure and the level of disclosure on CBMT mechanisms. The more women on board, the more efforts the management will consider CBMT towards I4.0 strategy.

Table 5: Regression analysis (Dependent Variables: Total disclosure of CTTI4 ; Benefits of I4 score)

VARIABLES	(OLS) Tscore	(RE) Tscore	(OLS) Benscore	(RE) Benscore
BS	11.14***	3.817**	4.850***	1.148**
	(1.425)	(0.576)	(0.848)	(0.801)
Ind	0.587***	0.0493**	0.169	-0.0479

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	(0.219)	(0.211)	(0.130)	(0.104)
GD	0.872***	0.376***	0.540	0.237
	(0.275)	(0.249)	(0.163)	(0.123)
ROA	0.131	0.659	0.0807	0.176
	(0.565)	(0.506)	(0.336)	(0.249)
Lev	0.335***	0.352***	0.177**	0.136**
	(0.124)	(0.130)	(0.0736)	(0.0656)
FA	0.269***	0.327***	0.0943***	0.127**
	(0.0523)	(0.0936)	(0.0311)	(0.0580)
FS	0.000396***	0.000731***	0.000241***	0.000325***
	(0.000111)	(0.000182)	(6.61e-05)	(0.000103)
Constant	-18.53	72.33***	10.65	53.12***
	(17.47)	(18.72)	(10.39)	(9.835)
Observations	1,001	1,001	1,001	1,001
R-squared	0.193		0.115	
Number of group_id		208		208

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 6: Regression analysis (Dependent Variables: Challenges of I4 score; I4 score)

VARIABLES	(OLS) Chalscore	(RE) Chalscore	(OLS) I4score	(RE) I4score
BS	0.935***	0.328**	3.447***	1.224**
	(0.173)	(0.210)	(0.554)	(0.622)
Ind	0.120***	0.0353*	0.0915	-0.0384
	(0.0266)	(0.0290)	(0.0850)	(0.0831)
GD	-0.00402	-0.00640	0.251**	0.371**
	(0.0334)	(0.0345)	(0.107)	(0.0982)
ROA	-0.292***	-0.0973	0.421*	0.360*
	(0.0687)	(0.0703)	(0.220)	(0.200)
Lev	0.0353**	0.0422**	-0.0287	0.0271
	(0.0150)	(0.0174)	(0.0480)	(0.0512)
FA	-0.00568	0.00601	0.0940***	0.106***
	(0.00636)	(0.0106)	(0.0203)	(0.0370)
FS	8.09e-05***	9.89e-05***	3.81e-06	0.000125*
	(1.35e-05)	(2.19e-05)	(4.31e-05)	(7.19e-05)
Constant	1.879	9.145***	-17.64***	10.57
	(2.124)	(2.475)	(6.786)	(7.392)
Observations	1,001	1,001	1,001	1,001
R-squared	0.171		0.088	
Number of group_id		208		208

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 7: Regression analysis (Dependent Variables: Transformation toward I4 score)

VARIABLES	(OLS) Transformscore	(RE) Transformscore
BS	1.912***	0.895**
	(0.363)	(0.436)
Ind	0.207***	0.115*
	(0.0558)	(0.0599)
GD	0.285***	0.120*

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	(0.0700)	(0.0713)
ROA	-0.0783	0.167
	(0.144)	(0.145)
Lev	0.152***	0.142***
	(0.0315)	(0.0361)
FA	0.0865***	0.0911***
	(0.0133)	(0.0225)
FS	6.98e-05**	0.000157***
	(2.83e-05)	(4.60e-05)
Constant	-13.42***	0.830
	(4.454)	(5.136)
Observations	1,001	1,001
R-squared	0.200	
Number of group_id		208

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

4.3 Additional analysis and robustness checks

We use governance pillar as an alternative variable, we also apply the two-stage least squares 2SLS to mitigate the endogeneity problem. We use a first-order lagged term for governance quality as an instrumental variable. As can be seen from Tables 8, 9 and 10, the results remain consistent, which means that our results are not severely influenced by the possible occurrence of endogeneity problems. The total score of governance positively affects the disclosure on CTTI4 strategy and the coefficient is positive and significant at 1% in all models. Further, by looking at the results of sub categories, benefits disclosure score, challenges score, I4.0 components disclosure, CBMT mechanisms disclosure. This indicates that the relationship between the governance pillar and the disclosure level of CBMT towards I4.0 strategy is positively significant. Thus, we can say the better company's capacity through its use of best management practice, which reflects stronger governance power within the firm and the stronger the company's system and process in order to ensure that board members act into best interest of long-term shareholders, will lead to more total disclosure on CTTI4 reporting, and that remains the same when considering the sub categories of the total disclosure towards I4.0 strategy. Overall, it is very clear that better corporate governance enhances the level of reporting on CTTI4.

Table 8: Regression analysis (Dependent Variables: Total disclosure of CTTI4 ; Benefits of I4 score; Independent variable: governance quality pillar)

VARIABLES	(OLS) Tscore	(RE) Tscore	(2SLS) Tscore	(OLS) Benscore	(RE) Benscore	(2SLS) Benscore
Gscore	0.796***	0.254**	0.731***	0.556***	0.145**	0.377***
	(0.138)	(0.132)	(0.147)	(0.0828)	(0.0656)	(0.0819)

ROA	1.271**	0.984*	1.181**	0.767**	0.259	0.767**
	(0.557)	(0.506)	(0.541)	(0.333)	(0.250)	(0.330)
Lev	0.544***	0.394***	0.414***	0.237***	0.139**	0.237***
	(0.119)	(0.129)	(0.118)	(0.0713)	(0.0655)	(0.0706)
FA	0.286***	0.342***	0.276***	0.101***	0.139**	0.101***
	(0.0513)	(0.0943)	(0.0508)	(0.0307)	(0.0592)	(0.0303)
FS	0.000611***	0.000759***	0.000611***	0.000274***	0.000296***	0.000274***
	(0.000103)	(0.000179)	(0.000102)	(0.000104)	(0.000103)	(0.000101)
Constant	10.11***	10.27***	10.76***	6.049***	6.288***	6.045***
	(1.194)	(1.460)	(1.900)	(0.145)	(0.177)	(0.118)
Observations	1,008	1,008	1,008	1,008	1,008	1,008
R-squared	0.278		0.278	0.202		0.202
Number of group_id		208			208	

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 9: Regression analysis (Dependent Variables: Challenges of I4 score; I4 score; Independent variable: governance quality pillar)

VAR	(OLS) Chalscore	(RE) Chalscore	(2SLS) Chalscore	(OLS) I4score	(RE) I4score	(2SLS) I4score
gscore	0.101***	0.0658***	0.101***	0.165***	0.0877***	0.170***
	(0.0172)	(0.0182)	(0.0170)	(0.0527)	(0.0518)	(0.0522)
ROA	-0.181***	-0.0372	-0.181***	0.453**	0.387*	0.453**
	(0.0693)	(0.0705)	(0.0685)	(0.212)	(0.109)	(0.210)
Lev	0.0401***	0.0416**	0.0401***	0.0912**	0.0593	0.0912**
	(0.0148)	(0.0173)	(0.0147)	(0.0454)	(0.0502)	(0.0450)
FA	-0.0126**	-0.00106	-0.0126**	0.103***	0.111***	0.103***
	(0.00638)	(0.0109)	(0.00631)	(0.0195)	(0.0357)	(0.0193)
FS	0.000100***	0.000110***	0.000100***	0.000114***	0.000173**	0.000114***
	(1.28e-05)	(2.18e-05)	(1.27e-05)	(3.93e-05)	(6.86e-05)	(3.89e-05)
Constant	8.297***	8.495***	8.281***	6.051***	6.46***	6.049***
	(2.544)	(2.723)	(2.354)	(0.126)	(0.180)	(0.144)
Observations	1,008	1,008	1,008	1,008	1,008	1,008
R-squared	0.228		0.228	0.217		0.217
Number of group_id		208			208	

Table 10: Regression analysis (Dependent Variables: Transformation toward I4 score; Independent variable: governance quality pillar)

VARIABLES	(OLS) Transformscore	(RE) Transformscore	(2SLS) Transformscore
gscore	0.149***	0.0707*	0.149***
	(0.0364)	(0.0379)	(0.0361)
ROA	0.232	0.300**	0.232
	(0.147)	(0.146)	(0.145)
Lev	0.176***	0.146***	0.176***
	(0.0314)	(0.0361)	(0.0311)

FA	0.0943***	0.0972***	0.0943***
	(0.0135)	(0.0231)	(0.0134)
FS	0.000123***	0.000175***	0.000123***
	(0.0000162)	(0.0000141)	(0.0000195)
Constant	20.44	-12.02	8.297***
	(22.13)	(16.91)	(2.535)
Observations	1,008	1,008	1,008
R-squared	0.239		0.239
Number of group_id		208	

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

5. Conclusions

In the current paper, we examined the trends in CTTI4 reporting in UK companies. Finding of this study reveal that I4.0 strategy cannot be viewed merely as a technology roadmap, rather as a strategic investment decision-making roadmap regarding strategic choices to achieve successful long-term performance. These findings are consistent with Frank, Dalenogare, and Ayala (2019) that shows that organisations differ greatly in terms of what types and the number of technologies they adopt and how advanced their level of I4.0 implementation is. This finding is not surprising as CTTI4 vary according to boardrooms practices, companies' strategies and industry type. This result confirms the view of Warner and Wäger that incumbents built different types of dynamic capabilities for the strategic renewal of business models. UK companies are aware of benefits and challenges associated with CBMT mechanisms towards I4.0 strategy implementation.

This study contributes to the narrative disclosure measurement literature through provide a new measure of narrative reporting of CTTI4. Findings of this study also contribute to the literature on the impact of governance on non-financial reporting. We focus on the overall governance mechanisms and some board characteristics, we use computer-based content analysis, and we used quantitative methods to test our research hypotheses. Our findings show positive associations between governance and CTTI4 reporting. This suggests that reporting on the strategic transition towards the I4.0 strategy is shaped by strategic choices at boardroom practices as well as other contextual factors such as the quality of corporate

governance. Furthermore, the findings provide significant implications for both manufacturing companies and the UK government. These results can be viewed as benchmarking approach or roadmapping support for decision-makers and regulators regarding evaluating, adjusting or developing actionable strategies for UK industry to direct I4.0 strategy endeavours. This finding is consistent with the view of earlier studies (e.g. Alcácer and Cruz-Machado, 2019). CTTI4 can be viewed as a strategic transition in boardrooms practices at UK companies.

This study has its own limitations due to its time, location, and sample selection, the size and the sector of the selected companies and questions addressed. To move this agenda forward, we suggest future research may adopt our conceptual framework to provide new insights into the long-term organisational effects of such strategic transformation. Future research may examine the reporting of CTTI4 strategy in different settings to explore the relative impact of other contextual factors such as national culture, political, legal and social factors. Finally, qualitative research paradigms may examine how decision makers' attributes shape such strategic choices.

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Appendix 1: Corporate transformation towards Industry 4.0

CBMT mechanisms	
brexit	restructuring programme
digital economy	revolutionary change
i4.0 initiatives	revolutionary process
i4.0 technology	roadmap#
implementing i4.0 transformation	shift our focus to
industry 4.0	smart factory
long term decision	smart manufacturing
long-term business	strategic acquisition
long-term future	strategic alliance
long-term goals	strategic changes

long-term growth	strategic control
long-term importance	strategic decision
long-term profit growth	strategic focus
long-term projects	strategic investment
long-term returns	strategic objectives
long-term strategic decision	strategic performance
long-term strategic growth	strategic plan
long-term strategic vision	strategic portfolio
long-term strategy	strategic priorities
long-term sustainability	strategic programs
long-term sustainable value for shareholders	strategic transformation
long-term sustainable value for stakeholders	strategy review
long-term targets	technology leadership
long-term value	technology roadmap
long-term value for shareholders	technology strategy
long-term value for stakeholders	the fourth industrial revolution
lon-term strategic investments	transform the efficiency of our business
new business model	transformation journey
new organisational structure	transformation of our business
new perspectives	transformation of our company
new perspectives for business	transformation of our operating model
new strategic portfolio	transformation of our strategy
radical transformation	uk to leave the eu
	uncertainty created by brexit
	upgraded infrastructure
	upgraded infrastructure

I4.0 components	
3d printing	iot
advanced technolog#	machine learning
artificial intelligence	new technologies
automation	next generation technolog#
cloud-based technologies	next technolog#
cutting-edge technologies	novel computing technologies
data analytics	process automation
data as an asset	robotic#
digital applications	robots
digital capabilities	smart analytics
digital communication interfaces	technological advancement
digital modelling	technological innovation
digital technologies and analytics	the next generation of tools
digital transformation	
digitalization strategies	
disruptive technology	
driverless vehicles	
drones	
emerging technolog#	

greater automation hybrid technology innovation processes integrated data platform integrated data platform intelligent algorithms internet of things investment in advanced technolog#	

Benefits	
accelerate product development	intelligent operation#
additive manufacturing	keep people safe
agile decision making	long-term competitiveness
attractiveness with respect to tax	long-term growth
augmented decision support	make operations safer
automating activit#	more efficient
better connected	more flexible resource allocation
blockchain transaction	more productive through digital solutions
communicating data	more transformative and digital capabilities
confidentiality and integrity	most value to our customers
cost efficiency	new digital service model
demand-driven supply chain	new opportunities
digital capabilit#	operational decision#
digital solutions	optimise business processes
digitalisation of trade	optimise working capital
enhance communication	product improvement
enhance decision making	product improvement and innovation
enhance our productivity	product innovation
enhance product safety evaluation	provide greater automation
enhance risk mitigation capabilities	reduce documentation
enhance scientific innovation	reduce operating costs
enhance the long-term efficiency	reduce turnaround times
enhanced service level#	reduction in inventories
enhancing long-term efficiency	revenue growth
flexible product#	revenue growth and profitability
flexible resource allocation	revenue profitability
greater leadership accountability	rising customer loyalty
high levels of efficiency	rising customer satisfaction
improve data analytics capability	risk mitigation capabilities
improve data governance	safeguarding and communicating data
improve decision making	safeguarding data
improve overall customer experience	save business money
improved transport flows and costs	serve our customers better
improvement of the business	simplify and improve processes
increase collaboration	simplify processes
increasing customer satisfaction	simplifying systems

	stay competitive
	support decision making
	support manufacturing process
	support operational process
	support sales capabilities
	support supply chain
	support the evolving needs of the business
	tax incentives
	to keep people safe
	trade incentives
	transformative and digital capabilit#
Challenges	
cyber risk	new threat#
cyberattack	operational challenge#
cybercrime	real threat#
disruptive technolog#	security exposure#
long-term challenges#	strategic challenge#
	strategic risk

Appendix 2: Variables definitions

Tscore	Total score for CBMT towards I4.0 strategy
Benscore	Disclosure of the benefits
Chalscore	Disclosure of Challenges
I4score	Disclosure on I4.0 strategy's components
Transscore	Disclosure on CBMT mechanisms
Board Size (BS)	The number of directors on the firm's board
Independent directors (Ind):	The percentage of independent non-executive directors on the firm's board
Gender diversity (GD):	The percentage of women on board of directors
gscore	Corporate governance pillar-measures company's system and process which ensure that board members act into best interest of long-term shareholders- it reflects company's capacity through its use of best management practice
ROA	Return on Assets
LEV	Debt to Equity
FA	Firm age-Number of years since the foundation
FS	Firm size- Total assets